# Tender Document for Works

## (Two-Envelope Tendering Process Without Prequalification)

# Procurement of:

C-4: Composite Contract package in connection with New BG Railway Line of HORC project for:

(i) Design & Construction of Twin Tunnel using NATM and Cut & Cover method from km24.880 to km 29.580.

(ii) Design & Installation of Ballastless Track (excluding supply of rails) from km 24.856 to km29.680;

(iii) Detailed Design, Supply, Installation, Testing & Commissioning of General Electrical Services including Supply, Erection, Testing and Commissioning of 11kV HT/LT Power and Control Cable Network, GIS Substation (11/0.433) kVA , Tunnel lighting system etc. from km 24.880 to km 29.680.

(iv) Design & Construction of Embankment, Bridges and other miscellaneous works from Ch. km 12.00 to Ch. km 18.00.

## Summary

**Specific Procurement Notice (SPN)**

**PART 1 – TENDERING PROCEDURES**

Section I - Instructions to Tenderers (ITT)

Section II - Tender Data Sheet (TDS)

Section III - Evaluation and Qualification Criteria

Section IV - Tender Forms

Section V - Eligible Countries

Section VI - Prohibited Practices

**PART 2 – EMPLOYERS' REQUIREMENTS**

Section VII – Employer's Requirements

**PART 3 – CONDITIONS OF CONTRACT AND CONTRACT FORMS**

Section VIII - General Conditions of Contract (GCC)

Section IX - Particular Conditions of Contract (PCC)

Section X - Contract Forms

# PART 2 – Employer's Requirements

**Summary Table**

Section VII-1: General

Section VII-2: Functional (Civil and BLT)

Section VII-3: Design (Civil)

Section VII-4: Construction (Civil)

Section VII-5: Outline Design Specifications (ODS)- Civil and BLT

Section VII-6: Outline Construction Specifications (OCS)-Civil and BLT

Section VII-7: General Electrical Services

Section VII-8: Tender drawings and documents

Section VII-9: Appendices

# Section VII: Employer's Requirements

## Section VII-1: GENERAL

# EMPLOYER'S REQUIREMENTS - GENERAL

## 1 Project Profile and Background.

### 1.1 General

State of Haryana is strategically located bordering the National capital of Delhi. NCT, Delhi shares three fourth of its border with Haryana alone and remaining with Uttar Pradesh. The development of Haryana region, bordering Delhi is very important for balanced growth of NCR as it acts as buffer zone against rampant migration and other support infrastructure. At present on account of growth of Metro network in Delhi & NCR, there is radial movement of commuters to and from, Delhi being in centre. This "Hub and Spoke" traffic planning has resulted in rapid growth of Noida, Greater Noida, Faridabad and Gurugram. However, for hub and spoke concept to sustain it is necessary to link the ends of spoke by ring connectivity. There will be natural demand for commuter movement within these towns like Gurugram, Faridabad, Ballabhgarh, Palwal, Sohna, Manesar etc. Peripheral roads have been commissioned recently, linking these towns around Delhi but Rail link provides economical, sustainable, eco-friendly and bulk freight transport option. The peripheral Rail link will also help in growth of other cities within the same distance from Delhi like Sonipat, Panipat, and Rohtak. Western DFC originating from Dadri station is passing through Asaoti Station on Delhi- Mathura route, providing connectivity to Haryana Orbital Rail Corridor (HORC). This will also help in easing the pressure on the transport network of Delhi as some of the commuter traffic moving on the radials will get shifted to HORC. Apart from passenger traffic, substantial amount of freight traffic, which is entering the Delhi area of rail network but is not meant to be consumed in Delhi, will also get diverted via this corridor. Apart from this, there are major goods sheds in the heart of Delhi causing endless avoidable traffic jams. The goods sheds in west Delhi are Azadpur, Shakurbasti, Dayabasti, Sabzi Mandi which are located on prime commercial land and are black spots of the urban planning. Previously moving out commercial activity to other states had interstate taxation issues but now with GST in place, there is no reason of not shifting these activities to the peripheral region. In any case, if freight traffic movement through Delhi is restricted, then these goods sheds or alternatives will be serviced via the proposed HORC. Haryana Orbital Rail Corridor (HORC) from Palwal to Sonipat Via Sohna, Manesar, Kharkhoda and Harsana Kalan is to be constructed as an Electrified (1X25kV AC-50Hz) double line track, capable of operating at a maximum train speed of 160 kmph.

### 1.2 Forest and Environmental Clearance

It is mentioned that for railway projects no prior environmental clearance is required as per Environment Impact Assessment (EIA) Notification, 2006. Further, the Forest (Conservation) Act, 1980 is not applicable to the Project in terms of Ministry of Environment, Forest and Climate Change (MoEFCC's) OM No.11-37/2016 FC dated 10.03.2022. However, certain part of the Project falls in specified area of Aravalli range. The clearance for specified area of Aravalli range is under process and is likely to be obtained before the award of contract.

## 2. DEFINITIONS AND INTERPRETATIONS

In addition to the words and expressions defined in the General Conditions of Contract, further following words and expressions shall have the meaning assigned to them except where the context otherwise requires:

- "**Availability**" shall mean the probability that an item will be in a state to perform a required function under given conditions at a given instant or over a given time interval assuming that the required external resources are provided.

- **"As-Built Drawings"** means those drawings produced by the Contractor and endorsed by its true records of construction of the Permanent Works and which have been given a consent from the Engineer.

- **"As-Built Documents"** mean the set of drawings and documents which are a true record of the construction of the Permanent Works prepared by the Contractor.

- **"CAD Standards"** means requirements for CAD, as specified in the Appendix 9 of Employer's Requirements.

- **"Charted Utilities"** mean identified Utilities listed in Employer's Requirements- Tender Drawings and Documents, which may be affected by the execution of the Works under the Contract.

- **"Cold Joint"** means a joint or discontinuity formed when a concrete surface hardens before the next batch is placed against it, characterised by poor bond unless necessary procedures are observed.

- **"Combined Services Drawings" (CSD):** means drawings showing the locations, layouts and sizes of all services including those of other contractors co-ordinated so as to eliminate all clashes.

- **"Construction Phase":** has the meaning identified in the Employer's Requirements - General.

- **"Construction Reference Drawings":** means those drawings referred in the Employer's Requirements - Design in respect of which a Notice has been issued.

- **"Construction Reference Drawings Submission":** means the submission of Construction Reference Drawings representing elements of the Permanent Works and for which the Contractor seeks a Notice.

- **"Contract Spares"** means any Spare Parts recommended by the Contractor for the operation and maintenance of the Permanent Works following the Taking Over of the Works.

- **"Contractor's Project Plan"** means the plan to provide a clear overview of the Contractor's organisation, management systems and the methods to be used for the execution and completion of the Works

- **"Controlled Blasting"** means a method of blasting which is aimed at reducing vibration and noise due to blasting.

- **"Construction/Installation and/or Manufacture Documents"** means the document which contain all drawings, calculations, computer software, samples, patterns, models, operation / maintenance manuals and other information to be submitted by the Contractor and approved by the Engineer.

- **"Consumables"** means those parts that are not repairable and usually have a relatively short life span.

- **"Critical Path Method"** means a schedule network analysis technique used to determine the amount of scheduling flexibility (the amount of float) on various logical network paths in the project schedule network, and to determine the minimum total project duration.

- **"Definitive Design Submission":** means the submission of documents which comprise the whole or parts of the proposed Definitive Design and for which the Contractor seeks a Notice.

- **"Design Criteria":** means the criteria defined in Employer's Requirements-Design and Outline Design Specifications.

- **"Design Manual":** means the manual to be prepared and submitted by The Contractor as part of the Definitive Design and as described in the Employer's Requirements - Design.

- **"DN Line"** means the down line of the HORC double line track route from Sonipat to Palwal.

- "**Final Design":** has the meaning identified in the Employer's Requirements – Design.

- **"Fixed Structure Gauge":** means the profile related to the designed normal co-ordinated axis of the track into which no part of any structures or fixed equipment may penetrate.

- **"Good For Construction Drawings (GFC)":** Construction Reference Drawings or Working Drawings which have received Notice from the Engineer, shall be endorsed as "Good For Construction Drawings" and will be issued to the Site. Execution of work shall be carried out only as per drawings which have been endorsed as GFC.

- **"Interface Management Plan"** means the plan for all interface issues that may arise during the design, construction, testing and commissioning of the Works, in consultation with the Interfacing Contractors/ Interfacing Parties and the Engineer.

- **"Isolation"** means isolating and earthing of the electrical equipment, by disconnection of the respective section from all incoming sources of electricity supply and also outgoing connections.

- **"Independent Laboratory"** means a laboratory, submitted by the Contractor to the Engineer for approval, that is free from outside control and not subject to direct or indirect influence or authority of the Employer, the Engineer, or the Contractor

- **"Inspection and Test Plan"** means a document that states inspection and testing requirements and actions provisioned for the Works, related process, Plant, or Materials. It is used to control, check, monitor and record; testing procedures that are required for quality assurance and to achieve the agreed quality requirements for the Works.

- **"Installation Tests"** means the tests to be performed to verify the conformity of completion of an installation/assembly to the design documents approved by the Engineer prior to the start of Commissioning, and they must be successfully completed before the Tests on Completion.

- **"Interface Coordinator"** means the person who has the responsibility, and authority with substantial experience to resolve interface matters to the satisfaction of the Engineer and provide the necessary support team for the Interface Management System as specified in Appendix 5

- **"Interfacing Contractor"** means the Contractor engaged by the Employer or other agencies having an interface issue with the Contractor for the Works.

- **"Interfacing Parties"** comprises the interfacing contractors / consultants / service providers, who are engaged in part of the works, relevant authorities and public utility agency.

- **"Interface Table"** means the table that describes the relationships between the Contractor and Interfacing Contractors / Interfacing Parties and their roles and responsibilities is a key document.

- **"Kick-Off Meeting"** means the meeting held by the Engineer to formally notify all parties concerned under the Contract that the project has commenced and to ensure that every party has a common understanding of their role from the Commencement Date up until issuance of the Performance Certificate.

- **"Maintainability"** means a characteristic expressed as the probability that an item will be retained in or restored to a specified condition within a given period, when the maintenance is performed in accordance with prescribed procedures and resources.

- **"Maintenance Manuals"** means the manuals providing detailed instructions for the maintenance of infrastructure and maintenance facilities.

- **"Method Statement"** means a document that states the way a particular work, task, or process along with various associated aspects such as quality, safety, environment protection, time and resources; are planned to be directly controlled by the Contractor or its Subcontractor.

- **"Monthly Progress Meeting"** means the meeting specified under Appendix 7 of the Employer's Requirements.

- **"Monthly Progress Report"** means the report that the Contractor shall prepare and submit to the Engineer.

- **"Nonconformity Report"** means a report documenting non-fulfilment of a requirement, with objective evidence, the location and time of occurrence or detection, and provision for its proper resolution by the concerned responsible.

- **"Notice":** means a Notice of No Objection.

- **"Notice of Objection"** means a category of Engineer's response, issued by the Engineer to the Contractor.

- **"Not Reviewed"** means a category of Engineer's response, issued by the Engineer to the Contractor.

- **"On-Site Laboratory"** means Contractor's own laboratory submitted by the Contractor to the Engineer for approval as specified in Appendix 12 of the Employer's Requirements.

- **"Operation and Maintenance Manuals (O&M Manuals)"** means the manual that will be indicating the provisions which are required for maintenance of various assets created under the Contract by the Employer under their operation phase.

- **"Priority Section"** means the section from Km 49.7 to Km 55.6 of HORC Main line and connectivity line from Manesar station on HORC and Patli station on Delhi-Rewari section of Indian Railway Network.

- **"Programme Analysis Report"** means the report submitted to the Engineer that shall, in narrative format, describe the basis and assumptions used to develop each programme.

- **"Project"** means the project named as "Haryana Orbital Rail Corridor (HORC)".

- **"Project Management Plan"** refers to the plan that will be established by the Contractor for the management of activities related to design, procurement, manufacture, execution/construction, delivery, installation, testing and commissioning.

- **"Project Management Information System"** means a document, information and communication technology system (platform) that is to be implemented by the Contractor so that the management of information between the Contractor, the Employer and the Engineer is efficient, reliable, and secure.

- **"Preliminary Design":** means the submission of documents which comprise the initial stage of the design phase.

- **"Indian Railway"** means the rail tracks of the Indian Railway and any ancillary areas of Indian Railway such as the depots, sidings, stations, terminus, traction power stations, etc.

- **"Request for Inspection"** means the form used to give notice by the Contractor to the Engineer.

- **"Railway Representative"** means a person, or persons, nominated by the Employer / Engineer to liaise with the Contractor and the Engineer on matters affecting the operation of Indian Railway.

- **"Restriction"** means speed restriction, which is a limitation of the normal permitted speed of rail traffic over a specified length of the Railway.

- **"Tender Drawings and Documents"** means the drawings and documents prepared by the Employer for reference purposes only and included in the Tender Documents.

- **"Reliability"** means the probability that an item/equipment/system can perform a required function under given conditions for a given time interval.

- **"Routine Test"** means the test which is required to perform or undergo on each Plant, Contractor's Equipment and Materials during or after manufacture to ascertain that it complies with specified criteria.

- **"Right of Way"** means the land area of the Project, either acquired by the Employer or for which the Employer has the permission of the Stakeholder to construct the embankment & bridges, etc. over their area.

- **"Environmental, Social, Health and Safety Management Plan"** means the plan in accordance with the requirements of Appendix 13 of the Employer's Requirements.

- "**Safety**" freedom from unacceptable risk of harm.

- "**Safety Integrity Level**" One of a number of defined discrete levels for specifying the safety integrity requirements of the safety functions to be allocated to the safety related systems. Safety Integrity Level with the highest figure has the highest level of safety integrity.

- **"Safety-Critical"** means failure of the system, sub-system or equipment that directly leads to a situation with the potential to cause harm, injury, damage to property, plant or equipment, damage to the environment, or economic loss.

- **"Smooth Blasting"** means a type of controlled blasting which achieves minimum rock damage and a smooth surface. This is achieved by drilling a line of closely spaced parallel holes along the excavation surface with a suitable burden/spacing ratio, loading all the holes lightly with an appropriate amount of explosive and detonating all these charges simultaneously after the detonation of main production blast.

- **"Software Related Items"** comprises (but not limited to) erasable programmable read only memory (EPROM), digital versatile disc (DVD), other related items which are the most updated items used in relation to the Works, and those to be supplied by Subcontractors of any tiers

- **"Site Offices"** means Site Office for Employer's/Engineer's Personnel constructed by the Contractor.

- **"Spare Parts"** means those parts which are generally repairable and have normally a service life of several years.

- **"Specification":** has the meaning identified in the Employer's Requirements - General.

- **"Sub-system"** Each system comprises of sub systems. Signalling System comprise sub systems of Electronic Interlocking System, Train Detection System, Point Operation System, Absolute Block Working with BPAC, Power Supply System etc. Telecommunication System comprise sub systems of Optical Fiber Communication System, Quad cable system, Data Networking System, Telephone System, Emergency Communication System, VHF Communication System, Master Clock System, Integrated train platform announcement and display system and 48 volt DC Battery Backup System etc.

- **"Temporary Benchmarks (TBM)"** means the benchmarks provided by the Employer, used to locate & confirm the Right of Way (ROW) and its co-ordinates including levels.

- **"Three Months Rolling Programme"** means the programme which the Contractor shall prepare and update monthly as per Appendix 6 of the Employer's Requirements.

- **"Three Weeks Rolling Programme"** means the programme which the Contractor shall prepare and update weekly per Appendix 6 of the Employer's Requirements.

- **"Time Bar Chart",** known as "Gantt Chart" too is a type of bar chart which illustrates a project schedule. i.e. the start and finish dates of the activities and summary elements of a project

- **"Uncharted Utilities"** mean Utilities other than Charted Utilities which are identified during a survey conducted by the Contractor or encountered during excavation/ other works.

- **"UP Line"** means the up line of the HORC double line track route from Palwal to Sonipat.

- **"Utilities"** means the electricity, lighting, traffic control, telephone and/or communication cables, gas, water, sewage and drainage pipes, including all associated protection, supports, ancillary structures, fittings and equipment.

- **"Working Drawing"** means additional drawings developed by the Contractor as necessary to supplement the Construction Reference Drawings and to specify additional details and procedures for construction of the Works, such as shop drawings, fabrication drawings, erection drawings, Temporary Works drawings, bar bending schedules, bar reference drawings, embankment/cutting cross sections. All such drawings shall comply with the requirements of the Contract.

- **"Works Programme"** means the time-scaled and resource-loaded critical path network, updated from time to time in accordance with the General Conditions of

Contract and Employer's Requirements, depicting activities, durations, sequences and interrelationships that represent the Contractor's work plan, work breakdown, schedule structure for constructing and completing the Works, distributed over the Time for Completion of the Contract.

- **Abbreviations**

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| **AC** | **:** | **Alternating Current** |
| **ACB** | **:** | **Air Circuit Breaker** |
| **AIIB** | **:** | **Asian Infrastructure Investment Bank** |
| **ALARP** | **:** | **As Low As Reasonably Practicable** |
| **ASLI** | **:** | **Automatic Safe Load Indicator** |
| **BG** | **:** | **Broad Gauge** |
| **BIS** | **:** | **Bureau Of Indian Standards** |
| **BLT** | **:** | **Ballastless Track** |
| **BOCW** | **:** | **Building Or Other Construction Work** |
| **BS** | **:** | **British Standards** |
| **CAD** | **:** | **Computer Aided Design** |
| **CCTV** | **:** | **Closed Circuit Television** |
| **CD** | **:** | **Compact Disc** |
| **CIF** | **:** | **Cost, Insurance And Freight** |
| **CIP** | **:** | **Co-Ordinated Installation Plan** |
| **CP** | **:** | **Contract Package** |
| **CPCB** | **:** | **Centre Pollution Control Board** |
| **CPM** | **:** | **Critical Path Method** |
| **CRS** | **:** | **Commissioner Of Railway Safety** |
| **CSD** | **:** | **Combined Service Drawings** |
| **CTC** | **:** | **Centralized Traffic Control** |
| **CV** | **:** | **Curriculum Vitae** |
| **D&B** | **:** | **Drill And Blast** |

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| **DB** | **:** | **Decibel** |
| **DB** | **:** | **Distribution Box** |
| **DC** | **:** | **Direct Current** |
| **DCN** | **:** | **Design Change Notice** |
| **DDF** | **:** | **Digital Distribution Frame** |
| **DFC** | **:** | **Dedicated Freight Corridor** |
| **DFCCIL** | **:** | **Dedicated Freight Corridor Corporation of India Limited** |
| **DG** | **:** | **Diesel Generator** |
| **DGPS** | **:** | **Differential Global Positioning System** |
| **DIN** | **:** | **Deutsche Industrial Norms** |
| **DL** | **:** | **Double Line** |
| **DNP** | **:** | **Defects Notification Period** |
| **DP** | **:** | **Detection Point** |
| **DPI** | **:** | **Dots Per Inch** |
| **DPR** | **:** | **Daily Progress Report** |
| **DSS** | **:** | **Distribution Substation** |
| **DT** | **:** | **Down Time** |
| **DTN** | **:** | **Data Transmission Network** |
| **DVD** | **:** | **Digital Versatile Disc** |
| **DVT** | **:** | **Design Verification Table** |
| **E&M** | **:** | **Electrical & Mechanical** |
| **EIA** | **:** | **Environmental Impact Assessment** |
| **ELCB** | **:** | **Earth Leakage Circuit Breaker** |
| **EMC** | **:** | **Electro Magnetic Compatibility** |
| **EMI** | **:** | **Electro Magnetic Interference** |
| **EPROM** | **:** | **Erasable Programmable Read Only Memory** |

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| **ERP** | **:** | **Enterprise Resource Planning** |
| **ESHS** | **:** | **Environmental, Social, Health and Safety** |
| **FAT** | **:** | **Factory Acceptance Test(S)** |
| **FCN** | **:** | **Field Change Notice** |
| **FFL** | **:** | **Finished Floor Level** |
| **FL** | **:** | **Formation Level** |
| **FMECA** | **:** | **Failure Modes Effect and Criticality Analysis** |
| **FRACAS** | **:** | **Failure Report and Corrective Action System** |
| **FTA** | **:** | **Fault Tree Analysis** |
| **GAD** | **:** | **General Arrangement Drawing** |
| **GCC** | **:** | **General Conditions Of Contract** |
| **GE** | **:** | **Geotechnical Engineering** |
| **GFL** | **:** | **Ground Floor Level** |
| **GIS** | **:** | **Geographical Information System** |
| **GL** | **:** | **Ground Level** |
| **GNSS** | **:** | **Global Navigation Satellite System** |
| **GOI** | **:** | **Government Of India** |
| **GPR** | **:** | **Ground Penetrating Radar** |
| **GPS** | **:** | **Global Positioning System** |
| **GRC** | **:** | **Grievance Redress Committee** |
| **GRM** | **:** | **Grievance Redress Mechanism** |
| **GS** | **:** | **General Specifications** |
| **GSM-R** | **:** | **Global System For Mobile Communication - Railway** |
| **HDPE** | **:** | **High Density Polyethylene** |
| **HFL** | **:** | **Highest Flood Level** |
| **HORC** | **:** | **Haryana Orbital Rail Corridor** |

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| **HP/BHP** | **:** | **Horse Power / Brake Horse Power** |
| **HT** | **:** | **High Tension** |
| **HTML** | **:** | **Hyper Text Markup Language** |
| **HV** | **:** | **High Voltage** |
| **HVAC** | **:** | **Heating, Ventilation And Air Conditioning** |
| **Hz** | **:** | **Hertz** |
| **IC** | **:** | **Integrated Circuit** |
| **ICD** | **:** | **Interface Co-Ordination Document** |
| **ID** | **:** | **Identification** |
| **IEC** | **:** | **International Electro – Technical Commission** |
| **IHA** | **:** | **Interface Hazard Analysis** |
| **IISWBM** | **:** | **Indian Institute Of Social Welfare & Business Management** |
| **IMD** | **:** | **Integrated Maintenance Depot** |
| **IMP** | **:** | **Interface Management Plan** |
| **INR** | **:** | **Indian Rupee** |
| **IP** | **:** | **Point Of Intersection** |
| **IPS** | **:** | **Integrated Power Supply** |
| **IR** | **:** | **Indian Railways** |
| **IRC** | **:** | **Indian Road Congress** |
| **IRJ** | **:** | **Insulated Rail Joints** |
| **IRS** | **:** | **Indian Railway Standards** |
| **IRSEM** | **:** | **Indian Railway Signal Engineering Manual** |
| **IS** | **:** | **Indian Standards** |
| **ISO** | **:** | **International Organization For Standardization** |
| **IT** | **:** | **Information Technology** |
| **ITP** | **:** | **Inspection And Test Plan** |

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| **ITT** | **:** | **Instruction To Tenderers** |
| **KM / KM** | **:** | **Kilo meter** |
| **kV** | **:** | **Kilo Volt** |
| **LAN** | **:** | **Local Area Network** |
| **LCD** | **:** | **Liquid Crystal Display** |
| **LCX** | **:** | **Leaky Coaxial Cable** |
| **LED** | **:** | **Light Emitting Diode** |
| **LRU** | **:** | **Line Replaceable Units** |
| **LT** | **:** | **Low Tension** |
| **LV** | **:** | **Low Voltage** |
| **LWL** | **:** | **Lowest Water Level** |
| **MC** | **:** | **Municipal Corporation** |
| **MCB/LV** | **:** | **Miniature Circuit Breaker / Low Voltage** |
| **MCCB** | **:** | **Moulded Case Circuit Breaker** |
| **MCIL** | **:** | **Maintainability Critical Items List** |
| **MDR** | **:** | **Major District Roads** |
| **MMI** | **:** | **Man Machine Interface** |
| **MOR** | **:** | **Ministry Of Railway** |
| **MPR** | **:** | **Monthly Progress Report** |
| **MQR** | **:** | **Monthly Quality Report** |
| **MS** | **:** | **Method Statement** |
| **MSDS** | **:** | **Material Safety Data Sheet** |
| **MSL** | **:** | **Mean Sea Level** |
| **MTBF** | **:** | **Mean Time Between Failure** |
| **MTBSAF** | **:** | **Mean Time Between Service Affecting Failure** |
| **MTTR** | **:** | **Mean Time To Repair** |
| **MTTR** | **:** | **Mean Time To Restore** |

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| **NABL** | **:** | **National Accreditation Board For Testing And Calibration Laboratories** |
| **NATM** | **:** | **New Austrian Tunnelling Method** |
| **NCR** | **:** | **Nonconformity Report** |
| **NFPA** | **:** | **National Fire Protection Association** |
| **NGO** | **:** | **Non-Governmental Organization** |
| **NH** | **:** | **National Highway** |
| **NHAI** | **:** | **National Highway Authority Of India** |
| **NOC** | **:** | **No Objection Certificate** |
| **NONO** | **:** | **Notice Of No Objection** |
| **NONOC** | **:** | **Notice Of No Objection With Comments** |
| **NOO** | **:** | **Notice Of Objection** |
| **NR** | **:** | **Not Reviewed** |
| **O&M** | **:** | **Operation And Maintenance** |
| **O&SHA** | **:** | **Operating And Support Hazard Analysis** |
| **OCS** | **:** | **Overhead Catenary System** |
| **ODBC** | **:** | **Open Data Base Connectivity** |
| **ODF** | **:** | **Optical Equipment Manufacturer** |
| **ODR** | **:** | **Other District Roads** |
| **OEM** | **:** | **Original Equipment Manufacturer** |
| **OFC** | **:** | **Optical Fibre Cable** |
| **OHE** | **:** | **Over Head Electrification** |
| **OHSAS** | **:** | **Occupational Health And Safety Assessment Series** |
| **OHTL** | **:** | **Over Head Transmission Lines** |
| **OPM** | **:** | **Other Preventive Measures** |
| **PCC** | **:** | **Particular Conditions Of Contract** |
| **PDF** | **:** | **Portable Document Format** |

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| **PHA** | **:** | **Preliminary Hazard Analysis** |
| **PMIS** | **:** | **Project Management Information System** |
| **PPE** | **:** | **Personal Protective Equipment** |
| **PR** | **:** | **Public Relation** |
| **PS** | **:** | **Particular Specifications** |
| **PVC** | **:** | **Polyvinyl Chloride** |
| **PWD** | **:** | **Public Works Department** |
| **QA** | **:** | **Quality Assurance** |
| **RAMS** | **:** | **Reliability, Availability, Maintainability And Safety** |
| **RAP** | **:** | **Resettlement Action Plan** |
| **RBD** | **:** | **Reliability Block Diagram** |
| **RC** | **:** | **Reinforced Concrete** |
| **RCC** | **:** | **Reinforced Cement Concrete** |
| **RCIL** | **:** | **Reliability Critical Item List** |
| **RDSO** | **:** | **Research Designs And Standards Organization** |
| **RDT** | **:** | **Reliability Demonstration Testing** |
| **RFI** | **:** | **Request For Inspection** |
| **RFO** | **:** | **Rail Fly Over** |
| **RINL** | **:** | **Rashtriya Ispat Nigam Limited** |
| **RL** | **:** | **Rail Level** |
| **ROB** | **:** | **Road Over Bridge** |
| **ROCS** | **:** | **Rigid Overhead Conductor System** |
| **ROM** | **:** | **Read Only Memory** |
| **ROW** | **:** | **Right Of Way** |
| **RUB** | **:** | **Road Under Bridge** |
| **S&T** | **:** | **Signalling And Telecommunication** |

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| **SAIL** | **:** | **Steel Authority Of India Limited** |
| **SAT** | **:** | **System Acceptance Test(S)** |
| **SCADA** | **:** | **Supervisory Control And Data Acquisition** |
| **SCC** | **:** | **Sectional Control Centre** |
| **SCIL** | **:** | **Safety Critical Items List** |
| **SER** | **:** | **Signalling Equipment Room** |
| **SH** | **:** | **State Highway** |
| **SI** | **:** | **International System Of Units** |
| **SIL** | **:** | **Safety Integrity Level** |
| **SL** | **:** | **Single Line** |
| **SM** | **:** | **Station Master** |
| **SOD** | **:** | **Schedule Of Dimensions** |
| **SP** | **:** | **Sectioning Post** |
| **SRR** | **:** | **Submission Review Request** |
| **SRS** | **:** | **System Requirement Specifications** |
| **SSHA** | **:** | **Subsystem Hazard Analysis** |
| **SSP** | **:** | **Sub-Sectioning Post** |
| **SWR** | **:** | **Station Working Rules** |
| **TCAS** | **:** | **Train Collision Avoidance System** |
| **TCP** | **:** | **Traffic Control Plan** |
| **TER** | **:** | **Telecommunication Equipment Room** |
| **TMS** | **:** | **Train Management System** |
| **TOT** | **:** | **Transfer Of Technology** |
| **TSS** | **:** | **Traction Substation** |
| **UG** | **:** | **Under Ground** |
| **UPS** | **:** | **Uninterrupted Power Supply** |
| **USB** | **:** | **Universal Serial Bus** |

| | | |
|---|---|---|
| **UTM** | **:** | **Universal Transverse Mercator** |
| **VDU** | **:** | **Video Display Unit** |
| **VHF** | **:** | **Very High Frequency** |
| **VN** | **:** | **Variation Notice** |
| **WGS84** | **:** | **World Geodetic System 84** |
| **WHO** | **:** | **World Health Organization** |
| **WQMP** | **:** | **Works Quality Management Plan** |
| **XLPE** | **:** | **Cross Linked Polyethylene** |

## 3 RELEVANT DOCUMENTS

The Design Criteria shall be read in conjunction with the General Conditions of Contract (GCC), the Particular Conditions of Contract (PCC), the Employer's Requirements, the drawings and any other document forming part of the Contract.

Notwithstanding the precedence specified above the Contractor shall always immediately seek advice from the Engineer in the event of conflicts between Specifications.

In case of conflict in Design Criteria in various Sub-Sections of Section VII, Employer's Requirements the order of precedence shall be as follows:

**CIVIL &BLT**

i. Outline Design Specifications (ODS)-Civil & BLT
ii. Outline Construction Specification (OCS)-Civil & BLT
iii. Tender Drawings
iv. Functional, Design, Construction, General
v. Appendices
vi. Indian and other International Standards referenced herein.
vii. Indian and other International Standards.

**ELECTRICAL**

i. Particular Specifications (PS)-General Electrical Services
ii. General Specifications
iii. Tender Drawings
iv. General
v. Appendices

## 4 PHASES (DESIGN AND CONSTRUCTION)

a) The Contractor shall execute the Works in two phases, the Design Phase and the Construction Phase.

b) The Design Phase shall commence upon the date of Letter of Acceptance (LOA). This phase shall include the preparation and submission of:

i. the Preliminary Design,

ii. the Definitive Design;

iii. the Construction Reference Drawings.

iv. The Design Phase will be complete upon the issue of a Notice in respect of the comprehensive and complete Construction Reference Drawings Submission for the whole of the Permanent Works.

c) The requirements for the Preliminary Design, Definitive Design and Construction Reference Drawings are stated in Clause 2 of the Employer's Requirements -Design.

d) The Construction Phase for the whole or a part of the Permanent Works shall commence immediately upon the issue of a Notice by the Engineer/Employer in respect of the relevant Construction Reference Drawings Submission. Such Notice may be issued by the Engineer in respect of a Construction Reference Drawing Submission covering a major and distinctive part of the Permanent Works. However, construction shall not be commenced until the appropriate Working Drawings have been endorsed:

i. by the Contractor as "Good for Construction"; and

ii. by the Engineer that he has no objections to the drawing.

The Construction Phase shall include the completion and submission of the Final Design and the preparation and submission of the As Built Drawings and other records as specified.

e) Notwithstanding Clause 4 b (iv) above, for those elements identified under Sub-Clause 2.5 of the Employer's Requirements - Design, the Construction Phase may commence immediately upon the issue of the Notice in respect of the Definitive Design Submission in respect of each such element subject to availability of the site in accordance with agreed programme.

f) The Contractor shall furnish Contractor's Warranty in the format approved by the Employer given in Section X – Contract Forms.

## 5. SPECIFICATIONS

In accordance with the provisions of these Employer's Requirements (Section VII-1 to Section VII-9), the Contract Specification contained in the Contract shall be developed during the design stage and submitted as part of the Definitive Design Submission. When the Specification has received a Notice of No Objection from the Engineer it shall become the Particular Specifications and shall take precedence over the other Specifications for construction purposes.

## 6. SPECIFICATIONS IN METRIC AND IMPERIAL UNITS

a) The Contract shall utilise the SI system of units. Codes and Standards in imperial units shall not be used unless the Engineer has given his consent.

b) Conversion between metric units and imperial units shall be in accordance with the relevant Indian Standards.

## 7. WORKS PROGRAMME

a) The Key Dates are defined in Appendix 2 to these Employer's Requirements.

b) The Contractor shall prepare and submit its Works Programme and three-month rolling programmes and the detailed requirements contained in Appendix 6 to these Employer's Requirements.

c) In compiling its Works Programme and in all subsequent updating and reporting, the Contractor shall make provision for the time required for co-ordinating and completing the design, testing, commissioning and integrated testing of the Works, including, inter alia, design co-ordination periods during which the Contractor shall co-ordinate its design with those of Interfacing Contractors, the review procedures, determining and complying with the requirements of all Government Departments and all others whose consent, permissions, authority or licence is required prior to the execution of any work.

d) The Works Programme shall take full account of the Design Submission Programme.

## 8. MONITORING OF PROGRESS

a) Project Monitoring shall be done by Integrated Project Monitoring Software (IPMS). The contractor has to prepare Primavera P6 schedule as per the Programme Requirements provided in Appendix 6.

b) The Contractor shall submit to the Engineer three copies (along with an additional copy in digital format) of a Monthly Progress Report (MPR), as described in Appendix 7 to these Employer's Requirements, describing the progress and current status of the Works. The MPR shall address the matters set out in the Works Programme.

c) The MPR shall be submitted by the end of each calendar month. It shall account for all works actually performed in the current month.

d) The MPR shall be divided into two sections. The first section shall cover progress and current status relating to design and the second section shall cover progress and current status relating to construction.

e) A monthly meeting to monitor & review the progress of the project shall be convened by the Engineer. Contractor’s site Representative & Designer Representative of Contractor and site representative of all Interfacing Contractors shall also attend the meeting. The Employer may also be present in the meeting.

f) The Engineer or Employer may also conduct progress review meetings and Interface meetings on weekly /bi-weekly intervals depending upon the requirements or urgency of works. In these review meetings Engineer may call Contractor’s Supplier/Sub-Contractor/Designer etc. as per the requirements.

## 9. QUALITY ASSURANCE

The Contractor shall establish and maintain a Quality Assurance System in accordance with Appendix 11 to these Employer's Requirements for design and construction procedures and the interfaces between them. This Quality Assurance system shall be applied without prejudice to, or without in any way limiting, any Quality Assurance Systems that the Contractor already maintains.

## 10 SOFTWARE SUPPORT

## 10.1 GENERAL

a) The Contractor shall provide full support to the Engineer for all computer programs provided by the Contractor under the Contract.

b) The Contractor shall submit a software support plan at least 90 days before commencement of software installation. This plan shall require the Contractor to provide all changes, bug fixes, updates, modifications, amendments, and new versions of the program as required by the Engineer.

c) The Contractor shall provide all tools, equipment, manuals and training necessary for the Employer / Engineer to maintain and re-configure all the software provided under the Contract.

d) The Contractor shall submit all new versions to the Engineer for review at least 2 weeks prior to their installation. New Versions of any program shall not result in any non-conformance with the Specification or degrade the operation of the System. The Contractor shall:

   i. Ensure that all new versions are fully tested and validated on the simulation and development system prior to installation.

   ii. Ensure that all new versions are fully tested and commissioned once installed on the Site.

   iii. Deliver to the Employer/Engineer any new version, together with the updated Operation and Maintenance Manuals.

e) The Engineer shall not be obliged to use any new version and that shall not relieve the Contractor of any of its obligations. Any effect upon the performance or operation of the computer-controlled system that may be caused by a new version shall be brought to the Engineer attention including updating the files to suit new version.

## 10.2 IMPLEMENTATION OF SOFTWARE BASED BILLING & PROJECT MANAGEMENT SYSTEMS

The contractor shall perform all billing processes through the software-based billing system as and when introduced by HORC. The Contractor shall also introduce appropriate Project Management Systems during the project execution phase.

## 10.3 ERROR CORRECTION

a) When a fault is discovered within delivered software or documentation, the Contractor shall take necessary steps to rectify errors or faults at the earliest.

b) The Contractor shall provide written details as to the nature of the proposed correction to the Engineer.

c) The Contractor shall notify the Employer promptly of any fixes or patches that are available to correct or patch faults.

d) The Contractor shall detail any effect such fixes or patches are expected to have, upon the applications.

## 10.4 TRAINING

The Contractor shall provide training for the Employer's/Engineer's staff to enable the Employer/Engineer to make proper use of any software and its new versions. In case Contractor fails or unable to provide training, the Engineer may ask for proposal.

# 11. CO-ORDINATION WITH INTERFACING CONTRACTORS

## 11.1 General

a) The Contractor is responsible for detailed co-ordination of his design and construction activities with Interfacing Contractors. Such co-ordination responsibilities of the Contractor shall include the following:

   i. To provide all information reasonably required by the Interfacing Contractors in a timely and professional manner to allow them to proceed with their design or construction activities, and specifically to meet their contractual obligations.

   ii. To ensure that the Contractor's requirements are provided to all other Interfacing Contractors before the cut-off dates to be identified in the Interface Management Plan (IMP).

   iii. To obtain from the Interfacing Contractors information reasonably required to enable the Contractor to meet the design submission dates as identified in Appendix 2.

   iv. Where the execution of the work of the Interfacing Contractors depends upon the site management or information to be given by the Contractor, the Contractor shall provide to such Interfacing Contractors the services or correct and accurate information required to enable them to meet their own programme or construct their work.

   v. To attend regular co-ordination meetings convened by the Engineer with the Interfacing Contractors. The Contractor shall conduct separate meetings with the Interfacing Contractors as necessary to clarify particular aspects of the interfacing requirements of the Works. The party who convenes the meeting shall prepare minutes recording all matters discussed and agreed at the meeting.

   vi. To ensure that copies of all correspondence, drawings, meeting minutes, programmes, etc. relating to the Contractor's co-ordination with the Interfacing Contractors are issued to all concerned parties and the Engineer no later than two (2) calendar days from the date of such correspondence and meetings.

b) The Contractor, shall in carrying out his co-ordination responsibilities, raise in good time and provide sufficient information for the Engineer to decide on any disagreement between the Contractor and the Interfacing Contractors as to the extent of services or information required to pass between them. If such disagreement cannot be resolved by the Contractor despite having taken all reasonable efforts, then the decision of the Engineer shall be final and binding on the Contractor.

c) Where an Interfacing Contract is yet to be awarded the Contractor shall proceed with the co-ordination activities with the Engineer until such time when the Interfacing Contractor is available. The Contractor shall provide the Interfacing Contractor with all information necessary to enable the Interfacing Contractor to follow-on and proceed with their co-ordination.

d) The cut-off dates to be identified in the IMP are the latest dates. Any claim of additional costs by the Interfacing Contractors as a result of the Contractor's failure in adhering to these dates shall be borne by the Contractor. The Contractor shall note that the information exchange is an iterative process requiring the exchange and update of information at the earliest opportunity and shall be carried out on a regular and progressive basis so that the process is completed for each design stage by the cut-off dates.

e) The Contractor shall co-ordinate with the Engineer on all matters relating to works that may affect the Operation & Maintenance of the already operational Section corridor of the of Employer in general. Such work shall be subject to the rules and regulations imposed by the Employer.

### 11.2 Design & Construction Interface

a) The dates shown in Employer's Requirements Appendix 2 are critical to the timely completion of the project. The Contractor shall commence design interface with the Interfacing Contractors as soon as he has been notified by the Engineer that such Interfacing Contract has been awarded. In the case of utility agencies and other statutory boards, interface shall commence as soon as it is practicable. Where no design interface date has been established whether because the Interfacing Contractor(s) have not been identified or for whatever reason, the Contractor shall liase with such Interfacing Contractor/s as soon as they have been awarded.

b) The Contractor shall immediately upon award of the Contract gather all necessary information and develop his design to a level where meaningful interaction can take place as soon as the Interfacing Contracts are available. The Contractor shall submit together with each of his Design Submissions a joint statement from the Contractor and the relevant Interfacing Contractor confirming that design co-ordination has been completed and that they have jointly reviewed the appropriate document to ensure that a consistent design is being presented.

c) The design interface is an iterative process requiring regular exchange and update of interfacing information. The Contractor shall ensure that the information he requires from the Interfacing Contractors is made known at the outset of each design interface and vice versa so that the information can be provided in time for the Contractor and the Interfacing Contractors to complete their design to meet their various design submission stages.

### 11.3 Construction Interface

a) Construction interface will be necessary throughout the duration of the Works commencing from the time the Contractor mobilises to the Site to the completion of the Works. Construction interface will overlap design interface, involving cast-in and buried items such as pipes for electrical and mechanical services, supports, brackets, plinths, ducts, service buildings, openings, cableways, trenches etc. that are to be incorporated at the early stage of the construction up to provision of attendance during the testing and commissioning stage.

b) The Contractor shall ensure that there is no interference with the Works of the Interfacing Contractors and shall maintain close co-ordination with them to ensure that his work progresses in a smooth and orderly manner. The Contractor shall carry out and complete the Works, or any part thereof, in such order as may be agreed by the Engineer or in such revised order as may be requested by the Engineer from time to time. The Contractor shall, unless otherwise provided, be liable for and shall indemnify the Employer against all costs, charges, expenses and the like resulting from failure of the Contractor to co-ordinate the Works as specified.

## 12. SURVEY AND SITE INVESTIGATIONS

a) The datum used for the Contract shall be Mean Sea Level Datum

b) The Contractor shall carry out all further site investigations (such as detailed utility identification, detailed geo technical investigation etc.) necessary for the design of the Permanent Works and to enable the determination of the methods of construction and the nature, extent and design of the Temporary Works.

c) The Contractor shall carry out geotechnical investigation using conventional method of boreholes and geo-physical methods for the entire alignment.

## 13. CLIMATIC CONDITIONS

a) The entire section of HORC with connecting IR Station is situated in the state of Haryana. During summer months the temperature can be as high as 45°C with a high level of humidity, nights can be relatively cool with temperatures dipping to 30°C. Torrential rains and high humidity accompany the monsoon in late June to early September. In the winter months temperatures can vary from a high of 21°C during day to a low of 2°C during night.

b) The information given above is only indicative. The contractor shall obtain detailed climatic data in respect of minimum & maximum temperatures, rain, relative humidity, sunshine, and wind velocity/pressure etc. from "India Meteorological Department publications" and the same shall be taken into account by the Contractor when designing any part of the Permanent Works. The Contractor shall ensure that due allowance is made for more severe local conditions when Permanent Works are required to operate, for example, with restricted ventilation that may lead to higher local ambient temperatures, and any other factors that may affect the operating environment in any way.

c) Unless specific figures are provided elsewhere, the Permanent Works will generally be required to function at its rated value with the values of ambient temperature and relative humidity appropriate to the location of the equipment within the classifications shown in Table given below. Certain parts of the Permanent Works may need to be rated for more or less onerous conditions as required by the PS.

d) The Contractor's attention is drawn to the more severe environmental conditions that may exist during the construction/installation period and shall take adequate measures to protect the Permanent works against any deleterious effects of such conditions during the time between installation and final completion of the project. Also, Air throughout the project will contain considerable moisture content, hence the permanent works shall be tropicalized and vermin proof.

## 14. PROJECT MANAGEMENT INFORMATION SYSTEM (PMIS)

The Contractor shall use PMIS developed by the Employer. All documents generated by the Contractor should be transmitted to the Engineer by electronic means (and vice versa) and that all documents generated by either party will be electronically captured at the point of origin and can be reproduced later, electronically and in hard copy.

## 15. CONTRACTOR'S PROJECT ORGANISATION

a) The Contractor shall have a competent team of Managers, Engineers, Technical staff etc. so as to complete the work satisfactory as per various requirements of the Contract.

b) The designations of the various project organisations team members shall be got approved by the Engineer before adoption so as to avoid any duplication of the designations with those of the Employer or the Engineer.

## 16. CONTRACTOR'S CERTIFICATE

The Contractor shall provide his registration details for GST Registration, EPF registration, ESI registration, Statutory Certificate, Certificate as per ESHS Manual etc. as required for the execution and completion of the Works.

## 17. DELETED

## 18. MAINTENANCE REPORT

i. The Maintenance Report shall be submitted as part of the Definitive Design and shall include full details of the long term inspection and maintenance operations for each major component of tunnels and drainage.

ii. The Contractor shall provide inspection and maintenance manuals for the civil and electrical services.

iii. For each area an inspection checklist shall be supplied giving inspection frequency, items to be inspected, criteria for acceptance, criteria for remedial works and details of the remedial works, including proposed materials and method statements. The recommended regular maintenance regime of each area shall also be given including cleaning methods and frequency for different surfaces; removal of leakage borne salts from concrete surfaces; cleaning of drainage channels, sumps and pipes; repainting of metallic items;

iv. All instruments necessary to carry out the inspections and monitoring that are identified in the report shall be provided by the Contractor within the lump sum tender price.

# Section VII: Employer's Requirements
# Section VII-2: Functional (Civil & BLT)

**EMPLOYER'S REQUIREMENTS –FUNCTIONAL (CIVIL & BLT)**

# OBJECTIVE

The objective of the Contract is the design, construction completion, testing and commissioning of the permanent works by the Contractor (including without limitation, the design, installation and removal of the Temporary Works) and the rectification of defects appearing in Permanent Works in the manner and to the standards and within the time stipulated by the Contract. In full recognition of this objective, and with full acceptance of the obligations, liabilities and risks which may be involved, the Contractor shall undertake the execution of the Works.

# 1 GENERAL

**1.1** The design and performance of the Permanent Works shall comply with the specific core requirements contained in these Employer's Requirements – Functional (Civil &BLT).

**1.2** The design of the Permanent Works shall be developed in accordance with these Employer's Requirements – Functional (Civil & BLT), the Contractor's Technical Proposals, submitted along with this tender and the other requirements of the Contract.

**1.3** The Permanent Works shall be designed and constructed to the highest standards available using proven up-to-date good Engineering practices. The Specification shall in any case not specify standards which, in the Engineer's opinion, are less than or inferior to those described in, Section VII-5: Outline Design Specifications (ODS)-Civil & BLT and Section VII-6: Outline Construction Specifications (OCS)-Civil & BLT contained in the Tender Documents. Construction shall be carried out employing the procedures established by the Contractor as per approved Quality Assurance and Quality Control plan and Environmental, Social, Health and Safety (ESHS) Plan.

**1.4** The Contractor shall be responsible for obtaining all necessary approvals from the relevant Public/Government/Local/Statutory or any agencies in the design and construction of the works.

**1.5** Employer's Requirements- Functional (Civil & BLT) shall be read in conjunction with Employer's Requirements-Design, Construction, Outline Design Specification (ODS)-Civil & BLT, Outline Construction Specifications (OCS)-Civil & BLT and other requirements of the Contract.

# 2 SCOPE OF THE WORKS

## 2.1 Scope under Lumpsum Price Schedule 'A'

HORC project crosses Aravalli Range between Sohna and Dhulawat stations through a tunnel to be constructed in C-4 Package from Ch.24880 m to Ch.29580 m. The tunnelling is required to be done in rock as well as in soil. It involves tunnelling by NATM method and Cut and Cover method. Two separate tunnels are to be constructed - one for Up line and one for Down line. The tunnel is to be provided with Ballastless track (BLT). NATM work is required to be carried out from fourteen faces as shown in Tender drawings. The tunnel has got four permanent ventilation shafts and one construction cum utility shaft. Tentative location of the shafts and area of land which will be made available to the Contractor for working is shown in Tender drawings. The soil excavated from the tunnel will be used for construction of embankment from Ch. km12 to km18. Certain bridges are also involved in formation from Ch. km 12 to km 18.

The Scope of the Works for C-4 Package will be, but not limited to, as follows:

### 2.1.1 Design and Construction of Twin Tunnel

a) Design and Construction of NATM twin Tunnels from Ch. 24880 m to Ch. 28480 m in all types of strata (rock and soil).

b) Design and Construction of Cut & Cover Tunnels from Ch. 28480 m to Ch. 29580 m

c) Design and Construction of four (02x02) Nos. of permanent ventilation shafts and other associated structures shown in the Tender drawings. These permanent ventilation shafts may initially be used for construction of tunnels.

d) Design and Construction of one (01) No. construction cum utility shaft as shown in the Tender drawings. Cross passage between two tunnels of the same size as that of NATM tunnel shall be provided at the location of construction shaft to accommodate electrical installations.

e) Design and Construction of cross passages at an interval of approximately 350m including fire stop doors at both ends as shown in the Tender drawings.

f) Design and construction of portals at both ends of tunnel including drainage arrangement for surface runoff from cut slopes and protection against fall of boulders.

g) Design and construction of drainage system for catering to storm water entering the tunnel from open cutting at approach of Portal P-2 and outfall arrangements near Portal P-1.

h) Design and construction of abutment A-2 of viaduct near Portal P-1.

i) Providing about 500 sqm egress area at Portal P-1 and P-2 along with road connection with existing road for evacuation of passengers during emergency as shown in Tender drawings.

**Note-**Excavated earth/rock from tunnelling/cutting shall be property of the Contractor. Royalty for using the excavated earth/rock for construction of the Works shall be borne by the Contractor. Surplus excavated earth/rock from tunnel shall be disposed off by the Contractor at his own cost.

### 2.1.2 Design and Construction of Ballastless Track

Design and construction of ballastless track including transition from ballastless track to ballasted track at each end and derailment guard in entire length of tunnel as well as in approach of tunnels. The work also includes supply of spares and maintenance of ballastless track for a period of one year after start of traffic.

### 2.1.3 Design and construction of railway formation

Design and construction of railway formation including blanketing (primarily using excavated material from tunnelling/cutting) from Chainage km12.00 to Chainage km 18.00 and from abutment A-2 of viaduct to Chainage km 24.880 for double track of Main line as shown in tender drawings and as per RDSO Guidelines. It shall include the following items also:

a) Design and construction of precast RCC drains on berms.
b) Design and construction of chutes for discharge of water from drains on about 1.0m beyond toe of embankment berms to at an interval of 50 m

The Contractor shall arrange borrow areas for earthwork (required in addition to earth obtained from cutting/tunnelling) in embankment at his own cost.

### 2.1.4 Design and construction of cutting, sump, precast RCC drain on berms in the approach of Portal P-2

a) Design and construction of cutting in a length of 100 m or equal to transition length required between BLT and ballasted track in open cutting in the approach of Portal P-2, whichever is more.
b) Design and construction of side drains and catch water drains in cutting on both sides along with two (02) sumps i.e. one (01) No. on outer side of each track at the junction of Cut and Cover tunnel and cutting.
c) Design and construction of precast RCC drains on berms.
d) Design and construction of chutes for discharge of water from drains on berms to side drain of cutting.
e) Protection of slope of cutting by turfing over coir netting as per IS: 15869, IS:15872 and IRC: 56.

### 2.1.5 Design and construction of slope protection works of embankment

Design and construction of slope protection work of embankment from Chainage km12.00 to Chainage km18.00 by turfing over coir netting as per IS: 15869, IS:15872 and IRC: 56.

### 2.1.6 Design and construction of minor bridges

The Contractor shall design and construct minor bridges (RUBs and waterway bridges) as per list given in **Annexure-F-1.** Minor bridges shall include all components of bridges such as RCC box/RCC hume pipe, wing wall, return wall, face wall, curtain/drop wall, flooring, ground improvement if required, protection of approach embankment slopes for a length of 15 m on each side, boulder backing, granular backfill, inspection steps on both sides of embankment and other incidental works to complete the bridge in all respects as shown in the Tender drawings. RUBs shall be provided with height gauges on each approach road as per RDSO drawing No. M-0001. Drainage arrangement shall be provided for RUBs wherever natural drainage is not available. Repairs to approach roads, wherever required, shall also be carried out by the Contractor.

### 2.1.7 Design and construction of major bridge

The Contractor shall design and construct substructure and superstructure of major bridges as shown in **Annexure- F-2**. Substructure of major bridge shall include foundation, abutment/pier, wing wall, return wall, ground improvement if required, protection of approach embankment slopes for a length of 30 m on each side, boulder backing & granular back fill behind abutment/wing/return wall, inspection platforms for abutments/piers, inspection steps on both sides of embankment, bridge plaque, bridge board and other incidental works to complete in all respects as shown in tender drawings.

**2.1.8** Design of bridges as given in **Annexure-F-3**. These bridge shall be constructed by the Contractor and shall be paid under Schedule-'B'

**2.1.9** Design and construction of precast RCC retaining wall near the toe of embankment wherever ROW is inadequate. Approximate locations of retaining wall is shown in **Annexure- F-4**.

**2.1.10** Design and construction of RCC hume pipe (NP-4) of 450 mm dia/precast RCC box (500mm x 500mm, clear opening) in the embankment from Ch. km 12 to Ch. km 18 at approximately 500m interval for crossing utilities in future.

**2.1.11** All temporary works associated with construction of the works, including construction and maintenance of site office(s) for Engineer's/Employer's staff complete in all respects as per the details given in the Employer's Requirement (Appendix 10 of Section VII-9: Appendices) to the satisfaction of the Engineer for the duration of the Contract.

**2.1.12** Construction of diversion roads and their maintenance based on MORTH specifications including widening, to ensure smooth flow of traffic as per the Traffic Control and Management Plan approved by the Engineer.

**2.1.13** Maintenance of existing roads as per MORTH or DSR specifications as applicable within the length of this contract package in good condition at all times, and restoration to original specifications of all roads and all other works, to complete the Works as contained in the tender documents.

**2.1.14** Provision of barricading including their maintenance and painting in accordance with Section VII-8, Tender drawings and documents and OCS-Civil & BLT for the works & the areas occupied by the Contractor to segregate them from public area.

**2.1.15** Surveying, instrumentation and monitoring, as per Section VII-5: Outline Design Specifications (ODS)-Civil &BLT, for settlement and building protection, risk analysis, settlement prediction, preventive and corrective actions.

**2.1.16** All interfacing works with the Interfacing Contractors as defined in the Appendix 5 of the Contract.

**2.1.17** The Contractor shall be responsible for obtaining approval of drawings of structures by all relevant authorities through the Employer, if required.

**2.1.18** The work content against the lump sum component of the work shall also include, but not limited to, the following:

a) Site clearance and dismantling of obstructions etc., before commencement of work as specified or as directed by the Engineer;

b) True and proper setting out and layout of the Works, benchmarks and provision of all necessary labour, instruments and appliances in connection therewith as specified or as directed by the Engineer;

c) All aspects of quality assurance, including testing of materials as per the approved inspection and test plan and other components of the work, as specified or as directed by the Engineer;

d) Day to day cleaning of worksite throughout the execution period;

e) Maintenance of BLT for one(01) year after Taking Over of the Works;

f) Submission of completion (i.e., 'As-Built') drawings 06 (Six) sets in A-1 size and all other related documents as specified including scanned and AutoCAD copy with soft copies in both formats of all As-built drawings & documents.

g) Preparing detailed designs, general drawings and working drawings for various components of the works and obtaining approval in respect thereof from the Engineer, inclusive of incorporation of all modifications, alterations, changes, etc. that may be required to be carried as directed by the Engineer ;

h) Compliance of requirements of Environmental, Social, Health and Safety (ESHS) Plan.

i) Results of sub-surface investigations conducted at project site are enclosed with the Tender document. This information about the rock, soil and sub-soil water conditions is being made available to the contractor in good faith and the contractor shall have to obtain the details of sub soil parameters independently. No claim whatsoever on account of any discrepancy about the rock/soil parameters and sub soil water conditions that may be actually encountered at the time of execution of the work and those given in these tender documents shall be admissible to the contractor under any circumstances.

### 2.1.19 CONTRACTOR'S FACILITIES & SITE OFFICE

For batching plant, field quality control laboratory, site office and other activities (excluding labour camps) certain area of land as shown in Tender drawings will be made available by the Employer on as is where is basis free of cost. This land shall be made good for such offsite activities as needed by the Contractor at no extra cost to the Employer. The land shall be cleared from debris, all structures made by the contractor including, RCC footings and rafts etc. and reinstated to the line, level and to the same conditions as existed before the work started before handing over back to the Employer within 91 days after Taking over Certificate. The final bill shall be released to the contractor after all structures from the Contractor facility and site office are removed & clearance of site. The cost of setting up of all the above mentioned facilities & the office and reinstatement of site is included in lump sum price in Schedule 'A'.

## 2.2 Scope under BOQ Schedule 'B'

Under this Schedule, the Contractor is required to carry out works which are not covered in Schedule 'A'. Broadly following works shall be carried out under this Schedule 'B':

a) Construction of approach roads for shafts and portals including paving of area.

b) Construction of bridges as per list given in Annexure-F-3

c) Any other item as directed by the Engineer related to the Works.

## 2.3 Scope under Schedule 'C' (Item Rate for miscellaneous works)

Under this Schedule, the Contractor is required to carry out works which are not covered in Schedule 'A' or Schedule 'B'.

a) Diversion of all uncharted utilities, if required, as per approved plan.

b) Any other activity as directed by the Engineer

## 2.4 REFERENCE TO THE STANDARD CODES OF PRACTICE

**2.4.1** All Standards, Outline Construction Specifications (OCS)-Civil & BLT, Technical Specifications and Codes of Practice referred to shall be latest editions including all applicable official amendments and revisions. The Contractor shall make available at site all relevant Indian Standard Codes of practice, IRS, IS, IRC, UIC, as applicable.

**2.4.2** Wherever Indian Standards do not cover some particular aspects of design/ construction, relevant International Standards will be referred to. The Contractor shall make available at site such standard codes of practice.

**2.4.3** In case of discrepancy among Standard codes of practice and Section VII-6: Outline Construction Specifications (OCS)-Civil &BLT, the order of precedence shall be as given below:

a) Outline Design Specifications-Civil &BLT

b) Outline Construction Specifications-Civil &BLT
c) Standard Codes of Practice.
   In case of discrepancy among Standard Codes of Practice, the order of precedence will be
   (i) IRS,
   (ii) IS,
   (iii) IRC,
   (iv) other International codes
d) Indian Railway Unified Standard Specifications,
e) CPWD specifications,
f) NBC 2016,
g) MORTH Specification for Road & Bridges,

## 2.5 DIMENSIONS

As regards errors, omissions and discrepancies in Specifications and Drawings, relevant clause of Particular Specification will apply. The levels, measurements and other information concerning the existing site as shown on the conceptual / layout drawings are believed to be correct, but the Contractor should verify them for himself and also examine the nature of the ground as no claim or allowance whatsoever shall be entertained on account of any errors or omissions in the levels or strata turning out different from what is shown on the drawings**.**

## 2.6 INSPECTION

The Employer may appoint an independent agency to ensure the quality checking of design, supply, fabrication, erection and construction of all works under Scope of the Works. The Contractor shall ensure the complete co-operation with the agency to perform their work satisfactorily. In addition, the Employer also reserves right to undertake quality check and inspection directly by itself.

## 2.7 ALIGNMENT OF TRACKS (TUNNEL, CUTTING & EMBANKMENT)

**2.7.1** The alignment shall be as shown in the Tender drawings. The alignment has been developed by the Employer to meet operational and technical criteria. The Contractor is not required to evaluate the alignment for compliance with these criteria, but shall review it with respect to his own design and construction proposals and shall also satisfy himself that it suits to the available land width and there is no conflict with any existing and planned structures which are to be preserved.

**2.7.2** The Contractor is permitted to propose deviations in alignment to suit his construction proposals, but he must demonstrate that any such deviations do not reduce the technical and operational performance. The Contractor needs to verify the contract boundaries while proposing any change in vertical and/or horizontal alignment but such deviations shall require prior approval of the Employer subject to following conditions: -

a) There is no extra cost to the Employer

b) Changes proposed are essentially required to suit the contractor's specific design

c) There is no change at the contract boundaries or if there is any, the same is agreed by the Contractor of the adjoining section without any extra cost to the Employer.

## 2.8 CLEARANCES

**2.8.1** The Permanent Works shall not infringe the Fixed Structure Gauge in tunnels as shown in the drawings and Indian Railway Schedule of Dimensions (IR SOD) at other places. Extra clearance shall be provided on curved alignment as per IR SOD.

**2.8.2** The Permanent Works shall provide for the installation of operating equipment for the railway without infringement of the Fixed Structure Gauge and IR SOD.

## 2.9 DURABILITY AND MAINTENANCE

**2.9.1** The Permanent Works shall be designed and constructed such that, if maintained reasonably and in accordance with the Contractor's statement of maintainability contained in the Contract, they shall endure in a serviceable condition throughout their minimum lives as described under Sub-Clause 1.3.2 and 1.3.3 of the Section VII-5: Outline Design Specifications (ODS)-Civil & BLT and in above mentioned paragraphs.

The Permanent Works shall be designed and constructed so as to minimise the cost of maintenance whilst not compromising the performance characteristics and ride quality of the railway.

## 2.10 OPERATIONAL REQUIREMENTS

**2.10.1** The Permanent Works shall be designed to permit the railway to operate satisfactorily at a maximum design speed of 160 kmph where applicable.

**2.10.2** During construction the Contractor shall be responsible for providing and maintaining adequate flood protection to the works.

## 2.11 ENVIRONMENTAL CONSIDERATIONS

All provisions and conditions contained in the Environmental, Social, Health and Safety (ESHS) Manual as per Appendix 13 of Section VII-9: Appendices, Part 2, Employer's Requirements shall be strictly complied with.

## 2.12 FUNCTIONAL REQUIREMENTS REGARDING INTERFACE WITH CONCERNED AUTHORITIES

Requests for temporary power supplies for the construction of the works must be submitted by the Contractor to the concerned authorities. Alternatively separate power supplies may be arranged by the Contractor subject to compliance with all necessary statutory requirements, especially pollution control.

## 2.13 TRAFFIC MANAGEMENT

The Contractor shall carry out the Works so as to minimise disruption to road and pedestrian traffic. The Contractor shall prepare his traffic management plan based on his proposed construction methodology in co-ordination with Engineer and in conjunction with the concerned road authority as per Appendix 10. He shall comply strictly with the approved plan during construction of his plan.

## 2.14 CRS INSPECTION

The Contractor shall note that the Commissioner for Railway Safety (CRS) will inspect the Works from time to time for the purpose of determining whether the HORC Project complies in terms of operational and infrastructural safety in accordance with the Laws of India. The contractor shall note that CRS approval is mandatory for commissioning the system. Notwithstanding other provisions of the Contract, the Contractor shall ensure that the Works comply with the requirements of CRS. The Contractor shall make all necessary arrangements for assisting CRS in carrying out his inspection duties and also comply with his instructions regarding rectifying any defects and making good any deficiencies. Contractor shall prepare and make available all drawings, documents, sketches, photographs etc. as required for submission of application for inspection of CRS as instructed by the Engineer.

## 2.15 STANDARDS

**2.15.1** Equipment, materials and systems shall be designed, manufactured and tested in accordance with the latest issue of National and/or International codes and standards. The Contractor shall submit copies to the Engineer of all codes and standards used for the work.

**2.15.2** Reference to standards or to materials and equipment of a particular manufacturer shall be regarded as followed by the words "or equivalent". The Contractor may propose alternative standard materials, or equipment that shall be equal to or better than those specified. If the Contractor for any reason proposes alternatives to or deviations from the specified standards, or desires to use materials or equipment not covered by the specified standards, the Contractor shall apply for the consent of the Engineer. The Contractor shall state the exact nature of the change, the reason for making the change and relevant specifications of the materials and equipment in the English language. The decision of the Engineer in the matter of quality will be final.

**ANNEXURE-F-1**

**LIST OF MINOR BRIDGES UNDER SCHEDULE-A**

| MAIN LINE | | | | | |
|---|---|---|---|---|---|
| **S.NO.** | **Br. No.** | **Chainage (M)** | **Type of Crossing** | **Type of Bridge** | **SPAN No. x L (in m) x H (in m)** |
| 1. | 47 | 12208.018 | Balancing Culvert | RCC Box | 1x2.00x2.00 |
| 2. | 48 | 12298.018 | Road + Drain | 2 Cell RCC Box | 5.00x5.00+4.00x5.00 |
| 3. | 49 | 12341.836 | Balancing Culvert | RCC Pipe | 1x1.8 |
| 4. | 50 | 12645.715 | Balancing Culvert | RCC Box | 1x2.00x2.00 |
| 5. | 51 | 13114.998 | Field Canal | RCC Box | 1x3.00x3.00 |
| 6. | 52 | 13903.112 | Field Canal | RCC Box | 1x3.00x3.00 |
| 7. | 54 | 14601.627 | Field Canal | RCC Box | 1x3.00x3.00 |
| 8. | 55 | 14756.727 | Road | RCC Box | 1x5.00x5.00 |
| 9. | 56 | 15100.394 | Balancing Culvert | RCC Box | 1x2.00x2.00 |
| 10. | 57 | 15944 | Road | RCC Box | 1x5.00x5.00 |

*Main line Chainages start from Prithla station of HORC.

**ANNEXURE-F-2**

**LIST OF MAJOR BRIDGES UNDER SCHEDULE-A**

| MAIN LINE | | | | | |
|---|---|---|---|---|---|
| **S.NO.** | **Br. No.** | ***Chainage (M)** | **Type of Crossing** | **Type of Bridge** | **SPAN**<br>**No. x L (in m) H (in m)** |
| 1. | 62 | 17500 | Road | PSC U-Slab | 1x12.20 |

*Main line Chainages start from Prithla station of HORC.

**ANNEXURE-F-3**

**LIST OF BRIDGES UNDER SCHEDULE-B**

| | | | | | |
|---|---|---|---|---|---|
| **S.NO.** | **Br. No.** | ***Chainage (M)** | **Type of Crossing** | **Type of Bridge** | **SPAN**<br><br>**No. x L (in m) H (in m)** |
| 1. | 53 | 14472.112 | Stream | Composite Girder | 2x24.40** |
| 2. | 58 | 16127 | Canal | PSC U-Slab+ RCC box abutment | 1x12.20 + 1x5.00x5.00 |
| 3. | 59 | 16727 | Road | PSC U-Slab | 2x12.20 |
| 4. | 60 | 16827 | Road | RCC Box | 2x7.00x5.60 |
| 5. | 61 | 16917 | Canal | PSC U-Slab | 1x12.20 |

*Main line Chainages start from Prithla station of HORC.
**Fabrication & erection of composite steel superstructure is not in the scope of work.

**ANNEXURE-F-4**

**APPROXIMATE LOCATIONS OF RETAINING WALL**

| S.NO. | Location (Chainage m) and Length (m) | | | Approx. height (m) |
|---|---|---|---|---|
| | From | To | | |
| 1 | 12000 | 12040 | 40 | 1.25 to 1.75 |
| 2 | 12040 | 12080 | 40 | 1.0 to 1.25 |
| 3 | 12100 | 12140 | 40 | 0.5 to 1.0 |
| 4 | 17300 | 17360 | 60 | 1.25 to 1.75 |
| 5 | 17380 | 17400 | 20 | 0.5 to 1.0 |
| | Total Length(m) | | 200 | |

# Section VII: Employer's Requirements

## Section VII-3: Design (Civil and BLT)

**EMPLOYER'S REQUIREMENTS – DESIGN (CIVIL & BLT)**

## 1. INTRODUCTION

1.1 The Employer's Requirements - Design, specifies the procedural requirements for the preparation of the design of the Permanent Works. These requirements are subdivided into: **Design Phase**, **Construction Phase** and **General Application**.

1.2 In addition to the express requirements herein, the Contractor shall, whenever the Engineer so requests, provide information and participate in discussions that relate to design matters.

1.3 The Contractor shall engage the Designer who shall undertake and prepare the design of the Permanent Works and Temporary Works. The Contractor shall place his core design team at Gurugram.

1.4 The Contractor shall ensure that the Designer shall be associated during construction of NATM tunnel at least throughout the NATM Main Drive and shall review the primary support adequacy as the excavation proceeds and propose any change in primary support system requirement due to encountered geology for the approval of Engineer including the interpretations of monitoring Data.

1.5 The Contractor shall submit his Quality Assurance Plan as required in Appendix 11, Section VII-9: Appendices, Part 2- Employer's Requirements for the design required by the Contract.

1.6 The Design and Construction Standards shall be in conformity with the requirements of "Rules for Opening of a Railway or a Section of a Railway for Public Carriage of Passengers" and to the satisfaction of the Commissioner of Railway Safety whose sanction is mandatory for commissioning of the System.

1.7 The Contractor shall get the design of NATM tunnel, Cut & Cover tunnel, BLT, Permanent Ventilation Shafts and Portals, proof checked by Detailed Design Consultant appointed by the Employer. The cost of proof checking shall be borne by the Employer. Proof checked design shall be submitted to the Engineer for approval.

## 2. REQUIREMENTS DURING DESIGN PHASE

2.1 The principal requirements of the Design Phase are the production of the Preliminary Design and General Arrangement Drawings, the Definitive Design and the Construction Reference Drawings. It should be clearly understood that the Tenderer's technical proposal submitted along-with his tender including any modifications to the same during negotiations stage shall only form the basis for further design development into the preliminary and Definitive design, subject to the same conforming to the Outline Design Specifications.

2.2 Preliminary Design

The Preliminary Design shall define the main structural elements. In addition, General arrangement drawing, general construction methods and documentation needed to develop the Definitive Design shall be submitted.

2.3 Definitive Design -Tunnel

2.3.1 The Definitive Design shall accord with and incorporate the Preliminary design and shall be the design developed to the stage at which all elements of the primary support of the tunnel, final lining and structures are fully defined and specified and in particular:

(a) Calculation and analysis duly incorporating the expected geological variations are complete for primary support system required for NATM tunnel, final lining and temporary support system for any other works;

(b) all element of primary support for NATM tunnel are delineated;

(c) all main and all other significant elements are delineated;

(d) all field and laboratory tests are carried out to a reasonable extent to evaluate geological conditions and geotechnical parameters required for design of NATM tunnel and other associated works;

(e) all tests and trials for the performance of NATM tunnels, primary support system elements such as rock bolts/dowels, shotcrete creep tests, etc. and selection of materials and equipment required for installation of primary support system and final lining of tunnel;

(f) shall take full account of effect on the permanent works of the proposed excavation schemes and primary support system used herein on the final lining to be installed and commissioned for NATM tunnel;

(g) shall take full account of the effect on the Permanent Works of the proposed methods of construction and of the Temporary Works.

(h) Interface Management Plan (IMP).

2.3.2 During the preparation of the Definitive Design, the Contractor shall complete all surveys investigations, Geological investigation and related field and laboratory test and shall submit Geotechnical interpretative report for the full alignment. The Geotechnical interpretative report shall clearly include all parameters (elastic and strength parameters) required for analysis and design of primary and secondary support system for the tunnel.

2.4 Definitive Design -Bridges, BLT and other civil structures

2.4.1 Definitive Design shall be the design developed to the stage at which all elements of the structures are fully defined and specified and in particular:

**a)** Calculation and analysis are complete;

**b)** All main and all other significant elements are delineated;

**c)** All tests and trials and all selection of materials and equipment are complete;

**d)** Shall take full account of the effect on the Permanent Works of the proposed methods of construction and of the Temporary Works.

**e)** Interface Management Plan (IMP).

2.4.2 During the preparation of the Definitive Design, the Contractor shall complete all surveys investigations and testing necessary to complete the design of the Permanent Works.

2.5 The Contractor shall sub-divide the proposed Definitive Design into Design Packages to be submitted in advance of the Definitive Design Submission and to be identified in the Design Submission Programme. The Design Packages are to relate to the significant and clearly identifiable parts of the proposed Definitive Design and shall address the design requirements as described herein. The Design Packages shall facilitate the review and understanding of the Definitive Design as a whole and shall be produced and submitted in an orderly, sequential and progressive manner.

2.6 Separate Definitive Design Submissions may be prepared for those major elements to be procured by sub-contract and which sub-contracts include design. Where such work is to be procured by the Contractor on the basis of outline design, design briefs and performance specifications, such documents may be submitted as Definitive Design Submissions.

2.7 Upon issue of the Notice in respect of the Definitive Design Submission, the Contractor shall complete the design in all respects and produce the Construction Reference Drawings, the purpose of which is to illustrate all kinds of primary support system suiting to geological variations expected to be encountered along the alignment and in case of geological conditions encountered or not envisages one of the situation, the proposal shall be submitted to the Engineer for approval and immediate requirement of support shall be carried out at least with the consent of the Engineer and detailed scheme with supporting calculations shall be submitted for the approval of the Engineer. For the Permanent Works construction reference drawings shall be submitted complete in all respect for the purpose they are intended.

2.8 Construction Reference Drawings shall fully detail for the construction of the elements covered by the Definitive Design and shall show in full the works to be constructed.

## 3. REQUIREMENTS DURING CONSTRUCTION PHASE

**3.1** The selection of the support system on the basis of geological conditions encountered during excavation

**3.2** The review of adequacy of primary support on the basis of geological conditions variations encountered with respect to expected geological conditions assumed at Definitive Design Stage

**3.3** Performance/adequacy of the primary support system elements for NATM tunnel by conducting pull-out test on support elements such as rock bolts/dowels, creep test of shotcrete.

**3.4** The response of tunnel after installation of primary support in terms of inward movements and loading on the support elements evaluated on the basis of instrumented data gathered from load cells, strain gauges, etc. for shotcrete as well as rock bolts/dowels.

**3.5** The principal requirements relating to design during the Construction Phase are the production of Working Drawings, the preparation of technical submissions as required under the Contract, the compilation of the Final Design and the production of the "As-Built" Drawings.

**3.6** Working Drawings shall be prepared as required under the Contract. They shall be endorsed by the Contractor as being in accordance with the Construction Reference Drawings.

**3.7** The Contractor shall endorse the submissions required under the Contract that "all effects of the design comprising the submission on the design of adjacent or other parts of the works have been fully taken into account in the design of these parts"

**3.8** At least 3 months but not more than 6 months prior to the anticipated date of substantial completion of the Works, the Contractor shall submit the Final Design to the Engineer.

**3.9** The Final Design is the design of the Permanent Works embodied in:

a) the latest revisions of the documents comprised in the Definitive Design, taking account of comments in the schedules appended to Notices of No Objection
b) the latest revisions of the Construction Reference Drawings;
c) the calculations (see Clause 11 below); and
d) co-ordinated interfaces and such other documents as may be submitted by the Contractor at the request of the Engineer to illustrate and describe the Permanent Works and for which a Notice has been issued.

**3.10** The Contractor shall maintain all records necessary for the preparation of the As-Built Drawings. Upon completion of the Works or at such time as agreed to or required by the Engineer, the Contractor shall prepare drawings which, subject to the Engineer's agreement, shall become the As-Built Drawings. All such drawings shall be endorsed by the Contractor as true records of the construction of the Permanent Works and of all temporary works that are to remain on the site. The Contractor shall also show the locations of utilities exposed, and retained as directed.

## 4. DESIGN INTERFACES WITH INTERFACING CONTRACTS

The Contractor shall co-ordinate all design and installation work with the various Interfacing Contractors as described in Appendix 5, Section VII-9: Appendices, Part 2- Employer's Requirements.

## 5. DESIGN SUBMISSIONS

### 5.1 Preliminary Design Submission

The preliminary design shall provide initial design documents for review and shall be sufficiently detailed to show the element of the design main and documents required for preparation of the definitive design. It shall also include:

(a) the quality assurance plan for design

(b) review of the outline design criteria

(c) the submission of design manuals

(d) the submission of proposed software

(e) the proposed geological/ geotechnical investigations/ test

(f) the preliminary onsite testing recommendation for bridges and other civil structures

(g) outline of proposed design philosophy (NATM)

(h) Equipment likely to be used for excavation and installation of support system including shotcrete

(i) the preliminary equipment layouts and details

(j) the preliminary off site testing recommendation

(k) the submission of specifications proposed for NATM, BLT, Bridges and other civil works

(l) the identification of design codes and standards

(m) the CAD procedures

(n) preliminary section of the NATM tunnel shape and size, keeping the rail level same as indicated in the tender drawings and keeping the provisions for systems such as OHE, walkway and other Electrical services

(o) outline primary support system for NATM tunnel in soil or rock or partially in rock and partially in soil

(p) an alignment review

(q) the preliminary construction methodology for NATM tunnel, Cut & Cover tunnel, portals and permanent ventilation shafts, BLT, Bridges and other civil works

(r) the design submission programme (update)

(s) the utility diversion plan

(t) proposed site surveys and other field surveys

(u) the preliminary ground treatment proposal

(v) The preliminary reinstatement drawings.

(w) GAD of bridges

## 5.2 Definitive Design Submission

5.2.1 General

The Definitive Design Submission shall be a coherent and complete set of documents properly consolidated and indexed and shall fully describe the proposed Definitive Design. In particular, and where appropriate, it shall define:

a) the dimensions of all major features, primary and secondary support system for NATM tunnel, structural elements and members;

b) the details of the portals and primary support system at permanent ventilation shafts;

c) all materials including rock bolts/dowels, pipe roofing, lattice girder and shotcrete;

d) Submission of GIR

e) expected loading on the primary and secondary support system depending upon geological conditions & overburden, deformations inside the tunnel and surface settlements;

f) potential forces and movements due to excavation on the primary support system and final lining of the NATM tunnel,

g) potential forces and movements due to all possible loadings and actions, and their accommodation;

h) all second order effects;

i) the layout and typical details of reinforcement in structural concrete members including tunnel lining;

j) the locations and nature of all relevant joints and connections and details thereof;

k) standard details;

l) location, geometry and setting-out of all main elements and features;

m) provisions and proposals for construction interfacing with the Interfacing Contractors;

n) construction sequences and shuttering arrangements for tunnel lining;

o) utilities to be diverted /supported;

p) proposed methods of predicting the ground movements due to work and adjacent to the excavations;

q) Erection/launching scheme of bridge girders/slabs.

r) predictions of effect on structures due to ground movements and the proposed protective measures to limit the effects to a degree not exceeding the limit as defined under the Outline Design Specifications (Design Criteria);

s) Traffic or other civic service affected;

t) Prediction of lowering of water table and its effect on the works; and

u) Cross Passages.

**5.2.2 Drawings**

The Definitive Design Submission shall include drawings that shall illustrate the proposed Definitive Design and in particular shall include, without limitation:

a) General Arrangements;

b) Layouts and details of structural elements for BLT, bridges and other civil works

c) Expected geological conditions along the alignment;

d) Support arrangement and construction methodology for portals, and permanent ventilation shafts,

e) Excavations sequence and details of the support system and their sequencing for the tunnel in all kind of expected geological strata;

f) Detail of the portals and permanent ventilation shafts;

g) Associated support arrangements;

h) Earthwork in formation and cutting including slope protection;

i) Structural and surface drainage;

j) Access roads and temporary road works;

k) Bridge works

l) Existing and proposed utilities;

m) Road works and works related to traffic management including decking.

n) Embedded items

o) Excavation Machines and Back-up Equipment

p) Cross passages

5.2.3 *Contract Specification*

The Specification included in Outline Design Specification and Outline Construction Specifications shall be amplified so as to specify comprehensively the design and construction of the Permanent Works.

*5.2.4 Design Manual*

The Design Manual shall incorporate all design requirements, standards, codes, loading cases, permissible movements and deflections, excavations scheme, characteristics of primary and secondary support system including shotcrete, limit states, design stresses and strains, material properties and all other documents or matters which are relevant to and govern the design. The Design Manual shall refer to all materials, codes and standards used, making clear their specific applications. The Design Manual of tunnel shall specifically state methodology of design of excavation of tunnel, adequacy of the primary and secondary support system of the tunnel including excavation scheme, Permanent Works as a comprehensive reference text and efficient working document

5.2.5 Interface Report on Interfacing Contractors

This will include the following:

(i) Details of the design and construction of the Works adjacent to other contracts.

5.2.6 Testing and Commissioning Report: Details of proposals for testing and commissioning procedures for all relevant elements and equipment contained in the Permanent Works.

**5.2.7 Supporting Documents**

The Definitive Design Submission shall be accompanied by the following documents, which will be considered by the Engineer in his review of the Definitive Design Submission. Where relevant or required, these documents shall be accompanied by a design note stating clearly how information has been used in the design of the Permanent Works.

***5.2.8 Geotechnical Interpretative Report***

A report including site investigation results and covering the geotechnical interpretation of site investigation work including that undertaken by the Contractor in sufficient detail to confirm and justify parameters used in the tunnel foundation and geotechnical designs. The report shall include the full logs and descriptions of confirmatory boreholes drilled by the Contractor.

***5.2.9 Survey Report***

A report on all survey work undertaken by the Contractor, including checks on mapping, survey stations, co-ordinates and setting-out. Updated topographical and survey drawings shall also be included.

***5.2.10 Utilities Report***

A report giving details of arrangements and working methods in respect of the existing utilities, including protection measures, diversions, reinstatements and programme allowances.

***5.2.11 Temporary Works Design Report***

A report which provides sufficient information on the design of the Temporary Works to allow the Engineer to assess their effects on the Permanent Works and to enable these to be taken into account in the review of the Definitive Design.

***5.2.12 Primary Support Design Report for NATM***

A comprehensive report which provides sufficient details for primary support design including calculations as well as for final tunnel lining shall be furnished. The primary support system shall be designed for various geological conditions expected to be encountered during excavation.

***5.2.13 Construction / Installation Analysis Report***

A report containing a stage-by-stage construction/installation sequence for all structures/equipment.

***5.2.14 Construction Method Statement***

A report which provides sufficient information on primary and secondary support system including elements of support system and list of the equipment proposed to be used and for other works, the methods of construction and Contractor's Equipment to allow the Engineer to assess their effects on the Permanent Works and to enable these to be taken into account in the review of the Definitive Design.

***5.2.15 Project Schedule Review***

(i) The Contractor shall, prior to submitting the Definitive Design Submission, review the Project Schedule against the current version of the Design Submission Programme.

(ii) In the event that the Contractor considers that there are any discrepancies or inconsistencies between the Design Submission Programme and the Project Schedule, the Contractor shall submit with the Definitive Design Submission its proposed revisions to the Project Schedule such that the discrepancies or inconsistencies are removed.

(iii) The Contractor shall provide details of submissions of the proposed Working Drawings and their anticipated timing during the Construction Phase and shall identify information required from or actions to be undertaken by the Employer or others which are necessary to permit the completion of the design of the Permanent Works and the Working Drawings. Desired Dates for the receipt required by the Contractor of such information or for the completion of such actions shall be included with appropriate justification.

### 5.2.16 Report on the Use of Works Areas

A report updating the proposals from those contained in the Contractor's Technical Proposals for the use of Works Areas and their reinstatement, detailing the tunnel accesses and accesses facilities.

### 5.2.17 Notices on Definitive Design Submission

The Contractor may make Definitive Design Submissions and seek separate Notices in respect of:

a) The temporary works for bridges, permanent construction shaft and portals of the underground works.

b) All works related to the lengths or sequence of excavation scheme for tunnel which will be excavated from one location together with any intervening works.

c) Major elements as identified under Sub-Clause 2.7 above.

The issue of such separate Notices under above mentioned points shall be conditional upon the Contractor having demonstrated, to the satisfaction of the Engineer, that the effect of each structure on other structures, utilities, etc., has been fully accommodated in the design.

## 6 DESIGN SUBMISSIONS – CONSTRUCTION REFERENCE DRAWINGS SUBMISSIONS

6.1 The Construction Reference Drawings shall be derived directly from the Definitive Design and shall detail and illustrate in full the Permanent Works. The Construction Reference Drawings shall form part of the Working Drawings to be used for construction purposes.

6.2 Prior to any Construction Reference Drawings Submission, the Contractor shall prepare a full list of Construction Reference Drawings in order to demonstrate, to the satisfaction of the Engineer, that such Construction Reference Drawings will be sufficient in extent to cover the construction of the whole of the Permanent Works.

6.3 Unless otherwise required by the Engineer, the Construction Reference Drawings need not include bar bending schedules, bar reference drawings, fabrication or shop drawings as well as other schedules or erection drawings which are to be provided by the Contractor during the Construction Phase.

6.4 The latest Construction Reference Drawing for which Notice has been issued by the Engineer shall be drawn on a tracing film duly signed by the Designer and the Contractor and shall be submitted to the Engineer for his approval. The Engineer will issue Notice in respect of such drawings, endorse them and return to the Contractor. The Contractor shall endorse such drawings as "Good For Construction (GFC)" and shall issue them to the Site for execution of the works.

## 7 DESIGN SUBMISSIONS – CONSTRUCTION PHASE

7.1 The Contractor shall prepare proposed Working Drawings such as site sketches, bar bending schedules, bar reference drawings, fabrication and shop drawings, construction erection sequences and the like. All such drawings shall be based on Construction Reference Drawings and shall comply with the requirements of the Contract. Working Drawings shall be submitted to the Engineer for his approval.

7.2 If the Working Drawings are considered in order, the Engineer shall issue Notice in respect of such drawings, endorse them and return to the Contractor. On the endorsement by the Engineer, the original will forthwith be returned to the Contractor as the Working Drawings. The Contractor shall endorse such drawings as "Good For Construction (GFC)" and shall issue them to the Site for execution of the works.

7.3 The contractor shall finalize details of the excavation scheme and installation sequence of primary support system and submit such finalized details to the Engineer for review. The proposed excavation scheme and primary support system requirement and installation sequence shall not adversely affect the final lining.

7.4 The Contractor shall finalise details of the proposed method of construction and submit such finalised details to the Engineer for review. The proposed method shall have no adverse effects on the partially completed Permanent Works and shall ensure the Works are statically and, if appropriate, aerodynamically stable.

7.5 The Contractor shall undertake and submit a stage by stage construction sequence and the effect of any Temporary Works and the Contractor's Equipment on the Permanent Works. This analysis shall be in sufficient detail to demonstrate that the Contractor's proposals are safe and have no adverse effects upon any parts of the Permanent Works.

7.6 As-Built Drawings, endorsed by the Contractor shall be submitted to the Engineer for agreement in accordance with Clause 5.5 of the GCC and in electronic format using a commercially available CAD program.

## 8 DESIGN SUBMISSIONS - REVIEW PROCEDURES

8.1 Submissions of Design Data shall be made and reviewed by the Engineer. The form and detail of the review shall be as determined by the Engineer and will not release or remove the contractor's responsibility for the design under the contract.

8.2 The issue of a Notice shall be without prejudice to the issue of any future Notices.

8.3 The Contractor shall, prior to the submission of the Design Data, obtain all required and/or statutory approvals that relate to that submission including, where appropriate, the approval of the Concerned Government Authorities and utility undertakings, and demonstrate that all required approvals have been obtained.

8.4 All submissions shall be accompanied by two original copies of a `Design Certificate' as set out in Attachment D1 hereto and signed by the Contractor and the Designer.

## 9 DESIGN SUBMISSION PROGRAMME

9.1 The Contractor shall prepare the Design Submission Programme which is to set out fully the Contractor's anticipated programme for the preparation, submission and review of the Design Packages, the Definitive Design Submission and the Construction Reference Drawings Submissions and for the issue of Notices in relation thereto.

9.2 The Design Submission Programme shall:

(a) be consistent with and its principal features integrated into the Works

Programme, and show all relevant Key Dates;

(b) identify dates and subjects by which the Engineer's decisions should be made;

(c) make adequate allowance for periods of time for review by the Engineer and other review bodies;

(d) make adequate allowance for the design and development of specialist works;

(e) include a schedule identifying, describing, cross-referencing and explaining the Design Packages into which the Contractor intends to divide the Definitive Design and Construction Reference Drawings; and

(f) indicate the Design Interface and Co-ordination periods for the Concessionaire and each Designated Contractor.

9.3 The Contractor shall submit the Design Submission Programme to the Engineer within thirty (30) days of the Commencement Date, and thereafter up-dated versions thereof at intervals of not more than one (1) month throughout the Design Phase.

## 10 PROGRAMME FOR SUBMISSIONS DURING THE CONSTRUCTION PHASE

In accordance with Clause 4 of the Employer's Requirements - General, the Contractor shall identify submissions required during the Construction Phase.

## 11 CALCULATIONS

11.1 Unless otherwise required by the Engineer, calculations relevant to the Definitive Design and Construction Reference Drawings shall be submitted for review with the respective Design Packages or Submissions. The Engineer may require the submission of applicable software including in house software programmes/worksheets developed by the Contractor, computer input and programme logic for its review prior to the acceptance of the computer output.

11.2 The Contractor shall prepare and submit a comprehensive set of calculations for the Definitive Design in a form acceptable to the Engineer. If the design of the Permanent Works be revised thereafter and such revision renders the calculations as submitted obsolete or inaccurate, the Contractor shall prepare and submit the revised calculations

11.3 Similarly, the Contractor shall submit such further calculations as have been prepared in connection with the Construction Reference Drawings. Calculations to be included as part of the submission herein shall comprise the up- to-date calculations in respect of the Definitive Design, the Construction Reference Drawings and such further calculations which the Contractor has prepared during the production of Working Drawings.

11.4 The Contractor shall submit all calculations necessary to support proposals relating to the construction methods.

## 12 DOCUMENTS REQUIREMENTS

12.1 Drawings shall be prepared generally to A1 size, but to ISO AO size where appropriate. Appendix 7 of Section VII-9: Appendices, Part 2 -Employer's

Requirements defines the Drawings and CAD Standards required for drawing preparation and submittal.

12.2 The Contractor shall submit 3 copies of his design and/or drawings for review by the Engineer. After receipt of "No Objection" from the Engineer, the Contractor shall submit 6 copies of design and/or drawing for the use of the Engineer.

12.3 The submission of drawings may be by CAD Media files and Appendix 9 specifies drawing Submission requirements for CAD Media files.

12.4 The contractor to provide two licensed working software copy being used by its DDC to Employer/Engineer's design department maintained for the entire contract period.

## 13 Detail Design Consultant (DDC) for Ballastless Track (BLT) System

13.1 Upon award of the Contract, the Contractor shall engage Detail Design Consultant for design of BLT. The Contractor shall submit details of DDC proposed to be engaged for Design of Ballastless track system for the approval of the Engineer. DDC shall be engaged within twelve months of the Commencement Date.

13.2 DDC shall have the experience of design of BLT of at least 10 Km length having satisfactory working performance under mixed traffic conditions with at least 22 tonne axle load and at an operational speed of at least 130 kmph for at least 5 years since the date of its operation as on date of opening of the Tender.

13.3 DDC shall submit experience certificate for design of ballastless track system issued by the user railway administration. The certificate shall specifically indicate that the designer has designed ballastless track system (including fastening system) of at least 10 Km length. The certificate shall clearly state that ballastless track system is having satisfactory working performance under mixed traffic conditions with at least 22T axle load and at an operational speed of at least 130Kmph. The certificate shall state the date of start of operation on ballastless track system and the duration for which ballastless track system has been in continuous operation.

In case the user railway administration is from foreign country and the certificate is issued in language other than English, the supporting documents shall be translated into English. The translation of the certificate shall be either stamped by Embassy/High Commission of India or Partner Countries of Hague convention may submit these documents with "Apostille" stamp. The experience certificate issued by foreign user railway administration in English shall also be either stamped by Embassy/High Commission of India or submitted with "Apostille" stamp.

13.4 DDC proposed to be engaged shall submit details containing, but not limited to, the name of line in which the system is in use for minimum 5 years, details of user railway administration such as name of the Railway administration and its contact person, address, telephone number, E-mail id etc.

13.5 The Contractor shall submit test report of the proposed fastening system from a reputed independent institute/laboratory. The test report shall be accompanied with the drawing of the fastening system including its components which have been tested and reported upon. The Contractor shall propose the same fastening system for which test report has been submitted. The testing shall be done for Cat 'E' as specified in EN-13401 Pt-1:2012 & EN-13401 Pt-5:2012 for 60Kg UIC rail section. The Contractor shall also submit a statement showing compliance or otherwise, in juxtaposition to each Clause and Sub-Clause as specified in EN-13401 Pt-1:2012 & EN-13401 Pt-5:2012.

13.6 The Contractor shall submit detailed design and drawings of ballastless track for main line including fastening system, derailment prevention arrangement, arrangement for provision of ducts for signal/telecommunication/electrical in longitudinal and transverse direction, transition system, drainage system with construction procedure & maintenance /repair procedure, QAP etc. to the Engineer for approval.

13.7 The Contractor shall indemnify HORCL and HRIDC against any claims from any other party in connection with the intellectual property rights of the drawings and design/fastening system/ballastless track system or any other documents submitted by the Contractor or any other patent rights.

## 14 Detailed Design Consultant (DDC) for Tunnel by NATM

14.1 Upon award of the Contract, the Contractor shall engage Detail Design Consultant (DDC) for design of tunnel. DDC must have experience of design of minimum 2.0 km length of tunnel by New Austrian Tunnelling Method (NATM) in a single contract during the last seven years. The Contractor shall submit details DDC proposed to be engaged to the Engineer for approval.

**ATTACHMENT D 1**

**DESIGN CERTIFICATE**

This Design Certificate refers to design submission no. ......................, which comprises of Definitive Design submission / Construction Reference Drawings submission, working drawing submission scheduled in the attached transmittal, in respect of:

*(Description of Permanent Works to which the submission refers)*

**DESIGNER'S STATEMENT:**

We certify that:

a) the outline designs, design briefs and performance specifications of those elements of the Permanent works as illustrated and described in the documents scheduled in the attached transmittal, complies with the Outline Design Specifications and other contract provisions.

b) an in-house check has been undertaken and completed in accordance to approved Quality Assurance Plan (QAP) to confirm the completeness, adequacy and validity of the design of the Permanent Works as illustrated and described in the documents scheduled in the attached transmittal.

c) all necessary and required approval relating to the design of the Permanent Works, as illustrated and described in the documents listed in the attached transmittal, have been obtained.

d) all effects of the design comprising the submission on the design of adjacent or other parts of the works have been fully taken into account in the design of those parts.

Signed by Designer's Authorised Representative

Name : ................

Position : ................

Date : ................

**CONTRACTOR'S CERTIFICATE:**

The Certifies that all design has been performed utilizing the skill and care to be expected of a professionally qualified and competent designer, experienced in work of similar nature and scope. This further certifies that all works relating to the preparation, review, checking and certification of design has been verified by us and the design proposed by the designer has been accepted by us.

**Signed by Contractor's authorised representative**

Name : ................

Position : ................

Date : ................

***Note 1***

*The Contractor shall insert one of the following, as applicable:*

(i) the Contractor's Technical Proposals

(ii) the Contractor's Technical Proposals and Design Packages Nos. ........ for which a Notice of No Objection has been issued.

(iii) Design Packages Nos. ....…... for which a Notice of No Objection has been issued if such Design Packages develop and amplify the Contractor's Technical Proposals.

(iv) The Definitive Design

**SAMPLE DESIGN/DRAWING TEMPLATE**

**(a) 'Design Quality Assurance' by designer & contractor:**

<table>
<tr><td colspan="4">DESIGN QUALITY ASSURANCE</td></tr>
<tr><td colspan="4">The responsibility of control, check and verification of accuracy, correctness, completeness, integration and full compliance of contract provisions in respect of design analysis and drawings rests with the design consultants and the contractor.</td></tr>
<tr><td colspan="3">By Designer</td><td>By Contractor</td></tr>
<tr><td>Sig. :</td><td>Sig. :</td><td>Sig. :</td><td>Sig. :</td></tr>
<tr><td>Date. :</td><td>Date. :</td><td>Date. :</td><td>Date. :</td></tr>
<tr><td>Name :</td><td>Name :</td><td>Name :</td><td>Name :</td></tr>
<tr><td>Designed by</td><td>Checked by</td><td>Approved by</td><td>Accepted By</td></tr>
</table>

**(b) Notice of 'No Objection' from the Engineer:**

| **Notice of 'No Objections' from the Engineer** | | | |
|---|---|---|---|
| **Notice of "No Objections" from the Engineer is being accorded for design Principles. However, the overall responsibility for the detailing and design accuracy lies with Design and Build Contractor.** | | | |
| | **REMARKS** | | |
| Design Engineer (GC/HORC) | Reviewed | | |
| Senior Design Expert (GC/HORC) | Reviewed | | |
| Chief Design Expert (GC/HORC) | Reviewed | | |
| DPD (GC/HORC) | Reviewed & comments as marked on drawing | | |

**Section C**

*[Contractor to attach copies of necessary and required approvals]*

**MINIMUM REQUIREMENT OF THE DDC'S ORGANIZATIONAL STRUCTURE**

The DDC shall submit an Organisation Chart together with clear description of the responsibilities of each member within the overall works programme.

| Sr.NO | Designation | Numbers | Experience |
|---|---|---|---|
| **1** | Team Leader | 01 | Graduate degree in Civil Engineering having experience not less than 15 years and would have handled minimum 02 projects involving design of tunnel by NATM as Team Leader. |
| **2** | Tunnel Design Expert (NATM) | 02 | Graduate degree in Civil Engineering and minimum 10 years of relevant experience in the concerned field and would have handled minimum 01 project involving design of tunnel by NATM. |
| **3** | Tunnel Design Expert (Cut & Cover) | 02 | Graduate degree in Civil Engineering and minimum 10 years of relevant experience in the concerned field and would have handled minimum 01 project involving design of tunnel by Cut & Cover. |
| **4** | Bridge Design Expert | 01 | Graduate degree in Civil Engineering and minimum 05 years of relevant experience in the concerned field and would have handled minimum 01 project involving railway bridge involving deep foundation. |
| **5** | Embankment Design Expert | 01 | Graduate degree in Civil Engineering with total experience of 10 years and minimum 5 years of relevant experience in the concerned field and would have handled minimum 01 project involving railway/highway embankment of minimum 6 m height. |

**NOTE:**

1. Sufficient documentary proof to substantiate the qualification and work experience shall be submitted. The Contractor shall submit proposal of DDC experts having experience as mentioned above to the Engineer for approval before deployment.

2. The requirement given above is minimum. The Contractor shall be required to supplement the above mentioned design team as per requirement of the Works so as to adhere to the timelines given in Appendix-2- Contract Key Dates and Completion Date, Section VII-9: Appendices, Part 2- Employer's Requirements under the Contract.

# Section VII: Employer’s Requirements

## Section VII-4: Construction (Civil &BLT)

## Contents

# EMPLOYER'S REQUIREMENTS – CONSTRUCTION (CIVIL & BLT)

## 1. CONTRACTOR'S SUPERINTENDENCE

The Contractor shall submit a Staff Organization Plan in accordance with the Attachment C-1

This plan shall be updated and resubmitted whenever there are changes to the staff. The plan shall show the management structure and state clearly the duties, responsibilities and authority of each staff member.

The contractor's representative and his associates/supervisors shall have experience and qualification appropriate to the type and magnitude of the Works as per Attachment C-2. Full details shall be submitted of the qualifications and experience of all proposed staff to the Engineer for his approval.

## 2. CHECKING OF THE CONTRACTOR'S DESIGN OF TUNNEL EXCAVATION AND TEMPORARY WORKS

i. The Contractor shall, prior to commencing the Excavation of the tunnel shall submit certificate to the Engineer certifying that excavation schemes, adequacy of primary support system and its installation sequence are sufficient on the basis of geological and geotechnical information's gathered/derived (from field and laboratory testing) for the most probable geological conditions, However, the adequacy of the support system shall be checked on the basis of geological conditions encountered during excavations and on the basis of instrumented data.

ii. For works other the NATM tunnel, the Contractor shall submit the certificates that the Temporary Works have been properly and safely designed and checked and that the Contractor has checked the effect of the Temporary Works on the Permanent Works and has found this to be satisfactory.

## 3. CARE OF THE WORKS

(i) Unless otherwise permitted by the Engineer all work shall be carried out in dry conditions.

(ii) The Works, including materials for use in the Works, shall be protected from damage due to water. Water on the Site and water entering the Site shall be promptly removed by temporary drainage or pumping systems or by other methods capable of keeping the Works free of water. Silt and debris shall be removed by traps before the water is discharged and shall be disposed of at a location or locations to which the Engineer has given his consent.

(iii) The discharge points of the temporary systems shall be as per the consent of the Engineer. The Contractor shall make all arrangements with and obtain the necessary approval from the relevant authorities for discharging water to drains, watercourses, etc. The relevant work shall not be commenced until the approved arrangements for disposal of the water have been implemented.

(iv) The methods used for keeping the Works free from water shall be such that settlement of, or damage to, new and existing structures do not occur.

(v) Measures shall be taken to prevent flotation of new and existing structures.

(vi) Inward movement in the NATM tunnel shall be monitored by using 3-D laser targets at an appropriate locations approved by the Engineer the results shall be reviewed by the designer on regular basis and submitted to the Engineer with the comments and interpretation. If results are beyond permissible limits the remedial measures shall be adopted immediately with consent of the Engineer.

(vii) The results for load cells, strain gauges etc shall be reviewed by the designer and interpreted in acceptable form and submitted to the Engineer on regular basis with the comments and recommendation of the designer.

## 4. Protection of the Works from Weather

(i) Work shall not be carried out in weather conditions that may adversely affect the Works unless proper protection is provided to the satisfaction of the Engineer.

(ii) Permanent Works, including materials for such Works, shall be protected from exposures of weather conditions that may adversely affect such Permanent Works or materials.

(iii) During construction of the Works storm restraint systems shall be provided where appropriate. These systems shall ensure the security of the partially completed and on going stages of construction and in all weather conditions. Such storm restraint systems shall be installed as soon as practicable and shall be compatible with the right of way, or other access around or through- out the Site.

(iv) The Contractor shall, at all times programme and order progress of the work and make all protective arrangements such that the Works can be made safe in the event of storms.

(v) The finished works shall be protected from any damage that could arise from any activities on the adjacent site/ works.

### 4.1 Utilities

Please refer to Appendix 10 of Section VII-9: Appendices, Part 2- Employer's Requirements of this document

## 5. TESTING

### 5.1 General

The Contractor shall provide and perform all forms of testing procedures applicable to the NATM Works and various elements of the primary support and shall conduct all necessary laboratory and site acceptance tests.

All testing procedures shall be submitted at least thirty (30) days prior to conducting any Test. The Testing procedures shall show unambiguously the extent of testing covered by each submission, the method of testing, the Acceptance Criteria, the relevant drawing (or modification) status and the location.

The testing Procedures shall be submitted, as required, by the Contractor during the duration of the contract to reflect changes in primary support system or the identification of additional support requirement.

The Engineer shall have the facilities for monitoring all tests and have access to all testing records.

All costs associated with the Testing shall be borne by the Contractor, unless otherwise specified, including the services of any specialised personnel or independent assessors.

All testing equipment shall carry an appropriate and valid calibration labels.

### 5.2 Batches, Samples and Specimens

A batch of material is a specified quantity of the material that satisfies the specified conditions. If one of the specified conditions is that the material is delivered to the Site at the same time, then material delivered to the Site over a period of a few days may be considered as part of the same batch if in the opinion of the Engineer there is sufficient proof that the other specified conditions applying to the batch apply to all of the material delivered over the period.A sample is a specified quantity of material that is taken from a batch for testing and which consists of a specified amount, or a specified number of pieces or units, of the material.A specimen is the portion of a sample that is to be tested.

### 5.3 Samples for Testing

Samples shall be of sufficient size and in accordance with relevant Standards to carry out all specified tests.

Samples taken on the Site shall be selected by, and taken in the presence of, the Engineer and shall be suitably marked for their identification. An identification marking system should be evolved at the start of works in consultation with the Engineer.

Samples shall be protected, handled and stored in such a manner that they are not damaged or contaminated and such that the properties of the sample do not change.

Samples shall be delivered by the Contractor, under the supervision of the Engineer, to the specified place of testing. Samples on which non-destructive tests have been carried out shall be collected from the place of testing after testing and delivered to the Site or other locations instructed by the Engineer.

Samples which have been tested may be incorporated in the Permanent Works provided that:

(i) the sample complies with the specified requirements;

(ii) the sample is not damaged; and

(iii) the sample is not required to be retained under any other provision of the Contract.

Additional samples shall be provided for testing if in the opinion of the Engineer:

(i) material previously tested no longer complies with the specified requirements; or

(ii) material has been handled or stored in such a manner that it may not comply with the specified requirements.

### 5.4 Testing

The Contractor shall be responsible for all on-site and off-site testing and for all in-situ testing.

All appropriate laboratory tests shall be carried out in the Contractor's laboratory, unless otherwise permitted or required by the Engineer. Where the laboratory is not appropriately equipped and/or staffed for some tests, or if agreed to by the Engineer, tests may be carried out in other laboratories provided that:

(i) they are accredited for the relevant work at least NABL approved to a standard acceptable to the Engineer ; and
(ii) particulars of the proposed laboratory are submitted to the Engineer for his consent shall be at least NABL approved.

In-situ tests shall be done in the presence of the Engineer.

Equipment, apparatus and materials for in-situ tests and laboratory compliance tests carried out by the Contractor shall be provided by the Contractor. The equipment and apparatus shall be maintained by the Contractor and shall be calibrated before the testing starts and at regular intervals as permitted by the Engineer. The equipment, apparatus and materials for in-the situ tests shall be removed by the Contractor as soon as practicable after the testing is complete.

The Contractor shall be entitled in all cases to attend the testing carried out in the Employer's or other laboratories, to inspect the calibration certificates of the testing machines and to undertake the testing on counterpart samples. Testing of such samples shall be undertaken in laboratories complying with Sub-section 4.12.4(i) above and particulars of the laboratory proposed shall be submitted to the Engineer for consent prior to the testing.

Attendance on tests, including that by the Engineer, Contractor and Designer, shall be as laid down in the Quality Assurance procedures.

## 5.5 Compliance of Batch

The results of tests on samples or specimens shall be considered to represent the whole batch from which the sample was taken.

A batch shall be considered as complying with the specified requirements for a material if the results of specific tests for of the specified properties comply with the specified requirements for the properties.

If additional tests are permitted or required by the Engineer but separate compliance criteria for the additional tests are not stated in the Contract, the Engineer shall determine if the batch complies with the specified requirements for the material on the basis of the results of all tests, including the additional tests, for every property.

### 5.6 Records of Tests

Records of in-situ tests and laboratory compliance tests carried out by the Contractor shall be kept by the Contractor on the Site and a report shall be submitted to the Engineer within seven (7) days, or such other time stated in the Contract or in the Quality Assurance Programme, after completion of each test. In addition to any other requirements, the report shall contain the following details:

(a) material or part of the Works tested;

(b) location of the batch from which the samples were taken or location of the part of the Works;

(c) place of testing;

(d) date and time of tests;

(e) weather conditions in the case of in-situ tests;

(f) technical personnel supervising or carrying out the tests;

(g) size and description of samples and specimens;

(h) method of sampling;

(i) properties tested;

(j) method of testing;

(k) readings and measurements taken during the tests;

(l) test results, including any calculations and graphs;

(m) specified acceptance criteria; and

(n) other details stated in the Contract.

Reports of tests shall be signed by the site agent or his assistant, or by another representative authorised by the Contractor.

If requested, records of tests carried out by the Employer's staff or by the Engineer shall be given to the Contractor.

### 5.7 Test for Shotcrete Operators

Shotcrete operators are to be tested for their performance by performing an in-situ test for spraying of shotcrete in a desired manner. Successful operators should be issued a competency certificate and record for all such competent operators shall be maintained. Shotcreting for the NATM tunnelling work should be done only by operators having competency certificate.

## 6. MATERIALS

Materials and goods for inclusion in the Permanent Works shall be new unless the Engineer has consented otherwise. Preference shall be given to local materials where available. Approved Manufacturers/Suppliers of few important items have been given in Section VII-8: Tender drawings and documents of this document. These materials shall be procured only from approved manufacturers/Suppliers.

Certificates of tests by manufacturers which are to be submitted to the Engineer shall be current and shall relate to the batch of material delivered to the Site. Certified true copies of certificates may be submitted if the original certificates could not be obtained from the manufacturer.

Parts of materials which are to be assembled on the Site shall be marked to identify the different parts.

Materials which are specified by means of trade or proprietary names may be substituted by materials from a different manufacturer which has received the consent of the Engineer provided that the materials are of the same or better quality and comply with the specified requirements.

Samples of materials submitted to the Engineer for information or consent shall be kept on the Site and shall not be returned to the Contractor or used in the Permanent Works unless permitted by the Engineer. The samples shall be used as a mean of comparison which the Engineer shall use to determine the quality of the materials subsequently delivered. Materials delivered to the Site for use in the Permanent Works shall be of the same or better quality as the samples which have received consent.

## 7. TAKING OVER OF WORKS / SECTIONS

### 7.1 Inspection

**a)** General

Within seven (7) days of receipt of the Contractor's written application for a Taking-Over Certificate, pursuant to Sub-Clause 10.1 of the General Conditions of Contract, the Engineer, in the company of the Contractor, will inspect the Works or Section covered bythe application, as per the requirements described in this Sub-Clause. During the joint inspection, the Works or Section will be examined and relevant documentation will be reviewed. The Engineer will prepare a written list of outstanding items, if any, to be completed or corrected before issuance of the Taking-Over Certificate and a separate written list of items to be completed or corrected during the remainder of the Contract orthe Defects Notification Period. The list shall include an agreed date of correction for each deficiency.

The Contractor shall also obtain written confirmation from all applicable Interfacing Contractors that all interfacing matters have been concluded.

If there are no outstanding items to be completed or corrected before the Taking Over ofthe Works or a Section, the Contractor shall submit to the Engineer all guarantees, warranties, final certifications or similar documents or both as are required under the Contract.

**b)** Static Inspection

The inspection listed in the following table shall be conducted by the Engineer, in coordination with Interfacing Contractors as necessary.

The Contractor shall prepare and submit for review and approval by the Engineer a Static Inspection Plan detailing and explaining how the Contractor will plan, perform and document all tests and inspections that shall be conducted to verify and validate the Works.The Static Inspection Plan shall consist of a narrative description supported by graphics, diagrams and tabulations as required.

| **Structure** | **Inspection Item** | | **Inspection Method** | | |
|---|---|---|---|---|---|
| | | | **Confirmation of "As-Built" Records** | **Visual Inspection** | **Measurement Test Check** |
| Earthwork | Formation width | At every 100m on straight line, at every 20m on curved line, at each terminal point of structures | ✓ | | ✓ |
| | Cross section | Drawings at every 100m on straight line, | ✓ | | ✓ |

| Structure | Inspection Item | | Inspection Method | | |
|---|---|---|---|---|---|
| | | | Confirmation of "As-Built" Records | Visual Inspection | Measurement Test Check |
| | | at every 20m on curved line, at each terminal point of structures. | | | |
| | Retaining wall | List of location of retaining walls | ✓ | ✓ | |
| | Construction | Soil test records, compaction records, CBR & deformation modulus ($Ev_2$) records, construction photos | ✓ | | |
| | Blanketing layer | Blanket material test records, compaction test records, CBR & deformation modulus (Ev2) test records. | ✓ | | |
| | | Thickness | ✓ | | ✓ |
| | Structures Crossing | List of structures crossing the Railway (earth cover, overhead clearance, etc.) | ✓ | | ✓ |
| | Drainage system | Drainage works at embankment/cutting, drainage diagram | ✓ | | ✓ |
| Bridges | Formation width | At each bridge | ✓ | | ✓ |
| | Construction | Quality records of aggregate used, reinforcement, cement concrete quality control data, | ✓ | | |

| Structure | Inspection Item | | Inspection Method | | |
|---|---|---|---|---|---|
| | | | Confirmation of "As-Built" Records | Visual Inspection | Measurement Test Check |
| | | measurement records of cast-in-situ piles/ open foundation etc. | | | |
| | Repairing of structures | Records of repaired parts of structures | ✓ | ✓ | |
| | Rebar cover | Records of measurement of rebar cover | ✓ | | |
| | Clearance under girder/slab | Above roads/rail | ✓ | | ✓ |
| | Abutment/pier structures/RCC box etc. | All Structural drawings | ✓ | ✓ | |
| | Concrete strength | Schmidt hammer tests | ✓ | | ✓ |
| | List of bridges | List of bridges | ✓ | ✓ | |
| | PSC slab/girder | Test record of prestressing cable, anchorage system & prestressing record. | ✓ | | |
| | Pile load test | Pile load test parameters | NA | | |
| | Steel Girder | Material test record, fabrication, welding & trial assembly records, dead load camber | NA | | |
| | Bearings | Acceptance test record | NA | | |

| Structure | Inspection Item | | Inspection Method | | |
|---|---|---|---|---|---|
| | | | Confirmation of "As-Built" Records | Visual Inspection | Measurement Test Check |
| | Track on OWG | Track parameters at every sleeper location | NA | | |
| | Load test | Load test parameters of superstructure (PSC girder/slab) | ✓ | | ✓ |
| | | Load test parameters of skew RCC box | ✓ | | |
| Station | Platform length, width | At every 10m on straight line, at every 5m on curved line, control points of curve | NA | | |
| | Clearance of isolated and continuous structures on platform as per SOD | All structures | | | |
| | Staircase and pavement | Results of stair width measurement | | | |
| | Drainage of platform & yard | Section & slope at every 20m | | | |
| | Safety fence, etc. | List of facilities (clearance from platform end to fixed/movable fence, etc.) | | | |
| Protective facilities | Abutment/ Pier protection | Drawings | ✓ | ✓ | |

| Structure | Inspection Item | | Inspection Method | | |
|---|---|---|---|---|---|
| | | | Confirmation of "As-Built" Records | Visual Inspection | Measurement Test Check |
| | Slope protection works | List, location and Drawings of slope protection works | ✓ | ✓ | |

After Static Inspection of the Works as mentioned above the Contractor shall submit the Inspection Report in the agreed format in four (4) signed copies to the Engineer for review and approval.

### 7.2 Remedial Action and Re-inspection

Within twenty-eight (28) days of receipt of a written application for a Taking-Over Certificate,the Engineer shall proceed in accordance with Sub-Clause 10.1 of the General Conditions of Contract.

### 7.3 Taking Over Certificate

If the Engineer does not issue a Taking-Over Certificate, but gives instructions in accordance with sub-paragraph (ii) of Sub-Clause 10.1 of the General Conditions of Contract, the Contractor shall, when he considers the work specified by the Engineer completed, give written notice to the Engineer and the Contractor.

The Contractor shall submit documents required by Commissioner of Railway Safety (CRS) and shall accompany him during his inspection along with necessary records.

## 8. Sub-Contractor for Construction of Ballast less Track System

8.1 Upon award of the Contract, the Contractor shall engage Sub-Contractor for Construction of ballast less Track System. The Contractor shall submit details of Sub-Contractor proposed to be engaged for Construction of ballast less Track System for the approval of the Engineer. Sub-Contractor for Construction of ballast less track system shall be engaged within twelve months of the Commencement Date.

8.2 Sub-Contractor to be engaged shall have the experience of Construction of ballast less track system for a minimum length of 2.0 km in a single contract during last seven years from the last date of submission of Tender.

8.3 Sub-Contractor to be engaged shall submit experience certificate for construction of ballast less track system issued by the user railway administration.

In case the user railway administration is from foreign country and the certificate is issued in language other than English, the supporting documents shall be translated into English. The translation of the certificate shall be either stamped by Embassy/High Commission of India or

Partner Countries of Hague convention may submit these documents with "Apostille" stamp. The experience certificate issued by foreign user railway administration in English shall also be either stamped by Embassy/High Commission of India or submitted with "Apostille" stamp.

8.4 Proposed Sub-Contractor shall submit details containing, but not limited to the name of line in which the system is in use for minimum 5 years, details of user railway administration such as name of the Railway administration and its contact person, address, telephone number, E-mail id etc.

8.5 Upon approval of the Sub-Contractor, the Contractor is required to enter into legally enforceable agreement with the Sub-Contractor within 60 days of approval of designer and submit a copy of the agreement to the Engineer. The agreement must specify the specific role and responsibility of the Sub-Contractor.

8.6 No construction of BLT shall be started unless agreement with the Sub-Contractor is submitted to the Engineer.

## ATTACHMENT - C-1

## MINIMUM ORGANISATION STRUCTURE REQUIRED

The figures indicated in Table 1 below are the minimum number of Project-Personnel required which are to be deployed as per the minimum level of supervision. The qualification/experience of such Project personnel is given under Annexure-C-2

### TABLE-1 LIST OF MINIMUM ORGANISATION STRUCTURE REQUIRED

| S. No. | Designation of Project Personnel | Minimum no. of Project-Personnel required | Penalty for Non-deployment per week or part thereof per person |
|---|---|---|---|
| 1. | Contractor's Representative/ Project Manager | 1 | Rs 50,000/- |
| 2. | Senior Tunnel Expert (NATM) | 4 | Rs 40,000/- |
| 3. | Tunnel Expert(NATM) | 4 | |
| 4. | Ballast less Track Expert | 1 | - |
| 5. | Planning Engineer | 1 | Rs 40,000/- |
| 6. | Senior Quality Assurance /Quality Control | 2 | |
| 7. | Quality Assurance /Quality Control Expert | 2 | Rs 50,000/- |
| 8. | Health & Safety Expert | 4 | Rs 50,000/- |
| 9. | Surveyor | 5 | - |
| 10. | Tunnel Expert (Cut & Cover) | 2 | Rs 40,000/- |
| 11. | Bridge Expert | 1 | - |
| 12. | Procurement Manager | 1 | Rs 40,000/- |
| 13. | Senior Geologist | 1 | |
| 14. | Geologist | 1 | - |
| 15. | Environmental Expert | 1 | Rs 40,000/- |
| 16. | Senior Geotechnical Engineer | 1 | |
| 17. | Geotechnical Engineer | 1 | |

| | | | |
|---|---|---|---|
| 18. | Blast Expert | 1 | |
| 19. | Civil Engineer (Concrete Expert) | 4 | |

**NOTES:-**

i. The Contractor shall deploy resources as per the above-mentioned table. The Contractor shall also confirm to deploy manpower over and above the minimum numbers indicated above, if the work so requires.

ii. The performance of project personnel deployed will be evaluated periodically by the Engineer during the contract period. In case the performance of any of the project personnel is not satisfactory, the Contractor shall replace them with good personnel immediately as per directions of the Engineer.

iii. The personnel at Sr.No.1, must be deployed by Commencement Date. Personnel at Sr.No.2, 4, 5, 6, 8, 10 & 12 in the above table must be deployed within 30 days of Commencement Date. Non adherence to these provisions shall attract penalty as indicated in the table above.

iv. The resources indicated in table above are for peak requirement. All resources need not be mobilized simultaneously for entire duration of the contract. The Contractor shall mobilize the resources as per the deployment programme approved by the Engineer.

v. In case of non-deployment of project personnel, the penalty shall be imposed as indicated above and deducted from Contractor's running / final bills. The decision of the Engineer in this regard shall be final and binding.

**UNDERTAKING:**

i. We confirm to deploy project-personnel required to achieve progress of work as per construction work program submitted along with the tender or as approved by the Engineer.

ii. We confirm to deploy manpower over and above the minimum numbers, if the work so requires.

**SIGNATURE OF AUTHORIZED SIGNATORY OF CONTRACTOR**

## ATTACHMENT C-2

## MINIMUM QUALIFICATION & EXPERIENCE OF PROJECT PERSONNEL

| S. No. | DESIGNATION | QUALIFICATION | EXPERIENCE LEVEL |
|---|---|---|---|
| 1. | Contractor's Representative/ Project Manager (Team Leader) | Graduate in Civil Engineering | Minimum total experience of 15 years out of which, minimum 10 years as In-charge in Infrastructure projects*. |
| 2. | Tunnel Expert (NATM) | Graduate/Diploma in Civil Engineering | Minimum total experience of 10/12 years out of which minimum 05/08 years in relevant field in Infrastructure projects |
| 3. | Tunnel Expert (Cut & Cover) | Graduate/Diploma in Civil Engineering | Minimum total experience of 10/12 years out of which minimum 05/08 years in relevant field in Infrastructure projects |
| 4. | Ballasteless Track Expert | Graduate/Diploma in Civil Engineering | Minimum total experience of 10/12 years out of which minimum 05/08 years in relevant field in Infrastructure projects |
| 5. | Bridge Expert | Graduate/Diploma in Civil Engineering | Minimum total experience of 10/12 years out of which minimum 05/08 years in relevant field in Infrastructure projects |
| 6. | Planning Engineer | Graduate in Civil Engineering with certification Primavera software | Minimum total experience of 10 years out of which minimum 05 years in relevant field in Planning of Infrastructure projects. |
| 7. | Quality Assurance (QA) /Quality control (QC) Expert | Graduate/Diploma in Civil Engineering | Minimum total experience of 10/13 years out of which minimum 05 Yrs. In QA (Field) And At Least One Year as In-Charge in Infrastructure Project |
| 8. | Procurement Manager | Graduate in Engineering / Diploma in procurement | Minimum total experience of 05/08 years in Procurement in Infrastructure Project. |
| 9. | Geologist | Master's degree in Geology | Minimum total experience of 10 years out of which minimum 05 years in relevant field in Infrastructure projects. |
| 10. | Health & Safety Expert | Graduate/Diploma in Engineering/Science with one year full time Diploma in Industrial safety | Minimum total experience of 06/08 years with relevant experience of 3 years in Infrastructure projects. |
| 11. | Environment Expert | Graduate in Environmental Engineering/ Master's degree in Environmental Engineering/Environmental Science | Minimum total experience of 06 years out of which 3 years of experience of working on environmental aspects in railways/roads linear projects. |
| 12. | Surveyor | Diploma in Civil Engineering / ITI | Minimum Total Experience of 05/08 Years in Survey Work for Infrastructure project |

| | | | |
|---|---|---|---|
| 13. | Blast Expert | Graduate/Diploma in Civil Engineering | Minimum Experience of 15 years in blasting |
| 14. | Civil Engineer (concrete expert) | Post Graduate in structures and Graduate in Civil Engineering | Minimum total experience of 10 years out of which minimum 05 years in relevant field in Infrastructure projects. |

**NOTES:**

i. *Infrastructure project includes Railway, DFC, Metro, RRTS and Highway tunnel projects.

**SIGNATURE OF AUTHORIZED SIGNATORY OF CONTRACTOR**

## ATTACHMENT C-3

## MINIMUM RESOURCES REQUIRED FOR THE PROJECT- PLANTS & EQUIPMENT

**The figures indicated below are the minimum number of equipment required.**

| S. No. | Types of Equipment Required for the Work | Minimum No. of Unit of Equipment Required for the Work |
|---|---|---|
| 1. | Double Boomer | 02 |
| 2. | Robotic Shotcrete Machine | 08 |
| 3. | Concrete Batching Plant (each 60 cum/hr) | 02 |
| 4. | Excavator (75 cum/hr) | 12 |
| 5. | Grader | 02 |
| 6. | Dozer (150 Cum/hr) | 04 |
| 7. | Vibratory Roller (10 T) | 04 |
| 8. | Pugmil/Crusher(200MT/hr) | 01 |
| 9. | Concrete Pump with Boom Placer | 02 |
| 10. | Stationary Concrete Pumps (36 cum/hr) | 05 |
| 11. | Transit mixtures | 10 |
| 12. | Survey Instruments (Total Station) | 04 |
| 13. | Lab Testing equipment- fully equipped for site tests. | As per Appendix 12 of Section VII-9: Appendices, Part 2- Employer's Requirements |
| 14. | Digital Level (Leica, Sokia) | 04 |
| 15. | Tunnel lining gantry of minimum length 15 m | 08 |

**Note:**

i. These resources are for peak period of each activity. All plants and equipment need not be mobilized simultaneously. Plants and equipment as required as per the progress of the work shall be brought at site in advance as directed by the Engineer.

**UNDERTAKING:**

We confirm to deploy resources as per the above-mentioned minimum requirement and also confirm to deploy plants & equipment over and above the minimum numbers indicated above, if the work requires so.

**SIGNATURE OF AUTHORIZED SIGNATORY OF CONTRACTOR**

CONTENTS

# CHAPTER 1

# INTRODUCTION

This part lays down the specifications/criteria for design of civil structures i.e. tunnels(NATM and Cut & Cover), permanent ventilation shafts, ballastless track, bridges, embankments, retaining walls and other civil structures.

The broad parameters covered in these specifications are listed below:

1. Material Parameters (Concrete, Reinforcement steel & Structural Steel etc.)
2. Design Parameters
3. Loadings
4. Load Combinations
5. Allowable stresses
6. Design Methodology
7. List of Design Codes and Standards

# CHAPTER 2

# OUTLINE DESIGN SPECIFICATION -GENERAL

# CHAPTER 2

# OUTLINE DESIGN SPECIFICATIONS- GENERAL

## 2.1 General

The structures to be designed in C-4 Package are mentioned in the Employer's Requirements, Section VII-2, Functional (Civil and BLT), Sub-Clause 2, Scope of Works.

The design works include the preparation and approval of GADs/architectural drawings, Definitive Design and Construction Design for structures as per the Employer's Requirements, Section VII-3, Design (Civil and BLT).

Initially GADs of bridges shall be prepared by the Contractor after carrying out detailed topographical survey and will be based on conceptual GAD and preliminary design. These GADs will be sent to the Site for checking feasibility of construction by Engineers Representative and Contractors Representative. The initial GADs shall be modified incorporating remarks of construction feasibility and submitted to the Engineer along with the preliminary design calculations. After approval of the Engineer, GADs shall be submitted to the stakeholders for approval, if any. Getting approval of GAD from the concerned stakeholders is the responsibility of the Contractor. The Contractor shall address all the queries of the stakeholders. However, the Employer will assist the Contractor in obtaining approval from the concerned stakeholders. The Contractor shall attend any meeting/presentation/joint site visit with stakeholders, as per the requirement, for the approval of GADs. After approval of the stakeholders, the GAD shall be finally approved by the Employer.

## 2.2 Employer's Inputs

The Employer shall furnish following documents to the Contractor: -

a) Plan and L-section of the main line

b) Conceptual GAD of bridges

c) Conceptual layout plan for tunnel

d) Geotechnical Interpretive Report (GIR) for tunnel

e) Design Basis Report (DBR) for tunnel

f) Geo-technical investigation reports for tunnel and bridges

## 2.3 Design Life

The design life of a structure is that period for which it shall be designed to fulfill its intended function.

The Contractor is required to submit a report demonstrating the approach in design, construction and selection of material so as to achieve the design life as specified.

The design life of tunnel and bridges shall be as follows:

**a)** Tunnels works

The design life of all tunnel structures shall be 120 years.

**b)** Bridges

The design life of bridges shall be 100 years.

**c)** Retaining Wall

The design life of retaining walls shall be 100 years.

**d)** Other Civil Structures

The design life of Other Civil Structures shall conform to relevant codal provisions.

## 2.4 Schedule of Dimensions, Fixed Structure Gauge (FSG) and Clearances

Tunnel, bridges and other structures shall be designed to cater for movement of double stack containers. FSG for tunnel shall be as shown in Employer's Requirements, Section VII-8, Tender drawings and documents and clearances shall be as per IR Schedule of Dimensions for Broad Gauge.

## 2.5 Rock and Soil Parameters

Geotechnical investigation reports shared with the Tender Documents are indicative in nature and the Contractor shall carry out independent detailed GT investigations as per codal provisions. However, if there is a wide variation (>15%) in the design rock/soil parameters compared to the parameters as per GT report of nearest bore hole given in the Tender Documents, the same shall be brought to the knowledge of the Engineer and a confirmatory (repeat) bore hole shall be done to ascertain design soil parameters.

## 2.6 Liquefaction of soil

Liquefaction of soil shall be considered as per IS 1893-Part-1. The design ground water table shall be used for liquefaction potential calculation. The moment magnitude Mw to be taken in design shall be 7.0. The factor of safety shall be more than 1.0 to ascertain that the strata is not liquefiable.

### 2.6.1 Design Ground Water Table

Base value of ground water table shall be considered as the highest level of the following:

(a) Data published by Central Ground Water Board (CGWB),

(b) Ground water table reported in Geotechnical report provided in Tender Documents,

(c) Ground water table encountered by the Contractor during GT investigation.

The design ground water table shall be taken as minimum 3.0m higher than the base value of ground water table as given above.

## 2.7 Differential Settlement in continuous structures

Differential Settlement between two adjacent bridge piers shall not be more than-

**a)** 12mm for Long Term Settlement;

**b)** 6mm for Short Term Settlement

## 2.8 General Design Requirements

2.8.1 The Project entails construction of BG double-track electrified railway lines capable of handling "25t loading -2008" double stack containers for a maximum speed of 100 kmph. The design speed for passenger train shall be 160 kmph. The Project is a feeder route to DFC also. The embankment and cutting shall be designed for "DFC loading (32.5t axle load)". Bridge substructure shall be designed for "DFC loading (32.5t axle load)"and superstructure shall be designed for "25t loading – 2008" unless specified otherwise in the Contract.

2.8.2 All levels shall be quoted in meters correct to three decimal places and shall be to Mean Sea Level (MSL) Datum India. The rail level on a track shall refer to the top of the inner rail of the UP Line i.e. line going from New Prithala to Sonipat.

2.8.3 The Contractor shall comply with the provisions of IR Schedule of Dimensions, with regard to the clearance over the existing IR network.

2.8.4 Horizontal and vertical alignment has been given in the Final Alignment Drawings. Proposed Right of Way (ROW) has also been marked on the Alignment Drawings. The Contractor should check the feasibility of alignment at site and may propose minor modification, if required.

2.8.5 All structures shall be designed and detailed to withstand earthquake forces for Seismic Zone IV.

2.8.6 Exposure conditions shall be considered as 'moderate' for design of all type of structures/bridges.

2.8.7 Minimum grade of reinforcement steel shall be Fe 500D conforming to IS 1786.

2.8.8 The data like bridge length, size, barrel length, type of crossing, highest flood level (HFL), total waterway and indicative span configuration etc. in respect of the proposed road/ waterway bridges has been shown in the conceptual GAD of the bridges. While designing the bridges, it shall be obligatory that in case of parallel section, the total bridge length, box opening and/or HFL for an individual bridge for HORC project shall not be less than that of the corresponding KMP/DFC bridge. Also, the span configuration for the proposed bridges shall match the span configuration of the corresponding KMP/DFC bridge, to the maximum extent possible, to avoid obstruction and to bring the abutment/piers in line with the existing abutment/piers. Deviation from above shall be in consultation and with approval of the Engineer.

2.8.9 Precast RCC drains shall be designed for drainage of storm water from embankments between existing KMP expressway and HORC embankment.

2.8.10 In case of pile foundation, bored cast in-situ concrete piles of diameter 1.2m shall be provided.

2.8.11 Inspection platform all-round the abutment caps/pier caps shall be provided along with access ladder.

2.8.12 Trolley refuge on bridges shall be provided as per provisions of IRSOD.

2.8.13 In case, the bridge is at a location where the Right of Way is restricted, special type of abutment / pier / return wall / wing wall shall be designed subject to approval of the Engineer.

2.8.14 Protection of embankment on approaches of bridges shall be by CC blocks of suitable sizes, over consolidated gravel bed of minimum thickness of 150 mm, encased in cast in-situ RCC grid frames of suitable cross section having opening size of approximately 1.75m x 1.75m, for a length of 30m on both sides for major bridges and 15m on both sides for RCC boxes. The above protection works shall be provided with toe wall at the end of slope. Adequate drainage arrangement shall be provided in protection works.

2.8.15 Inspection steps (1m wide) on either side of formation shall be provided with CC of M20 grade at all bridges.

2.8.16 Adequate provision shall be made for inspection and replacement of bearings without major disruption to railway operations or any activity underneath the bridge.

2.8.17 Necessary provisions for OHE mast shall be made on piers of bridges having multiple CG/ OWG spans.

2.8.18 Precast retaining walls shall be designed upto 2m height above ground level. Beyond 2m height, cast in-situ retaining wall may be used. Reinforced Earth (RE) wall shall not be permitted.

2.8.19 Precast CC coping shall be provided over the return wall, wing wall & retaining wall with minimum thickness of 75mm at the edge and 100mm at the centre. It shall project 75mm beyond the wall thickness on either side.

2.8.20 NP-4 pipe of 450mm diameter, conforming to IS 458, shall be designed at about 500m interval throughout the alignment in embankments having fill heights upto 5m. In embankments having fill heights more than 5m precast RCC box of 500mmx500mm clear size shall be designed for the purpose of future utilities. RCC pipe shall be designed for appropriate installation conditions as per IS-783, according to the fill height.

# CHAPTER 3

# OUTLINE DESIGN SPECIFICATIONS - TUNNEL

# CHAPTER 3

# ALIGNMENT, CROSS SECTION and LOADING REQUIREMENTS FOR TUNNEL

## 3.1 GENERAL

The Outline Design Criteria hereto provide minimum standards that are to govern the design of NATM tunnel, Cut & Cover tunnel, Permanent Ventilation Shafts, portals and other Permanent Works. The Outline Design Criteria shall be read in conjunction with DBR and Outline Construction Specifications (Civil and BLT) where appropriate.
Wherever in contract documents any term provides for consent, concurrence, no-objection or agreement of the Employer or the Engineer, the same shall mean and denote consent concurrence or agreement in writing (even if not so expressly stated).

## 3.2 CODES AND STANDARDS

The design and construction of the Permanent Works shall comply with codes of practice and standards prevalent at the time of submission of Tender Documents. Regulations made and requirements issued by the Indian Government and by relevant utility authorities shall be followed and specified.

Alternative or additional codes, standards and specifications proposed by the Contractor shall be internationally recognized codes including Austrian Standards for NATM shall be equivalent to or better than, Indian Standards issued by the Bureau of Indian Standards or any other Indian professional bodies or organizations, subject to being, in the opinion of the Engineer, suitable for incorporation into the Specifications.

Subject to the requirement of this specification and other control documents all design work will comply with the appropriate current standards issued by the Bureau of Indian Standards (BIS), or subject to approval by the authority, an appropriate current standard from a reputable institution may be used. All standards shall be that including Amendments and Addenda, current at the date of tender.

## 3.3 HORIZONTAL AND VERTICAL ALIGNMENT OF TUNNEL

The horizontal and vertical alignments of the HORC Project are given in the Tender drawings as listed in Employer's Requirements, Section VII-8, Tender drawings and documents.
The Contractor shall design the tunnel works to these alignments. However, subject to the provisions of the Contract, changes to the given alignments may be permitted to suit the specific characteristics of his design as per Sub-Clause 2.7 of Employer’s Requirements – Functional(Civil and BLT), at no extra cost to the Employer subject to prior approval of the Employer. While fixing the design alignment of tunnel, due consideration for lateral and vertical clearances as per IRSOD on curves shall be given.

## 3.4 TUNNEL CROSS SECTION

The cross section of tunnel shall be determined in accordance with DBR. The cross section of the tunnel shall ensure provision of space for associated structures and equipment required for operation and maintenance of the tunnel.

## 3.5 CROSS SECTION OF PERMANENT VENTILATION SHAFTS AND CONSTRUCTION CUM UTILITY SHAFT

**3.5.1** The cross section of permanent ventilation shaft has been shown as rectangular in tender drawings. The Contractor may modify the cross section to any other shape provided clear opening along the length of the tunnel is not less than 25 m and clear opening perpendicular to the track is not less than 12 m. The cross section of construction cum utility shaft can be decided by the Contractor depending upon construction requirement for introduction of four nos. of working faces for both tunnels.

## 3.6 LOADING REQUIREMENTS

### 3.6.2 General

The loads for design of tunnel shall broadly be taken as given in the DBR in Employer's Requirements, Section VII-8, Tender drawings and documents unless stated otherwise in the Contract.

### 3.5.2 Design Loads and Loading Combinations

Each component of the structure shall be designed/checked for all possible combinations of loads indicated in DBR of tunnel in Employer's Requirements, Section VII-8, Tender drawings and documents but not limited to these only.

# CHAPTER 4

# GEOLOGICAL AND GEOTECHINICAL INVESTIGATIONS AND FIELD TRIALS

# CHAPTER 4

# GEOLOGICAL AND GEOTECHINICAL INVESTIGATIONS AND FIELD TRIALS

## 4.1 GENERAL

The Contractor shall be responsible for determining for his design purposes the Geology and the Geotechnical parameters of the sub-surface strata along the route. Geotechnical Investigations have been carried out by the Employer and the Geotechnical Investigations Reports are given in Employer's Requirements, Section VII-8, Tender drawings and documents for information only. These shall be confirmed and supplemented if considered necessary by the Contractor by way of additional boreholes.

## 4.2 FIELD TRIALS FOR PRIMARY SUPPORT SYSTEM

The Contractor shall carry out intensive field testing in order to evaluate the geological conditions expected to be encountered during tunnel excavation and to evaluate the design parameters required for design of the NATM tunnel. The trial may be made to the primary support system such as rock bolts/dowels, shotcrete, forepoling and pipe roofing in order to evaluate their performance in different geological conditions to the extent possible prior to the design of works so that more appropriate designs for different geological conditions can be established before the execution of work. Otherwise, such tests may be recommended at a suitable frequency in different geological conditions and change in geological conditions during excavation and design of primary support system shall be reviewed on the basis of the interpretation of the results obtained from instrumented data.

# CHAPTER 5

# DESIGN OF CUT & COVER TWIN TUNNEL AND PERMANENT VENTILATION SHAFTS

# CHAPTER 5

# DESIGN OF CUT & COVER TWIN TUNNEL AND PERMANENT VENTILATION SHAFTS

## 5.1 GENERAL PRINCIPLES

The Contractor shall use design methods for the analysis of the permanent ventilation shafts that take into account, but not limited to:

a. the method of construction, including temporary works;
b. the ground/structure interaction, including the effects of temporary works;
c. ground pressure redistribution and bending moment redistribution;
d. short and long term heave and settlement;
e. Groundwater loading, backfill and other imposed loading, if any.

For the purposes of assessing ground pressures the shafts shall be considered as effectively a rigid box structure subject to earth pressure at rest.

Temporary Ground Support shall be designed in accordance with the requirements of Chapter 6.

In preparing his designs and method statements the Contractor shall carry out his own assessment of the adequacy of the available geotechnical information, and shall indicate where he considers such information to be deficient having regard to the particular works or activities to which the design or method statement relates.

The Contractor shall at his own expense conduct further soil investigations where his designs or method statements identify that it is necessary or prudent to do so to enable him to identify all foreseeable circumstances which may affect the execution of the works and to ensure that there is no likelihood of meeting unexpected conditions of a critical nature.

If the Contractor intends to carry out additional ground investigation from the surface, beyond the limits of the worksite, he shall make his own arrangements with landowners and occupiers for the necessary access. He shall not assume that such access will necessarily be granted, although the Engineer will provide assistance where it appears that this would be beneficial.
The design life required shall be obtained by the use of durable materials, corrosion protection, resistance to or avoidance of wear etc.

## 5.2 DESIGN PRINCIPLES

The design method for construction of the cut and cover tunnels/ shafts shall take into account at least:

a) the geology along the length and depth of the cutting;

b) the hydrology and the permeabilities of the strata encountered along the length of the cutting;

c) the magnitude of settlement which could be expected. In this context the location of the works in relation to existing structures shall be considered.

d) the depth of construction required;

e) any particular difficulties that special plant might meet with in respect of access, clearances and working space;

f) the noise levels produced;

g) the methods by which the completed structure shall be secured against flotation;

h) the method of waterproofing the completed structure:

i) Slope instability.

## 5.3 EXCAVATION WITHOUT SUPPORT SYSTEM (OPEN EXCAVATION) FOR CUT & COVER TUNNEL

The open excavation shall be carried out in the area, where, there are no structures/ utilities/other establishment in the influence Zone of the excavation and does not involve extra tree cuttings. The detailed excavation scheme along with complete details of the scheme shall be submitted for prior approval of the Engineer.

## 5.4 FLOTATION

Minimum depth of overburden on underground structures should not be less than 2 metres in general. The Contractor shall check the cut and cover tunnels for the possibility of flotation due to differential water pressure and shall design the structure such that adequate factors of safety against flotation are provided as set out below.

A load factor of 0.90 shall be applied to the self weight of the structure, including the first stage only of the track concrete. A load factor of 1.0 shall be applied to the weight of backfill material over the structure.

The overall factor of safety against flotation shall not be less than 1.05 and 1.10 for any construction stage and after the completion of the Permanent Works respectively.

Suitable measures to counteract flotation forces for the Permanent Works shall be incorporated in the Contractor's design. The measure(s) chosen shall suit the particular conditions and the method of construction:

a) Toeing-in of the base slab into the surrounding ground;

b) increasing the dead weight of the structure by: thickening of structural members;

c) providing an extra thickness of concrete beneath the base slab tied into the structural base slab;

It will not normally be acceptable to modify the vertical alignment of the tunnels solely to counteract flotation forces. The use of ground anchors as a permanent measure to counteract flotation forces will not be permitted.

Where the base slab is toed-in to the surrounding ground a partial safety factor of 2.0 shall be applied to the shear resistance of the ground above the toe and the adhesion factor shall not apply. The value of the weight of ground above the toe shall be calculated as for the backfill material.

The value of the weight of any additional thickness of concrete shall take account of the increased volume of water displaced.

The Contractor shall ensure that his method and sequence of construction is such that an adequate resistance to uplift is maintained at all times, and shall put forward his proposal to this effect.

## 5.5 CRACKING OF CONCRETE

Anti-crack reinforcement shall be provided in all walls and slabs more than 250 mm thick to distribute cracking arising from shrinkage, early thermal and temperature effects.

Minimum reinforcement on each face in each direction shall be at least 0.125% of the concrete cross-sectional area for grades 415 and above.

In addition, spacing between the bars should not be greater than 150 mm.

Generally, pairing of bars and more than one layer of bars is not preferred for such structures. It is preferred that smaller diameter bars in any direction are placed at closer intervals to prevent early thermal and shrinkage cracks.

## 5.6 THERMAL CRACKING

Walls and slabs of underground structures are usually thick. Therefore, adequate consideration shall be given to the risk of early thermal cracking and shrinkage effects. Suitable property enhancers/blending material conforming to relevant codes shall be used by the weight of cement in such a manner that it shall replace the cement quantity for the same grade of concrete to reduce the risk of early thermal cracks. This concrete shall serve as a measure to reduce the thickness of walls & slab to minimise the risk of thermal cracks. The designer shall ensure that any requirements considered appropriate such as cement chemistry and curing methods are properly addressed.

## 5.7 CORNER DETAILS

Particular attention shall be paid to the corner joints of large structural members. External wall/slab junctions shall be provided with crack control steel and transverse ties. Radius of bend of main tension bars shall be increased to cater for the high bearing stresses within the bend.

## 5.8 CONSTRUCTION JOINTS

The design and detailing shall be such that the number of construction joints will be as few as practicable and shall minimise leakage.

## 5.9 BASE STABILITY

The Contractor shall include in design adequate precautions against base heave in the clayey silts during construction. The stability of the bottom of the excavation shall be checked in accordance with an acceptable method of analysis. A surcharge of 20 kN/m$^2$ shall be allowed for, applied at ground level to the ground surrounding the excavation.
The Contractor shall show in his calculations the contribution made to the base stability of the excavation by his proposed method of construction and shall state the factor(s) of safety used in the design. The factor(s) of safety shall relate to the method of construction and to the particular location of the Works and shall be subject to the consent of The Engineer.The Contractor shall check the stability of the completed structure against failure due to base heave under the structure.

## 5.10 WATERPROOFING

The grade of concrete, treatment of construction joints, areas of slab pours and external protection shall be chosen such that the required standard of waterproofing can be achieved and maintained. Materials for expansion joints, caulking etc. shall have acceptable fire performance for use on an underground railway line.

**5.11** Material parameters, loads & loading combinations, concrete cover and crack width shall be taken as per Design Basis Report given in Employer's Requirements, Section VII-8,Tender drawings and documents.

# CHAPTER 6

## TEMPORARY GROUND SUPPORT SYSTEM & OTHER REQUIREMENTS FOR EXCAVATION TO CUT & COVER TWIN TUNNEL AND PERMANENT VENTILATION SHAFTS

# CHAPTER 6

# TEMPORARY GROUND SUPPORT SYSTEM & OTHER REQUIREMENTS FOR EXCAVATION TO CUT & COVER TWIN TUNNEL, PERMANENT VENTILATION SHAFTS AND CONSTRUCTION CUM UTILITY SHAFT

## 6.1 TEMPORARY GROUND SUPPORT SYSTEM

Excavation will be required in soil as well as in rock or partially in rock and partially in soil for Cut & Cover tunnel and shafts. The design of temporary ground support system for Cut & Cover tunnel and shafts shall take into account all prevailing factors, loading and circumstances to ensure safety of temporary ground support system till permanent structures are constructed.

## 6.2 DESIGN OF TEMPORARY WORKS

Temporary works shall in general be designed in accordance with the same design standards as the permanent works. However, the design may take into account the limited duration over which the temporary works are expected to function. The calculations and drawings shall make clear where provision for limited life has been taken into account, particularly where this may have a substantial influence on the stability of the temporary works.

The design of temporary works shall take account of all the applied external forces and imposed structural deformations, and, additionally for underground works, the effects of removal of load from the ground and the movement of the ground independent of the load.

# CHAPTER 7

# DESIGN OF PRIMARY SUPPORT SYSTEM FOR NATM MAIN DRIVE AND PORTALS

# CHAPTER 7

# DESIGN OF PRIMARY SUPPORT SYSTEM FOR NATM MAIN DRIVE AND PORTALS

## 7.1 GENERAL

**7.1.1** In preparing his designs and method statements the Contractor shall carry out his own assessment of the adequacy of the available geological and geotechnical information, and shall indicate where he considers such information to be deficient having regard to the particular works or activities to which the design or method statement relates.

**7.1.2** The Contractor shall at his own expense conduct further soil/rock investigations in additions to investigations where his designs or method statements identify that it is necessary or prudent to do so to enable him to identify all foreseeable circumstances which may affect the execution of the works and to ensure that there is no likelihood of meeting unexpected conditions of a critical nature.

**7.1.3** If the Contractor intends to carry out additional ground investigation from the surface, beyond the limits of the worksite, he shall make his own arrangements with land owners and occupiers for the necessary access. He shall not assume that such access will necessarily be granted, although the Engineer will provide assistance where it appears that this would be beneficial.

## 7.2 DESIGN PRINCIPLES

The design method for construction of the NATM main drive and final lining of NATM tunnel shall take into account at least:

a) the expected geological conditions along the length and depth of the tunnel alignment;

b) the hydrology and the permeabilities of the strata encountered along tunnel alignment;

c) the depth of construction required;

d) any particular difficulties that special plant might meet with in respect of access, clearances and working space;

e) the noise levels produced;

f) control over heave, swell, piping and instability of the base of construction;

g) the methods by which the completed permanent ventilation shafts shall be secured against flotation;

h) the method of water proofing the completed structure;

i) expected performance of the proposed support system for NATM main drive

j) support system requirements for various expected geological conditions

k) type of construction equipment proposed for the NATM main drive

l) sequence of primary supports installations

### 7.2.1 NATM Main Drive in Soil

In some portion of the works, it is expected that tunnel is to be constructed in soil portion specifically from CH 26000 m to CH 28880 m. The excavation sequences for heading, benching and invert shall be designed in such a manner that the deformations inside the tunnel shall be limited to the design deformations considered in fixing the excavation profile. The design calculations for the support system shall be carried out with standard software available in the market, e.g. FLAC, PLAXIS, RS2 etc. The design submitted for the same shall also indicate for adjustment for support system requirement with respect to the instrumented data gathered during execution.

### 7.2.2 NATM Main Drive Partially in Alluvium and partially in Rock

In such a situation the primary support system shall be designed keeping in view of the requirements indicated in Sub-section 7.2.1 above with due consideration in the modelling for these geological variations and interfaces in between soil and rock.

### 7.2.3 NATM Main Drive in Rock

In rocky strata it is expected on the basis of observations made for the outcrops around the work site that the strata will be highly fractured. Special precaution shall be taken in the design for excavation sequence and support system in order to avoid collapse of the ground in any case. Due to highly fractured rock the analysis shall be carried out for excavation sequence and support system requirements and their installation sequences. The adequacy of the support system shall be ensured by means of detailed analysis and design of the construction sequences and installation of primary support systems and proposing the adjustment for these support systems after reviewing the instrumented data during excavation.

## 7.3 DESIGN OF NATM MAIN DRIVE

### 7.3.1 General

The Contractor shall prepare and submit to the Engineer for his consent a detailed design including calculations schedules and drawings for primary support system requirements and sequences of installations vis-à-vis excavations sequences for all kind of geological variations expected to be encountered along the tunnel alignment. The design of NATM main drive shall be carried out in accordance with provisions of DBR.

### 7.3.2 Method Statement

The Contractor shall prepare a method statement giving the full details of materials, plant and operations involved in the excavation and installation of primary support system for NATM main drive. This shall be incorporated into the design submission for consent and shall include details of:

a) Sequences of excavations;

b) The method of producing the shotcrete

c) The method of application of shotcrete

d) The method of placement of seal coat of shotcrete to the excavation;

e) Method of installations of rock bolt/dowel

f) Method of installation of lattice girder

g) Method of installation of shotcrete lining of required thickness

h) Method of installation of fore poling / pipe roofing

i) The methods of monitoring tunnel convergence and checking the stability of tunnel;

j) The methods of monitoring and checking the stability of neighbouring properties, highways, utilities and other underground structures;

k) Emergency procedures to be implemented in the event that monitoring indicates instability of tunnel excavation.

### 7.3.3 Ground Movements

The design of temporary ground-support works shall limit ground movement around the site and thereby avoid damage to adjacent structures and properties, roads, utilities, and footpaths.

During the Preliminary Design phase, all existing structures that may be influenced by construction of the works shall be investigated to establish allowable settlement criteria for each structure or group of structures. Establishment of an appropriate zone of influence shall be accepted as 50m either side of the tunnel centre-line or the base of the excavation plus a spread of 45° to the horizontal in areas where structures are located whichever is more.

The design of all ground-support walls shall limit settlement in the adjacent structures or ground to 25 mm maximum.

The design shall also include provisions to limit angular distortions in adjacent structures to 1:500 maximum. Angular distortion to sensitive structures may be limited to maximum

1:2000 depending upon nature and type of structures.

The above limits/provisions are upper limits. However, this may have to be restricted further if required to avoid damage to the adjacent structure or causing discomfort to the occupants.

These requirements are in addition to any other requirements imposed by applicable government agencies and the Employer.

#### 7.3.4 Limiting Construction-Induced Vibrations at Existing Adjacent Structures

In the design, the effects of construction-related vibrations shall be considered. Unless otherwise accepted by the applicable government agencies and the Employer, peak particle velocities at existing adjacent structures shall not exceed the values in the Table below:

**Table 7.1: Peak Particle Velocities in mm/sec (Maximum Allowable) at Existing Adjacent Structures**

| | |
|---|---|
| Most structures in "good" condition | 25 |
| Most structures in "fair" condition | 12 |
| Most structures in "poor" condition | 5 |
| Water-supply structures | 5 |
| Heritage structures/bridge structures | 5 |

Above limits are maximum permissible. However, this may have to restricted further if required to avoid damage to the adjacent structure or causing discomfort to the occupants. Methods of reducing vibration, such as limiting explosive charge per delay or operating pile-driving equipment at lower energy levels, may be required. The use of expansive agents or mechanical excavation methods shall be required in place of blasting at certain critical locations. In addition working hours for such equipment causing vibrations may have to restricted, keeping the convenience and comfort of the occupants in mind.

### 7.4 DESIGN OF FINAL TUNNEL LINING

#### 7.4.1 General

The Contractor shall prepare and submit to The Engineer for his consent a detailed design including calculations schedules and drawings for final lining for all kind of geological variations expected to be encountered along the tunnel alignment. Design of lining shall be carried out in accordance with provisions of DBR.

### 7.4.2 Cracking of Concrete

Anti-crack reinforcement shall be provided in all walls and slabs more than 250 mm thick to distribute cracking arising from shrinkage, early thermal and temperature effects.Reinforcement on each face in each direction should be at least 0.125% of the concrete cross-sectional area for grades 415 and above. In addition, spacing between the bars should not be greater than 150 mm.

Generally, pairing of bars and more than one layer of bars is not preferred for such structures. It is preferred that smaller diameter bars in any direction are placed at closer intervals to prevent early thermal and shrinkage cracks.

**Thermal Cracking**

Walls and slabs of underground structures are usually thick. Therefore adequate consideration shall be given to the risk of early thermal cracking and shrinkage effects. Suitable property enhancers/blending material conforming to relevant codes shall be used by the weight of cement in such a manner that it shall replace the cement quantity for the same grade of concrete to reduce the risk of early thermal cracks. This concrete shall serve as a measure to reduce the thickness of walls & slab to minimise the risk of thermal cracks. The designer shall ensure that any requirements considered appropriate such as cement chemistry and curing methods are properly addressed.

### 7.4.4 Construction Joints

The design and detailing shall be such that the number of construction joints will be as few as practicable and shall minimise leakage.

### 7.4.5 Waterproofing

Ground water Leakage rates shall not exceed a general value of 0.1 litres/sqm/day. For any 10 metre length of tunnel, the leakage rate shall not exceed 0.2 litres/sqm/day

The grade of concrete, treatment of construction joints, areas of pours and external membranes shall be chosen such that the required standard of waterproofing can be achieved and maintained without using waterproofing membrane.

### 7.4.6 Cross Passages

Design of cross passages shall be carried out on the lines of NATM main drive.
The locations of cross passages shall be chosen to avoid critical sections of the alignment where their construction could have an adverse effect on adjacent structures.

The openings into the running tunnels shall have a minimum width of 3.5 m and a minimum height of 3.5 m. Throughout the cross passage minimum headroom of 3.5 m shall be maintained over a width of 3.5 m.

The cross passage floor screed shall be laid to fall and drain into the running tunnel drainage system. Floor level shall correspond with the level of the tunnel escape route.

A concrete bulkhead with the provisions of fitting steel door and frame shall be provided to isolate the cross passage from each running tunnel. The door along with frame shall be provided and fitted (fixed) by the Contractor. The door shall be self-latching and have a fire resistance of 2 hours minimum and shall be capable of withstanding the maximum differential pressures on either side created by the passage of trains. Maximum force to open shall not exceed 150N. Any mechanism needed to operate the door must be demonstrated to be of adequate reliability.

#### 7.4.7 Design of Portals

Portals P1 and P2 shall be designed in accordance with provisions of DBR.

# CHAPTER 8

# INSTRUMENTATION AND MONITORING IN NATM TUNNEL

# CHAPTER 8

# INSTRUMENTATION AND MONITORING IN NATM TUNNEL

## 8.1 GENERAL

The Contractor shall submit a complete comprehensive instrumentation scheme with the Preliminary Design to achieve the following:-

- Safety during and after the construction by providing early warning of any excessive and undue ground movement inside the tunnel.
- To provide deformations and loading data for the verification of initial design of the primary and secondary support.
- To provide early information about tunnel behaviour in order to optimize excavation and support activities during construction and to recognize in time the requirements for remedial measures (Observational Approach)

The instruments shall be designed to meet the basic and minimum standards indicated in the specifications for designing, furnishing, installing, maintaining and removing instrumentation systems for the detection of ground movements, settlements and displacements, performance of tunnel ground support, measurement of loads, stress and strain in structural elements for the support of excavations. Associated field surveying work, development, processing and visualization of data shall also be carried out. Contractor shall be responsible for the supply and installation of the instrumentation, monitoring which includes taking of readings and the presentation of the results in a report form as per specifications and as directed by the Engineer.

## 8.2 SUBMISSIONS

### 8.2.1 General

All technical submissions are subject to the approval of the Engineer.

### 8.2.2 Method Statement for instrumentation

The Contractor shall submit together with Method Statement along with specifications, how he intends to run the specified monitoring system. The Method Statement shall include but not necessarily be limited to, the following:

- Proposed programme and procedures for obtaining and installing instruments and for performing the works. Quality Assurance Plan including various tests for quality control shall be submitted.

- Site organisation and a plan for his personnel deployment (no of crews and person per crew) and how he intends to perform the specified work. The program shall consider the following conditions and time frame for excavation activities:

- Tunnel excavation works will be day and night 7 days a week.
- Instrument and material information shall consist of complete instrument description and specification; calibration test results and certificates of compliance; replacements, spares, maintenance requirements and suppliers details.
- Details of the system, which shall be used for data collection and data transfer to a computer unit and/or recording unit. This is related to all monitoring devices, which are equipped with remote reading facilities.
- Type and presentation of output to be produced by the Contractor.
- Detailed procedures applied during acceptance tests, function testing and calibrations for all monitoring equipment.
- Proforma Sheets as applicable.

### 8.2.3 Working drawings, records and procedures

**(i)** Working drawings and complete installation procedures including checks and calibrations.

**(ii)** Principal features of the work to establish and reference instrumentation locations.

**(iii)** Established elevation of each cased deep benchmark and the initial elevation of each settlement reference point.

**(iv)** Working drawing or in report form showing the following:

(a) Installation procedure used for the installation of each instrument. Include date of installation.

(b) As built configuration of each instrument including depths, lengths, elevations, station, offset and other dimensions of key elements of each installed instrument.

(c) Verification of records that instruments meet specified tolerances.

**(v)** Daily logs and survey notes:

(a) Keep logs and survey notes stating all instrument readings and observations made about events regarding temperature, weather, soil and groundwater conditions on the Site, and all other information required to properly interpret the data.

(b) The notes and logs shall include at least the following additional information:

- Temperature.
- Water ingress.
- List of instrument observations performed.
- Date and time of observations.
- Coordinates of locations.
- Names of the operators.
- Types and serial numbers of measuring devices used.
- Construction loading or other activities in the vicinity of instrumentation.
- Duration and cause of interruptions or delays to progress.
- Any cracks in or damage to any structures, or other events.

## 8.3 SPECIFICATIONS FOR NATM INSTRUMENTS

### 8.3.1 General

The essential requirements of any instrument shall be reliability and provide easy and fast installation, operation and calibration. The instruments must be durable and not prone to damage during and after installation.

In the case of electrical readout devices and electrical remote reading facilities, the reliability of the measured signals shall be such that the instrument's accuracy fulfils the short term as well as the long term requirements under the prevailing environmental conditions underground with cable lengths of more than 250 m.

The device shall be designed to deliver stable electrical signals during the intended service life of the instrument.

### 8.3.2 Instrument's Specifications

#### i) Level Points

a) For the determination of elevation of tunnel crown or at other points only approved pins or bolts shall be used.

b) Levelling of the tunnel crown and other specific points (sidewalls etc.) shall be done during tunnel excavation to monitor settlements and bottom heaves. The method of performing the level measurements shall be such as to ensure an accuracy of ± 1 mm.

**ii) Convergence Bolts**

a) Convergence bolts or pins shall consist of ribbed bars protected against corrosion with a minimum length of 250 mm.

b) The pins shall be securely attached to the exposed rock or shotcrete surface.

c) After installation, the convergence pins shall be protected by a protective cap.

**iii) Targets or Reflectors**

a) For opto-electronical measurements the bolts shall be provided with a plastic cap with a predetermined breaking point serving as an adapter for the mounting of a reflector with a marked centre point. This device shall be designed for high precision measurements with two axes of rotation and to be observable from both sides. The manufacturing accuracy must be better than □ 0.1mm in order to achieve an overall accuracy of □ 1mm within the measuring section. The targets must be replaceable without loss of accuracy.

b) This plastic reflector can be replaced by a positive centered prism if required with the same standard as the reflector above.

**iv) Borehole Extensometer**

a) Borehole extensometers shall be multiple position rod type or single rod type with mechanical anchors at fixed points.

b) The minimum lengths of anchor parts must be 500mm, the minimum diameter should be 20mm.

c) Each rod must be protected by a waterproof tube so as to be able to move freely.

d) Multiple rod type extensometers shall be designed to read at least at three positions.

e) The instruments shall be resistant to corrosion.

f) The diameter of the bore hole for installation of the extensometers depends on the type (single/multiple rod type) and it shall be in accordance with the manufacturer's recommendations.

g) The dial gauge stop shall be adjustable to □ 100mm.

h) Initial readings shall be done by a dial gauge and calibration standard. Following measurements will be done remotely by using electrical transducers. These sensors must have a measuring range of 50mm and must guarantee an accuracy of the extensometer readings better than 0.05 mm. The sensor element shall be of vibrating wire type suitable to transfer the data without loss of information.The replaceable sensors must be robust, stainless and waterproof, suitable for rough environment near the excavation area at the tunnel face. Cabling must withstand shotcreting.

i) Provide weatherproof enclosures, sealed against the intrusion of dust and water, for termination of electrical cables. These connection boxes will be placed on both sides of the measuring section and will contain a terminal board with clearly marked and identified connectors or rotary switches to read each displacement transducer. Provide compatible connection between terminal board connectors and readout.

j) Provide readout unit compatible with the provided displacement transducers showing measured values in real physical units [mm]. The readout units with data storage capability not less than 2 MB and shall also be lightweight, portable, battery operated, rechargeable and sealed against dust and moisture.

k) Provide a mechanical dial gauge with calibration standard for initial readings.

**v) Strain Gauges (Strain Meters)**

a) Provide resistance type strain gauges, or equivalent, with the following minimum requirements.

- Strain range, $10*10^{-3}$ m/m for compression, $4*10^{-3}$ m/m for tension
- Accuracy of least $10^{-5}$ m/m
- Average sensitivity, one microstrain
- Temperature range, minus 10 to plus 60°C
- Active gauge length, 200 mm minimum
- Electrical cable, shielded, and rubber insulated
- Optional thermistors shall be furnished with the strain gauges, and shall be incorporated with the strain gauge in the same instrument.

b) Provide the waterproof shielded electrical cable resistant to shotcreteting and water.

c) Provide weatherproof enclosures, sealed against the intrusion of dust and water, for termination of electrical cables. These connection boxes will be placed on both sides of the measuring section and will contain a terminalboard with clearly marked and identified connectors or rotary switches to read each strain gauge. Provide compatible connection between terminal board connectors and readout.

d) Provide readout unit compatible with the provided strain gauges showing measured values in real physical units [□m/m]. The readout units with data storage capability not less than 2 MB and shall also be lightweight, portable, battery operated, rechargeable, and sealed against dust and moisture.

**vi) Shotcrete Creep Test Equipment**

a) Provide an **in situ** shotcrete creep test stand consisting of a hydraulic piston with precise automatic load control, strain measurement installed on one specimen (200x200x400mm), temperature measurement within the specimen as well as shrinkage monitoring on two, non stressed specimens. The test stand shall be installed in the vicinity of the excavation area, the specimen shall be produced by means of the shotcreting equipment and shotcrete used for regular support. Time dependent stress levels shall be applied to the specimen and by means of the resulting stress-strain-time relation necessary parameters for the shotcrete material law shall be generated.

b) Specifications

- Max. hydraulic cell force = 1000 kN
- Stroke = 50 mm
- Duration of one creep test: 20 to 28 days
- Number of programmable force levels: 6
- Accuracy of force control: < 1% FS
- Data storage: 20.000 measurements (Date/Time; Load; Strain)
- Range of strain measurement: 4%
- Sensitivity of strain measurement: 1,5E-6
- Accuracy of strain measurement: 10E-6
- Download of data: via PC or laptop, EXCEL compatible file format

**(vii) Load Cells (Center-hole type)**

a. Provide hydraulic/electrical center-hole or strut-installation type load cells with capacities and accuracies as given below.

b. Provide reinforcement steel plate and set screws for the installation of strutted type load cell.

c. Provide distribution plate and abutment plate for the installation of center- hole type load cell.

d. Provide calibration sheet for each load cell.

e. Both types of load cell shall be electron beam welded type to comply with the following general requirements:

- Sensitivity of Cell: 0.5% of full range
- Equipped with an electrical sensor for remote reading. The output interface must be designed to transmit data without loss of accuracy via cabling longer than 250m.
- Total System Accuracy: ± 2.0% of full range
- Operation Range: Up to 2 times maximum design load

f. Provide readout unit compatible with the provided load cells showing measured values in real physical units [kN]. The readout units with data storage capability not less than 2 MB and shall also be lightweight, portable, battery operated, rechargeable and sealed against dust and moisture.

g. Provide weatherproof enclosures, sealed against the intrusion of dust and water, for termination of electrical cables. These connection boxes will be placed on both sides of the measuring section and will contain a terminal board with clearly marked and identified connectors or rotary switches to read each load cell. Provide compatible connection between terminal board connectors and readout.

**(viii) Rock Bolt Axial Force Meter "Measuring Anchor"**

a) Provide complete hollow bar rock bolt with an integrated precise 4-fold extensometer:

- Resolution of integrated extensometer : 0,01mm
- Total System Accuracy for load calculation: ± 2% of nominal load
- Nominal load of anchor: 250kN (optional 350kN)
- Length of rock bolt: 4m or otherwise decided by the Engineer.

b) Provide nut and spacer to block and tension bolt after placement of shotcrete.

c) Initial readings shall be done by a dial gauge and calibration standard. Following measurements will be done remotely by using electrical transducers. These sensors must have a measuring range of 10mm and must guarantee an accuracy of the readings better than 0.02 mm. Thesensor element must be equipped with a 4-20mA interface to ensure a data transmission without loss of information. The replaceable sensors must be roboust, stainless and waterproof, suitable for rough environment near the excavation area at the tunnel face. Cabling must withstand shotcreting.

d) Provide readout unit compatible with the provided displacement transducers showing measured values in real physical units [mm]. The readout units with data storage capability not less than 2 MB and shall also be lightweight, portable, battery operated, rechargeable and sealed against dust and moisture.

e) Provide weatherproof enclosures, sealed against the intrusion of dust and water, for termination of electrical cables. These connection boxes will be placed on both sides of the measuring section and will contain a terminal board with clearly marked and identified connectors or rotary switches to read each displacement transducer. Provide compatible connection between terminal board connectors and readout.

**(ix) Radial Pressure Cell**

a) Provide pressure cell to comply with following general requirements:

- Sensitivity: 0.2% of full scale
- Measuring range of electrical sensor: 5 MPa
- Total System Accuracy: ± 2% of full scale
- Active measuring area: 300x300mm

b) Provide couplers for mounting cells onto protective wire mesh lining.

c) Instead of a simple re-pressuring device the flat jack must be equipped with devices for re-grouting the gap between pad and shotcrete/concrete which might appear due to shrinkage of shotcrete/concrete.

d) The sensor must be equipped with Vibrating Wire type enclosed in electronic beam welded case suitable to transmit data without loss of accuracy due to long cabling.

e) Provide shielded cable or tube for con tnnectioo terminal panel.

f) Provide weatherproof enclosures, sealed against the intrusion of dust and water, for termination of electrical cables. These connection boxes will be placed on both sides of the measuring section and will contain a terminal board with clearly marked and identified connectors or rotary switches to read each pressure transducer. Provide compatible connection between terminal board connectors and readout.

g) Provide readout unit compatible with the provided pressure transducers showing measured values in real physical units [Mpa or bar]. The readout units with data storage capability shall also be lightweight, portable, battery operated and rechargeable, and sealed against dust and.

## 8.4 EXECUTION AND MONITORING

### 8.4.1 General requirements

(i) The instruments shall be installed at locations and in accordance with a time schedule as per approved scheme or at vulnerable locations encountered during excavation.

(ii) The geotechnical instrumentation and the monitoring program may be subject to alterations and modifications if required by the actual geological or geotechnical conditions.

(iii) All instrumentation shall be installed in accordance with the manufacturer's recommendations and with the additional requirements specified in this section.

(iv) The installed measuring equipment as well as the required space for measuring must be kept free and accessible for all the duration of construction.

(v) All instruments shall be protected against damage by blasting and tunnel traffic. Where required protective covers or housings may be used to prevent damage of the instruments.

(vi) Readout units as dial gauges or tape extensometers shall be available at any time during tunnel construction. Spare parts and spare units shall be maintained on site.

(vii) All instruments and equipment used and required for the geotechnical measurements shall be made available to the Engineer throughout the construction period.

### 8.4.2 Reading and Plotting

(i) Reading of the instruments, data processing and plotting of the measurement results shall be carried out by qualified personnel of the Contractor subject to approval of the Engineer.

(ii) For the optical displacement monitoring a software package shall be used which allows a direct data flow. This software shall include features as follows:

a. Free stationing of the theodolite and calculation of standard deviation in all three coordinate directions.

b. Automatic target identification and recognition of new zero readings.

c. Calculation of 3D-coordinates and displacements of any desired point and its radial distance to the theoretical profile.

d. Correction of errors based on physical effects.

e. Transformation of coordinates after control measurements.

f. Measurement results shall be tabulated and presented in graphs.

**2.** The provided software shall include following features**:**

a. Development of displacements with time, directly associated with driving activities.

b. Plot of displacement vectors within the cross section.

c. 3D Displacement vector orientations

d. Excavation program related evaluation and presentation of displacements (Influence lines showing the influence of daily excavation on displacements of measuring points).

e. Assessment of displacements prior to zero measurement.

f. Development of differences in displacement with time e.g. roof settlement minus settlement of top heading footing.

g. Calculation of stresses and safety factors or degree of utilisation for the shotcrete lining based on optical displacement monitoring, and time dependent shotcrete strength.

h. Other evaluations as required by the Engineer & Designer.

(iii) For the monitoring of geotechnical instruments a software package shall be used which allows a direct data flow. This software shall include features as follows.

a. Presentation of data related to the time and excavation progress within one plot.

b. Cross-sectional visualisation of measuring anchor and extensometer data.

c. Multiple plot capabilities (Forces / Radial strains in rock mass / displacements).

d. Shotcrete stress calculation based on strain measurements material law for young shotcrete as tested in situ.

(iv) The first measurements (zero-readings) shall, for each measuring instrument, be made immediately after installation or as soon as the particular instrument may allow.

(v) The frequency of the further measurements or readings can be envisaged for each measuring section as follows:

| | |
|---|---|
| 1st week: | daily |
| 2nd week: | twice a week |

| | |
|---|---|
| 3rd & 4th week: | once per week |
| Later: | monthly and bi-monthly |

When the bench is approaching the instrumentation section installed during top heading, reading frequencies shall be increased again.

The actual frequency of readings will however be influenced by the construction stages top heading/bench heading in the tunnel and shall be proposed by the Contractor.

Data of the optical displacement monitoring shall be processed on the same day and plots shall be available at late afternoon or as requested by the Engineer. Other data from measurements must be processed within 24 hours after the readings have been taken and must be plotted. All processed data and visualized diagrams must be available and open for the Engineer at any time. A copy of all records shall be permanently kept on site and made available to the Engineer. If required the Engineer may instruct shorter data processing and visualisation time.

(vi) The contractor has to inform immediately the Engineer in the case he observes obvious unusual and unexpected readings or makes other unusual observations in the tunnel.

# CHAPTER 9

# MONITORING SECTIONS AND MONITORING DEVICES FOR NATM TUNNELS

# CHAPTER 9

# MONITORING SECTIONS AND MONITORING DEVICES FOR NATM TUNNELS

## 9.1 GENERAL

In principle, the various monitoring devices shall be installed in monitoring sections. Monitoring sections can be subdivided according to the instrumentation installed. For this project, the following types of instrumented sections shall be applied:

**Table 9.1: Definition of Monitoring Sections**

| Monitoring Section Type | Monitoring Devices Surface | Monitoring Devices Underground |
|---|---|---|
| Standard (Type A) | Precise Leveling (only for Open Excavations near portal) | Absolute Displacement Monitoring |
| Main (Type B) | Extensometers (only in soft ground sections with shallow overburden) | For Tunnels:<br>Absolute Displacement Monitoring, Extensometers, Pressure Cells, Shotcrete Strain Meters<br>For Shafts:<br>Absolute displacement monitoring and shotcrete strain meters |
| Special | To be defined according to requirements | |

Standard Monitoring Sections (Type A) consist only of targets for absolute displacement monitoring underground. They shall be installed at regular intervals in the tunnels (approximately every 10 meters). For the excavations near portals surface markers at suitable distances shall be installed and precise leveling carried out.

In "Main" Monitoring Sections (Type B) additionally the monitoring devices given in the table above shall be installed. They shall allow additionally an assessment of the loading of the primary support and of ground movements outside the excavation for design verification purposes. At present it is envisaged to install these sections at approximately 150m to 200m distance. This distance may be changed as per site conditions.
Special monitoring instruments shall be installed for special purposes and may contain rock bolt strain meters and rock bolt load cells.

## 9.2 PRECISION LEVELING

Precision Leveling shall be performed at the surface for control of the slopes near the portal. All settlement points shall be installed at construction activities or to allow for reliable zero readings without any influence of construction activities.
It has to be guaranteed that the settlement pins are properly connected to the ground and their movement is not restricted or hindered by application of any structural elements to the location.

All precise leveling points shall be sufficiently protected against any damage due to traffic, vehicles, etc.

## 9.3 3D ABSOLUTE DISPLACEMENT MONITORING

Monitoring of absolute displacements improved rapidly with improvements in electronic surveying instruments and computer software. With absolute displacement monitoring it is possible to determine 3D-coordinates of defined targets (reflectors) fixed to the tunnel wall. This information is used to track the target movements in space and allows a realistic assessment of the deformation behavior of the tunnel.

It is obvious that the layout of monitoring stations respectively their spacing between each other is depending on the geological conditions.

In general, the following scheme shall be applied:

**Table 9.2: Installation Scheme of Targets for 3D – Absolute Displacement Monitoring**

| Structure | No. of Targets in Cross Section | Longitudinal Spacing | |
|---|---|---|---|
| | | Good Ground Condition | Poor Ground Condition |
| Main Tunnel | 7 (5 in top heading, 2 at bench) | 10 ~ 20 m | 5 m |

Additional targets and displacement monitoring sections (type A) might be required in special areas such as intersections and niches. However, the installation of these sections shall be decided by the Geotechnical Engineer on site during execution of the works.

## 9.4 EXTENSOMETERS

Extensometers are used for determination of ground movements outside of the excavated structure. They allow an assessment of the development of strains in the surrounding ground and stabilization of movements around an excavation.

Extensometers shall be multiple rod type with anchors connected to the ground by grouting at predefined positions.

Extensometers installed shall be sufficiently protected against any damages by construction or equipment.

| Structure | No. of Targets in Cross Section | Longitudinal Spacing |
|---|---|---|
| Main Tunnel | 3 Nos. 3 points MPBX | 50m |

## 9.5 SHOTCRETE STRAIN MEASUREMENTS

Shotcrete strain meters are used for determination of the stress development in the shotcrete lining by measuring strains. They are always installed pair wise to allow a determination of sectional forces such as normal thrust and bending moments.

Based on the measured strains stresses in the shotcrete lining are calculated by utilization of a nonlinear material law. As several input parameters are required for this material law long term creep tests on young shotcrete shall be performed, allowing a determination of the required material parameters.

Shotcrete strain meters shall be temperature compensated to compensate for temperature increase of the shotcrete during the hardening process. Shotcrete strain gauges shall be installed at following sections:

| Structure | No. of Targets in Cross Section | Longitudinal Spacing |
|---|---|---|
| Main Tunnel | 7 Nos. | 100m |

## 9.6 PRESSURE CELLS

### 9.6.1 Radial Pressure Cells

With radial pressure cells the development of ground pressure acting on the primary support structure (shotcrete lining) is measured. To get reliable results the following requirements shall be met:

1. Large size pressure cells, as a larger area of the cell gives more reliable results (larger area of influence)

2. Possibility of Rerouting; caused by thermal effects a shrinkage gap develops between the cell and the shotcrete lining, which has to be closed to provide accurate cell readings.

Therefore pressure cells shall be of size 300 x 300 mm. Readings shall be taken remote controlled with electrical transducers.

### 9.6.2 Tangential Pressure Cells

Tangential Pressure cells are used for determination of the shotcrete lining stress. They shall only be installed in areas of special interest such as intersections. They shall have a dimension of 100 × 200 mm. Readings shall be remote controlled with electrical transducers.

### 9.6.3 Following scheme shall be followed:

| Structure | No. of Targets in Cross Section | Longitudinal Spacing |
|---|---|---|
| Main Tunnel | 7 Nos. | 100m |

## 9.7 ROCK BOLT AXIAL FORCE METER "MEASURING ANCHOR"

Measuring Anchors are used to determine the load development along the anchor. This will provide information how load increases from the anchor tip to the anchor plate. Measuring anchors shall be installed together with rock bolt load cell and extensometers. These shall be installed at least at 3 locations.

## 9.8 ROCK BOLT LOAD CELL (CENTER HOLE TYPE)

The load cell(accuracy 0.5% and of 250 kN capacity) is installed at the anchor plate, It gives information on the maximum anchor load and the degree of utilization of the anchor. These shall be provided at least at 3 locations.

| Structure | No. of Targets in Cross Section |
|---|---|
| Main Tunnel | 5 Nos. center hole load cells |

## 9.9 SWITCH BOX

2 Nos. of switch boxex shall be provided at every 50 m.

# CHAPTER 10

# EVALUATION AND INTERPRETATION OF MONITORING RESULTS

# CHAPTER 10

# EVALUATION AND INTERPRETATION OF MONITORING RESULTS

## 10.1 GENERAL PROCEDURE

In general, the data handling and information flow of monitoring results shall be as follows:

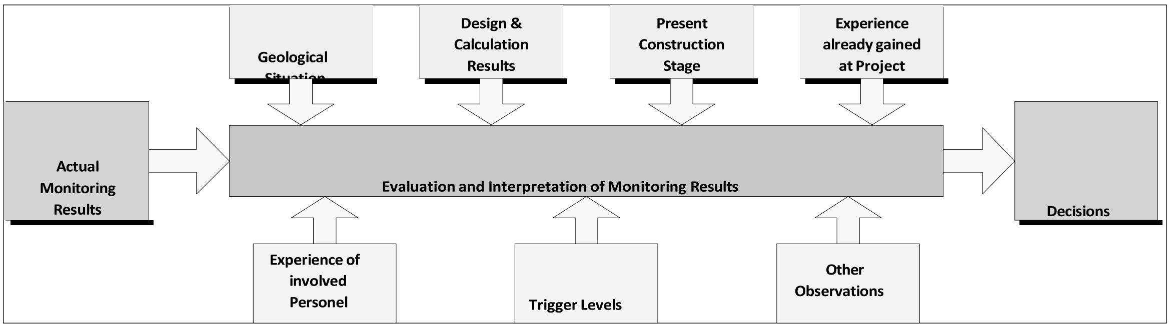



**Fig. 10.1: Input Parameters for Evaluation and Interpretation of Monitoring Results**

This will provide information how load increases from the anchor tip to the anchorplate. Measuring devices shall be installed together with rock bolt load cell and extensometers.

Upon completion of daily monitoring activities and preprocessing of monitoring raw data a preliminary evaluation of the monitoring results by a plausibility check shall be performed. Only after the results have to be found reasonable and eventual errors have been excluded and corrected, an update of the database shall be performed. Plausibility checking shall be performed by the monitoring contractor together with the DDC Instrumentation /Survey Engineer.

When the database has been updated with the actual monitoring results, Data are provided to Engineer with evaluation and interpretation of the results. To guarantee a quick decision with regard to support requirements and working procedures the database must be updated with the daily, measurements each afternoon as directed by the Engineer.

If the monitoring results are outside of the range of expected behavior the Contractor has to make immediately required decisions and notify the Engineer.

## 10.2 METHODS OF DATA EVALUATION AND INTERPRETATION

### 10.2.1 General

**According to their geomechanical relevance, the main monitoring parameters for tunneling are as follows:**

**Table 10.1: Parameters and their Geomechanical Relevance of 3D-Monitoring Results**

| Parameter | Geomechanic Relevance |
|---|---|
| Trend of Time Histories | |
| Time - Displacement Diagram | Useful for assessment of time dependent components of displacement and stabilization of construction steps |
| Distribution of Cross Section Displacemen t Vectors in | Reflects the effects of geological structures subparallel to the tunnel axis |
| Influence Lines (General) | Reflects the geomechanical conditions of the ground along the tunnel and the effect of individual excavation steps on the already excavated section |
| Trend Lines | Useful for o changes in determination ground f indicator for conditions and critical as developments |
| Development of longitudinal Displacements close to the excavation face | Indicates changes in ground stiffness ahead of the face |
| Trend of advancing displacements due to bench excavation | Reflects the influence on individual bench excavation steps on the already excavated tunnel sections |
| Development of differential settlements between crown and top heading footings | Reflects the bearing behavior of the primary lining and the quality of the primary lining foundations |

### 10.2.2 Time – Displacement Diagrams, Magnitude of Displacements

Time-Displacement diagrams show the development of the displacement of one point versus time. Time-displacement diagrams can be generated for all three components of the displacement vector (vertical, horizontal and longitudinal displacement). Construction phases (top heading, bench, and invert) are usually shown on the same diagram to allow for an easy correlation between displacement behavior and construction activities.

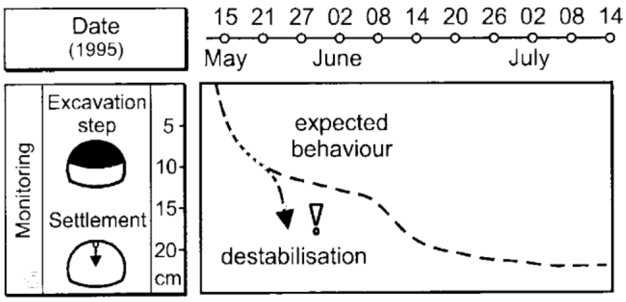



**Fig. 10.2: Schematic Time- Displacement Diagram (Settlement for Crown Point)**

When a constant face advance rate is assumed, the displacement rate over time has to decrease continuously. Any acceleration indicates a destabilization, unless construction activities in the vicinity of the monitored tunnel section such as bench or invert excavation are ongoing. Usually after each excavation step a tendency towards stabilization must occur.

It is essential to consider that the displacements monitored in the tunnel are only a part of the total amount of displacements occurring. Fig. 8.3 shows a principle sketch of the total vertical displacements and the measurable amount of displacements in the tunnel. A certain amount of predeformation occurs already ahead of the face. When the excavation has reached the chainage of the monitoring section, an additional part of the total displacements cannot be measured due to the time required between excavation, installation of the monitoring section and the following zero reading of the section. Therefore it is essential that installation and zero reading of monitoring sections are performed as fast as possible without any unnecessary delays.

In this respect, all zero readings in the tunnels shall be taken latest 6 hours after excavation of the relevant monitoring section.

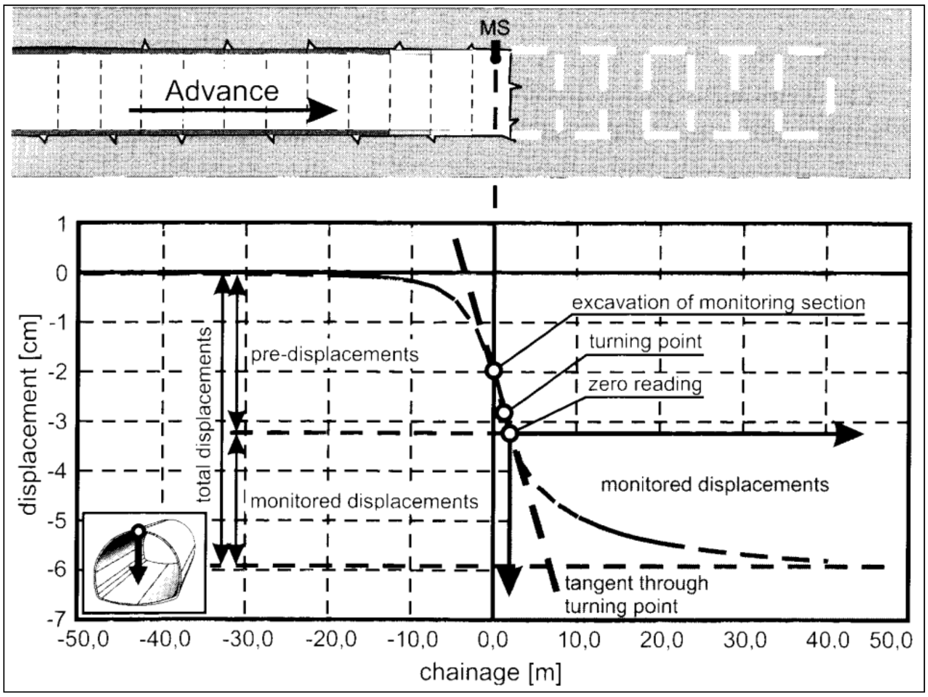



**Fig. 10.3: Schematic Representation of Pre-Displacements and Monitored Displacements in Tunneling**

### 10.2.3 Distribution of Displacements in Vector Diagrams

Displacement Vector plots allow the representation of the cross sectional displacements and their development with time.

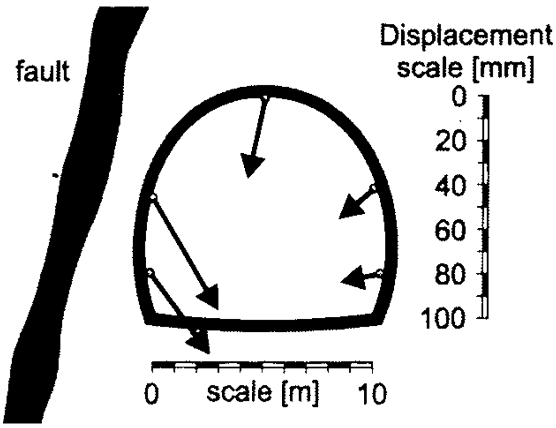



**Fig. 10.4: Vector Diagram – Influence of Stratification**

Displacement vector plots allow the detection of weak zones and / or faults outside the excavation area. They provide additional information about the rock mass structure and deformation phenomena close to the tunnel. In general, the displacement vector orientation in cross section reflects the influence of geological structures on the deformation behavior subparallel to the tunnel.

#### 10.2.4 Lines of Influence

Lines of Influence are produced by connecting displacement values of a number of monitoring points along the tunnel axis at the same time, similar to a "deflection curve". Normally, a number of lines for a specified time span are shown on one plot. In addition, construction phases (top heading, bench, invert) are shown to allow for an immediate correlation between measured displacements and and construction activities.

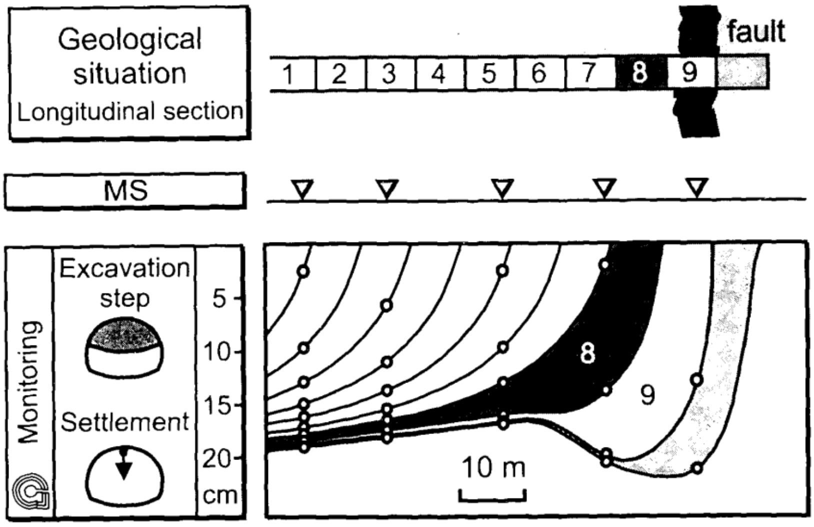



**Fig. 10.5: Development of Lines of Influence when Excavation approaches a "Weak Zone"**

The lines of influence in the simplified diagram above show the settlement of the crown resulting from top heading excavation. The uniform shape of lines corresponding to excavation steps 1 to 7 reflect a homogeneous ground mass with uniform behavior. As the excavation approaches the fault (9), in excavation step 8 already a significant deviation of the previously uniform behavior can be observed, extending also significantly behind the face. During tunneling through the fault a further increase in settlements is measured.

#### 10.2.5 Trend Lines

Trend lines are generated by connecting settlement values of individual lines of influence at a predefined distance behind the face. They give a good overview of the displacement development along the tunnel and are quite useful for extrapolation of the displacement behavior ahead of the excavation face.

Trend lines which show increasing displacement can indicate critical situations and must be considered as a serious warning signal.

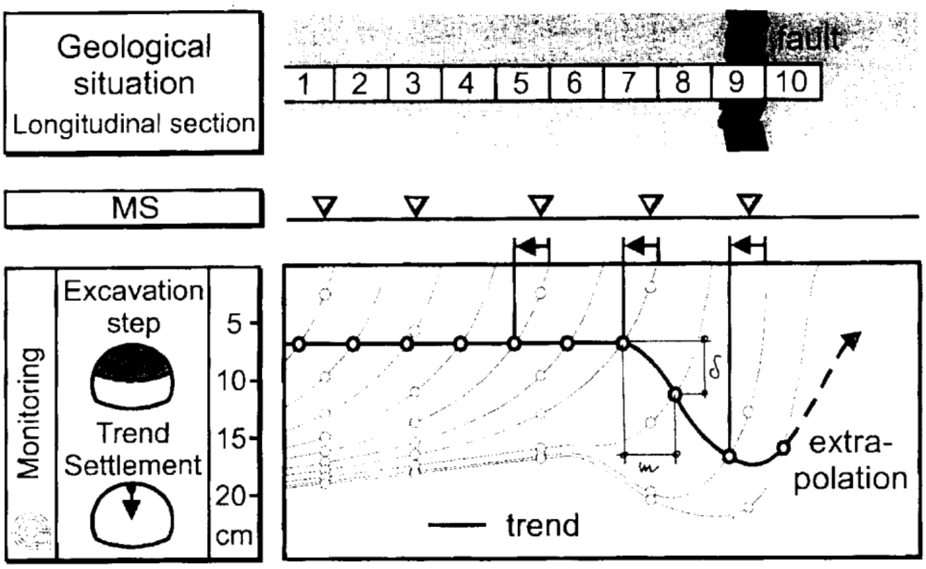



**Fig. 10.6: Development of Trend Line when Excavation approaches a "Weak Zone"**

#### 10.2.6 Differential Settlements

This displacement option is used to show the difference in displacements between two monitoring points belonging to the same monitoring section.

Usually, the difference in settlements is displayed between:

- Crown and sidewall ($S_{crown} - S_{sidewall}$) $= \Delta S$
- $\Delta$ S for both side walls shall be observed.
- And for horizontal displacements between:Left and right sidewall ($H_{left} - H_{right}$)
  - The values of ($S_{crown} - S_{sidewall}$) and ($H_{left} - H_{right}$) can provide valuable information foundation condition of the footing.

### 10.3 CONTROL LIMITS

Comparison of monitoring data with control limits will give a first indication for the identification of potential areas which are close to or exceeding design limits.

For the judgement of rock mass behavior and performance of the primary support, control limits are established in terms of primary lining displacements, displacement velocities, shotcrete strains, settlements etc.

### 10.3.1 Types of Control Limits

Under expected construction conditions the monitored displacements and other monitored data will be below the established threshold values, called control limits, which define certain design limitations.

The control limits are established by the following trigger levels.

#### (i) Alert Level

The alert level relates to threshold values representing the assessed behavior (predicted values), on accidence of which, certain routines will be started to impose an increased attention and surveillance to these specific areas.

The alert values indicate that the specific area is approaching a level where additional actions and / or contingency measures may be necessary. The need for adjustment of excavation and support procedures and / or monitoring shall be considered.

#### (ii) Alarm Level

The Alarm level relates to threshold values, on accidence of which the element of work may be approaching a critical state. The Geotechnical Engineer shall convene for judgement of the specific case and the overall support and rock mass performance. Implementation of additional support and / or contingency measures to avoid the accidence of the Action Level shall be considered.

#### (iii) Action Level

This level relates to threshold values on accidence of which the element of work is considered to be outside the expected range of assessed behavior and may be close to its ultimate limit capacity.

The overall performance shall be rechecked together with a related risk assessment. A design review shall be performed together with an assessment of the need for additional support. Additional support and / or contingency measures to guarantee the safety of the works shall be implemented.

For the case of identification of an unacceptable safety risk, the works shall be stopped and remedial measures shall be implemented immediately.

## 10.4 DEFINED MONITORING PARAMETERS

### 10.4.1 General

Control limits shall be defined by the Geotechnical Engineer for the following monitoring parameters:

a. Displacement velocities derived from 3D absolute displacement monitoring

b. Differential Settlements

i. Shotcrete strains derived from strain measurements with shotcrete strain meters in the shotcrete lining

Information derived from other monitoring results such as extensometers, ground pressure cells etc. are used to confirm and supplement monitoring data and trends derived from the instruments above and to judge the overall performance and safety of the construction in case of exceedance of control limits.

The definition of control limits shall be considered as flexible and adjustable, which means control limits shall be updated regularly, if necessary. The control limits shall be adjusted on basis of experience gained during construction, if required.

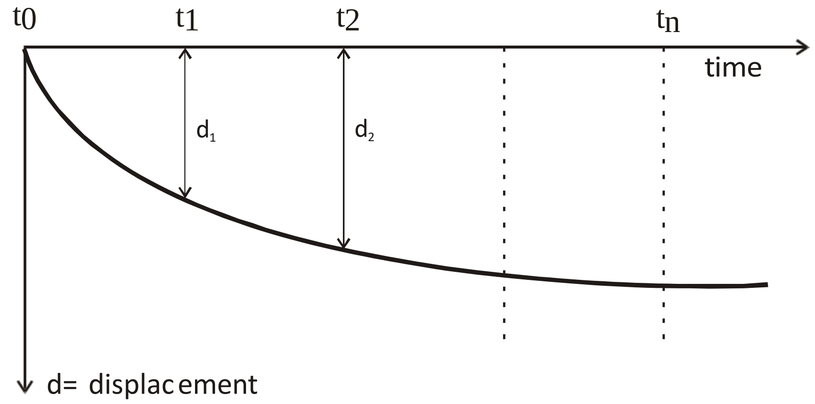
### 10.4.2 Displacement Velocity

Displacement velocities are calculated from the measured 3D optical displacements and are an important indicator for stability development. Usually, time intervals between observation points "$t_n$" are taken as one day. However, if the elimination of scatter effects related to monitoring inaccuracies is required, larger time intervals may occasionally be applied.

It is assumed that progress in the top heading will be 2 ~ 3 m per day.

Continuing or increasing displacement velocity indicates that the rock mass is not stable and may be indicative for progressive destabilization.

However, immediately after excavation an increase of displacement velocities is an expected phenomenon caused by stress redistribution. After installation of the primary support, these displacement velocities must decrease and stabilize after the excavation face has advanced further and the stress redistribution is completed.




$$v_1 = \frac{d_1}{t_1 - t_0}, \quad v_2 = \frac{d_2 - d_1}{t_2 - t_1}, \quad v_n = \frac{d_n - d_{n-1}}{t_n - t_{n-1}}$$

**Fig. 10 .7: Definition of Control Limits for Displacement Velocities**

As a guideline, the control limits related to measured displacement velocities are defined as follows:

**Table 10 .2: Control Limits for Displacement Velocities**

| Control Limit | Displacement Velocity |
|---|---|
| ALERT | $\Delta_n = 0.8\ \Delta_{n-1}$ |
| ALARM | $\Delta_n = 1.0\ \Delta_{n-1}$ |
| ACTION | $\Delta_n = 1.1\ \Delta_{n-1}$ |

### 10.4.2 Differential Settlements Top Heading Crown – Top Heading Footing

Differential Settlements between the top heading crown and the top heading footing shall be monitored to identify potential instabilities at the shotcrete lining footing:

Differential Settlement: $\Delta s = S_{crown} - S_{footing}$

**Table 10 .3: Control Limits for Differential Settlements Top Heading Crown**

**– Top Heading Footing**

| Control Limit | Differential Settlement |
|---|---|
| ALERT | + 5 mm |
| ALARM | + 1 mm |
| ACTION | - 3 mm |

### 10.4.3 Trend Lines

Control Limits for trend lines are defined in terms of:

fadvance

With = Increase in displacement

*Advance* = corresponding face advance

**Table 10.4: Control Limits for Trend Lines**

| Control Limit | Limiting Value [mm/mm] |
|---|---|
| ALERT | $10^{-3}$ |
| ALARM | $5 \times 10^{-3}$ |
| ACTION | $10^{-2}$ |

#### 10.4.4 Shotcrete Lining Strains

**Table 10.5: Control Limits for Strains in Shotcrete Lining**

| Control Limit | strain in [%] |
|---|---|
| ALERT | 0.2 |
| ALARM | 0.4 |
| ACTION | 0.6 |

## 10.5 CONCLUSION

This report provides information on the methodology of an Observational Design Approach, for tunnel Design after the principles of NATM.

Control parameters are used as an indicator to quickly identify areas of potential stability problems or risk, which consequently shall be observed closer and in more detail. Accidence of control limits may result in application of additional support or implementation of contingency measures. All available monitoring information together with other additional site related information (like geology, excavation activities, etc.) shall be used, compared and related to each other to judge the performance of the rock support and the rock mass behavior, whether it is stable, stabilizing, creeping or unstable.

Regarding control levels and limits it must be emphasized that these limits shall be understood as flexible and adjustable, as during construction activities additional experiences regarding rock mass behavior and rock mass – support interaction will be gained, thus allowing improvements in the definition of limits.

# CHAPTER 11

# SETTLEMENT AND BUILDING PROTECTION

# CHAPTER 11

# SETTLEMENT AND BUILDING PROTECTION

## 11.1 GENERAL

The Contractor shall design both his temporary and permanent works to ensure that ground movements at the ground are kept to an absolute minimum. The Contractor shall use proven techniques. Good workmanship is essential to restrict ground loss.

The Contractor shall be responsible for the control of all ground movements and for any resulting damage to buildings, bridges, tracks and roads. The Contractor's attention is drawn to the General Conditions of Contract and Employer's Requirements relating to repair of damage should any arise as a result of the Contractor's construction activities.

The Contractor shall take due regard of the presence of utilities over and adjacent to the Works. The Contractor shall carefully and regularly monitor the ground adjacent to open cut excavations and along tunnel drives to determine the rate and magnitude of any settlements.

Settlement shall be limited such that any individual structure or buildings shall not suffer damage greater than "Slight" as defined in the Damage Classification Table 11.1.

Settlement to Important Structures, Bridges, and Heritage Buildings shall be limited to "Negligible" as defined in the Damage Classification Table 11.1.

The general approach to settlement control and building protection shall involve the procedures described below.

**Table 11.1: Building Damage Classification[1]**
**(After Burland et al, 1977 and Boscardin and Cording, 1989)**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| **Risk Category** | **Description of Degree of Damage** | **Description of Typical Damage and Likely Form of Repair for Typical Masonry Buildings** | **Approx[2] Crack Width (mm)** | **Max Tensile Strain %** |
| 0 | Negligible | Hairline cracks. | | Less than 0.05 |
| 1 | Very Slight | Fine cracks easily treated during normal redecorations. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection. | 0.1 to 1 | 0.05 to 0.075 |
| 2 | Slight | Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible: some re-pointing may be required for weather tightness. Doors and windows may stick slightly. | 1 to 5 | 0.075 to 0.15 |
| 3 | Moderate | Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Tack-pointing and possibly replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Water tightness often impaired. | 5 to 15 or a number of cracks greater than 3 | 0.15 to 0.3 |

| | | | | |
|---|---|---|---|---|
| 4 | Severe | Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted. | 15 to 25 but also depends on number of cracks | Greater than 0.3 |
| 5 | Very Severe | Major repair required involving partial or complete reconstruction. Beams, load-bearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability. | Usually greater than 25 but depends on number of cracks | |

[1] The table is based on the work of Burland et al (1977) and includes typical maximum tensile strains for the various damage categories (column 5) used in the stage 2 settlement analyses.

[2] Crack width is only one aspect of damage & should not be used on its own as its direct measure.

### 11.2 MINIMISING GROUND MOVEMENTS

The work shall be carried out in such a way as to minimize ground movements through immediate installation of support to the ground and to minimize the inflow of water. Care should be exercised to ensure that over excavation does not take place.

Construction from the surface shall be undertaken with due regard to the settlement associated with the particular method chosen.

### 11.3 PREDICTION OF GROUND MOVEMENTS

The Contractor shall obtain consent from the Engineer for his proposed methods of supporting and predicting settlements adjacent to structures. Proven methods based on practical experience shall be used.

The Contractor shall provide predictive assessments of the anticipated ground movements when making submittal for consent of his proposed method of construction of particular sections of tunnel.

## 11.4 STRUCTURE CONDITION SURVEY

The Contractor shall undertake a condition survey of all structures within the zone of potential influence as determined by the Contractor's analysis which are anticipated to incur movements in excess of the action level for Stage 1 specified in table 12.1 above. `Structures` includes all surface and sub-surface structures including historical monuments, buildings, bridges, roads, tunnels, utilities, culverts and sewers.

## 11.5 ASSESSMENT OF IMPACT ON STRUCTURES

The Contractor shall provide an assessment of the effect of the predicted movement on all structures within the zone of influence.

Settlements shall be limited as defined in Sub-Section 12.1 above.

Each building shall be categorised into one of the risk categories, in accordance with criteria listed in column of the Damage Classification Table 10.1.

Depending upon the level of risk, precautionary and protective measures shall be proposed by the Contractor and put into effect after consent from Engineer.

## 11.6 STAGED ASSESSMENT

Assessment of the effects of settlement shall be undertaken in one, two or three stages, depending upon the findings at each stage, as described below:-

### 11.6.1 Stage 1

The effect of building foundations on the pattern of settlement is ignored. Any structure where the predicted settlement is less than 10mm and the predicted ground slope is lessthan 1/500 need not be subject to further assessment. All other structures within the zone of influence shall be subjected to a Stage 2 assessment.

### 11.6.2 Stage 2

Structures subject to settlement from bored tunnels shall be individually assessed using a limiting tensile strain approach. This method of assessment takes into account the tensile strains in the ground and uses a simple idealised model of the building. Tried and tested references from the literature may be utilised as an alternative.

In the case of cut and cover excavations, the assessment shall be based on the work of Peck and Clough and O'Rourke using parameters derived from recent case histories or any other tried and tested method.

### 11.6.3 Stage 3

All structures which are placed in Category 3 or above in the Damage Classification Table 10.1, during the second stage assessment, shall be subjected to a further settlement assessment. A structural survey shall be undertaken by the Contractor to determine the structural form and condition of a building, followed by an analysis of how individual elements of the building would be affected by the predicted settlement. The method, extent and detail of the analysis will be determined on a case-by-case basis and may include, inter alia, an analysis of the soil/structure interaction, structural behaviour, and the possible effects of differential stiffness of the foundations.

As a result of the Stage 3 analysis, the requirement for any protective works shall be established and the details of any protective works including designs and method of working determined. Details of such works shall be submitted to The Engineer for his consent.

## 11.7 MONITORING

Monitoring of ground settlement shall be carried out during construction by the Contractor, to check that the ground is behaving as predicted. The Contractor shall submit for The Engineer's consent a monitoring system and procedures to immediately detect movements.

The extent of monitoring of structures shall be carried out on a case-by-case day to day or more frequent basis depending upon the assessment of risk of damage. Special attention shall be paid to the historical buildings located along the alignment. Monitoring shall begin prior to commencement of the Works to enable base-line values to be determined accurately, and shall continue until all settlements due to the underground works, as shown by the monitoring, has effectively stopped for a period of three months.

The Contractor shall make monitoring results available for inspection by The Engineer at the construction site offices.

# CHAPTER 12

# OUTLINE DESIGN SPECIFICATION- EARTHWORK IN FORMATION

# CHAPTER 12

# OUTLINE DESIGN SPECIFICATIONS - EARTHWORK IN FORMATION

## 12.1 General

This part lays down criteria for design of formation in embankment.

## 12.2 Details of Structures to be designed

The Contractor shall design formation in embankment/cutting for various heights that are coming in C4 Package.

Design of embankment/cutting shall include, but not limited to, the following: -–

a) Design of formation for "DFC loading (32.5t axle load)"

b) Slope stability analysis and design of protection measures for erosion control

c) Design of drainage system- longitudinal and cross drains including catch water drains in cuttings.

d) Design of Trolley refuge

e) Design of hume pipe (NP-4)/RCC box crossings for utilities

f) Any other item which is required for complete design of formation in embankment/cutting

## 12.3 Design Criteria

For design of formation, the "Comprehensive Guidelines and Specifications for Railway Formation: RDSO/2020/GE: IRS 0004", issued by RDSO (hereinafter written as RDSO Guidelines) shall be followed. The geometric parameters of embankment/cutting shall also conform to Indian Railway Schedule of Dimensions (IRSOD) and Indian Railway Permanent Way Manual (IRPWM). Blanket material shall conform to RDSO Guidelines.

The design criteria for design of embankment/cutting slopes shall be as under-

**a)** A minimum side slope of 2H:1V for embankment shall be adopted up to 4m height. For higher embankments (more than 4m height.), the slopes shall be designed, however side slope shall not be steeper than 2H:1V.

**b)** Both 'End-of-Construction' (EOC) and 'Long-Term' (LT) stability with most adverse drainage conditions shall be considered, in design of slope.

**c)** Design shall be done using effective stress analysis method both for EOC and LT stability conditions, adopting realistic values of shear strength and pore water pressure parameters.

**d)** Width of berm shall be adequate to suit the mechanical compaction of earth with heavy rollers. However, berm width shall be kept minimum 2m.

**e)** Erosion Control

i. The slopes of embankments and cuts shall be protected against erosion by providing coir netting for promotion of vegetative turfing.

ii. The coir netting shall not be lighter than 600 g/sqm. It shall conform to IS: 15869 'Open weave Coir Bhoovastra-Specification' and laid as per IS: 15872 'Application of Coir Geotextiles (coir woven Bhoovastra) for Rainwater Erosion Control in Roads, Railway Embankments and Hill Slopes-Guidelines' and IRC: 56

iii. The seeds of grass species used for vegetative cover should be compatible with the local soil and climatic conditions.

iv. The materials and techniques proposed by the Contractor shall be suitable for the slope height and angle, soil type and climatic conditions and shall perform its function with minimum maintenance requirements.

v. The contractor shall water and maintain the vegetation cover provided on slopes for a period of 12 months.

vi. On approaches bridges stone block pitching shall be provided on each side for a length of 30m at major bridges and 15m at minor bridges.

~~**f)** Width of berm shall be adequate to suit the mechanical compaction of earth with heavy rollers. However, berm width shall be kept minimum 2m.~~

~~**g)** Blanket material shall conform to RDSO Guidelines.~~

**h)** Drainage Arrangement

**i.** Top of the formation shall be finished to cross slope of 1 in 30 from centre of formation to both sides in case of single/ double line. However, in case of multiple lines, the cross slope shall be from one end to the other towards cess/drain provided in between.

**ii.** In the double track section, the longitudinal drain between two tracks shall not be provided. However, in case of parallel Section, if toe of the new embankment overlaps the toe of the existing KMP embankment, longitudinal CC drain of suitable capacity, for satisfactory evacuation of storm water, shall be designed between new HORC embankment and existing KMP embankment.

**iii.** In station yard a system of covered/underground pucca longitudinal and cross drains of adequate section shall be designed to ensure efficient drainage as shown in tender drawings. The Contractor shall submit a drainage plan for approval of the Engineer. Such plans should be sufficiently detailed. The longitudinal drains shall be extended as necessary to lead the water clear of the Works to natural drainage courses, culverts or any other suitable outlets.

**iv.** In high embankments (height > 6m), a system of RCC precast longitudinal drain of adequate capacity shall be desined along the toe of berm and RCC precast chute (at about 50 m interval) to collect and lead the surface runoff safely away from the toe of embankment. A concrete chamber shall be provided at the junction of longitudinal berm drain and chute. The chute shall be extended by about 1.0m beyond the toe of embankment to avoid erosion near the toe of embankment. At locations where retaining is provided, suitable outfall arrangement shall be provided to avoid of retaining wall foundation.

**v.** All the drains shall be lined with CC of M20 grade.

**vi.** All the drains shall slope towards the nearest culvert or natural low ground or natural outlets existing nearby where the water shall be discharged with appropriately designed outfall arrangement duly consented by the Engineer.

### 12.3.1 Trolley Refuge

Trolly refuge shall be designed as shown in tender drawing. It shall be provided at 100m center to center on both Up and Dn tracks in a staggered manner.

**vii.** NP-4 pipe of 450mm diameter, conforming to IS 458, shall be provided at about 500m interval throughout the alignment in embankments having fill heights upto 5m. In embankments having fill heights more than 5m precast RCC box of 500mmx500mm clear size shall be provided for the purpose of future utilities. Installation conditions for the pipe shall be designed as per the IS-783, according to the fill height.

## 12.4 Submittals

Prior to the start of construction operations, the Contractor shall submit to the Engineer all relevant documents, drawings, calculations and data including, but not limited to the following, and shall obtain the approval of the Engineer for the proposed materials, design, construction methods and quality control procedures

a) Geotechnical investigation reports and evaluation of sub-surface conditions along the alignment.

b) The Contractor shall submit the report detailing the identification of borrow areas for formation, blanket material, prepared subgrade. Geotechnical investigation reports for borrow areas duly indicating the soil properties of the proposed borrow areas.

c) Details of earthwork balance (cut & fill), properties of materials to be imported/exported, and management of excess materials. Material test reports for embankment fill, prepared sub-grade and blanket.

d) Cross-section of embankment/cutting along the alignment, at every 50 m interval in straight, at 20 m interval on curve and at junction with the structures

e) Slope stability calculations. Analysis of the stability and settlement of formation and design of remedial measures if required. Details of earthwork design solutions and criteria used

f) Details of proposed instrumentation and monitoring

g) Details of construction equipment.

# CHAPTER 13

# OUTLINE DESIGN SPECIFICATIONS -: BRIDGES

# CHAPTER 13

# OUTLINE DESIGN SPECIFICATIONS -: BRIDGES

## 13.1 General

The Bridges in HORC Project comprises of simply supported Prestressed U-slab / Steel Composite Girders with RCC sub-structure with open/deep foundation and RCC Box Bridges/Culverts.

Minimum Centre to Centre distance between two tracks has been kept as 5.3m according to IRSOD (BG).

## 13.2 Details of Structures to be designed

### 13.2.1 Bridges with superstructure of Composite Girder (CG)

Standard RDSO drawings for "25t Loading-2008" will be used for superstructure of bridges with CG. The Contractor is required to design foundation and substructure of these bridges for "DFC loading (32.5T axle load)".

Bridge elements to be designed by the Contractor includes, but not limited to, the following: -

i. Abutments & abutment caps including foundations & wing/return walls

ii. Piers & pier caps including foundations

iii. Load on bearings, design and drawings of bearing pedestals, inspection platforms including arrangements for access from track. Spherical bearings shall be designed and provided at locations where Composite girders are used at gradient.

iv. Provision of jacking arrangements on abutment caps & pier caps for lifting of superstructure

v. Seismic arrestors in pier/abutment cap

vi. Trolley refuge and man refuse on bridges, if required as per IR standards

vii. Provision of supports for placing OHE mast for traction system

viii. Protection works of abutments as per tender drawings

ix. Inspection steps on approaches of bridges

x. Side pathway on bridges for maintenance (Arrangement for pathway shall be provided as per RDSO drawings No. CBS-0046)

xi. Drainage arrangements

xii. Arrangement for supporting signalling & telecom cables and other utilities

xiii. Ground improvement technique/procedures, if required according to the GT data and design requirements along with the method of verification of the bearing capacity after implementation of ground improvement technique.

xiv. Construction methodology

xv. Any other item which is required for complete design and construction of the bridges.

### 13.2.2 Bridges with superstructure of PSC U- slab

Standard RDSO drawings for "25t Loading-2008" will be used for superstructure of bridges with **PSC U- slab (**post tensioned). The Contractor is required to design foundation and substructure for these bridges for "DFC loading (32.5T axle load)".

Bridge elements to be designed by the Contractor includes, but not limited to, the following: -

i. Abutments & abutment caps including foundations & wing/return walls

ii. Piers & pier caps including foundations

iii. Load on bearings, bearing pedestals, inspection platforms.

iv. Provision of jacking arrangements on abutment caps & pier caps for lifting of superstructure

v. Seismic arrestors in pier/abutment cap

vi. Trolley refuge and man refuse on bridges, if required as per IR standards

vii. Provision of supports for placing OHE mast for traction system

viii. Protection works of abutments as per tender drawings

ix. Inspection steps on approaches of bridges

x. Drainage arrangements

xi. Arrangement for supporting signalling & telecom cables and other utilities

xii. Ground improvement technique/procedures, if required according to the GT data and design requirements along with the method of verification of the bearing capacity after implementation of ground improvement technique.

xiii. Construction methodology

xiv. Any other item which is required for complete design and construction of the bridges.

### 13.2.3 RCC Box Bridges

RCC Box bridges shall be designed for "DFC loading (32.5t axle load)".

Bridge elements to be designed by the Contractor includes, but not limited to, the following: -

i. RCC Box

ii. Wing wall, return wall, drop wall, curtain wall

iii. Protection works as per tender drawings

iv. Inspection steps at approaches of bridges

v. Ground improvement technique/procedures, if required according to the GT data and design requirements along with the method of verification of the bearing capacity after implementation of ground improvement technique.

vi. Construction methodology

vii. Any other item which is required for complete design of RCC box bridge

Standard RDSO drawing for box culvert shall be followed to the maximum extent. If standard RDSO drawing is not available for desired sizes/fill height, box shall be designed by the Contractor. However, thickness and reinforcement of the box shall not be less than the closest available box size & fill height of RDSO drawing.

RDSO box culvert for double track are available upto 2m fill height. In case of higher fill heights, the size and reinforcement of box shall not be less than the that of RDSO box for single track with fill height of minimum 2m more than actual fill height.

Any variation from the above, if required due to site constraints shall be adopted after the prior approval of the Engineer.

### 13.3 Design Requirements

For loadings, load combinations, analysis, and design of structures, all relevant IRS, IS, IRC and other relevant codes shall be followed.

The superstructure/bearing, sub-structure and foundation will be checked for one track loaded condition as well as multiple/all track loaded conditions as well as for single span and two adjacent spans loaded conditions, as the case may be. The analysis and design will be carried out for all possible cases of loadings.

Design of structures shall take into account construction methodology/ construction sequence to be adopted during execution.

#### 13.3.1 Railway Bridges with Steel/PSC superstructure

i. Superstructure and bearings shall conform to standard RDSO drawings for "25t Loading-2008" except for OWG bridges. Standard RDSO drawings for "DFC loading (32.5t Axle load)" shall be used for OWG.

ii. Substructure and foundation of bridges shall be designed for DFC loading (32.5T Axle load) as per IRS Bridge Rules and other relevant codes.

iii. Bridges shall be designed to accommodate curvature of the track alignment, wherever required.

iv. All ballasted deck bridges shall be capable of carrying long/continuously welded rail (LWR / CWR) as per the provisions of "UIC-774(3R) and RDSO guidelines.

v. Side pathway with hand railing shall be provided on steel superstructure bridges on outer side of Up & Down track.

vi. Hand railing shall be provided for trolley/man refuge and inspection platforms on bridges. The design shall be such that it can be easily maintained and replaced, if required.

vii. Adequate arrangement shall be made on the bridges for providing electrical/ telecommunication cables and other utilities as required. Specifications and guidelines of the owning agencies in such cases shall be followed.

viii. Arrangements for enabling inspection of superstructure and bearings shall be provided as per RDSO report BS-113.

ix. Bridge bearings shall be as per corresponding standard RDSO drawings for bearings. All bearings shall be replaceable without major disruption to railway operations or to any activity underneath the bridge. Bearings shall be placed on bearing pedestals designed in accordance with applicable codes. Appropriate jacking points, on the pier/abutment cap in consideration with the requirements for lifting of superstructure, shall also be provided. The bearings shall be sandwiched between two true horizontal surfaces. Steel Wedge shall be provided to cater to longitudinal slope of superstructure, wherever required.

x. Expansion/Movement Joints/gaps and other necessary measures to control shrinkage and thermal effects shall be incorporated in the structural design so that the performance of the bridge/structures are not adversely affected during normal working conditions. Movement joints shall be designed so as to be easily maintained and replaceable.

### 13.3.2 RCC Box Bridges

i. Bridges shall be designed for “DFC loading (32.5t axle load)”. In addition, the design shall consider the loading standards as applicable to the type of the crossing/existing road or Class A/Class 70R loading as per IRC 6-2017, as the case may be.

ii. Size of the Box openings (minimum required) has been shown in the conceptual GADs. Height of box shown includes clear height and wearing coarse of 150mm.Overall height of box may vary as per site requirement and actual road/ground profile. Any variation, due to site constraints, shall be done with the consent of the Engineer

iii. Barrel length of the culvert shall be decided based on the fill height and ROW.

iv. The clear inner dimension of the box shall cater to the requirements of type of crossing. The height of box shall include the thickness of wearing coarse provided inside the box.

v. Fill Depth shall be the height of fill from the bottom of the sleepers to the top of the box and shall be inclusive of depth of ballast and depth of soil fill as per IRS Concrete Bridge Code (CBC).

vi. All waterway bridges shall be protected by a well-designed flooring system. The concrete floor shall be protected by curtain wall at upstream side and drop wall at downstream side, wherever applicable.

vii. Other Requirements:

a. All RUBs shall be provided with 1m wide walkway on one side of the carriageway.

b. The approaches / approach ramps to the RUBs shall be of concrete of minimum M25 grade.

c. Suitable height gauges shall be provided on both sides of RUBs as per RDSO Drawing No. RDSO/M-0001.

d. Crash Barriers / medians / footpaths / railings shall be provided as per the requirements of IRC Codes.

e. Inspection Steps shall be provided wherever required.

f. Provision for lighting shall be kept in the design of bridges.

g. Provision for signages shall be kept on both side of RUBs.

h. Suitable drainage system including sump and discharge arrangement (as required) and protection works / ancillary works shall be designed.

Detailed Design criteria for of the Bridges shall be as per the below mentioned Outline design specifications criteria .

## 13.4 Outline Design Specifications Criteria

### 13.4.1 ROADWAY AND RAILWAY CLEARANCES

The alignment of HORC crosses several existing roadways and existing railways. The general clearance requirements for these crossings shall be as follows:

#### a) CLEARANCES FOR ROAD TRAFFIC

Vertical clearance for road traffic shall generally be 100 mm more than the clearance specified in Clause 104.4.2 of IRC: 5.

General Arrangement Drawings at road crossings shall be approved by the owning authorities/stake holders.

#### b) CLEARANCES FOR ROLLING STOCK

Clearance for railway traffic shall be as per Schedule of Dimensions of Indian Railways. General Arrangement Drawing at railway crossings shall be approved by the relevant Railway Authority.

### 13.4.2 MATERIALS PARAMETERS

#### a) CONCRETE

1) Grade of Concrete & Cover

Grade of concrete shall be M-35 for RCC works and M-20 for plain cement concrete including levelling course. However, grade of concrete for bearing pedestals and seismic restrainers can be higher if required.

In case of foundation, cover shall be taken as 75mm for all conditions of exposure. For substructure, cover shall be taken as 50mm.

2) Cement

The minimum cementitious material content, maximum water-cement ratio, total chloride content by weight of cement shall be as per IRS-CBC.

3) Density

Density of concrete shall be taken as 25 kN/$m^3$ for PSC and RCC, 25 kN/m3 for Plain cement concrete and 26 kN/m3 for wet concrete.

4) Poisson's Ratio

Poisson's ratio for all grades of concrete shall be taken as 0.15.

5) Thermal Expansion Coefficient

Coefficient of thermal expansion shall be taken as 11.7 x10-6 $^{o}$C in accordance with IRS-Bridge Rules.

6) Time-Dependent Characteristics of Materials

Long-term losses should be calculated in accordance with IRS- CBC.

The design shall be done according to construction sequence to be adopted at site.

**b) REINFORCEMENT STEEL (REBARS)**

High strength deformed (HYSD) reinforcement bars of minimum Fe-500D grade, conforming to IS 1786 shall be used.

| | | |
|---|---|---|
| Young's Modulus (E ) | = | 200,000 Mpa |
| Yield Stress(fy) | = | 500 MPa. |
| Density | = | 78.5 kN/m3 |

**c) STRUCTURAL STEEL (FOR COMPOSITE GIRDERS & OTHER STEEL STRUCTURES, IF ANY)**

Structural steel used for composite girders and miscellaneous use such as railing, supporting utilities, coverings etc. shall be as follows:

1) Structural Steel for Composite Girders

(a) General

Structural steel conforming to IS: 2062(Grade E250/E350 – B0) shall be adopted.

Fabrication shall be done as per provisions of IRS B1 (Fabrication Code).

Design of steel structures shall be done as per IRS steel Bridge Code.

IRC Code: 22 shall be referred for steel-RCC composite construction.

Welding shall be done following IRS Steel Bridge Code, IRS Welded Bridge code or relevant IS codes for welding.

(b) Young's Modulus shall be taken as 210000MPa as per IRS- Steel Bridge Code.

(c) Density: 7850 kg/m3

(d) Poisson's Ratio: 0.30 as per IRC: 24-2010.

(e) Thermal Expansion Coefficient: 12x10-6 as per IRC: 24-2010

2) Structural Steel for Miscellaneous Use

The design of miscellaneous steel structures shall be done as per IS: 800 and related provisions.

Hollow steel sections for structural use shall be as per IS: 4923.

Steel tubes for structural purpose shall be as per IS: 1161.

Steel for General Structural Purposes shall be as per IS: 2062(Grade E250/E350 – B0).

### 13.4.3 LOADS TO BE CONSIDERED FOR DESIGN

Following loads shall be taken into consideration for analysis and design of structures as prescribed in IRS-Bridge Rules up to latest up-to-date correction slip.

**i. DEAD LOAD**

Dead load shall be based on the actual cross section area and unit weights of materials and shall include the weight of the materials that are structural components of the bridge and permanent in nature.

**ii. SUPER IMPOSED DEAD LOAD (SIDL)**

Superimposed dead loads include all the weights of materials on the structure that are not structural elements but are permanent. It includes weight of track from ballast/sleepers/rails/ fasteners/ cables/parapet/ hand-rail OHE mast/ cable trough/ Signaling equipment etc.

**iii. SHRINKAGE & CREEP**

Shrinkage and Creep effects will be calculated as per IRS CBC.

**iv. LIVE LOAD (LL)**

**(a) Railway Vehicular Load**

Live load shall be followed as per Sub-Clause 2.3 of IRS Bridge Rules.

**(b) Dynamic Augmentation**

CDA shall be considered as specified in IRS Bridge Rules.

**(c) Footpath Live Load**

Footpath live load shall be taken as 490 kg/m$^2$ as per IRS Bridge Rules

**(d) Longitudinal Force**

Longitudinal force shall be followed as per clause 2.8 of IRS Bridge Rules.

Tractive force of one track and braking force of another track will be taken in the same direction to produce worst condition of loading.

**(e) Centrifugal Forces Due to Curvature of Superstructure**

The horizontal centrifugal force due to moving load in curved alignment is to be considered as per IRS: Bridge Rules.

For double stack containers, this force shall be considered to act at a height of 3m (same as in case of DFC loading) above rail top level.

**(f) Racking Force**

The horizontal transverse force due to racking as specified in IRS-Bridge Rules shall be considered.

**v. Earth/Surcharge load**

Earth pressure and surcharge load/pressure shall be taken as per the provisions of IRS Substructure & Foundation Code.

**vi. TEMPERATURE EFFECTS**

**(a) Temperature**

- Overall Temperature (OT)

The loads shall be considered as per IRS-Bridge Rules and IRC:6. Temperature variation of +/- 35°C shall be considered, details of which are given below

Maximum Temperature considered as per Annex. F of IRC 6: +49°C

Minimum Temperature considered as per Annex. F of IRC 6: -0.4°C

Temperature variation as per Clause 215.2 of IRC 6 will be = (49-(-0.4)/2+10=34.7°C say 35°C.

- Differential Temperature (DT)

The provision given in IRC 6, shall be considered to compute effect of differential temperature gradient in the absence of any provisions in IRS code.

**(b) Rail Structure Interaction (LWR Forces)**

A rail structure interaction [RSI] analysis for continuing Continuous Welded Rail/Long Welded Rail over ballasted bridge decks shall be carried out as per provisions of “RDSO Guidelines for carrying out Rail-Structure Interaction studies on Indian Railways (BS 114 (version-2))”.

- The following shall be adhered to:

a. Track resistance in loaded and unloaded conditions shall be obtained from Sub-Clause 3.2.6 Track Stiffness of BS 114 (version-2). The recommended values for track stiffness for ballasted tracks are 60kN/m and 20kN/m for loaded and unloaded track respectively. The elastic limit is 2 mm for ballasted tracks. No change in track stiffness is permitted on account of actual track behavior.

b. The temperature variations, to be used for analysis, shall be taken as per provisions of Sub-Clause 3.2.8 Temperature Variations of "BS 114 (version-2)". The following shall be used for analysis:

- The temperature of the bridge does not deviate from the reference temperature by more than 35 $^{o}$C
- The temperature of the rail does not deviate by more than 50$^{o}$C.
- The difference in temperature between deck and track does not exceed 20$^{o}$C.
- The reference temperature is the temperature of the deck and the rail when the rail is fixed.

c. Maximum additional stresses in rail in tension as well as compression on account of rail-structure interaction shall be within the permissible limits as prescribed in Sub-Clause 3.3.1 of "BS 114 (version-2)" for additional stresses in Rails The limit prescribed in the document shall be used as it is and no benefit on account of lesser axle load of actual rolling stock shall be permitted.

d. The provisions of Sub-Clause 3.3.2 of "BS 114 (version-2)" Displacements of Bridge Elements shall be adhered to.

e. Checks must be performed for break in rail continuity due to unusual conditions such as fractures or for maintenance purposes. The provisions of Sub-Clause 4.7 of "BS 114 (version-2)" for Rail Gap Analysis shall be followed.

f. Minimum (unfactored) LWR force of 1.6t/m of span length shall be considered for design irrespective of number of tracks.

- Software and general methodology to be used for carrying out Rail Structure interaction analysis must be validated before adopting the same. A well-established document such as UIC 774-3R may be used for validation.
- Representative stretches must be chosen for carrying out Rail-Structure interaction which shall include special spans. The same shall be got approved from the engineer.

**Note-** In the present C-2 tender package all major bridges are non-ballasted and therefore, RSI study for continuing CWR/LWR over bridge is not required to be carried out.

**vii. WIND LOAD (WL)**

The wind load shall be calculated as per IRS: Bridge Rules and IS: 875 (Part 3).

Vb = Basic wind speed = 47 m/s for Delhi Zone (as per IS 875).

**viii. SEISMIC FORCE (EQ)**

Seismic design philosophy as stated in IRS Seismic Code shall be adopted.

HORC project area lies in Seismic Zone IV of seismic zone map of India. The peak ground acceleration denoted as zone factor shall be taken as 0.24 for zone IV.

Seismic Coefficient Method (SCM) shall be adopted for calculation of seismic forces.

Design horizontal seismic coefficient (Ah) shall be calculated as per Sub-Clause 9.4.1 of IRS Seismic Code. The expression is -

Ah = (Z/2) * (I/R) * (Sa/g)

Where,

| | | |
|---|---|---|
| Z | = | zone factor = 0.24 |
| I | = | importance factor = 1.5 |
| R | = | response reduction factor as per Table 3 |
| Sa/g | = | average acceleration coefficient |

The design vertical seismic coefficient shall be 2/3 of horizontal seismic coefficient.

Seismic load combinations shall be considered as per IRS Seicmic Code.

Seismic on soil mass behind the abutment and confined between the retaining wall shall be considered in addition to dynamic increment in earth pressure.

Reinforcement detailing of Piers/Portal Piers and joints with pier cap and foundations shall conform to ductility/capacity design requirements as per Annexure-B of IRS Seismic Code.

**ix. ERECTION TEMPORARY LOADS (ETL)**

Erection forces and effects shall be considered as per IRS-Bridge Rules.

The weight of all permanent and temporary materials together with all other forces and effects which can act on any part of structure during erection shall be considered in design.

Special care shall be taken that no damage is caused to the permanent structure during construction.

**x. DERAILMENT LOADS (DR)**

Check shall be made in accordance with the IRS-Bridge Rules.

**xi. FORCES ON PARAPET**

The parapets shall be designed to resist lateral horizontal force & a vertical force as per IRS Bridge Rules.

**xii. DIFFERENTIAL SETTLEMENT (DS)**

Differential Settlement (post construction) between two adjacent bridge piers shall be considered as follows:

12mm for Long Term Settlement

6mm for Short Term Settlement

Differential settlement shall be considered only in the design of continuous structures, if any.

**xiii. BUOYANCY LOADS**

The design of the foundation shall be done considering design ground water table as per Chapter-2 Outline Design Specifications-General.

In case of river/waterway bridges, stability check and calculation of base pressure, full buoyancy shall be considered on submerged portion of substructure and foundation up to HFL or LWL as the case may be, irrespective of the type of soil on which the foundation will rest.

Hydro dynamic forces will be considered as per IRS Seismic code.

**xiv. WATER CURRENT FORCES**

Water current force in submerged portion of substructures and foundations shall be calculated as per IRS Bridge Substructure & Foundation Code.

**(a)** VEHICLE COLLISION LOAD (VCL)

The vehicle collision load on piers: as per of IRC: 6.

All structure near railway track shall be checked for accidental impact from derailed trains as per IRS Bridge Rules as per Addendum & Corrigendum Slip No. 48 dated 22.06.2017.

**(b)** VIBRATION EFFECT

Effect of vibration due to movement of train on bridge structure shall be taken into consideration. This will be checked through dynamic analysis.

**xv. LOAD COMBINATIONS**

Provisions of IRS-CBC shall be followed. The partial load factors and load combinations shall be as per IRS-CBC.

Notes:

ULS-Ultimate Limit state.

SLS-Serviceability Limit state

Wind load and earthquake loads shall not be assumed to be acting simultaneously.

Load combination for Vehicle collision shall be as per IRC 6 but design of members under vehicle collision load combination shall be carried out as per IRS CBC.

### 13.4.4 DESIGN CHECK

**a)** FOR REINFORCED CONCRETE STRUCTURE

Design of all RCC/PSC structures shall be done as per IRS CBC for Serviceability Limit States (SLS) and Ultimate Limit State (ULS)

**b)** DESIGN CHECK FOR STEEL/COMPOSITE STRUCTURE

The design of steel structure shall be done as per IRS Steel Bridge Code/IRS-Welded Bridge Code. For composite action IRC :22 shall be referred.

**c)** DURABILITY & CRACK WIDTH

(a) DURABILITY

Provision of IRS-CBC shall be followed. The exposure condition is Moderate and in case of Nallah crossing the exposure condition may be treated as "Severe".

(b) CRACK WIDTH CHECK

For SLS Combination, crack width in reinforced concrete members shall be calculated as per IRS-CBC.

The allowable crack width shall be as per exposure conditions given in IRS-CBC.

(c) DEFLECTION

Deflections shall be taken into account as per IRS: CBC while checking appearance, efficiency of the structure and minimum specified clearances. Clause no. 13 of IRS CBC shall be kept in view while calculating deflection/deformation. Permissible values of deformation shall be in accordance with provision of UIC-776-3R.

**d)** FATIGUE

Fatigue phenomenon shall be analyzed for those structural elements that are subjected to repetition of significant stress variation (under traffic load).

(a) PRESTRESSED/REINFORCED CONCRETE STRUCTURE

The fatigue shall be checked as per IRS-CBC.

(b) STEEL/STEEL COMPOSITE STRUCTURES

IRS-Steel Bridge Code (up to latest correction slip) / IRS-Welded Bridge code shall be adopted for fatigue check of structural steel members and connections.

Annual Traffic Density for fatigue checks shall be considered as 50 GMT (Gross Million Tonnes per annum) per track (i.e. 100GMT for two tracks).

Simplified approach method given in Cl.14 of Appendix-G (Fatigue Assessment of steel bridges) shall be followed for fatigue assessment.

### 13.5 Drainage

The drainage of deck shall be designed to cater the maximum envisaged rainfall intensity and suitable longitudinal and transverse slope should be provided. Moreover the provisions of Clauses-10 & 15of IRS-CBC shall be followed.

The top of soffit slab will be profiled so as to collect the run-off water at multiple points by providing a cross slope of 2.5%. Drainage pipes will be provided to collect the run-off.

The drain pipe of double wall HDPE corrugated pipes with water collection box at top, shall be provided to discharge the water along pier with most pleasant aesthetics.

### 13.6 BEARING SYSTEM

(a) Type of Bearing System

In case of RDSO girders, standard bearing drawings shall be followed.

(b) Replaceability of Bearings

While finalizing the proposed bearing system, it shall be kept in mind that accessibility and replacement of each part of bearing are of paramount importance as the design life of bearings is shorter than that of the structure. Keeping in view the above cited criteria, all the bearings, pedestals and pier caps will be detailed for replacement of bearings in the future. The girders/end diaphragms shall be designed to facilitate the operations of jacks during maintenance.

(c) Uplift

If required a holding-down device connecting the deck and the pier head shall be placed in order to prevent the deck from overturning. The holding-down device may be integrated in the bearing system or be a separate system constituted of bars embedded in pier cap and bridge with appropriate details, permitting translation/rotation. Other systems can also be foreseen.

Due to the lack of appropriate guidelines in Indian codes, the design criteria for holding down device (upward force limit requiring holding down device, design formulas) will be taken from the latest international practice.

## 13.7 SUBSTRUCTURE SYSTEM

(a) Pier Cap

For designing the pier cap as corbel the provisions of IRS-CBC should be followed. In case of shear span to effective depth ratio being more than 0.6, pier cap will be designed as flexural member.

Height of pedestal should be in between 150mm and 500mm as per IRC: 78.

The Pier cap shape shall be suitable at transition pier supporting different types of superstructure instead of providing raised/column pedestal over pier cap.

(b) Piers

The effective length of a cantilever pier for the purpose of slenderness ratio calculation will be taken as per IRS-CBC. Ductile detailing is mandatory.

The design of pier shall be done as per IRS CBC.

In all SLS combinations, pier/column shall remain in compression.

(c) Foundation System

Foundation shall be designed as per IRS Bridge Substructure & Foundation Code, IRS Concrete Bridge Code, IRC-78, Manual on the design and construction of well foundation, IS- 2911.

Shear reinforcement & ductile detailing shall be done as per IRS/IS Codes.

i. Open Foundation

Open foundation has been contemplated as first choice. Soil replacement may also be resorted, if the difference of bearing pressure and bearing capacity is upto 20%, keeping other practical aspect and site conditions in mind.

Deep foundation shall be provided at the locations as shown in the tender drawings.

ii. Pile Foundation

In case of Pile foundation, foundation analysis and design will be based on IRS Code for Substructure & IRC-78. The forces applied by the pier are transferred to the bottom of the pile cap for this purpose. Reactions in pile are calculated using Rivet theory. The various specific assumptions made for the pile and pile cap design are as follows:

a. Bored-cast-in-situ multiple pile groups will be adopted.

b. Minimum 1.2m diameter (unless specified otherwise in tender drawing) bored cast-in-situ vertical piles in soil/rock have been contemplated for the foundation of piers. Minimum number of pile in each pile cap shall not be less than 4.

c. For piles and pile caps, load combinations shall be considered as per IRS-CBC, Table-12. The various specific assumptions made for the pile and pile cap design including pile load testing shall be as per IS: 2911, IRC-78 and IRS-Bridge Sub-structure and Foundation Code.

d. For pile bearing capacity, all SLS Load combinations as per IRS-CBC will be considered.

e. Increase in vertical load capacity of pile shall be done as per Table-1 of IS 1893-Part-1.

f. The lateral load capacity of pile shall be evaluated by using empirical formulae given in IS: 2911 (Part-1/ section-2) .

g. Initial load tests (not on working pile) will be conducted as per IS: 2911 - Part IV. Initial test is proposed to be conducted for a load of 2.5 times as per the safe load based on static formula.

h. The working load on pile for vertical and horizontal loads shall be verified through routine load tests during construction.

i. In case of multiple pile system, spacing between the piles shall not be less than 3 times the diameter of pile in soil and 2.5 times the diameter when founded on rock.

j. In general, the top of pile cap shall be kept about min 500mm below the existing ground level and weight of the earth cover will be applied on top of pile cap when unfavorable. The earth cover on pile cap for any favorable effect (stability, soil horizontal capacity.) will be neglected.

k. In case the location of foundation (all types) is within Load Impact Line of nearby passing load(rail/road) then the effect of surcharge (dead load + live load) corresponding to that passing load shall be taken into account.

l. Pile design shall be done according to IRS CBC. However, for crack control in piles, it will be clarified that actual axial load will be considered to act simultaneously.

m. Where there is a risk of liquefaction, the lateral soil resistance of the liquefied layer will be taken as zero.

n. Pile cap shall be designed based on IRS –CBC 1997. No support from soil below pile cap shall be considered.

o. The thickness of the pile cap shall be kept minimum 1.5 times diameter of the piles for multiple-pile group as per IRC 78.

p. The structural design of the pile cap shall be carried out as IRS CBC. Crack width shall be checked for load combination 1 IRS CBC.

q. Minimum reinforcement in pile caps at top shall be at least 0.12% in each direction in case of compression and in case of tension, it shall not be less than 0.2%.

iii. Well Foundation
Well Foundation shall be designed as per IRS Bridge Substructure & Foundation Code/ IRC: 78, IRS-CBC, Manual on the design and construction of well foundation.

## 13.8 CODAL PREFERENCE

The IRS Codes shall be followed in principle. Although main clauses have been mentioned in the ODS, the other relevant clauses as available in the IRS codes shall also be followed, whenever applicable. If provisions are not available in IRS, the order of preference shall be as follows, unless specified otherwise:

**For railway loading related issues:**

I. UIC Codes

II. Euro Codes

III. Any other code, which covers railway loading.

**For other Design/ detailing related issues:**

I. IS Codes

II. IRC Codes

III. EURO Codes

IV. AASHTO Codes

V. Any international code with approval of HRIDC.

# CHAPTER.14

# OUTLINE DESIGN SPECIFICATIONS: RETAINING WALLS

# CHAPTER.14

# OUTLINE DESIGN SPECIFICATIONS: RETAINING WALLS

## 14.1 General

This part lays down criteria for design of Retaining Wall.

## 14.2 Details of Structures to be designed

The Contractor shall design the retaining walls of various heights that are required in C4 Package.

Retaining wall is required to be provided at some of the locations along the alignment due to limited availability of ROW. Retaining wall shall be located near the edge of ROW. On LHS (i.e. on KMP side) of main line, no retaining wall shall be provided except at locations where private land falls between HORC ROW and KMP ROW. Further, some additional land is proposed to be acquired along the alignment. In case additional land is made available before undertaking the construction, provision of retaining wall shall be deleted and earthen slope shall be provided at that location. Cost of additional earthwork due to provision of slope shall be paid under the Schedule B.

Precast retaining walls shall be used up to 2m height height above the ground level. Beyond 2m height, cast in situ retaining wall may be used.

Reinforced Earth wall (RE wall) shall not be permitted.

## 14.3 Design Criteria

a) Wherever sufficient land is not available to provide a stable slope for the formation along the alignment without infringing ROW, suitable earth retaining structure as per the IRS-Bridge Substructure & Foundation Code shall be provided.

b) Earth retaining structure if required at any other critical location, shall be proposed by the Contractor and shall be subject to approval of the Engineer.

c) The earth retaining structures, if required, shall be designed as per the following criteria:

   i. In case the location of the earth retaining structure is within Axle Load Impact Line, it shall be designed for earth pressure as well as surcharge due to DFC loading (32.5T axle load).

   ii. In case the location of the earth retaining structure is beyond the Axle-Load Impact Line, it shall be designed for retaining the earth.

d) Design and reinforcement detailing shall suit the lifting and handling requirements of the segments of precast retaining wall.

e) Joints between the segments shall be properly designed for required lap length also.

f) Expansion joints at 30m .

# CHAPTER 15

# OUTLINE DESIGN SPECIFICATIONS: BALLASTLESS TRACK (BLT)

# CHAPTER 15

# OUTLINE DESIGN SPECIFICATIONS: BALLASTLESS TRACK (BLT)

## 15.1 GENERAL

i. HORC proposes to adopt BLT systems, which are proven and being used worldwide in railways successfully. The proven design may require some modifications to suit to HORC conditions.

ii. Operating Regime on HORC:

a) Axle load and Speed

| Traffic Type | Axle Load | Speed |
|---|---|---|
| Goods Train | 32.5T | 100 kmph |
| Passenger Train | 22T | 160 kmph |

b) Electric Traction (Minimum) : 25 kV AC.

c) Track Circuits : DC.

d) Gauge : Broad Gauge Nominal (1673mm)

e) Ambient Temperature : (-) 5˚C to 50˚C.

f) Rail Temperature : (-) 15˚C to (+) 76˚C.

g) Humidity : 100%

**Note:** The temperature range shall be commensurate with other provisions / guidelines through codes / manuals / specific circulars.

## 15.2 DESIGN REQUIREMENTS

i) BLT shall be designed for the following:-

a. Goods Traffic - 32.5T axle load & speed 100 kmph

b. Passenger Traffic- Main line for 22T axle load & speed 160 kmph (for passenger traffic)

ii. Dynamic augment may be taken as 2.5 (as prevailing on IR).

iii. Spacing of supports to rails – not more than 60 cm (wherever rails are supported on sleepers/ discrete supports) so that the permissible bending stress in rails are not exceeded beyond stipulated values. No joint shall be permitted in track on BLT and the transition portion. The values of permissible bending stress are as under:-

For LWR section – 25.25 km/mm² (for 90 UTS).

iv. Upward reaction / pressure from support base shall be clearly mentioned in design.

v. Design shall be as per relevant codes of practice such as BIS, EN, IRS, IRC and UIC with latest revision/ edition. If for any item/work, above mentioned codes are not relevant, best available Engineering practice / International codes shall be mentioned.

vi. Design & detail of suitable Transition System for smooth transition from ballasted track to BLT on both ends shall be part of the design.

vii. Design and detail of Expansion / Construction Joints in BLT at suitable intervals shall be part of the design.

viii. Technical parameters required for foundation of BLT shall be suitably considered for site conditions and shall be mentioned in the design along with their test code & procedure, A design monograph of varying sub-grade characteristics, if applicable, to be provided by the firm / designers.

ix. Design service life of BLT shall be a minimum of 60 years. Concrete for RCC structures shall comply with relevant para of Indian Standard IS: 456-2000 & relevant para of IRS-Concrete Bridge Code taking care of relevant durability clause for expected life of RCC as minimum 60 years.

x. BLT may get submerged during heavy rainfall. Suitable arrangement shall be provided for ensuring that BLT functions properly under submerged conditions. Provision of adequate cross slope for drainage purpose and suitable measures to prevent ingress of water must be considered. Design of proper drainage arrangements preferably sub-surface drains for BLT shall also be part of design. Design capacity of drainage system shall be adequate enough for the discharge from slab track and remaining catchment other than track slab for regular daily discharge and also discharge from rainfall as per the local conditions. Top surface of BLT shall have surface finish with proper cross slope such that there is no stagnation of water over it. Necessary field visit to ascertain local conditions may be done for suggesting suitable drainage system.

xi. No appreciable cracks or settlements or separation of parts shall be developed during service in the BLT leading to impaired service or failure. Minimum reinforcement must be ensured to achieve design crack width of 0.1 mm notwithstanding any provision in codes.

xii. BLT shall be designed for almost maintenance free conditions except replacement of worn-out fastening components after their service life is over. The 2% of the fastening components and other replacement items which are likely to be worn out / damaged ,shall be supplied as spares for need based replacement in this work. The offer shall be inclusive of the cost of 2% fastening components as spare. No additional cost shall be paid for the spares.

xiii. Stable formation is required to be provided below BLT as per the RDSO guidelines (No. RDSO/2020/GE: IRS-0004). Minimum bearing capacity at subgrade top level of 10 tons/sq.m shall be ensured. Ground improvement may be required before construction of BLT which need to be designed to avoid problems due to inadequacy of its formation.

xiv. The proposed system shall be easy to repair and expeditious to restore in case of damage due to derailment. The time & material requirement for repair shall be clearly defined along with detailed procedure of repair.

xv. Cost effective design & methodology with reasonably less construction period with opening of traffic with suitable speed restriction would be preferable.

xvi. A scheme giving details of the curing arrangements shall be submitted by the designer to ensure curing in conformity to the IRS- concrete Bridge Code and best international practices.

xvii. Adequate corrosion protection measures must be included in design to minimize corrosion of fastening components of proposed system for ballastless track as corrosion of fastening components in BLT is a major problem due to climatic condition and waterlogging due to rainfall. Adequate corrosion protection measures should be submitted as per EN 13146-6: 2012 –Test methods for fastening system – Effect of severe environmental conditions and corrosion test shall be done as per EN ISO 9227/ASTM B117-11, Corrosion tests in artificial atmospheres – salt spray tests for exposure period of 1000 hours (for Normal Salt Spray Test) and results shall meet the requirements of EN 13481-5:2012 regarding corrosion in fastening system.

xviii. The design shall be cost effective serving all functional requirements expected of BLT.

xix. Any other factor considered necessary by the designer.

Changes in the above parameters (ii) and (iii) may be considered, in case the Contractor is able to support it with the relevant documents and codes as per practice in other Railways.

## 15.3 TRACK DETAILS

BLT for HORC shall be designed for following track details:-

i. Rail section: Rail profile shall conform to UIC 60 (R260) and Rail material shall conform to IRS-T-12-2009 class-'A' including manufacturing and testing in accordance with IRS-T-12-2009 with latest amendments.

ii. Schedule of Dimensions (SOD) and Maximum Moving Dimension (MMD) of Indian Railways for BG shall be followed.

iii. Rail cant at Rail seat (inward): 1 in 20.

iv. Traffic: Mixed – passenger & freight.

v. During service if some parameter goes out in case of any unforeseen circumstances, the leeway / margin available to correct the parameter. Vertical: +10 mm / - 3mm, Horizontal: ± 3 mm.

vi. Design temperature range: 70 degree Celsius variation of rail temperature as per zone & chart of Indian Railway Permanent Way Manual and 40 Degree variation of ambient temperature.

vii. Long welded rails (LWR) are to be used. The proposed design of BLT shall take into consideration of the forces due to LWR and interaction of LWR.

viii. It should be possible to do in-situ AT/Flash Butt welding as per the Indian Railways welding manuals.

ix. Track tolerances: Track tolerances over BLT when installed and later during service under floating condition shall be as under.

**Note:** The temperature range shall be commensurate with other provisions / guidelines through codes / manuals / specific circulars.

**1.1 TABLE NO: 1**

| S. No. | Parameter | Installation | Service |
|---|---|---|---|
| 1 | Gauge (with reference to 1673 mm measured below 14 mm rail top) for straight track and for curve up to the radius of 350 m. | ± 1mm | ± 3mm |
| 2 | Cross level on straight and curved track | ± 1 mm | ± 3mm |
| 3 | Variation in versine on curved track(20 m chord with half overlapping) | ± 3 mm | ± 6mm |
| 4 | Vertical alignment over a 3.6 m chord | ± 1 mm | ± 6 mm |
| 5 | Lateral alignment over a 7.2 chord | ± 1 mm | ± 3 mm |
| 6 | Twist on 3.6 m base | ± 1mm | ± 5mm |

The above installation parameter are not sacrosanct and the Contractor can also advise their own limits for the above parameters along with basis for suggesting the changes. Variation in horizontal alignment, vertical alignment versine, twist and gauge shall not exhibit cyclic pattern.

## 15.4 TRACTION DETAILS

IR has diesels/Overhead Electric (25kV) traction. The BLT design shall have adequate electrical insulation for correct performance of signaling and traction equipment even in flooded condition during monsoon for which necessary local field visit may be done and the design should take care of return current as per traction.

## 15.5 SIGNALING DETAILS

For signaling, the track circuiting is provided through the rails. The BLT system should take care of the same with adequate insulation. A minimum electrical resistance of 40 Ω per km as per Indian railway signaling manual needs to be ensured.

## 15.6 DERAILMENT GUARDS

Suitable arrangements for prevention of derailment in tunnels/ viaducts as per instructions issued by Indian Railway from time to time in the form of derailment slab/ block shall be provided to keep the derailed wheels in confined space and prevent damage in case of derailment. Derailment guard shall be designed such that in case of derailment:

i. The wheels of a derailed vehicle under crush load, moving at maximum speed are retained on the viaduct or tunnel etc.

ii. Damage to track and supporting structures is minimum.

## 15.7 BALLASTLESS TRACK STRUCTURE

Track shall be laid on cast in situ reinforced concrete plinth or slab, herein after referred to as the "Track slab". The track slab shall be designed as plinth beam or slab type ballastless track structure. It shall accommodate the base plates of the fastening system. The minimum depth of concrete below the base plate should be decided based upon characteristics of underlying base and the design of the fastening system. In general, track slab on which the fastening and rail are to be fitted shall-

1. Resist the track forces.
2. Provide a level base for uniform transmission of forces from the rails.
3. Have geometrical accuracy and enable installation of track to the tolerances laid down.
4. Ensure drainage.
5. Resist weathering.
6. Be construction friendly, maintainable and quickly repairable in the event of a derailment. The Repair and Maintenance methods shall be detailed in the Maintenance Manual.
7. Ensure provision for electrical continuity between consecutive plinths/slabs by an appropriate design.

## 15.8 PERFORMANCE REQUIRED OF FASTENING SYSTEM

### 15.8.1 GENERAL

i. The fastening shall be designed to hold the two rails of the track strongly to the supporting structure in upright position by resisting the vertical, lateral and longitudinal forces and vibrations.

ii. The fastening shall be with a proven track record. Fastening system should have satisfactory performance record of minimum 5 years in service in BLT on any established railway system. In this regard, supplier should submit certificate of performance from user railways administration including proof of use of the fastening system.

iii. The fastening shall provide insulation to take care of return current traction system.

iv. Fastening shall satisfy the required performance norms as stated in the following paragraphs.

### 15.8.2 TECHNICAL PERFORMANCE REQUIREMENTS OF FASTENING

The fastening shall-

i. Have design service life of 30 years in general. However, its components such as rubber pad, rail clip etc. can be designed for 300 GMT or 15 years whichever is less.

ii. Anchor bolts or studs used for fixing base plate to the concrete should not be required to be replaced during service life. Its components must not suffer any degradation during its service life to a degree so as to affect the performance and safety of the track. Full service life is to be attained under the following condition-

   a. Atmospheric ultra violet radiation
   b. Proximity of track up to 10m from salt water source
   c. Contact with oil, grease or distillate dropped from track vehicles

iii. Hold the rails to gauge and at the correct inclination within, tolerances laid down against horizontal forces generated by vehicles in motion especially on curves, and wheel set hunting, alignment irregularities and thermal forces.

iv. Permit quick and easy installation and replacement with special tools.

v. Be capable of vertical adjustment during service life up to 12mm using shims.

vi. Detailed calculations for the number of anchor bolts required on tangent and curved tracks shall be furnished by the contractor, and approved by the Engineer.

vii. For all the fastening components as per approved assembly, the contractor shall furnish detail drawings, specifications and inspection & test plan to the Engineer.

viii. The contractor shall furnish the 'Installation and Maintenance Manual' which shall be approved by the Engineer.

### 15.9 SPARES

The Contractor shall supply fastening system @10% of the total requirement for the permanent works as maintenance spare.

# CHAPTER 16

# LIST OF CODES

# CHAPTER 16

# LIST OF CODES

## 16.1 Introduction

The Contractor shall carry out the design on the basis of the codes and specifications given below. The list of codes mentioned herein is only for guidance. The Contractor may supplement these codes and standards with the consent of the Engineer if in his opinion it is essential to do so to comply with the Employer's Requirements.

The Contractor shall be responsible for detailing in his design report and specifications of the standards on which his materials and workmanship will be based and these will be of similar or higher standard than those listed below.

The Contractor shall also be responsible for getting the approval from the Engineer for the standards which he intends to apply for the detailing of his design and specifications additionally.

**16.2** Relevant Standards

Apart from the basic data and specific requirements listed in the Employer's Requirement, all items of the Works shall be governed by the latest versions of the following codes and specifications as revised/corrected/amended (with latest correction slip) till the date of approval of design/drawings by the Engineer. In case of contradiction in various codal provisions, the order of precedence shall be as follows:-

i. Specific provisions in the Employer's Requirements.
ii. IRS Codes and specifications
iii. IS Codes
iv. IRC Codes and specifications
v. International Codes

However, in case of ROBs and other highway loading related structures, IRC Codal provisions shall prevail over IRS Codal provisions. Notwithstanding the precedence specified above, the Contractor shall always seek advice from the Engineer in the event of any conflict for a final decision.

**a)** Loading Standards shall be as given in Design Requirements Criteria

**b)** Indian Railway Standard Codes and Specifications (IRS)

i. Bridge Rules
ii. Indian Railways Schedule of Dimensions (BG)
iii. Concrete Bridge Code
iv. Steel Bridge Code
v. Fabrication Specification (B1)

vi. Welded Bridge Code

vii. Indian Railways Bridge Manual

viii. Indian Railways Permanent Way Manual

ix. Indian Railways Works Manual

x. Bridge Substructure & Foundation Code

xi. Well and Pile Foundation Code

xii. Seismic Code for Earthquake Resistant Design of Railway Bridges

**c)** RDSO Guidelines

i. BS-113 Guidelines for providing Arrangements for Bridge Inspection

ii. Comprehensive Guidelines and Specifications for Railway Formation: RDSO/2020/GE: IRS 0004

iii. BS-114 RDSO guidelines for carrying out rail-structure interaction studies on Indian Railways

iv. BS-126 Guidelines for continuation of LWR/CWR over ballasted deck bridges on Indian Railways

v. Report No. GE: R-50: Transitional System on approaches of bridges issued by RDSO.

vi. Report No. BS-111: Guidelines for use of High Strength Friction Grip (HSFG) bolts on bridges on Indian Railways.

vii. Guidelines for design of Spherical and Cylindrical bearings (in case of Steel Bridges).- Letter No.: RDSO/CBS/Bearing dated 22-06-2011

viii. RDSO drawing for H beam sleepers

**d)** Indian Road Congress (IRC) Codes and Specifications

i. IRC: 5 Standard Specifications and Codes of Practice for Road Bridges Section – I – General features of design.

ii. IRC: 6 Standard Specifications and Codes of Practice for Road Bridges –Section – II – Loads and Stresses – Seismic provisions of this standard are to be adopted for the bridge design.

iii. IRC:112 Code of Practice for Concrete Road Bridges

iv. IRC: 22 Standard Specifications and Codes of Practice for Road Bridges Section – VI – Composite Construction.

v. IRC: 24 Standard Specifications and Codes of Practice for Road Bridges – Section V, Steel Road Bridges.

vi. IRC: 54 – Lateral and Vertical Clearances for Vehicular Traffic.

vii. IRC: 83 (Part – III) – Standard Specifications and Codes of Practice for Road Bridges – Section – IX – Bearings Part – III, Pot, POT cum PTFE Pin and Metallic Guide Bearings.

viii. IRC: 83 (Part – IV) – Standard Specifications and Codes of Practice for Road Bridges – Section – IX- Bearings Part – IV, Spherical and Cylindrical

ix. IRC-78: Sub-structure for Road Bridges.

x. IRS-87: Design and erection of false work for road bridges.

xi. Specifications for Road and Bridge Works issued by Ministry of Road Transport & Highways (MORTH).

**e)** Indian Standards Codes and Specifications (IS)

i. IS: 456 Plain and reinforced concrete - code of practice

ii. IS: 800 Code of practice for General Construction Steel

iii. IS: 875 Code of Practice for Design Loads Part 1, 2 3, 4& 5 (Other than Earthquake)

iv. IS: 1080 Design and construction of shallow foundations in soils (other than raft ring and shell)

v. IS: 1364 Hexagon Head Bolts, Screws & nuts of product grades A & B Part 1 (part 1 Hexagon, Head Bolts (size range M 1:6 to M64)

vi. IS 1367 Threaded Steel Fasteners

vii. IS: 13920 Ductile detailing of reinforced concrete structures subjected to seismic forces code of practice

viii. IS: 1489 Specification for Portland pozzolana cement (Fly ash based)

ix. IS: 1786 High strength deformed steel bars and wires for concrete reinforcement

x. IS: 1893 Criteria for Earthquake Resistant Design of structures

xi. IS: 1904 Design and construction of Foundations in soils: general requirements.

xii. IS: 2062 Specifications for weldable Structural steel

xiii. IS: 2502 Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement

xiv. IS: 2911 Design and Construction of Pile Foundation- Code of practice Part 1Concrete Pile- Section 2 Board Cast-in-situ-piles

xv. IS 2911 Design and Construction of Pile Foundation- Code of practice Part 4 Load test on piles

xvi. IS: 2950 Design and construction of raft foundations

xvii. IS: 3935 Code of Practice for Composite Construction

xviii. IS: 4326 Code of practice for Earthquake resistant design and construction of Buildings

xix. IS: 4923 Hollow steel sections for structural use -specification

xx. IS: 8009 Calculation of settlements of shallow foundations

xxi. IS: 269 Specifications of OPC cement

xxii. IS: 9103 Specifications of Concrete admixtures

xxiii. IS: 11384 Code of practice for Composite Construction in Structural Steel and Concrete

xxiv. IS: 12070 Code of practice for Design and construction of shallow foundation on Rocks

xxv. IS: 14593 Design and Construction of Bored Cast-in-Situ Piles Founded on Rocks.

xxvi. IS 455Specifications for Portland Slag cement

**f)** International Standards

i. UIC Code 774-3 (R) Track and Bridge Interaction

ii. UIC Code 772-2 (R) Code for the use of rubber bearings for rail bridges

The list of standards given above is only indicative. The Contractor shall follow provisions of appropriate codes and standards in force for items which are not covered in the codes mentioned in foregoing paras.

# Section VII: Employer's Requirements

# Section VII-6: Outline Construction Specifications (OCS)-Civil &BLT

# Chapter 1
# GENERAL-CIVIL

## 1.1 GENERAL:

**1.1.1** These Specifications contained herein shall be read in conjunction with other tender documents.

**1.1.2** All Materials, works and construction operations for civil works shall conform to the following manuals:

a) Indian Railways Permanent Way Manual

b) Indian Railway Bridge Manual

c) Indian Railway Works Manual

d) Indian Railway Schedule of Dimensions

e) Indian Railways Unified Standard Specification (Formation Works, Bridge Works and P.Way Works)

f) The relevant IRS Specifications referred to in the above documents listed at (a), (b), (c), (d) & (e )

g) CPWD Specifications, Vol 1&2 – 2019 for building works

h) In case of any contradiction in the various codal provisions, the order of precedence shall be as follows:-

i. IRS Codal provisions

ii. IRC Codal provisions

iii. IS(BIS) Codal provisions

**1.1.3** The Work shall be carried out in accordance with the "Good for Construction" drawings and designs as would be issued to the Contractor by the Engineer duly signed and stamped by him. The Contractor shall not take cognizance of any drawings, designs, specifications, etc. not bearing Engineer's signature and stamp. Similarly, the Contractor shall not take cognizance of instructions given by any other Authority except the instructions given by the Engineer in writing.

**1.1.4** The work shall be executed and measured as per metric units given in the Schedule of Quantities, drawings etc. (FPS units where indicated are for guidance only).

**1.1.5** Absence of terms such as providing, supplying, laying, installing, fixing etc in the descriptions does not even remotely suggest that the Contractor is absolved of such providing, supplying etc. unless an explicit stipulation is made in this contract. The Employer shall bear no costs of materials, labour, equipment, duties, taxes, royalties etc.

**1.1.6** The specifications may have been divided into different sections / sub-heads for convenience only. They do not restrict any cross-references. The Contractor shall take into account inter-relations between various parts of works/trades. No claim shall be entertained on the basis of compartmental interpretations.

**1.1.7** Reference to the Standard Codes of Practice:

a) The contractor shall make available at site all relevant Codes of practice as applicable.

| Legends | Definition |
|---|---|
| IRS | Indian Railway Standards |
| IR specifications | Indian Railways Unified Standard Specification (Formation Works, Bridge Works and P.Way Works) |
| IS | Indian Standards |
| IRC | Indian Road Congress |
| CPWD | Central Public Works Department |
| RDSO | Research Designs and Standards Organisation |
| UIC | International Union of Railways (UIC, French: Union international des chemins de fer) |
| MORTH | Ministry of Road Transport and Highways |
| EN | European Standard |
| ISO | International Organization for Standardization |
| ASTM | American Section of the International Association for Testing and Materials |
| BS | British Standard |

**1.1.8** Alternative or additional codes and standards proposed by the contractor shall be internationally recognized codes and shall be equivalent to or better than, Indian Standards issued by the Bureau of Indian Standards or any other Indian professional body or organization, subject to being, in the opinion of the Employer’s Representative, suitable for incorporation or reference into the specifications.

**1.1.9 Contractor to Provide:**

The Contractor shall provide and maintain at site throughout the period of works the following at his own cost and without extra charge, except for the items specified in the Bill of Quantities the cost being held to be included in the Contract Rates:

a) General works such as setting out, site clearance before setting out and on completion of works. All weather approach roads to the site office should also be constructed and maintained in good condition.

b) All labour, materials, plant, equipment and temporary works, Overhead charges as well as general liabilities, obligations, insurance and risks arising out of GCC, required to complete and maintain the works to the satisfaction of the Engineer.

c) Adequate lighting for night work, and also whenever and wherever required by the Engineer.

d) Temporary fences, barricades, guards, lights and protective work necessary for protection of workmen, supervisors, engineers, General public and any other persons permitted access to the site. Contractor shall provide proper signages as directed.

e) All fences, barricade shall be painted with colour shades as specified by the Engineer. The barricading should be of adequate height to ensure visual obstruction of work from public view.

f) All equipment, instruments, labour and materials required by the Engineer for checking alignment, levels, slopes and evenness of surfaces measurements and quality etc.

g) Design mixes and testing them as per relevant clauses of specifications giving proportion of ingredients, sources of aggregates and binder along with accompanying trial mixes. Test results to be submitted to the Engineer for his approval before adoption on works.

h) Cost of Preparation and compliance with provision of a quality assurance control program.

i) Cost of safeguarding the environment.

j) A testing laboratory as specified by the Engineer equipped with the following minimum apparatus, materials and competent trained staff required for carrying out tests, as specified in the relevant sections of the specifications: -

   i. 1 Set of standard sieves for testing grading of sand with mechanical sieve shaker.

   ii. Sieves with openings respectively of 4.75mm, 10mm, 20mm, 25mm, 30mm for testing and grading of aggregates.

   iii. Weighing Balance of capacity up to 10 Kg. reading up to 5 gm.

   iv. Electric Thermostat controlled oven and pans for drying of sand and aggregates.

   v. Glass measuring flasks of 1/2, 1 liter & 2 liter capacity.

   vi. Flask for determining moisture content of sand.

   vii. Slump cone with rod and V B Apparatus, flow table to measure slump or DIN Specifications.

   viii. Apparatus to measure permeability of concrete as per Appendix 1700/II of MOST Specifications.

   ix. Minimum 24 Nos. steel moulds for 150mm x 150mm x 150mm concrete test cubes. It may be necessary to provide more steel cube moulds depending upon concreting program.

   x. 25mm dia vibrator for compaction of concrete in test cubes and also vibrating table.

   xi. Concrete cube testing machine of 200 tonnes capacity with 3 dial gauges electrically operated.

   xii. Work benches, shelves, desks, sinks and any other furniture and lighting as required by the Engineer.

xiii. Abrasion Flakiness & Impact testing Equipment for testing coarse aggregate.

xiv. Silt Testing Equipment.

xv. Equipments for field lab as per list given in Annexure-VIII of RDSO guidelines No. RDSO/2020/GE: IRS-0004, Sept-2020

xvi. Any other equipment specified by Engineer.

**1.1.10 Quality Assurance & Quality Control:**

a) The work shall conform to high standards of design and workmanship, shall be structurally sound and aesthetically pleasing. The Contractor shall conform to the Quality standards prescribed, which shall form the backbone for the Quality Assurance and Quality Control system.

b) At the site, the Contractor shall arrange the materials, their stacking/storage in appropriate manner to ensure the quality. The Contractor shall provide all the necessary equipment and qualified manpower to test the quality of materials, assemblies etc., as directed by the Engineer. The tests shall be conducted at specified intervals and the results of tests properly documented. In addition, the Contractor shall keep appropriate tools and equipment for checking alignments, levels, slopes, and evenness of the surfaces.

c) The Engineer shall be free to carry out such tests as may be decided by him at his sole discretion, from time to time, in addition to those specified in this document. The Contractor may provide the samples and labour for collecting the samples. Nothing extra shall be payable to the Contractor for samples or for the collection of the samples.

   i. The test shall be conducted at the Site laboratory that may be established by the Contractor or at any other Standard Laboratory selected by the Engineer.

   ii. The Contractor shall transport the samples to the laboratory for which nothing extra shall be payable. In the event of the Contractor failing to arrange transportation of the samples in proper time the Engineer shall have them transported and recover two times the actual cost from the Contractor's bills.

   iii. All testing shall be performed in the presence of Engineer. Testing may be witnessed by the Contractor or his authorised representative if permitted by the Test House. Whether witnessed by the Contractor or not, the test results shall be binding on the Contractor.

d) The Engineer shall have the right at all times to inspect all operations including the sources of materials, procurement, layout and storage of materials, all equipment including the concrete batching and mixing equipment, and the quality control system. Such an inspection shall be arranged, and the Engineer's approval obtained prior to starting of the particular item of work. This shall, however, not relieve the Contractor of his responsibilities. All materials which do not conform to these specifications shall be rejected and shall be removed from the site immediately. The Engineer shall have the powers to cause the Contractors to purchase and use materials from any particular source, as May in the Engineer's opinion be necessary for the proper execution of work.

**1.1.11 Training**

The Contractor shall arrange the following trainings for all his concerned persons and

25 persons of the Engineer and the Employer together:

a) 2 days training for Tunnelling by NATM and Cut & Cover method.

b) 2 days training for fabrication of welded steel girders for railway including one day for practical demonstration at site.

c) 2 days training for concrete, testing, scaffolding and formwork including one day for practical demonstration at site

d) The Contractor shall bear all the expenditure for training including boarding, lodging, airfare, transport, and remuneration of trainers. Training place shall be provided by the Employer free of cost. However, the Contractor shall bear the expenditure for refreshments and meals for all the participants during the training period. The syllabus of training and the names of the trainers shall be submitted to the Engineer for approval. Training shall be imparted only by those trainers who are approved by the Engineer.

**1.1.12 Dimensions:**

a) Figured dimensions on drawings shall only be followed and drawings to a large scale shall take precedence over those to a smaller scale. Special dimensions or directions in the specifications shall supersede all others. All dimensions shall be checked on site prior to execution.

b) The dimensions where stated do not allow for waste, laps, joints, etc. but the Contractor shall provide at his own cost sufficient labour and materials to cover such waste, laps, joints, etc.

c) The levels, measurements and other information concerning the existing site as shown on the drawings are believed to be correct, but the Contractor should verify them for himself and also examine the nature of the ground as no claim or allowance whatsoever will be entertained on account of any errors or omissions in the levels or the description of the ground levels or strata turning out different from what was expected or shown on the drawings.

**1.1.13 Setting out of Works:**

The Contractor shall set out the Works indicated in the Contract. The Contractor shall provide suitable stones with flat tops and build the same in concrete for temporary benchmarks. All the pegs for setting out the Works and fixing the levels required for the execution thereof shall, if desired by the Engineer, likewise be built in masonry at such places and in such a manner as the Engineer may direct. The Contractor shall carefully protect and preserve all benchmarks and other marks used in setting out the works. The contractor will make overall layout of complete work and get it checked from engineer. The cost of all operations of setting out including construction of benchmarks is deemed to be included in the quoted rates.

a) All the survey work except leveling work shall be carried out using total stations with one second accuracy. The leveling work shall be carried out using Auto level.

b) The triangulations point given by concerned organization before start of work shall be maintained during execution and handed over back to concerned organization after completion of work.

**1.1.14 Materials:**

a) Source of Materials:

It shall be the responsibility of the contractor to procure all the materials required for construction and completion of the contract. The contractor shall indicate in writing the source of materials well in advance to the Engineer, after the award of the work and before commencing the work. If the material from any source is found to be unacceptable at any time, it shall be rejected by the Engineer and the contractor shall forthwith remove the material immediately from the site as directed by the Engineer.

b) Quality:

All materials used in the works shall be of the best quality of their respective kinds as specified herein, obtained from sources and suppliers approved by the Engineer and shall comply strictly with the tests prescribed hereafter, or where tests are not laid down in the specifications, with the requirements of the latest issues of the relevant Indian Standards.

c) Sampling and Testing:

All materials used in the works shall be subjected to inspection and test in addition to test certificates. Samples of all materials proposed to be employed in the permanent works shall be submitted to the Engineer at least 45 days in advance for approval before they are brought to the site.

Samples provided to the Engineer for their retention are to be labeled in boxes suitable for storage. Materials or workmanship not corresponding in character and quality with approved samples will be rejected by the Engineer.

Samples required for approval and testing must be supplied sufficiently in advance if required quality and number to allow for testing and approval, due allowance being made for the fact that if the first samples are rejected further samples may be required. Delay to the works arising from the late submission of samples will not be acceptable as a reason for delay in completion of the works.

Materials shall be tested before leaving the manufacturer's premises, quarry or resource, wherever possible. Materials shall also be tested on the site and they may be rejected if not found suitable or in accordance with the specification, notwithstanding the results of the tests at the manufacturer's works or elsewhere or test certificates or any approval given earlier.

The contractor will bear all expenses for sampling and testing, whether at the manufacturer's premises at source, at site or at any testing laboratory or institution as directed by the Engineer. No extra payment shall be made on this account.

d) Dispatch of materials:

Materials shall not be dispatched from the manufacturer's works to the site without written authority from the Engineer.

e) Test certificates:

All manufacturer's certificates of test, proof sheets, etc. showing that the materials have been tested in accordance with the requirement of this specification and of the appropriate Indian Standard, are to be supplied free of charge on request to the Engineer.

f) Rejection:

Any materials that have not been found to conform to the specifications will be rejected forthwith and shall be removed from the site by the Contractor at his own cost within two weeks or as instructed by the Engineer.

g) The Engineer shall have power to cause the Contractors to purchase and use such materials from any particular source, as may in his opinion be necessary for the proper execution of the work.

**1.1.15 Storing of Materials at site:**

a) All materials used in the works shall be stored on racks, supports, in bins, under cover etc. as appropriate to prevent deterioration or damage from any cause whatsoever to the entire satisfaction of the Engineer.

b) The storage of materials shall be in accordance with IS 4082 "Recommendation on stacking and storage or construction materials on site" and as per IS 7969 "Safety code for handling and storage of building materials".

c) The materials shall be stored in a proper manner at places at site approved by the Engineer. Should the place where material is stored by the Contractor be required by the Employer for any other purpose, the Contractor shall forthwith remove the material from that place at his own cost and clear the place for the use of the Employer.

**1.1.16 Water:**

a) Water from approved source:

Potable water only shall be used for the works. Contractor shall have his own source of water duly approved by Engineer. The water shall be free from any deleterious matter in solution or in suspension and be obtained from an approved source. The quality of water shall conform to IS 456:.

b) Storage:

The Contractor shall make his own arrangements for storing water, if necessary, in drums or tanks or cisterns, to the approval of the Engineer. Care shall be exercised to see that water is not contaminated in any way.

c) Testing:

Before starting any concreting work and wherever the source of water changes, the water shall be tested for its chemical and other impurities to ascertain its suitability for use in concrete for approval of the Engineer. No water shall be used until tested and found satisfactory. Cost of all such Tests shall be borne by the contractor.

**1.1.17 Workmanship:**

a) All works shall be true to level, plumb and square and the corners, edges and arises in all cases shall be unbroken and neat.

Any work not to the satisfaction of the Engineer or his representative will be rejected and the same shall be rectified, or removed and replaced with work of the required standard of workmanship at no extra cost.

### 1.1.18 Load Testing on Completed Structures

a) Load Testing of superstructure, in case of major bridges with OWG/ composite girders/ PSC girders and minor bridges with skew shall be done by the Contractor as per the directions of the Engineer. Cost of span load test is included in Schedule-C.

b) During the period of construction or within the defect liability period the Engineer may at his discretion order the load testing of any completed structure or any part thereof if he has reasonable doubts about the adequacy of the strength of such structure for any of the following reasons:

   i. Results of compressive strength on concrete test cubes falling below the specified strength.

   ii. Premature removal of formwork.

   iii. Inadequate curing of concrete.

   iv. Over loading during the construction of the structure or part thereof.

   v. Carrying out concreting of any portion without prior approval of the Engineer.

   vi. Honey combed or damaged concrete which in the opinion of the Engineer

   vii. is particularly weak and will affect the stability of the structure to carry the design load, more so in important or critical areas of the structure.

   viii. Loss of camber in OWG beyond permissible range as specified by Railway Board/RDSO.

   ix. Any other circumstances attributable to alleged negligence of the contractor which in the opinion of the Engineer may result in the structure or any part thereof being of less than the expected strength.

c) All the loading tests shall be carried out by the contractor strictly in accordance with the instructions of the Engineer, as per IRS:CBC and IRC:SP-51. Such tests shall be carried out only after expiry of minimum 28 days or such longer period as directed by the Engineer.

d) The structure shall be subjected to the load as approved for SLS condition in the design. This load shall be maintained for a period of 24 hours before removal. Incremental loading shall be done in accordance with IRC:SP-51, unless otherwise directed by the Engineer.

e) In case the recovery of the structure is not as per codal provisions, the structure shall be considered to have failed to pass the test and shall be deemed to be unacceptable.

f) In such cases the portion of the work concerned shall be taken down or cut out and reconstructed to comply with the specifications. Other remedial measures may be taken to make the structure secure at the discretion of the Engineer. However, such remedial measures shall be carried out to the complete satisfaction of the Engineer. Again, Load test shall be conducted as per codal provisions.

g) All costs involved in carrying out the tests (except integrity test for piles) and other incidental expense thereto shall be borne by the contractor regardless of the result of the tests. The contractor shall take down or cut out and reconstruct the defective work or shall make the remedial measures instructed at his own cost.

h) If the load testing is instructed on any ground other than mentioned in (i) to (ix) of Cl. 1.1.18(b), the cost of the same shall be reimbursed to the Contractor, if the result of the test are found to be satisfactory.

i) In addition to the load tests mentioned in these document, non-destructive test methods such as core test and ultrasonic pulse velocity test shall be carried out by the contractor at his own expense if so desired by the Engineer. Such tests shall be carried out by an agency approved by the Engineer and shall be done using only recommended testing equipment. The acceptance criteria for these tests shall be as per provisions in the relevant Indian/International standards and as approved by the Engineer.

**1.2 STRUCTURAL WORK:**

**1.2.1** Unless specified, only controlled concrete with design mix and weigh batching is to be used for the work.

**1.2.2** Minimum cement content specified in the codal specifications is purely from durability point of view. Larger content of cement shall have to be provided if demanded by mix design.

**1.2.3** Provision of cement slurry to create bond between plain / reinforced concrete surface and subsequent applied finishes shall not be paid extra.

**1.2.4** Mix design using smaller aggregates of 10mm down shall also be done in advance for the use in the junction having congested reinforcement.

**1.2.5** Procedure of mixing the admixtures shall be strictly as per the manufacturer's recommendations if not otherwise directed by the Engineer.

**1.2.6** All the water tanks and other liquid retaining concrete structures shall undergo hydro-testing.

**1.2.7** Special benches shall be provided at site for stacking reinforcement bars of different sizes.

**1.2.8** Formwork for beams of RCC areas shall be designed in such a way that the formwork of the adjacent slabs can be removed without disturbing the props / supports of the beams.

**1.2.9** Wherever there are tension / suspended concrete members which are suspended from upper-level structural members, the shuttering / scaffolding of such members at lower level shall have to be kept in place till the time the upper level supporting members gain minimum required strength. Cost of such larger duration of keeping in place the shuttering/scaffolding shall be deemed to be included in the price quoted for respective structural members.

**1.2.10** Formwork is required for full height at all locations. Special precaution for such tall formwork shall be taken to ensure its safety. Extra costs for such formwork shall be deemed to have been included in the price quoted against relevant items.

**1.2.11** In the mobilization period, the contractor shall carry out expeditiously and without delay the following works:

i. Material testing and mix designs of concrete as contemplated in the specifications.

ii. Setting up of full-fledged site laboratory as per the requirements of these specifications.

iii. Any other pre-requisite items required for final execution.

iv. Site office for the use of the Engineer staff.

v. Casting yard with full facilities.

**1.2.12 Casting yard to have following minimum facilities:**

i. Casting beds as required.

ii. All handling facilities for precast elements.

iii. Curing arrangements as required.

iv. Stacking arrangements for precast elements.

v. Storing of materials.

vi. Proper drainage and approach roads.

**1.2.13 Fabrication yard to have following minimum facilities:**

i. Fabrication beds as required.

ii. All handling facilities.

iii. Stacking arrangements for precast elements.

iv. Storing of materials.

v. Proper drainage and approach roads.

**1.3 SUPPLY OF PROGRES PHOTOGRAPHS AND ALBUMS (DIGITAL):**

The work covers the supply of digital photographs to serve as a permanent record of various stages/facets of work needed for an authentic documentation as approved by the Engineer.

The photographs shall be of acceptable quality and they shall be taken by a professionally competent photographer with camera having the facility to record the date of the photographs taken in the soft copy. Each photograph in the album shall be suitably captioned and dated.

The photographs and materials shall form a part of the records of concerned organization and same cannot be supplied to anybody else or published without the written permission of concerned organization.

**1.4 SUPPLY OF VIDEO CDs:**

The work consists of taking video films of important activities of the works as directed by the Engineer during the currency of the Project and editing them to a video film of playing time not less than 60 minutes. It shall contain narration of the activities in English by a competent narrator. The edition of the film and script of the narration shall be approved by the Engineer.

Drone videography of the whole package for inspection and monitoring of structures, shall be done by the Contractor once in a month.

The record of progress (photographs and videos) shall be submitted to the engineer on monthly basis or as directed by engineer.

## 1.5 SURVEY WORK:

The said work involves at the very start of work taking-over of reference point from the Engineer, establishment of control points, triangulation points, bench marks, grid layout for all the piers and other structures maintaining horizontal and vertical control within the permissible limits, incorporating changes (if any), submission of full data in the tabulation form and survey drawings including setting and layout of various works during the progress of work and matching of the station area track alignment with the alignment of the approaches at station ends and incorporating the changes (if any).

## 1.6 BARRICADING AND PROJECT INFORMATION SIGNBOARDS

The Contractor shall provide barricading to demarcate Works Areas from the public area.. All barricading shall be done at own cost by the Contractor. The detailed scope of work is as follows:

i. Providing and installing the barricade of the design and type as shown in the Tender Drawings and as per the approved plan firmly to the ground and maintaining it during the progress of work.

ii. Painting of the barricades shall be carried out to the design and colours as directed by the Engineer and the Contractor shall carry out re-painting of the entire barricades on a bi-annual basis.

iii. Providing lighting on the periphery of barricades for direction illumination.

iv. Project information signboards at each works area and Site Office shall be erected, not later than four (4) weeks, or such other period as the Engineer has given his consent, after the Date of Commencement of the Works. The types, sizes and locations of project signboards shall be agreed with the Engineer before manufacture and erection. Other advertising signs shall not be erected on the Site.

v. The consent of the Engineer shall be obtained before barricading and ~~hoardings~~ signboards are removed.

vi. Barricades and signboards shall be maintained in clean and good order by the Contractor until the completion of the Works. All the barricadings and signboards etc. shall be mopped minimum once in a week and washed monthly.

vii. Damaged/worn-out barricades ~~/hoarding~~ shall be replaced by the Contractor within 24 hours. Engineer‘s decision regarding need for replacement shall be final and binding. If no action is taken by the Contractor, the cost of any repairs will be deducted by the Engineer from any payment due to the Contractor.

viii. Dismantling of barricading and other temporary installations from the site and cleaning the site as per direction of Engineer upon completion and acceptance of work.

## 1.7 FINISHING WORK:

**1.7.1** The Contractor shall incorporate seismic considerations of anchoring and isolation in the design and detailing of the finishes as directed by the Engineer. The element to be anchored shall have its motion suitably restrained whilst at the same time it shall be suitably isolated so as not to be affected by the deformations/ vibrations of the building during Construction.

**1.7.2 Sub-Contractor:**

Works as listed below and those dealing with proprietary materials/ products may be carried out by the Contractor through the Sub-Contractors as may be approved by the Engineer in writing. The Sub-Contractors must be firms of repute and long standing, having adequate experience and complete facilities to carry out all items of work required for completion as per Specifications and expected quality to the satisfaction of the Engineer. The Sub-Contractor must also have personnel experienced in preparing shop drawings. All such works, not limited to the following, shall be carried out under the direct supervision of the manufacturers of the proprietary materials/ products or their trained and accredited licensee.

i. Bearings

ii. Fabrication, assembly and launching of steel OWG

**1.7.3 Responsibility for Shop drawings, Samples and Mock-ups:**

Approval of shop drawings, samples and mock-ups for the various components shall not absolve the Contractor of his responsibility of completing the work to the specifications, standards, tests for performance and guarantees given in these documents and to a quality of finish as desired by the Engineer.

**1.7.4 Cleaning:**

Surfaces on which finishes are to be provided shall be cleaned with water jets or oil free compressed air or power tools with wire brushes and detergents all as approved by the Engineer.

**1.7.5 Applicable Codes, Standards & Publications for Structural & Architectural Work:**

The more important Codes, Standards and Publications to Contract are listed here under:

Any other code/publication, if found necessary by the engineer, may be referred to for such works. The latest revision along with all corrections slip & amendments shall only be followed

| Sr. No. | Code No. | Code Name |
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| **General** | | |
| 1. | IS: 875 | Code of Practice for design loads (other than earthquake) for buildings and structures |
| 2. | IS: 122 (part 4) | Methods of measurement of buildings and Civil engineering works-Stone masonry |
| 3. | IS:1237 | Specification for cement concrete flooring tiles |
| 4. | IS: 1322 | Bitumen felts for water proofing and damp-proofing |
| 5. | IS: 1893 | Criteria for earthquake resistant design of structures |
| 6. | IS: 2185 (Part 1) | Concrete masonry units: Hollow and solid concrete |
| 7. | IS: 2185 (Part 2) | Concrete masonry units: Hollow and solid light weight |
| 8. | IS: 2185 (Part 3) | Concrete masonry units: Autoclaved cellular aerated concrete blocks |
| 9. | IS: 2572 | Code of Practice for construction of hollow concrete block |

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| | | Masonry |
| 10. | IS: 3414 | Code of practice for design and installation of joints in Buildings |
| 11. | IS: 3462 | Specification for unbacked flexible PVC flooring |
| 12. | IS: 5318 | Code of practice for laying of flexible PVC sheet and tile Flooring |
| 13. | IS: 6408 (Parts 1,2) | Recommendations for modular co-ordination in building Industry-tolerances |
| 14. | IS: 8183 | Bonded mineral wool |
| 15. | IS:10958 | General check list of functions of joints in building |
| 16. | IS:11817 | Classification of joints in buildings for accommodation of dimensional deviations during construction |
| 17. | IS:11818 | Method of test for laboratory determination of air permeability of joints in buildings |
| 18. | IS:12440 | Precast concrete stone masonry blocks |
| 19. | CPWD | Specifications with up-to-date correction slips |
| 20. | BS:476 (Part 7) | Method for classification of the surface spread of flame of Products |
| 21. | BS:476 (Part 20) | Method of determination of the fire resistance of elements of construction (general principles) |
| 22. | BS:476 (Part 22) | Methods for determination of the fire resistance of non-load bearing elements of construction |
| 23. | BS: 1245 | Specification for metal door frames (steel) |
| 24. | BS: 3261 | Specification for unbacked flexible PVC flooring |
| 25. | BS:3261: Part 1 | Homogeneous flooring |
| 26. | BS:5215 | Specification for one-part gun grade polysulphide-based Sealants |
| 27. | BS:5606 | Guide to accuracy in building |
| 28. | BS:5725 (Part 1) | Specification for panic bolts and panic latches mechanically operated by a horizontal push-bar |
| 29. | BS:6093 | Code of practice for the design of joints and jointing in building construction |
| 30. | BS:8200 | Code of practice for the design of non-load bearing external vertical enclosure of building |
| 31. | ASTM C 332 | Specification for light weight aggregate for insulating Concrete |
| 32. | ASTM C 635 | Specification for the manufacture, performance and testing of metal suspension systems for acoustical tile and lay-in panel ceilings |
| 33. | SP 7 | National Building Code of India |
| 34. | SP 23 (S&T) | Hand Book on Concrete Mixes |
| **Bitumen** | | |
| 35. | IS:702 | Industrial Bitumen |
| 36. | IS:3384 | Specification for bitumen primer for use in waterproofing and damp-proofing |
| **Building Construction Practices** | | |

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| 37. | IS: 1838 Parts I and II. | Specifications for preformed fillers for expansion joint in concrete pavements and structures |
| 38. | IS: 1946 | Code of Practice for use of fixing devices in walls, ceilings, and floors of solid construction. |
| 39. | IS: 3414 | Code of Practice for design and installation of joints in buildings. |
| 40. | IS: 6509 | Code of Practice for installation of joints in concrete pavements. |
| 41. | IS: 11134 | Code of Practice for setting out of buildings. |
| 42. | IS: 11433 | Parts I and II. Specifications for one part Gun grade polysulphide based joint sealant |
| 43. | IS: 12200 | Code of Practice for provision of water stops at transverse construction joints in masonry and concrete dams |
| **Cement** | | |
| 44. | IS:269 | 33 grade ordinary Portland cement |
| 45. | IS: 455 | Portland Slag Cement |
| 46. | IS: 650 | Specification for standard sand for testing cement |
| 47. | IS: 1489 (Part 1) | Portland pozzolana cement: Fly ash based |
| 48. | IS: 1489 (Part 2) | Portland pozzolana cement: Calcined clay based |
| 49. | IS: 3535 | Method of Sampling Hydraulic Cements |
| 50. | IS: 4031 | (Parts 1 to 13) Methods of physical tests for hydraulic cement |
| 51. | IS:4032 | Methods of chemical analysis of hydraulic cement |
| 52. | IS: 6925 | Methods of test for determination of water-soluble chlorides in concrete admixtures |
| 53. | IS:8042 | White Portland Cement |
| 54. | IS: 8112 | Specification for 43 grade ordinary Portland cement |
| 55. | IS:12269 | Specification for 53 grade ordinary Portland cement |
| 56. | IS: 12330 | Specification for sulphate resistant Portland cement |
| 57. | IRS: T40 | Indian Railways standard specification for special grade cement for use in concrete sleepers |
| **Concrete** | | |
| 58. | IS:456 | Code of practice for plain and reinforced concrete |
| 59. | IS: 457 | Code of practice for general construction of plain and reinforced concrete for dams and other massive structures |
| 60. | IS: 460 (Part I TO III) | Specification for Test Sieves |
| 61. | IS: 516 | Methods of tests for strength of concrete |
| 62. | IS: 1199 | Methods of sampling & analysis of concrete |
| 63. | IS: 1200 | Methods of measurement of building and civil engineering |
| 64. | IS: 1343 | Code of practice for prestressed concrete |
| 65. | IS: 1607 | Methods of Test Sieving |
| 66. | IS:2386 | Parts I-VIII. Methods of tests for aggregates for concrete. |
| 67. | IS:2430 | Methods of Sampling of Aggregates of Concrete |
| 68. | IS:2438 | Specification for roller pan mixer |
| 69. | IS:2514 | Specification for concrete vibrating tables |
| 70. | IS:2571 | Code of practice for laying in-situ cement concrete Flooring |

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| 71. | IS:2645 | Specifications for integral cement water proofing Compounds |
| 72. | IS:2722 | Specifications for portable swing batchers for concrete (double bucket type) |
| 73. | IS:2770 | Methods of testing bond in reinforced concrete part I pull out test |
| 74. | IS:3025 | Methods of sampling and test (physical and chemical) for water & waste water |
| 75. | IS:3370 | Code of practice for concrete structures for storage of Liquids |
| 76. | IS:3935. | Code of practice for composite construction |
| 77. | IS:4326 | Code of practice for earthquake resistant construction of Building |
| 78. | IS:6925. | Methods of test for determination of water soluble chlorides in concrete Admixtures |
| 79. | IS:7242 | Specifications for concrete spreaders |
| 80. | IS:7251 | Specifications for concrete finishers |
| 81. | IS:7861 | Parts I & II. Code of practice for extreme weather concreting |
| 82. | IS:7969 | Safety code for handling and storage of building materials |
| 83. | IS:8989 | Safety code for erection of concrete framed structures |
| 84. | IS:8142 | Methods of test for determining setting time of concrete by penetration resistance |
| 85. | IS: 9103 | Specification for admixtures for concrete |
| 86. | IS: 9013 | Method of making, curing and determining compressive strengths of accelerated cured concrete test specimens |
| 87. | IS: 9284 | Method of test for abrasion resistance of concrete |
| 88. | IS:10262 | Recommended guidelines for concrete mix design |
| 89. | IS: 4926 | Code of Practice ready mixed concrete needs to be included in list |
| 90. | MORTH | Specifications for Road and Bridge Works, Ministry of Road Transport and Highways (Roads Wing) |
| 91. | SP 34 | Handbook on Concrete Reinforcement and Detailing |
| 92. | IRS | Concrete Bridge Code |
| 93. | IRC 112 | Code of Practice for Concrete Road Bridge |
| 94. | IRC 83 (Part 4) | Statndard Sepcifications and code of practice for road bridges Section IX Bearings (Spherical & Cylindrical) |

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| 95. | ASTM-C-94 | Ready Mix Concrete |
| **Construction Plant and Machinery** | | |
| 96. | IS: 1791 | Specification for batch type concrete mixers |
| 97. | IS: 2505 | General requirements for concrete vibrators: Immersion type. |
| 98. | IS: 2506 | General requirements for screed board concrete vibrators. |
| 99. | IS: 3366 | Specification for pan vibrators |
| 100. | IS: 3558 | Code of Practice for use of immersion vibrators for consolidating concrete |
| 101. | IS: 4656 | Specifications for form vibrators for concrete. |
| 102. | IS: 4925 | Specification for concrete batching and mixing plant. |
| 103. | IS: 11993 | Code of Practice for use of screed board concrete vibrators. |
| **Formwork** | | |
| 104. | IS: 4990 | Specifications for plywood for concrete shuttering work |
| 105. | IRC: 87 | Guidelines for the design and erection of false work for road bridges. |
| 106. | IS: 806 | Code of practice for use of steel tubes in general building construction. |
| 107. | IS: 1161 | Specification of steel tubes for structural purposes. |
| 108. | IS: 1239 | Specification for mild steel tubes, tubular and other wrought steel fittings |
| **Gypsum and Gypsum Board** | | |
| 109. | IS: 2095 | Gypsum plaster boards |
| 110. | IS: 2542 (Part 1/Sec to 12) | Methods of test for gypsum plaster, concrete and products: plaster and concrete |
| 111. | IS: 2542 (Part 2/Sec | Methods of test for gypsum plaster, concrete and |

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| | 1to 8) | products: Gypsum products |
| 112. | IS: 2542 (Part1) | Gypsum building plaster: Excluding premixed lightweight plaster |
| 113. | IS: 2547 (Part 2) | Gypsum building plaster: Premixed lightweight plaster |
| **Handling and Storage** | | |
| 114. | IS:4082 | Recommendation of Stacking and Storage of construction materials |
| 115. | IS:8348 | Code of practice for stacking and packing of stone slabs for transportation |
| 116. | IS:8759 | Code of practice for maintenance and preservation of stones in building |
| **Instruments for Testing Cement and Concrete** | | |
| 117. | IS:5513 | Specification for vicat apparatus. |
| 118. | IS:5514 | Specification for apparatus used in Le-Chaterlier test. |
| 119. | IS:5515 | Specification for compaction factor apparatus. |
| 120. | IS:7320 | Specification for concrete slump test apparatus. |
| 121. | IS:7325 | Specification for apparatus to determine constituents of fresh concrete. |
| 122. | IS:10080 | Specification for vibration machine. |
| 123. | IS:10086 | Specification for moulds for use in tests of cement and concrete. |
| 124. | IS:10510 | Specification for vee-bee consistometer. |
| | **Joint Fillers** | |
| 125. | IS:1838 (Part 1) | Preformed fillers for expansion joint in concrete pavements and structures (non extruding and resilient type): Bitumen impregnated fibre |
| **Paints and Coatings** | | |
| 126. | IS:102 | Ready mixed paint, brushing, red lead, non-setting, priming |
| 127. | IS:109 | Ready mixed paint, brushing, priming, plaster, to Indian Standard Colour No. 361 and 631 white and off white. |
| 128. | IS:218 | Creosote and anthracene oil for use as wood preservatives |
| 129. | IS:347 | Varnish, shellac, for general purpose |

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| 130. | IS:348 | French Polish |
| 131. | IS:2074 | Ready mixed paint, air drying, red oxide-zinc chrome, priming |
| 132. | IS: 4833 | Methods of field testing of preservatives in wood |
| 133. | IS:10013 (Parts 1 to 3) | (Part -1) Water soluble type wood preservatives |
| 134. | IS:10013 (Parts 1 to 3) | (Part-2) Acid-copper-chrome preservative |
| 135. | IS: 10013 (Part 1 to 3) | (Part-3) Copper-chrome-boron wood preservative |
| 136. | BS:6496 | Specification for powder organic coatings for application and stoving to aluminium alloy extrusions, sheet and preformed sections for external architectural purposes, and for the finish on aluminium alloy extrusions, sheet and preformed sections coated with powder organic coatings |
| 137. | BS:EN:10152 | Specification for electrolytically zinc coated cold rolled steel flat products. Technical delivery conditions |
| 138. | ASTM A 164-71 | Specification for electrodeposited coatings of zinc on steel |
| **Pigment for cement** | | |
| 139. | BS:1014 | Specification for pigments for Portland cement and Portland cement products |
| **Reinforcement & Structural Steel** | | |
| 140. | IS:206 | Code of Practice for use of Steel Tubes in General Building Construction |
| 141. | IS:210 | Grey Iron Castings |
| 142. | IS:280 | Mild steel wire for general engineering purposes |
| 143. | IS:432 | Part I. Mild steel and medium tensile steel bars. Part II Hard drawn steel wire. |
| 144. | IS:451 | Technical Supply conditions for Wood Screws |
| 145. | IS:806 | Code of practice for use of steel tubes in general building construction |
| 146. | IS:815 | Classification coding of covered electrodes for metal arc |

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| | | welding of structural steels |
| 147. | IS:1239 | Specification for mild steel tubes, tubulars and other wrought steel fittings |
| 148. | IS 1343 | Code of Practice for Prestressed Concrete |
| 149. | IS:1363 | Black hexagon bolts, nuts and lock nuts and black hexagon screws. |
| 150. | IS:1365 | Slotted countersunk screws. |
| 151. | IS:1566 | (Part I) Specifications for hard-drawn steel wire fabric for Concrete reinforcement |
| 152. | IS:1786 | Specification for high strength deformed steel bars and wires for concrete reinforcement. |
| 153. | IS:2502 | Code of Practice for bending and fixing of bars for concrete reinforcement. |
| 154. | IS:2629 | Recommended practice for hot-dip galvanising of iron and steel. |
| 155. | IS:2751 | Code of Practice for welding of mild steel plain and deformed bars for reinforced concrete construction. |
| 156. | IS 4000 | Code of practice for high strength bolts in steel structures |
| 157. | IS:4759 | Hot-dip zinc coating on structural steel and other allied products. |
| 158. | IS:5525 | Recommendations for detailing of reinforcement in reinforced concrete works |
| 159. | IS:9417 | Recommendations for welding cold-worked steel bars for reinforced concrete construction. |
| 160. | IS:14268 | Uncoated stress relieved low relaxation steel class 2 for Prestressed concrete |
| 161. | IS:226 | Structural steel (Standard Quality) |
| 162. | IS:800 | Code of practice for use of structural steel in general building construction. |
| 163. | IS:813 | Scheme of symbols for welding |
| 164. | IS:814 | Covered electrodes for metal arc welding of structural steel. (Part I & Part II) |
| 165. | IS:816 | Code of practice for use of metal arc welding for general construction in mild steel. |

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| 166. | IS:822 | Code of practice for inspection of welds. |
| 167. | IS:961 | Structural steel (High Tensile) |
| 168. | IS:1024 | Code of practice for use of welding in bridges and structures subject to dynamic loading. |
| 169. | IS:1030 | Carbon steel casting for General Engineering Purposes |
| 170. | IS:1120 | Coach Screws |
| 171. | IS:1367 | Technical Supply Conditions for Threaded Fasteners |
| 172. | IS:1161 | Steel tubes for structural purposes. |
| 173. | IS:1182 | Recommended practice for radiographic examination of fusion welded butt joints in steel plates. |
| 174. | IS:1915 | Code of Practice for Steel Bridges |
| 175. | IS:2016 | Plain Washers |
| 176. | IS:2062 | Structural steel (Fusion welding quality) |
| 177. | IS:3063 | Single Coil Rectangular Section Sprint Washers for Nuts, Bolts and Screws |
| 178. | IS:3443 | Crane Rail Sections |
| 179. | IS:3757 | Specification for high tensile friction grip bolts |
| 180. | IS:5624 | Specification for foundation bolts |
| 181. | IS:3600 | Code of practice for testing of fusion welded (Part I) joints and weld metal in steel |
| 182. | IS:4923 | Hollow steel sections for structural use. |
| 183. | IS:6227 | Code of practice for use of metal arc welding in tubular structure. |
| 184. | IS:801 | Code of practice for use of cold formed light gauge steel structural members in general building construction. |
| 185. | IS:811 | Specifications for cold formed light gauge structural steel sections. |
| 186. | IS:8500 | Structural steel Micro alloyed (Medium and high strength qualities) |
| 187. | IS:8910 | General requirements of supply of weldable structural steel |
| 188. | IS:9595 | Recommendations for metal arc welding of carbon & carbon- manganese steels. |

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| 189. | IS 16172 | Reinforced Couplers for Mechanical Splices of Bars in Concrete |
| **Sand** | | |
| 190. | IS:383 | Coarse and fine aggregates from natural sources for concrete. |
| **Scaffolding** | | |
| 191. | IS:2750 | Specification for steel scaffoldings |
| 192. | IS:3696 (Part 1) | Safety Code of scaffolds and ladders: Scaffolds |
| 193. | IS:3696 (Part 2) | Safety Code of scaffolds and ladders: Ladders |
| 194. | IS:4014 (Part 1) | Code of practice for steel tubular scaffolding: Definition and Materials |
| 195. | IS:4014 (Part 2) | Code of practice for steel tubular scaffolding: Safety regulations for scaffolding |
| 196. | IRC:87 | Guidelines for the design and erection of falsework for Road bridge |
| **Sealants** | | |
| 197. | IS: 10959 | Glossary of terms for sealants for building purposes |
| 198. | IS: 11433 (Part 1) | One part grade polysulphide base joint sealant: General requirements |
| 199. | IS: 11433 (Part 2) | One part grade polysulphide base joint sealant: Methods of test |
| 200. | IS: 13055 | Methods of sampling and test for anaerobic adhesives and sealants |
| 201. | BS: 5889 | Specification for one part gun grade silicone<br><br>based sealants. |
| **Wood** | | |
| 202. | IS: 303 | Plywood for General Purposes |
| 203. | IS: 848 | Synthetic resin adhesives for plywood (phenolic and aminoplastic) |
| 204. | IS: 1141 | Seasoning of Timber – Code of Practice |
| 205. | IS:1328 | Veneered decorative plywood |
| 206. | IS: 1659 | Blocks Boards |

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| 207. | IS: 2046 | Decorative thermosetting synthetic resin<br><br>bonded laminated sheets |
| 208. | IS: 2202 (Part 1) | Wooden flush door shutters (solid core type):<br><br>Plywood face panels |
| 209. | IS: 2202 (Part 2) | Wooden flush door shutters (solid core (type):<br>Particle face panels and hardboard face panels |
| **Bearing** | | |
| 210. | IRC: 83 Part-II | Standard specifications and code of practice for road bridges Elastomeric Bearings |
| 211. | IRC: 83 Part-III<br>EN 1337gh | Standard specifications and code of practice for road bridges Pot Bearings |
| 212. | IRC: 83 Part-IV | Standard Specifications and Code of Practice for Road Bridges (Section – IX) Bearings (Spherical and Cylindrical) |
| **Piling** | | |
| 213. | IS: 2911 (All Parts) | Bored Cast in-situ Concrete Piles |
| 214. | IRC: 78 | Standard specifications and code of practice for road bridges Foundation And Substructure |
| **All Indian Railway & RDSO Standards, any other code or publication as approved by engineer in-charge** | | |
| **Metal** | | |
| 215. | IS: 276 | Austenitic manganese steel castings |
| 216. | IS: 733 | Wrought aluminium and aluminium alloy bars, rods and sections for general engineering purpose. |
| 217. | IS: 737 | Specifications for wrought aluminium and aluminium alloy sheet and strip for general engineering purpose. |
| 218. | IS: 3614 (Part 1) | Specification for fire check doors: Plate metal covered and rolling type |
| 219. | IS: 3614 (Part 2) | Specification for metallic and non-metallic fire check doors: Resistance test and performance criteria |
| 220. | IS: 7196 | Specification for Hold Fasts |
| 221. | ASME set 2 Part A | Ferrous Material Specification |
| 222. | ASTM B 221 | Specification for aluminum-alloy extruded bars, rods, wires, shapes, and tubes |

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| 223. | BS: 4873 | Specification for Aluminum alloy windows |
| 224. | BS: 7352 | Specification for strength and durability performance of metal hinges for side hanging applications and dimensional requirements for template drilled hinges |
| 225. | BS EN: 10143 | Specification for continuously hot-dip metal coated steel sheet and strip. Tolerances on dimensions and shape |
| **Stone and Facings/Linings** | | |
| 226. | IS:1121-(Parts 1 to 4) | Methods of test for determination of strength properties of natural building stones |
| 227. | IS:1121-(Parts 1 to 4) | (Part-1 Compressive strength) |
| 228. | IS:1121-(Parts 1 to 4) | (Part-2 Transverse strength) |
| 229. | IS:1121-(Parts 1 to 4) | (Part-3 Tensile strength) |
| 230. | IS:1121-(Parts 1 to 4) | (Part-4 Shear strength) |
| 231. | IS:1122 | Method of test for determination of true specific gravity of natural building stones. |
| 232. | IS:1123 | Method of identification of natural building stones. |
| 233. | IS:1124 | Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones. |
| 234. | IS:1125 | Method of test for determination of weathering of natural building stones |
| 235. | IS:1126 | Method of test for determination of durability of natural building stones. |
| 236. | IS:1127 | Recommendations for dimensions and workmanship of natural building stones for masonry work. |
| 237. | IS:1128 | Specification for Limestone (Slabs and Tiles) |
| 238. | IS:1129 | Recommendation for dressing of natural building stones. |
| 239. | IS:1130 | Specification for marble (blocks, slabs and tiles) |
| 240. | IS:1597 (Part 2) | Code of practice for construction of stone masonry |

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| | | Ashlar masonry |
| 241. | IS:1706 | Method for determination of resistance to wear by abrasion of natural building stones |
| 242. | IS:1805 | Glossary of terms relating to stones, quarrying and Dressing |
| 243. | IS:3620 | Specification for laterite stone block for masonry |
| 244. | IS:3622 | Specification for Sandstone (slab & tiles) |
| 245. | IS:4101 (Part 1) | Code of practice for external facing and veneers: stone Facing |
| 246. | IS:4101 (Part 2) | Code of practice for external facing and veneers: Cement concrete facing |
| 247. | IS:4101 (Part 3) | Code of practice for external facing and veneers: Wall tiling and mosaics |
| 248. | IS:4121 | Method of test for determination of water transmission rate by capillary action through natural building stones |
| 249. | IS:4122 | Method of test for surface softening of natural building stones by exposure to acidic atmospheres |
| 250. | IS:4348 | Method of test for determination of permeability of natural building stones |
| 251. | IS:5218 | Method of test for toughness of natural building stones |
| 252. | IS:8381 | Recommended practice for quarrying stones for construction purposes |
| 253. | IS:14223 (Part 1) | Polished building stones: Granite |
| 254. | BS: 8298 | Code of practice for design and installation of natural stone cladding and lining |

# CHAPTER-2.
# SITE INSTALLATIONS AND SERVICES

## 2.1 GENERAL

**2.1.1** Site installations, site clearance (including removal), services shall be carried out in accordance with the provisions of the Employer’s Requirements.

**2.1.2** The Contractor shall be responsible for providing plant, equipment, materials and labour for the provision of all necessary Temporary Works and services adequate for the execution of the Work under this contract.

**2.1.3** The Contractor shall design, furnish, install, maintain and operate on the Site Constructional Plants as specified in this Chapter, including camps, workshops: warehouses, storage and assembly areas, all equipment, machinery, vehicles. Scaffolding, water and power supply etc.

**2.1.4** Obtaining necessary clearance/ permission that are needed for construction, from various state/ central authorities for the equipment, water, power, sanitary and explosives shall rest with the contractor.

**2.1.5** Temporary Works and services carried out by the Contractor shall conform to the applicable Indian Standard I Codes / laws, regulations and statutory requirements including compliance to railways codes/manuals/guidelines etc. stipulated for such purpose In-case no National Standard is available, International Standards are to be applied as approved by the Engineer.

**2.1.6** The design, construction, operation and maintenance of the Contractor's Temporary Works and services shall be subject to inspection and approval by the Engineer.

**2.1.7** The rights or customs of adjacent property occupiers for access shall not be infringed by the Contractor.

## 2.2 SUBMITTALS

**2.2.1** Within 28 days from the Letter of Acceptance, the Contractor shall submit to the Engineer, updated layout plans showing, to an adequate scale, the locations and arrangement of all enabling and temporary Works and facilities. These plans shall be consistent with the plans submitted by the Contractor with his tender as well as with any amendments and additions subsequently agreed to by the Engineer and the Contractor and shall include.

- **i.** Site offices, storages, parking areas, warehouses, materials yard, storage areas
- **ii.** Concrete and material processing plant including cement storage.
- **iii.** Temporary road including public road diversions.
- **iv.** Communication System.
- **v.** Service vehicles.
- **vi.** Camps for Contractor’s Employees.
- **vii.** Medical facilities.
- **viii.** Power supply and illumination, telephone services (radio and cable).
- **ix.** Maintenance of Traffic.
- **x.** Ventilation of Underground System.
- **xi.** Air-cooling in underground works.
- **xii.** Control of dust, silica and noxious gases in underground works.
- **xiii.** Water supply.

- **xiv.** Sanitation & sewerage, sewage treatment and disposal,
- **xv.** Waste & garbage disposal.
- **xvi.** Security and safety arrangements.
- **xvii.** Field laboratory along with list of equipment as required under Quality Assurance Programme.
- **xviii.** Equipment tools and mechanical workshops.
- **xix.** Dumping areas, borrow, quarry and stockpile areas with development plans.
- **xx.** Explosive magazines.
- **xxi.** Adequate back up power system.
- **xxii.** Measures to comply with environmental norms and various conditions.
- **xxiii.** Muck disposal management.
- **xxiv.** Site Signage.
- **xxv.** Drainage plan during construction.
- **xxvi.** Contractor Quality Plan
- **xxvii.** Emergency Plan.
- **xxviii.** Safety Plan

**2.2.2** Within 42days from the commencement date, the Contractor shall submit to the Engineer the following:

- **i.** Detailed drawings to a scale ranging from 1:100 to 1:500 showing the camp layout, buildings, roads, recreation areas, all utilities etc. and drawings to a scale of 1: 50 to 1: 1 00 showing typical building construction details.
- **ii.** Drawings and Specification for the establishment of primary first aid stations dispensary and ambulances.
- **iii.** Detailed design for industrial and potable water supply to the camps and working area as well as sewerage system, sewerage treatment and disposal with an estimate of number of people to be supplied with water. All the system shall comply with the environmental and pollution control norms as applicable.
- **iv.** Detailed layout drawings for electrical installations and distribution systems on the site, showing voltages, outlets and routing of power lines. The system should include necessary power back up arrangements for uninterrupted construction work.
- **v.** Detailed design and drawings including manufacturer's drawings for concrete and materials processing plants, including details of equipment for transportation and placement of concrete in accordance with the requirements of the pertinent Chapters of these Specifications.
- **vi.** Details of the excavation, drilling and grouting equipment in accordance with the requirements set out in the relevant Chapter of these Specifications.
- **vii.** Details of the underground ventilation system, which shall include all calculations of fresh air supply volume, type of ventilation scheme, duct diameters. Materials, equipment, position of ventilators and dust arresters. Description of the working cycle including number of persons employed, number and capacity of diesel-powered equipment working at each heading face shall also be included.
- **viii.** Details of the dewatering system.

ix. Details of Field laboratory to be set up at site by the contractor.

x. Details of muck disposal and protection measures for compliance with Environmental, Social, Health & Safety Management Plan of the work specifications.

xi. The designs shall be consistent with the proposal submitted by the Contractor with his tender as well as with any subsequent amendments and additions agreed to by the Engineer and the Contractor. (The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.)

## 2.3 DETAILS OF INSTALLATIONS AND SERVICES

The installations and services to be provided by the Contractor for the execution of Works under this Contract shall include, but not limited to, the following:

### 2.3.1 CAMPS FOR CONTRACTOR'S EMPLOYEES

i. The Contractor shall design, construct, provide furnishings, maintain and operate construction camps at the suitable locations. The construction camps shall provide for the housing, feeding and recreation of the Contractor's employees and those of his subcontractors. Kitchens with provision of LPG facility for cooking (Fire wood not to be used), dining rooms, outdoor and indoor recreation facilities, family dwellings, dormitories, sanitary facilities, medical service, places of worship, roadways, drainage, fire control, commercial centers and all utility services (potable water, power, lighting, heating ventilating, sewerage treatment and disposal, cleaning and sanitation, garbage collection and disposal, etc.) shall be provided. The camps shall be large enough to accommodate the anticipated peak work force. The construction labour camp should be as per BOCWA / BOCWR. The contractor has to provide bio-toilets (separate for male and female) at Camp site as well as at all the construction sites. The user ratio shall not be more than that specified in point (iv) below.

ii. No camp construction shall commence until the Contractor's drawings and Specifications have been approved by the Engineer.

iii. All camp building shall be of sound construction and connected to all utility services.

iv. Fixtures in the sanitary facilities shall be based on the following user ratios

a. 1 toilet for not more than 6 users

b. 1 tap for not more than 6 users

c. 1 washbasin for not more than 6 users.

**2.3.2** The sewerage from the labour camps, work sites is to be properly treated before discharge by providing septic tanks, soak pits etc. or any other treatment as per norms recommended by the concerned authority.

i. Canteen facilities shall be provided by the Contractor in properly equipped canteen buildings for all his and his subcontractor's employees, if it is considered expedient.

ii. The Contractor shall be responsible for keeping the camps and buildings within it, in good hygienic conditions. The standards regulations presently in force in the project area with regard to water treatment, sanitary conditions, and fire and accident prevention shall be duly taken into account.

**2.3.3** Site Offices, Stores, Warehouses, Materials Yards

**i.** The Contractor shall provide and equip, for his own and his subcontractors' use, main and secondary offices, warehouses, materials stock areas, fuel storage areas and explosive magazines, all of which shall be maintained in good condition until the completion of Works.

**ii.** The buildings and warehouses expected to be constructed and equipped by the Contractor for use in the execution of the Works under this Contract, in addition to the facilities explicitly specified elsewhere in these Specifications shall be, but not limited to, the following:

a. Mechanical repair shop
b. Electrical repair shop
c. Metalwork fabrication and carpentry shop
d. Main warehouse and parts store
e. Bulk cement silo/cement store
f. Spare parts store.

**iii.** No dangerous goods, explosives, chemicals, fuels or similar items shall be brought onto the Site unless the Contractor has advised the Engineer of the intention to do so and has complied with all statutory requirements for its safe storage and security.

**iv.** The Contractor shall minimize the use of the Site for the storage of fuels, explosives and other dangerous goods as may be required for the construction of the works and shall not use the site or allow access for any purpose not connected to the Contract.

**v.** Dangerous Goods are only to be stored in nominated and approved storage areas and facilities which must comply with the Indian regulations governing such facilities.

**vi.** The contractor has to make appropriate provision for material storage sheds and tarpaulin sheets for loose construction material.

**vii.** The contractor has to make appropriate provision for dustbins and corresponding disposal of waste at labour campsite and at each work site.

**2.3.4** Concrete and Materials Processing Plants

**i.** The Contractor shall install and erect all necessary material processing plants of sufficient capacity to meet the planned peak requirements during construction. The plants shall be subject to approval by the Engineer and shall be well designed and fabricated and kept in good running order to ensure compliance with the materials quality Specifications. All control and measuring equipment shall be regularly serviced and calibrated.

**ii.** The plants required to be assembled/erected by the Contractor shall be but not limited to the following:

a. Concrete plant (batching and mixing)
b. Concrete cooling plant (refrigeration and ice plant), if required.
c. Grouting plant.

iii. Concrete & material processing plants shall meet all environment guidelines, conditions imposed for construction of project by MOEF/ Government bodies/ State pollution control boards and other statutory bodies at no extra cost to the Employer.

**2.3.5** Temporary Roads

The contractor shall construct temporary roads / hauls roads, to various facilities. Contractor shall develop detailed drawings for the above and accordingly construct the same after approval of Engineer.

**2.3.6** Communication System

i. Outside / Site Communication

ii. The Contractor shall install his communication system in the project area for national/ international voice and data communication. These facilities can be availed from the existing network of tele-communication or the contractor shall make arrangement for providing these facilities through existing telecom operators.

iii. Communication System in Underground Works

a. Communication systems for underground space shall comprise of telephone/radio systems (walkie-talkie).

b. The Contractor shall install and maintain in operating condition, communication system by telephone or preferably an underground radio system approved by the Engineer between each heading face and entrance to the concerned tunnel / caverns. All the employer's site offices shall be well connected with the above communication system.

c. In case of telephone system, an intermediate Intercom station shall be located at least every 250m or less along the tunnel.

d. All Communication system shall have sources of energy independent of the main energy supply for Underground works.

e. The availability of the communication from inside to outside the tunnel shall be ensured at all times throughout the duration of the underground construction.

**2.3.7** Check In/Check Out Procedure for all persons entering any underground space:

i. The contractor must maintain an approved check-in/check-out procedure (in form of Name tag boards and RFID/Biometrics) to ensure that above ground personnel maintain an accurate accounting of the number of persons underground and to prevent unauthorized persons from gaining access to the site.

ii. At any time when underground operations are underway, at least one designated person must be on duty above ground. This person is responsible for calling for immediate assistance and keeping an accurate count of employees who remain underground in the event of an emergency.

iii. In addition to establishing a check-in/check-out procedure, the contractor must ensure safe access to and egress from all workstations at the construction site to protect employees from potential hazards, such as being struck by excavators, haulage machines, or other moving equipment.

iv. To help control access, all unused openings, including chutes and man ways, must be tightly covered, bulk headed, barricaded, or fenced off, and posted with warning signs that read, "Keep Out" or similar language.

v. RFID system/Bio-metric system for entry record into tunnel for all staff of contractor, employer and employer's representatives. Contractor shall submit record of entry and exit of all staff (Name, Personnel Type, Age, Gender and Agency) along with date and time every 1st and 15th date of month to the employer. The system should be able to transmit all recorded data between the desired dates through USB drive etc. Further the system should be able to generate fresh RFID tags/Bio-Metric entries when required for entry of new personnel previously not registered with the system.

**2.3.8** Entry/Exit records for all vehicles (Employer, contractor, consultant etc.) including tunneling machineries entering any underground space:

i. The contractor must maintain an approved Entry/Exit record (in form of RFID TAG system) to ensure that above ground personnel maintain an accurate record of time of Entry/Exit and prevent unauthorized vehicles from gaining access to the site.

ii. At any time when underground operations are underway, at least one designated person must be on duty above ground. This person is responsible for calling for immediate assistance and keeping an accurate count of the number and type of vehicles in the event of an emergency.

iii. RFID TAG System for record of entry/exit time for all vehicles: Contractor shall submit time record of entry and exit of all vehicles (Registration number, Vehicle Type and Agency) along with date and time every 1st and 15th date of month to the employer. The system should be able to transmit all recorded data between the desired dates through USB drive etc. Further the system should be able to generate fresh RFID tags when required for entry of new vehicles previously not registered with RFID system.

**2.3.9** SERVICE VEHICLES

i. The Contractor shall furnish, operate and maintain sufficient service vehicles for use by his own staff and employees in the management, supervision and performance of the Work.

**2.3.10** MEDICAL FACILITIES

i. Indoor medical facilities are available at Sohna/Gurugram.

ii. In addition to above, the Contractor shall construct, equip and maintain on the Site, the following medical facilities:

   a. One ambulance and driver at his main camp.
   b. One first aid station at each work site.

iii. The contractor shall comply with laws and health standards in force in the project area. In the event of an epidemic breaking out, the Contractor shall carry out and comply with all or arrangements or regulations, which may be issued by Government or local authorities.

iv. These facilities shall be fully equipped and staffed to meet requirements of the maximum anticipated workload and labour force, taking into consideration the nature of the Works, its occupational hazards, location and accessibility. These establishments shall be available and fully operational within 60 days after the date of issue the Letter of Acceptance.

**v.** Treatment facilities and care of seriously ill or injured persons shall be on an emergency basis until their transfer to an established hospital.

**vi.** All the labour to be engaged for construction work shall be thoroughly examined by health personnel and adequately treated before issuing them work permit by contractor.

**vii.** Throughout the project duration, the contractor must maintain one 5-person rescue team within 30 minutes travel time from the job site. Rescue team members must be trained in rescue procedures, the use and limitations of breathing apparatus, and the use of firefighting equipment with qualifications reviewed annually. When flammable or noxious gases are anticipated at a jobsite, rescue teams must practice using self-contained breathing apparatus once a month. The rescue teams must be available through the duration of a construction project.

**2.3.11** POWER SUPPLY AND ILLUMINATION

**i.** General.

a. Contractor has to make his arrangements at his own cost for entire construction power including any standby power requirements. Equipment/ transmission lines required for distribution and utilization of energy at Construction site for Power, light etc. shall be installed by the contractor on their own.

b. Power to be used by Contractor for their Labour and Staff Colony shall be arranged by contractor on their own and at their own cost.

c. Contractor shall arrange DG sets of adequate capacity at his cost to meet back up and emergency power supply requirement including lighting, dewatering & ventilation.

d. Contractor shall indicate in his proposal of the phase wise requirement of Construction power (HT) at above-mentioned locations.

**ii.** Power supply and Illumination provided by the Contractor

a. The Contractor shall install, operate and maintain electrical distribution system, which shall include transformers, circuit breakers, disconnection and safety switches, voltage regulators, lines, poles, pole hardware, conductors, meters and other equipment necessary for power distribution throughout the Site and temporary facilities.

b. An alternative source of emergency lighting system shall be provided every 50m at key points underground to allow emergency securing operations and evacuation safely in the event of a primary power failure.

c. The Contractor shall ensure adequate illumination for all his operations on the Site and at the Camps, including illumination of the streets. The contractor shall maintain equipment and arrange device to measure light intensities for illumination as follows:

| | **Area of Operation.** | **Luminous Intensity** |
|---|---|---|
| (a) | Excavation and dumping areas and outdoor access ways | 35 Lux |
| (b) | General construction areas, concrete placement, excavation and waste areas, access ways, active storage areas, loading platforms, refueling, and field maintenance areas. | 50 Lux |
| (c) | Indoors: warehouses, corridors, hallways, and exit ways. | 50 Lux |
| (d) | Tunnel and general Underground Work areas | 50 Lux |
| (e) | Tunnel headings during drilling, mucking and scaling | 100 Lux |
| (f) | General construction plant and shops, e.g. batching plants, mechanical and carpentry shops, active storerooms, barracks or living quarters, mess halls and indoor toilets | 100 Lux |
| (g) | First aid stations, infirmaries and offices. | 350 Lux |
| (h) | Welding | 300 Lux |

d. The vaults along the entire length of the tunnel shall be illuminated with electrical light throughout the duration of, construction works. The lamps shall be provided in two rows with each row lamp spacing of 10 m in unlined stretches and 20 m in lined stretches. Contractor shall suitably modify the spacing and capacity of lights to meet the illumination requirements mentioned above.

e. Electrical cables shall be well insulated, protected and firmly fixed to the walls of the tunnel by means of adequate insulators; lamps shall be well protected against damage.

f. The Contractor shall also provide suitable movable lamps to iIIuminate any area in Underground Works including areas for instrumentation and where the Engineer may wish to carry out inspection and rock mechanics tests or instrumentation.

g. No energized electrical cable shall be permitted nearer than 70 m to the heading face while charging explosives. Accordingly, suitable high-powered light arrangement shall be made to have adequate illumination at the tunnel face.

h. Lighting illumination by flame is expressly forbidden in the Underground Works.

i. Whenever more than one agency is working in the same area, the Contractor, who has already provided lighting I Power supply arrangements, shall extend the facilities to the other Contractor, who shall pay for such facility of utility at mutually agreed rates. In case of disputes, the matter shall be decided by the Engineer, whose decision shall be final.

**iii.** Earthing of Wet work Areas, Control of Electric Discharges

a. All equipment and appliances, which are exposed to lightning, shall be earthed electrically, and the Contractor's specialized personnel shall periodically check the effectiveness or such earthing.
b. Personnel standing in water shall operate no equipment electrically powered by more than 24 Volts.
c. Only air, battery-powered or hydraulic tools shall be permitted in the wet areas.
d. Where electrical blasting is used, equipment shall be installed to control possible electric discharge in the ground due to storms, electric motors, etc. As soon as such discharges are noted, electrical blasting operations shall be suspended, or the detonator type changed.

### 2.3.12 MAINTENANCE OF TRAFFIC

i. The Contractor shall be responsible for the safety along the roads related to the Site. Where the work is carried out on the Site of, or close to an existing road, the Contractor shall maintain the vehicular and pedestrian traffic safe at all times. If his operations can cause traffic hazards, he shall repair or fence or take such other measures for ensuring safety that are satisfactory to the Engineer.
ii. The Contractor shall submit his activity, schedule and the locations of his work along the existing public roads to the authorities concerned and obtain all necessary approval prior to the commencement of the respective work.
iii. At the road crossings or in heavy traffic locations, the Contractor shall carry out the Work within the working hours as directed by the Engineer, and after the completion of the work he shall immediately make the necessary backfill and pavement at the crossings.
iv. The Contractor shall provide temporary passes and badges to give an access to the existing village houses, etc., to the satisfaction of the Engineer and the authorities concerned whenever he disturbs such existing way during the execution of works.

### 2.3.13 VENTILATION OF UNDERGROUND WORKS

i. General

a. The Contractor shall design, install and operate ventilation system for the Underground Works and provide an underground atmosphere monitoring system.
b. All parts of the Works shall be maintained in a state, which will not be injurious to the health or the personnel. The air in underground works shall contain no less than 20% oxygen (by volume) and shall not contain concentration of gases, vapors or dust greater than is prescribed in the safety standards for the health or workmen.
c. If required, the ventilating system shall be kept in operation also after break-through in tunnels in order to maintain the fresh air-volume requirements stated hereinafter.
d. Intermediate fans attached to the main duel line shall be provided as required to

ensure satisfactory removal of contaminated air. All ventilation ducts shall be maintained in a good condition to prevent any leakage.

e. Ventilation ducts shall be firmly fixed to the vaults in such position that a minimum clearance of 30 cm remains between the duct and the extremities of vehicular traffic employed in the Underground Works.

f. The Contractor shall ensure the required quantity of fresh air at the heading face. The check of the airtightness of joints and control of the air ducts for leaks shall be performed periodically. The Contractor shall immediately repair any deficiency discovered or reported by the Engineer.

g. If the volume and quality of fresh air at the heading face is less than that specified, then the whole duct system shall be pressure and volume tested in portions not exceeding a few hundred meters. Measuring stations shall be located not closer than 10 times the duct diameter from any fan or other flow disturbance within the Main Line.

h. No work shall be permitted to be carried out unless the ventilation is provided to the satisfaction of the Engineer. Indoor Air Quality standards as described in EPA,1986 (with latest amendments) be adhered to.

**ii.** Ventilation System for Tunnel excavation

a. The ventilating system shall be of such efficiency that the average air velocity in the largest excavated profile is not less than 0.3 meters per second. In case the presence of methane gas is detected or suspected, this value shall be increased to 0.5 meters per second.

b. The main ventilation system shall ensure that both following minimum fresh air volume requirements are satisfied at all times

   (a) 5.70 $m^3$ per minute for each person employed in the Underground Works at one time.

   (b) A minimum of 2.00 $m^3$ of air per minute shall be supplied additionally for each metric horsepower of diesel-powered equipment deployed in the underground works alone time.

   These fresh air volumes shall be cumulative, and the Contractor shall allow, in his design calculations, for the maximum number of persons and diesel-powered equipment deployed in the Underground Works at any one time. Any estimated losses, e.g. due to the leaks in the ducts, shall be added to the figures stated above.

c. The secondary ventilation equipment of the forced type shall be installed to provide an adequate ventilation of the area between the heading face and the air intake/outlet of the main system. This system shall be switched on prior to the blasting and shall remain operative until the main system has been put into exhaust mode of operation. The air intake shall be located at a sufficient distance from the heading face to ensure that blasting fumes do not permeate into this area and cause a recycling of blasting fumes. The outlet of this duct shall be located so close to the heading face that the driving of the blasting fumes and dust away from the face into main system is ensured. The minimum capacity shall be at least 70% of the main system's capacity. The end diameter of the duct shall be such that the air discharge velocity is not less than 20 meters per second.

d. Re-entry into the heading face and resuming of the work shall not be permitted until all blasting fumes have been ejected out.

e. Subject to meeting the minimum functional and safety requirements of ventilation the engineer may allow other systems of ventilation also as proposed by contractor. This shall in no way absolve contractor from his obligation to meet the necessary requirements of ventilation at any time during work.

f. All equipment and ventilation duct shall always be maintained in sound working order. Any damage to ventilation duct shall be repaired within 12 hours of the damage.

g. Ventilation ducts must be maintained in straights alignments as much as possible and with plain cross sections avoiding unnecessary curves, reduction and rotations of the cross sections and always without any damage of the ducts.

h. Ventilation ducts must follow the advance of the tunnel excavation, being the extremity of the duct no more distant from the front face than 20m. In any case this distance shall be reduced if the quality of the air in the front face does not follow health and safety specifications.

i. Whenever excavation proceeds more than 2 kms from any portal then contractor will be required to install booster ventilation fans to enhance ventilation capacity and install LT lines to reduce transmission loss over long lengthsif other methods are not effective, for which nothing extra shall be paid.

**2.3.14** AIR COOLING IN UNDERGROUND WORKS

**i.** The Contractor shall make suitable arrangements for cooling of air so as to maintain the temperature in the underground construction sites below 300 Centigrade under all conditions.

**ii.** The temperature shall be measured by the Contractor daily. Temperature measurements shall be taken during normal working conditions with the specified degree of ventilation.

**iii.** The maintenance of construction progress and control of temperature shall be entirely the responsibility of the Contractor under all conditions. No claim or extension of time for the completion of Works shall be allowed on this basis of high / low temperatures experienced in the course of the work for any reasons, whatsoever. However, Geo-thermal conditions are not anticipated by employer, Temperature meter for measurement of temperature shall be supplied and or installed & maintained at required location by contractor at his own cost.

**2.3.15** CONTROL OF DUST, SILICA AND NOXIOUS GASES IN UNDERGROUND WORKS

**i.** The Contractor shall install and operate equipment for the monitoring and Control of dust, silica and noxious gases in Underground Works as described here under.

**ii.** Dust and Silica

a. To reduce the amount of dust, only wet drilling will be allowed and during mucking, muck piles shall be kept constantly damp by sprinkling with water.

The use of high-pressure water jets for this purpose will not be permitted.

b. The Contractor shall measure and monitor the concentration of fine dust and content of silicon dioxide. (Si02) in all dust producing underground operations by a method to be approved by the Engineer.
c. Air Samples shall be taken within 10 days of commencing underground excavation, at 30 days intervals thereafter and within 20 days following major changes in tunnel excavation operation, or whenever required by the Engineer. Samples shall be taken from actual working areas. A qualified person in laboratory to be proposed by the Contractor and approved by the Engineer shall perform the sampling and testing. A copy of the test results shall be submitted to the Engineer within 2 weeks of the sampling date.
d. The concentration of fine dust (diameter less than 0.005 mm) may not, in general exceed the value of 8.0 mg/m3 of air and this value will be further reduced depending upon the extent of SiO2 content in rock as detailed in the table below:

| **Content of $SiO_2$ in fine dust in percent by weight.** | **Concentration of fine dust in milligrams per cum of air.** |
|---|---|
| 1-15 % | 8.0 mg / $M^3$ |
| 20 % | 6.0 mg / $M^3$ |
| 30 % | 4.0 mg / $M^3$ |
| 60 % | 2.0 mg / $M^3$ |
| 80 % | 1.5 mg / $M^3$ |
| 100 % | 1.3 mg / $M^3$ |

e. Should the concentration of the fine dust exceed the limits stated above, the Contractor shall undertake such necessary measures and install such additional equipment which will ensure that the dust concentrations are within the specified safe hygienic limits.
f. All staff entering underground work site shall be equipped with PPE including respirators suited for the work.

**iii.** Noxious Gases

a. Use of internal combustion engines, other than approved mobile diesel-powered equipment will not be permitted in underground construction Sites.
b. The Contractor shall provide and maintain equipment for measuring and monitoring the content of noxious gases and oxygen at each heading face throughout the duration of excavation works. Tests for determining concentrations of carbon monoxide, carbon dioxide, nitrogen dioxide, methane, other inflammable gases, and oxygen Shall be made by qualified personnel before and after each blasting and at the beginning of each shift. A record of reading shall be maintained and be made available to the Engineer as and when asked for.
c. Gas concentrations in underground sites will not exceed the following limits:

| | |
|---|---|
| 0.005 % | 50 ppm of carbon monoxide. |
| 0.5 % | 5000 ppm of carbon dioxide. |
| 0.0005 % | 5 ppm of nitrogen dioxide. |
| 0.001 % | 10 ppm of hydrogen sulphide. |
| 0.1 % | 1000 ppm of methane. |
| 0.01 % | Milligrams per litre of nitrous oxide. |

d. After each blast, before entering the blast area, the concentration of toxic gases will be checked to ascertain the efficacy of ventilation system. The engineer in addition may direct the contractor to measure the concentration of toxic gases during other operations also. Contractor will always keep all measuring instruments in a ready state. All such records shall be signed jointly by both parties immediately after measurement.

e. Concentrations of other inflammable gases shall not exceed 40 % of the lower explosive limit at the heading face and 20 % of the lower explosive limit elsewhere in the tunnel.

f. If concentrations of noxious gases or other inflammable gases exceed the permissible limits set forth above, all operations shall be interrupted immediately, and personnel shall be removed to a safe area. All sources of ignition shall be extinguished or removed. All equipment with the exception of ventilation equipment shall be shut down.

g. The required measures will be mutually determined and agreed to by the Engineer and the Contractor. In case of need, the Contractor shall engage the services of an independent Consultant experienced in gaseous tunneling. Re-entry and resuming of the Work shall be prohibited until the Engineer has authorized re-entry.

**2.3.16** WATER SUPPLY

**i.** The Contractor shall design, Install, operate and maintain two separate water supply systems on the Sites

a. Industrial Water: For general construction use, treated to the extent necessary to meet specified requirements of Works.

b. Potable water: For supply to all buildings and plants requiring high quality water meeting requirements for drinking water supply.

**ii.** Water shall be, supplied by the Contractor from any suitable sources. The water being supplied shall be free of contamination and unaffected by the Site construction Work.

**iii.** The Contractor shall l furnish, install, operate and maintain all pumps, pipelines, fittings, valves, storage tanks purification plant and chlorination for the Water supply and distribution systems, adequate in quantity and pressure. Industrial water shall be used for construction purposes only. There shall be no cross connections of any kind between the industrial and potable water supply systems. Only potable water shall be piped into buildings.

iv. The Contractor shall provide adequate water treatment facilities so as to ensure that the treated water is supplied for drinking purposes to all the camps and construction places.

v. Ample number of drinking points of potable water shall be provided by the Contractor for the use of personnel in all working areas.

**2.3.17** SANITATION AND SEWERAGE

i. Toilets shall be provided and maintained by the Contractor for the use of all personnel at all work locations, which are remote from the fixed sanitary facilities. The Contractor shall arrange for all chemical toilets to be attended to daily for proper sanitary disposal.

ii. All offices, workshops, laboratory and other occupied work buildings shall be provided with toilets connected to property constructed and regularly maintained septic tanks approved by the Engineer.

iii. The camp sites shall be provided with a complete, properly maintained and operated sewerage system, including septic tanks, sewage treatment and disposal facilities. Facilities for washing clothes shall also be provided and linked to the sewerage system.

iv. Sanitation, sewerage system and contaminated water from the tunnel excavation shall meet all environment guidelines conditions imposed for construction of project by MOEF / Government Bodies at no extra cost to the Employer.

**2.3.18** DISPOSAL OF C & D WASTE

The contractor shall make necessary arrangements for the management of muck disposal so that it meets all the environment guidelines / conditions imposed for the construction of project by MOEF / Govt. bodies / State Pollution control board and/or other statutory bodies.

**2.3.19** WASTE AND GARBAGE DISPOSAL

i. The Contractor shall daily collect waste material and garbage from camps, offices and workshops and transport it to an area approved by the Engineer, where it shall be incinerated and buried or disposed off as approved by the Engineer.

ii. The site shall be kept clean and free of refuse at all times. No waste shall be dumped in areas other than those approved by the Engineer for waste disposal. No waste of any kind shall be deposited in any watercourses.

iii. Waste and Garbage disposal system shall meet all environment guidelines and conditions imposed for construction of project by MOEF/ Govt. bodies at no extra cost to The Employer.

iv. The contractor has to make appropriate provision for Oil / Grease interceptor at refueling stations and at fuel storage locations.

**2.3.20** SETTING UP OF FIELD LABORATORY

i. The Contractor shall establish a field laboratory for ensuring quality control measures for the Works, as detailed under Quality Assurance Programme described elsewhere in the tender documents.

ii. Prior to setting up of laboratory, Contractor shall submit detailed building plan with exhaustive equipment-list clearly showing the different area for equipment with sizes of the equipment and circulating area, and CV's of qualified personnel identified for laboratory work to the Engineer for approval. The laboratory shall be headed by an experienced graduate civil engineer. All the equipment shall be confirming to either the relevant IS or international standards.

iii. Upon receipt of Engineer's approval, the Contractor shall construct, maintain and operate an integrated laboratory which provides sufficient rooms and equipment to test aggregates, concrete samples, plain shotcrete and SFRS samples, soil and rock samples, rock bolts capacity tests, nuclear gauge tests to control the density of the compacted layers for earthworks, etc. The laboratory shall be established as early as possible as but not later than three months from the date of issue of Letter of Acceptance.

iv. The Contractor shall collect the samples, carry out the relevant tests, prepare the complete reports and submit them to the Engineer.

v. All tests will be made according to approved standards, and the testing equipment shall comply with the same standards. All relevant standards shall be made available in the laboratory by the Contractor.

vi. The laboratory shall be provided with light, ventilation, water supply, tank for curing, toilet, office for operators and responsible for laboratory, archive etc. and be spacious enough in order to store indoor the test samples

**2.3.21** LAND REQUIREMENT

i. Employer has acquired the required land for permanent components of the project work, approach roads to various project components which shall be handed over to the contractor on as is where is basis. Tender drawings show the available land acquired and major permanent structures required to be constructed. The contractor shall organize the installation site in a way that his temporary buildings, plants, equipment etc will not hinder the final/permanent works. The land shall be used primarily for execution of work of the project. The contractor will seek approval of the Engineer for setting up of site facilities on land acquired for the project. Employer's land shall not be used for setting up of labour camps. Nothing additional will be paid for re-shifting of any plants and machinery to the contractor. Extra land if needed by the contractor for setting up of any of his facilities, such cost of land will be borne by the contractor.

ii. Contractor shall submit his scheme of land utilization including muck disposal and subsequently construct the same after obtaining due approval of the Engineer.

iii. Muck generated in the works may be used by contractor for constructing his facilities / filling works etc. free of cost. The royalty payment and/or any cess leviable by the statutory authority shall however be payable by the contractor by such usage.

iv. Any Government duties, cess etc. levied by the statutory authority for land use outside railway land shall be borne by the Contractor at no extra cost to the Employer.

**v.** Before demobilization, the Contractor shall remove all his temporary facilities which were installed for execution of the work and restore the land to its original state for all such land used as in (i) above.

**2.3.22** FENCING AND SITE SECURITY

**i.** The Contractor's offices, workshops and storage compounds, camp sites and all construction areas, where exclusion of unauthorized personnel is necessary for safety and security, shall be adequately fenced, gated and guarded. A central guardhouse shall be established at each main entrance to the Site.

**ii.** The Contractor shall employ adequate force of properly trained security guards at the worksite and at the construction camps on 24 hours duty including Sundays and holidays. Storage areas shall be fenced, lighted and regularly patrolled by security guards. Warehouse buildings and explosive magazines shall be kept locked and keys accounted for at all times.

**iii.** All employees engaged in the execution and maintenance of the Works shall wear identification badges when at the worksite.

**iv.** The Contractor shall be entirely responsible for the losses occurring in his installations and those of the Engineer, resulting from carelessness on the Contractor's part.

**v.** The contractor has to make appropriate provision for LED Lights on top of the barricading and provision of the noise enclosures over the tunnel portals.

**2.3.23** SITE SIGNAGE

**i.** Prior to the commencement of work at the Site, the Contractor, at the direction of the Engineer, shall supply and erect reflector site sign at all work sites for the information of the public at all entrances to the Site, containing the following information, clearly visible and legible (In English and Hindi language) to passersby intended for the information of those affected by the Contract Works, for the guidance of those making deliveries and for general public safety:

a. Name of Project;
b. Name of Employer;
c. Name of Contractor;
d. Restrictions on access and appropriate safety warnings.

**ii.** The Contractor shall also maintain such signs throughout the contract period with up to date information and free from disfigurement.

**iii.** The Contractor shall also supply, erect and maintain appropriate reflector site signage and safety warning signs as are appropriate for the nature of the work being undertaken. No other signage or advertising materials shall be permitted on the Site, except with the specific consent of the Engineer.

**2.3.24**

# CHAPTER -3
# SURVEYING

## 3.1 GENERAL

**3.1.1** The employer has already established certain benchmarks and alignment references. These benchmarks and alignment markers are required to be validated by the contractor. Any error found in these benchmarks and alignment markers shall be rectified by the contractor with the approval of the Engineer. The contractor is also required to maintain these benchmarks provided by the employer throughout the period of construction. The survey to be done by the contractor shall be done by establishing the control points along the proposed railway alignment through the use of DGPS. All these control points will then be connected to the nearest GTS Benchmark using the Total Station.

**3.1.2** These services cover in general transfer of control points to working area, the establishment of axis, centerlines, alignments of project structures and features, the setting out for construction thereof; the accompanying control surveys for correct locations, dimensions and elevations as well as the necessary surveys for measurement to permit quantity calculations for billing.

**3.1.3** Such surveys shall be based on and/or referred to existing basic grid of datum points, triangulation points and benchmarks extended adjacent to the Work in the project area. This grid shall be the sole basis of reference for all survey work and measurement.

**3.1.4** High precision direction measurement of the alignment shall be done at every approx. one km of excavation or as decided by the ENGINEER by use of surveying gyroscopes i.e Gyromat or similar, at the cost of the contractor.

**3.1.5** Contractor has to make the survey of the excavated profile and control the tunnel sections after mucking, after installation of the primary support, prior to the installation of the felt for the protection of the water proofing membrane and after the lining works all along the length of the tunnels to control alignment, envelopes, excavated areas, primary support thickness and the position of the work-forms and final lining geometry, thickness and areas. The quality plan to be submitted by the contractor to the engineer should give a detailed methodology duly indicating the schedule required to cover all the aforesaid survey items that the contractor has to deliver to Engineer and also has to include when the topographical survey of the tunnels and portals has to be carried out.

**3.1.6** Responsibility of carrying out the work to correct line and level shall, however, continue to devolve on the contractor notwithstanding the fact that approval for any benchmark and/or alignment marker may inadvertently have been accorded by the Engineer. Consequently, any expenditure incurred by the contractor for rectification of the permanent and/or temporary works constructed to wrong line/level shall not be payable by the Employer.

## 3.2 SUBMITTAL

**3.2.1** Within 28 days from the Letter of Acceptance, the Contractor shall submit to the Engineer for his approval a proposal of the sequence of the survey works to be performed, the biodata of the key personnel & in-charge of survey works, the list of survey equipment and instruments the Contractor will have available at the site, and a brief outline on methodologies of survey works to be applied for the various types of survey.

**3.2.2** At least 7 days prior to the commencement of any survey work, the Contractor shall inform the Engineer of his intention to perform the survey work. The Contractor shall indicate the purpose of the survey, the area to be surveyed, the structure or facilities involved, the methods to be applied and the survey period.

## 3.3 MATERIAL AND INSTRUMENTS

**3.3.1** The Contractor shall provide, maintain and operate suitable and appropriate equipment, instruments, materials and auxiliary equipment, commensurate with various tasks and precision requirements of the survey works.

**3.3.2** Type and accuracy of the survey equipment to be used by the Contractor shall correspond to the nature of the construction, erection works and the construction technique.

**3.3.3** All equipment, instruments, materials and auxiliary equipment shall be in perfect operating condition. Prior to the start of survey activities, equipment, instruments, etc., shall be checked as to their proper functioning and accuracy.

**3.3.4** During the construction period, the survey instruments shall be checked and adjusted / calibrated at regular time intervals.

**3.3.5** Instruments and equipment which have suffered from use, damage or accidents to the extent that they are unfit for further use at the site, shall be removed from the site and replaced immediately.

**3.3.6** The contractor should ensure availability of sufficient quantity and quality of survey instruments including provision of professional staff, to avoid any delay in the construction.

## 3.4 EXECUTION

### 3.4.1 General

- **i.** For the execution of the survey work the Contractor shall employ and provide experienced professionals and auxiliary staff. All survey and measurement work shall be recorded and filed thoroughly.
- **ii.** The Contractor shall provide, maintain, adjust when necessary and operate the required survey and auxiliary equipment for the performance of the Work.
- **iii.** All survey and measurement activities shall be recorded in maps and field books as directed/approved by the engineer. Where required, the production of drawings and maps shall be deemed to be part of the work.
- **iv.** The Engineer shall have the right to check work performance, accuracy stations, etc., and all survey results, measurements and calculations as well as conformity with plans and drawings.
- **v.** The Contractor shall keep and maintain professional records of all field surveys and measurements, the related computations and calculations, manuscripts, plans, drawings and maps, and shall make them available to the Engineer whenever requested.
- **vi.** If in the opinion of the Engineer, deficiencies and/or inaccuracies in field and office work have been found, such work shall be repeated and made good to the satisfaction

of the Engineer at the Contractor's expense. The Contractor shall be solely responsible for accuracy of Survey maps and drawings prepared out of the surveys.

### 3.4.2 Preparatory Works

i. Prior to starting survey works, the Contractor shall inform his surveyors of the general construction procedure, survey requirements and time limits. The surveyors shall make adequate terrain investigations with respect to sightings, vegetation to be removed, placement of datum points, reference monuments and benchmarks, taking into consideration future construction work which may affect the survey. Based on these investigations, a survey plan shall be developed comprising existing basic data, the survey grid to be developed, the equipment required for the particular survey task. Staff and time requirements arrangement in a way to warrant smooth progress of construction works. The plan shall be submitted to Engineer in charge for approval.

ii. All survey work shall be done within greatest care and precision.

### 3.4.3 Verification of Survey Grid

i. The contractor shall verify the basic survey grid.

ii. All coordinates and elevations as shown on the Drawings are based on the basic survey grid. If after having executed the verification, the basic survey grid reveals inconsistencies, which may affect the location, alignment and elevation or structures of the works, the Engineer shall be forthwith informed of these inconsistencies by the Contractor.

iii. The Contractor shall record all calculations, control surveys, setting out and check surveying in a suitable permanent form for verification, which shall be available to the Engineer on request at all times.

### 3.4.4 Augmentation of Basic Survey Grid

i. Existing datum points and benchmark located very near to the permanent structures may be endangered by construction activities. The Contractor shall therefore in due time establish additional datum points at safe locations and elevations to augment or extend the basic grid.

ii. The new datum points shall be of permanent nature and shall be constructed as, directed by the Engineer.

iii. The Contractor shall also establish reference monuments for center lines and line control of structures, which need frequent and extended control surveys for tunnel alignment and connected works.

iv. New datum points, reference monuments and benchmarks shall be protected and maintained in the same way as the original grid points.

### 3.4.5 Survey of Ground Profiles

i. Original Ground Profiles.

The Contractor shall inform the Engineer in writing, at least 14 days before commencing such work, of his intentions to perform any work which will result in a change to the topography of the existing site for the permanent works and or for temporary works. Thereupon, before commencing any work, the contractor shall survey the original topography with the approval of the Engineer over the entire area to be occupied or disturbed. Such survey may again be required after removal, of vegetation, topsoil or other overburden. The Contractor and the Engineer shall record the information so obtained. The contractor shall then provide the Engineer with a reproducible copy of each drawing to serve as a permanent record of the purpose of determining the quantities of excavation or earth works carried out in the construction of the permanent structures, such records will also be required to ascertainthe extent to which Temporary works shall be removed or temporary excavations shall be refilled upon completion of the works.

ii. The Contractor shall also survey all excavated and final surfaces for the purpose of recording as constructed details, and for the measurement of quantities. Such survey shall be required at the following two stages:
   a. On completions of excavation and prior to placing concrete or other work.
   b. On completion of works.

### 3.4.6 Setting Out Works

i. The contractor shall perform all setting out and check surveying of the Works in accordance with methods approved by the Engineer. The methods and programme of checking shall be such as to ensure the construction of every part of the Work to the correct line and level. The Engineer may at any time ask the contractor to submit proof that his own setting out has been satisfactorily checked.

ii. The number of points required for setting out as well as the spacing between these points shall be determined by the Contractor in accordance with the type of work. The Engineer may require that some or all of the given points and datum levels be clearly marked during construction in such a way that the marks can be retained after completion of construction.

### 3.4.7 Setting Out Checks

i. Contractor should carry out the Net Survey (Close traverse) regularly at least once in two months while executing the work of underground excavation and will submit the results to the Engineer to ensure that progress of excavation is correct as per design alignment.

ii. The Contractor is expected to liaise with the Engineer to program the check survey to be carried out during non-production periods or in parallel to construction activities such that the minimum delay or inconvenience is caused to production works, wherever and whenever possible. The Contractor shall afford the Engineer, every cooperation and assistance in this regard including but not being limited to the provision of survey equipment, drainage, lighting, ventilation and the removal of Contractor's equipment and other obstructions such that they do not interfere with the setting out checks.

### 3.4.8 Tunnel Alignment and Gradients

i. The Contractor shall establish and maintain at suitable distances from tunnel portal at least three (03) reference monuments and benchmarks on the extended tunnel axis/alignment, to warrant that control surveys during tunnel construction can always be referred to such reference monuments. They shall be secured by auxiliary fixed points permitting the reconstruction of the reference monuments in case these have suffered any damage during tunnel excavation periods.

ii. Establishment and control surveys of the tunnel alignment and the gradient shall always be referred to such reference monuments.

iii. Underground alignment and level survey and control thereof shall be performed by the use of suitable precision instruments preferably of the pulsed laser type of equivalent instruments, and auxiliary equipment. Underground survey equipment and methodology shall be subject to the approval of the Engineer.

iv. In addition to the regular survey, carried out by the contractor, if required an independent survey organization engaged by Engineer at his own cost, will perform confirmatory survey of Tunnel alignments. The first confirmatory survey is likely to be performed after the 1st 100 m of tunnel has been excavated, following confirmatory survey will be carried out after every 200m of excavation or as decided by Engineer. The contractor shall be notified in advance about the date of such confirmatory surveys. The contractor shall cooperate with such surveyor and provide any assistance as required (including stoppage of work, if required) at no extra cost to employer. In this regard, the contractor may please note the contents of clause no. 2.4 of chapter 2 under section 5 of the tender document

v. Contractor should carry out precision gyroscopic measurements (GYROMAT equipment or equivalent) at regular intervals at least every 1 (one) Km progress of the main tunnel and escape tunnel, for accurate high-precision azimuth determination, by specialized agency. A detailed report should be submitted to the Engineer after every gyroscopic verification with the obtained results.

### 3.4.9 Accuracies and tolerances

i. Accuracies

Accuracy of survey works shall be within the following tolerances:

| | |
|---|---|
| **Triangulation** | |
| Allowable error of closure<br>• Average not to exceed<br>• Maximum not to exceed | 5 Seconds<br>10 Seconds |
| **Traversing** | |
| Allowable error of closure<br>Allowable error of distance | 10 mm per Kilometer |
| **Leveling** | |
| Allowable error for each 1 km measured forward and backward<br>Allowable error of closure | 10 mm<br>10 √S mm |

(Where S is the total distance of leveling expressed in km)

ii. Tolerances

a. The tolerance given below shall be the maximum permissible deviations from the specified dimensions, levels, alignments, positions etc. as shown on the Drawings of the structures of structural elements.

b. In addition, at the interfaces with mechanical components, concrete surface be finished flush and shall also meet any additional tolerances required by the mechanical designs or works respectively.

c. Where the tolerances overlap, the severer tolerance shall apply. Determination of centerlines for alignment of tunnels, access tunnels, galleries, caverns and shafts etc. shall meet the following criteria.

| | |
|---|---|
| Plan positions of central line | $\pm$30 mm |
| Elevation | $\pm$10 mm |

**3.4.10** Subsidiary Monuments and Benchmarks

**i.** The Contractor shall erect and establish all necessary additional survey monuments, fix points, benchmarks etc. required for setting out of the work and construction control including determination of coordinates and elevations.

**3.4.11** Handing over of Basic Survey Data

**i.** General Requirements

a. Prior to the commencement of the survey works, the Engineer shall hand over to the contractor all information and data of the verified basic survey gird and benchmarks to which the contractor's survey work shall refer. Upon handing over, the ontractor shall review this information and data and shall verify the existence of the datum points and benchmarks by field checks. Furthermore, the contractor shall take responsibility for maintenance and protection of these basic datum points and benchmarks.

b. Should field checks reveal that points and benchmarks have been damaged, displaced or destroyed, the contractor shall inform the Engineer of this facts, and the Engineer shall give instructions regarding the re-establishment of such datum points and benchmarks.

c. Should it become necessary that basic datum point and benchmarks be removed because of foreseeable construction works, the contractor shall inform the Engineer of the need thereof and obtain approval and instruction for the establishment of new basic datum points and benchmarks and/or auxiliary points.

d. If, within 2 months upon handing over, inconsistencies within the basic grid or related datum points and benchmarks are detected by the contractor, he shall inform the Engineer immediately thereof and produce the evidence. The Engineer shall subsequently inform and instruct the contractor on remedial measures to be taken. Any survey work, setting out or measurement already taken or performed prior to the detection of such inconsistency shall be rechecked and corrected by the contractor.

e. Additional basic datum points and benchmarks established by the contractor for the convenience of this work shall have at least the same quality and durability as those of the existing points and meets the accuracy requirements.

**ii.** Data and Documentation Available

a. Existing topographical maps based on the surveys, covering the area of the works can be made available to the Contractor upon request to the Engineer.

b. Topo mapping of areas for temporary facilities like the Contractor's camp, constructional buildings, construction plant, etc., shall be prepared by the Contractor prior to the construction of such facilities. The Contractor shall also perform surveys works for construction roads and bridgesincluding preparation of maps.

iii. Survey Records and Documentation

a. The Contractor shall keep records of all survey activities such as sketches, field books, calculations, etc., for the duration of the entire construction period. The Contractor shall upon request of the Engineer put at his disposal all records and documentation or provide copies thereofin format agreed by Engineer. On a monthly basis, the Contractor should submit along with the monthly progress report, a detailed report focused on the performed survey work (excavation profiles, tunnel alignment, traversing, etc) and relevant results. After every round, the Contractor shall submit to the Engineer the excavation profile obtained through Tunnel profiler

# CHAPTER -4
# DEWATERING, DRAINAGE AND PUMPING

## 4.1 GENERAL

**4.1.1** The specifications described herein under relate to the work of dewatering, drainage and pumping and installation of water proofing membrane to be carried out by the Contractor, which shall include supply of all labour, construction plant and materials and performance of all services required to remove service water and natural surface flow or ground water seepage under all conditions including rain and flood water from the working areas on the surface as well as from the underground sites for the construction of various structures covered under the contract.

**4.1.2** The Contractor shall design, furnish, build, install, operate, maintain and remove all the temporary dewatering facilities as specified herein or as required by the Engineer.

**4.1.3** Minimum buffer stock of one month is required to keep at site for all water proofing membranes, Geo-textiles and other water proofing structures as per agreed works program.

## 4.2 SUBMITTALS

**4.2.1** Within 28 day from the commencement date, the Contractor shall submit, to the Engineer, the detailed design of dewatering system.

**4.2.2** This design shall be consistent with the outline description submitted by the Contractor with his bid and shall include the following:

- **i.** Design assumptions and calculations.
- **ii.** Layouts of drainage facilities.
- **iii.** Layout and capacity of pumps and pipes, sumps, drains both open and covered, well points etc. and details of standby dewatering arrangements.
- **iv.** Any other arrangements or installation, the contractor may propose for dewatering of the working areas both in open and underground Construction sites.
- **v.** The dewatering design should include standby emergency pumping arrangement to deal with any kind of water inflow.

**4.2.3** At least 28 days prior to the scheduled construction of the particular work, the Contractor shall submit, to the Engineer, full details of the equipment to be installed and all necessary construction details required for dewatering purpose.

**4.2.4** The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.

**4.2.5** At least 56 days prior to the scheduled installation of water proofing membrane, the contractor shall submit, to the engineer, full details of:

- **i.** Certificates of compliance attesting that the materials meet specification requirements.
- **ii.** Manufacturer's instructions for installation of felt backing and water- proofing membrane, including procedures for preparation, fixing, welding and splicing, flashing etc.
- **iii.** Manufacturer's and installer's qualifications to include evidence of experience of the manufacturer and the installers, as well as resume of lining installation supervisors.
- **iv.** Samples as listed hereafter:

a. Membrane: One square meter of each type membrane (3 Nos.).
b. Protective felt: One square meter of each type of felt (3 Nos.).
c. Welded splice: 1 m of welded membrane splice for each type of membrane. (3 Nos.).
d. Fixings and fittings: 10 samples from different lots of rondels and nails, 2 samples of sealing flanges for projections passing through the membrane.

**v.** Shop drawings showing all necessary installation details for felt and waterproofing membrane, including installation sequence, position of joints, treatment of projections, connection to water stops, connection to waterproofing of structures in open cut, local reinforcements etc.

## 4.3 GENERAL

**4.3.1** Dewatering of the surface as well as the underground Construction sites shall be undertaken by gravity, wherever possible. Where, however, dewatering by gravity is not practical, pumping shall be resorted to after this mode has been approved by the Engineer.

**4.3.2** The pumped water carried in pipes or flumes shall be discharged at point sufficiently away from the edge of foundation excavation as directed by the Engineer. Care shall be taken to ensure that there is no seepage and flow of water back to the pit working area.

**4.3.3** Power for operating the dewatering system shall be arranged by the Contractor at his own cost. The Contractor shall make his own arrangements to ensure sufficient standby power at his cost to carry on the Works during any interruption of power.

**4.3.4 Water proofing membrane**

**i.** Shall be provided to prevent leakage of groundwater into the tunnel and to protect the final concrete lining against deleterious chemical influences. Waterproofing shall be applied to crown and sidewalls above footing or invert arch level. The waterproofing membrane shall always be located between primary shotcrete lining and the final concrete lining. No membrane waterproofing will be provided for tunnel inverts.

**ii.** The waterproofing system shall consist of two layers: the first shall consist of a protective felt fastened to the shotcrete surface; the second layer shall be the actual waterproofing membrane properly fixed by special means as recommended by the manufacturer.

**iii.** While the sealing function shall be provided by the membrane, the layer of felt is required to protect the waterproofing membrane against damage from contact with the shotcrete surface, to prevent interlocking between concrete and shotcrete in case of differential movements of primary shotcrete lining and final lining, and to provide a drainage layer allowing to drain off groundwater into the longitudinal lateral drainage pipes, thus preventing a build-up of hydrostatic pressure on the tunnel lining.

## 4.4 DEWATERING OF UNDERGROUND CONSTRUCTION SITES

### 4.4.1 General

i. The contractor shall perform all works necessary to collect and drain service and infiltrating ground water and flood water entered into the underground construction sites (if any), convey it to main HS/Conduits and lead it out from underground works such as tunnels and shafts. Water pumped or drained out of tunnels shall pass through oil skimmer or other oil separator, then through sedimentation basin or by other means as approved by engineer designed for the maximum expected flow before disposal into natural drain / river to ensure clear water discharge. Construction fencing of 1.8m minimum height or other effective protection shall be installed to prohibit unauthorized persons from trespassing into the area of the sedimentation pond.

ii. The work shall include, but not be limited to, the following,
   a. Design and construction of pits and trenches, flood protection walls at the entrance/exit portals of tunnels/shafts
   b. Design, furnishing, operation and maintenance of dewatering equipment.
   c. All auxiliary works required for the safe and continuous dewatering of the underground sites.

iii. The Treatment tank shall have arrangement to segregate the PP fibers from water before disposal into natural drain / River to ensure minimum damage to environment. All such fibers so collected shall not be used back on the project and shall be disposed off safely according to manufacturer's recommendations and engineer's approval.

### 4.4.2 Requirements and Design

i. The Contractor shall design and provide a complete dewatering system for all underground construction sites.

ii. All excavated areas shall be drained off all service and ground water. In order to keep the construction areas free from water, the dewatering systems shall be able to operate at any time during the whole construction period in any part of the works at the required design capacity.

iii. The contractor shall provide adequate pumping capacity, including a sufficient number of standby pumping units, to handle all water entering including sudden gush of water / flowing ground water condition/ flood water into any portion of Underground works. These units shall be connected to the dewatering systems in such a way that proper and uninterrupted drainage is guaranteed throughout the entire construction period.

iv. The contractor shall make arrangement for sufficient stand-by power at his own cost to carry on the works during any interruption of power. The standby power supply shall undergo weekly trial runs lasting at least 30 minutes. No claims shall be entertained, and contractor shall be answerable for lack of progress on this account.

- **v.** All components of the system shall always be maintained in ready for service condition and all access to pumps and other equipment shall be kept in good condition under the most adverse conditions.
- **vi.** The Contractor shall ensure that all drainage water is disposed off without causing interference to his own or other Contractor's operations elsewhere on the site, and that no drainage water runs into adjacent works.
- **vii.** The dewatering system shall be designed and installed in such a way that modifications and extensions to the system are possible while they are in full operation.
- **viii.** All the components of the dewatering system shall be installed and operated in accordance with the approved method and the construction time schedule, or approved modification thereof.
- **ix.** The approval by the Engineer of the dewatering system shall not relieve the Contractor from being fully responsible for the design, construction, operation, maintenance, safety and removal of the facilities provided for the dewatering system and he shall be liable for any damage or delays caused by its failure. The contractor shall indemnify the "Employer" against claims arising out of any such failure made by a third party.

### 4.4.3 Materials and Execution.

- **i.** The Contractor shall construct the drainage trench in invert of the tunnel as required at site and approved by the Engineer.
- **ii.** After the excavated profile has been checked, the ground water which runs or drips into the excavated space shall be diverted into the drainage trench by means of water collectors and pipes for collecting the seepage water from rock surfaces or laggings. Damp surfaces or seepage areas with low volume inflows can be sealed off with a quick setting-sealing compound.
- **iii.** Special care shall be exercised where excavation passes through material, which is liable to soften or swell when it comes in contact with water. In such locations, water entering the excavated space shall be collected as soon as possible and conveyed away / disposed off in such a way that the water does not come in contact with such material. Should the contractor neglect to observe this requirement and a deterioration of the excavated surface of tunnel invert results from water being allowed to flow over or stand upon the sensitive or swelling material, the Engineer may order the removal of the material from affected surface and its replacement with concrete. The Engineer may order installation of additional rock supports in connection with such remedial work at the cost of the Contractor.
- **iv.** If any water from another portion of the underground works flows into a lower section where concreting is being done, which is likely to be affected by water, all such water shall be diverted past this area in such a way that no damage occurs to the concrete. The length of the affected sections over which water has to be diverted shall be ordered by the Engineer.
- **v.** The contractor shall perform regular checking and cleaning of the drawing trench and all dewatering equipment and accessories during the construction period.

**vi.** The dewatering facilities shall be kept in operation according to the approved schedule, which shall be related to the progress of the work. No pumps shall be stopped, no pipes, ducts, trenches, etc. shall be taken out of service without the permission of the Engineer.

**vii.** Any openings such as pipes, boreholes, ducts, pumps, sumps etc. used for temporary drainage purposes. In any part of the work shall be completely sealed by filling with grout, mortar or concrete when no longer required, unless otherwise directed by the Engineer in writing. The Contractor shall notify the Engineer in writing before any such openings are permanently closed.

**viii.** Water proofing membrane (Material)

**A.** Protective Felt

**a.** The protective felt shall be a continuous filament non-woven poly-propylene geotextile of uniform thickness and surface texture meeting the requirements listed below.

| **Property** | **Specified Value** | **Standard** |
|---|---|---|
| Unit weight | 500g/m$^2$ min | DIN 854 |
| Thickness at 0.02 bar | 3.9 mm min | DIN 53855/3 |
| Thickness at 2.0 bar | 1.9 mm min | DIN 53855/3 |
| Tensile strength | 1000 N/cm$^2$ min | DIN 53857/2 |
| Extension at break | 70 % min | DIN 53857/2 |
| Extension at 30% of Tensile Strength | 20 % min | DIN 53857/2 |
| Permeability in plane at 0.02 bar | 5x10$^{-1}$ cm/s min | * |
| Permeability in plane at 2.00 bar | 5x10$^{-2}$ cm/s min | * |
| Resistance against acid and alkaline solutions (pH 2-13) | Loss of strength 10% max | DIN 53857/2 |
| Resistance to Punching | 2000 N | DIN 54307 |

**B.** Waterproofing Membrane

**a.** The waterproofing membrane shall be Polyvinyl Chloride (PVC).

**b.** The membrane shall be supplied with a signal layer, i.e. a thin sheeting of different color, bonded to one side, which is intended to facilitate the detection of damages.

**c.** PVC Waterproofing Membrane (poly-vinyl-chloride) will satisfy following specifications:

**d.** Accessories: Fixing material, flashing, reinforcement for expansion joints, sealing flanges and preparation of corners and intersections shall be made as recommended by the manufacturer of the membrane.

| **Property** | **Specified Value** | **Standard** |
|---|---|---|
| Thickness(mm) | ≥2.0 | EN1894-2 |
| Tensile strength at break(N/mm$^2$) Elongation at break (%) | ≥17<br>≥300% | EN12311-2 |
| Resistance to tearing (N/mm) | ≥100 | EN12310-2 |
| Puncture static test (kN) | ≥2.5 | ENISO12236 |
| Water tightness (B method–24hoursat0.5N/mm$^2$) | Watertight | EN1982 |
| Change of dimensioning after heatingat+70°Cfor2 hours | Stable | EN1110 |
| Cold bending(°C) | ≥-35 | EN495/5 |
| Resistance to acidic and alkaline at 28days | 20%maximum elongation. | DIN16726 |
| Resistance of joints (N/mm$^2$) | ≥10.5 | EN12317-2 |
| Fire reaction classification | Class E | EN13501-1 |

**C.** Waterproofing Membrane (Installation)

**D.** Surface Preparation

**a.** All surfaces to which waterproofing is to be applied shall be sufficiently clean, smooth and free from deleterious materials and projections.

**b.** The following treatment of surfaces shall be performed prior to the installation of waterproofing:

1. For the fixing of the protective felt and the waterproofing membrane, a minimum shotcrete cover of 50 mm to rock is required.
2. Irregularities of the shotcrete lining surface shall be eliminated by means of additional shotcrete. The ratio of the diameter to depth of irregularities shall be not less than 5:1. Rounding at rock bolts (where applicable), etc. shall have a min. radius "ra" of 0.3 m. Details are given in Figure below.
3. Transitions and intersections of tunnel profiles shall be rounded off with a minimum radius of 500 mm.
4. Protruding steel bars, wires, spacers, pipes etc. shall be cut off unless treated with additional shotcrete cover.
5. Exposed steel parts such as rock bolts, if not intended to remain accessible, shall be covered with shotcrete.

6. If required, as per the instruction of the Engineer shotcrete surface shall finally be smoothened with fine-graded shotcrete (rounded aggregates, grain size 0 - 4 mm), applied in a layer of 30 mm average thickness.

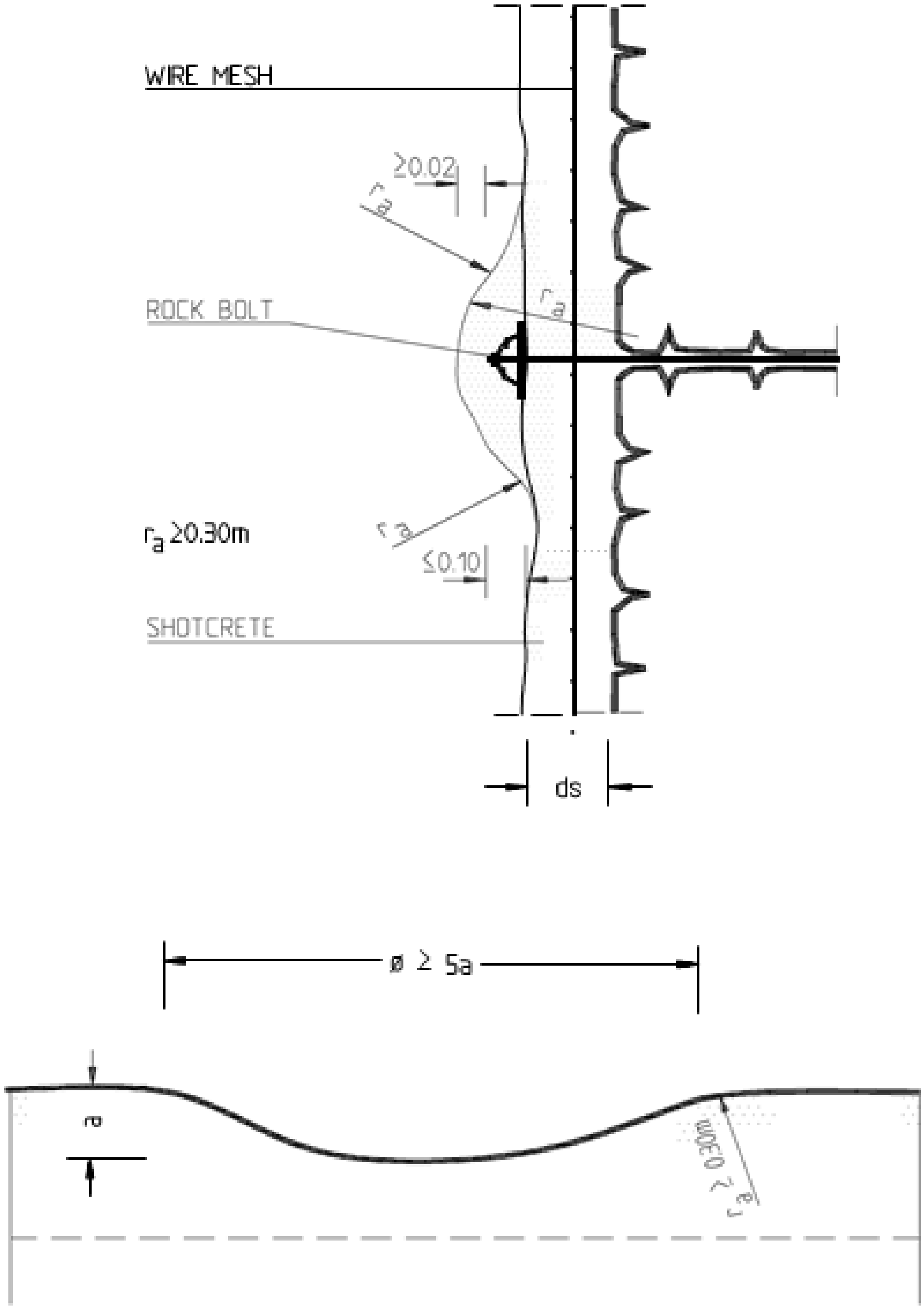



**Figure 1: Requirements on surface irregularities of shotcrete**

**E.** Application

**a.** General: Prior to the application of the waterproofing, all surfaces to which it shall be applied, shall be inspected and approved by the ENGINEER. The application shall follow the written instructions of the manufacturer. Special preparations will be required for waterproofing at tunnel intersections and for projections passing through the membrane. They shall be carried out according to the manufacturer's recommendation.

b. Fixing of Felt: The protective felt shall be attached to the shotcrete surface using suitable fixings specified by the manufacturer. Depending on the location 2 to 4 nos. fixing elements shall be used per square meter. The felt shall be laid with enough slack to avoid overstress during concreting. Adjacent sections of felt shall be overlapped by 100 mm and joined by point welding or similar suitable method. Along the bottom of the tunnel side walls the felt shall extend sufficiently to cover the lateral drainages as shown on the drawings.

c. Fixing of Waterproofing Membrane: The waterproofing membrane shall be installed to cover the felt and shall be attached to the felt fixings and to each other and to the washers by means of thermal welding. No perforation of the membrane shall be allowed for installation purposes. The waterproofing membrane shall be laid with the signal layer towards the inside and with enough slack to prevent overstressing during concreting. Adjacent sheets of waterproofing shall be joined by a double weld. Along the bottom of the tunnel side walls the membrane shall extend sufficiently to cover the lateral drainages as shown on the drawings. Connections to waterstops and to the waterproofing of structures in open cuts shall be carried out according to drawings to be furnished by the supplier.

F. Testing of seams

a. General: All seams shall be tested, and records of these tests shall be submitted by the CONTRACTOR to the ENGINEER.

b. Seam Test with Compressed Air: For seams between adjacent sheets of waterproofing membrane the testing for tightness shall be carried out by means of compressed air pumped into the test channel which is formed by the double welded joint. Initial test pressure shall be 2 bar for a test period of 5 minutes or 1.5 bar for a test period of 10 minutes. The joint shall be considered waterproof if the loss of air pressure is in both cases not more than 20%.

c. Seam Test with Vacuum Equipment: For the testing of areas of membrane of limited size such as special con- figurations of joints or local repairs with patches, vacuum equipment shall be employed, as instructed by the ENGINEER. This equipment consists of a vacuum bell which, after being fitted tightly over the area to be tested, is evacuated by pumping in order to detect leaks in the membrane.

d. Protective Measures: Every care shall be taken not to damage the waterproofing membrane during or after installation. Any damages occurred shall be repaired and tested before the casting of the final concrete lining.

### 4.4.4 WATER STOPPER

i. Polyvinyl Chloride (PVC)/ rubber water stops shall be furnished and installed for watertight construction at various locations of concrete structures / components covered under these specifications. In order to ensure proper alignment and fixing of water stops in correct position / place, the same shall be rigidly secured to the form work or reinforcement steel as direct/approved by the ENGINEER.

Number of joints in PVC/rubber water stops, when installed in place shall be the barest minimum and joints, thus made, shall be suitably vulcanized/welded using best method/Engineering practice satisfactory to the ENGINEER.

ii. All types of water stops shall be tested in a recognized laboratory prior to transport to the site. Test specimens shall be furnished by the manufacturer and the tests shall be carried out at the manufacturer's place.

iii. Water stops shall be tested as to their tensile strength, elongation, duration, water absorption, specific gravity, effect of alkali and impact resistance. The PVC Water stops shall meet the following requirements:

iv. The CONTRACTORs shall submit to the ENGINEER for approval the test results from recognized institution showing that the material supplied meets the requirements specified. The ENGINEER may carry out the additional tests, for which the CONTRACTOR shall supply specimens from the same material to be used in the work. Test specimens, if required shall be of the shape and dimensions as required in the individual test methods.

| Requirement | Method of Test |
|---|---|
| Tensile strength using die "C" not less than 150 kgf/cm2 | ASTM D-412 |
| Ultimate elongation using die "C" not less than 330% | ASTM D-412 |
| Stiffness in flexure, 6 mm span: not less than 28 kgf/cm2 | ASTM D-747 |
| Tear resistance: not less than 30 kgf/cm2 | ASTM D-624 |
| Specific Gravity: not less than 1.20 | ASTM D-792 |
| Shore Hardness: 60A to 80A | |
| Water Absorption: not more than 5% in a 7 days test | |

v. Precautions for Water stopper:

**a.** PVC water stops will be provided according to drawings in transversal and longitudinal positions at all along the lining tunnel extension. These bands must be welded (heat or vulcanization) among them at the intersection points. For the fault areas, an Omega PVC band will be affixed to the waterproofing membrane. The geometry and type of these water stop bands and Omega band are defined in specific project drawings. To weld the ends of the water, stop bands in transversal joints or in the intersections between transversal and longitudinal water stops bands the parts that must be vulcanized have to be prepared. It is responsibility of the contractor the preparation and the vulcanization of the water stops unions.

**b.** When delivered to site, the water stop products must be unloaded carefully and inspected immediately for completeness and integrity, including form and dimensions. Before installation the water stops must be kept in a sheltered place on boards or some other firm base (e.g. pallets, concrete surfaces) and protected from contamination or damage.

c. Water stops must be protected from direct sunlight, especially in summer, e.g. by covering. In high outside temperatures water stops must be taken to the point of installation and laid out under no tension.

d. Water stops should be kept in covered storage if possible and then be put in heated rooms for at least one full day prior to their installation, to make their handling and installation easier and less prone to damage (thermoplastic material).

vi. Installation of water stopper

a. Fixing Internal Water stops: Internal water stops are anchored to the reinforcement. The water stops are fixed to the edge anchors with the special waterstop clip or, in the case of waterstops with steel plates (FMS, FS) to the edge perforation of the steel plates at maximum intervals of 25 cm.

b. Spacing Between Joints in the waterstops Themselves: The spacing between two joins in the waterstops themselves should be 0.50 m minimum. In every configuration the length of the free waterstop ends should be1.00 m minimum so that these connection joints can be formed easily and correctly on site.

c. Embedding of External Waterstops: Waterstops must be free from contamination and ice when casted in. If necessary, they should be cleaned before concreting (e.g. removal of any accumulated site debris such as sawdust, sand, concrete residues, cement laitance, oil, grease, snow, ice etc.). This is particularly important for external waterstops in the base of a structure.

d. Clearance between Poker Vibrators and Waterstops: The poker vibrators must never touch the waterstop or its fixings (minimum clearance ≥10 cm). It is usually preferable to compact around external waterstops with external vibrators, which will also give better compaction around stop end anchors.

e. Protection of Exposed Waterstops on Site: The waterstops should be protected from damage until they are fully casted in.

**4.4.5** Permanent Groundwater Drainage

i. General

a. This Chapter applies to the installation of the permanent groundwater drainage system in the tunnel.

b. This Chapter covers the requirements for the permanent groundwater drainage system inside the tunnel.

c. The drained groundwater will flow from the highpoint of the tunnel alignment to Main tunnels.

d. The permanent groundwater drainage of the tunnel shall consist of a main collector pipe along the entire length tunnel and lateral drainage pipe(perforated) with transversal connection pipes to the main collector pipe at regular interval along tunnel sections where major water inflow occurs. The decision of the groundwater drainage system to be installed along a certain tunnel section will be made by the ENGINEER.

e. Drainage gutters shall be located along the entire length of the tunnel at the bottom of either tunnel side wall for collecting groundwater possibly entering through the tunnel lining. The water shall be diverted into the main collector pipe by means of transversal connection pipes.
f. Along tunnel sections with lateral drainage pipes and without invert arch, perforated pipe will be installed at the bottom of the tunnel as invert drainage.
g. At the intersections of the main collector pipe with the transversal connection pipes maintenance manholes shall be installed. Manholes shall also be installed for the maintenance of the invert drainage.

ii. Materials

a. The lateral drainage pipes shall consist of circumferentially slotted, PVC pipes with a minimum diameter of 200 mm as shown on the drawings. The slots shall be within the corrugated area. The width of slots shall not exceed 1.0 mm. The total area of the slots for water intake shall be more than 100 cm2 per metre length of pipe.
b. The main collector pipe in the main and escape tunnels shall be virgin HDPE pipes as per design drawings. The HDPE pipe shall be confirming to I.S. 4984/ 4151 / 12786/ 13488 with necessary jointing material like mechanical connectors i.e. thread / insert joint / quick release coupler joint / compression fitting joint or flanged joint
c. The transversal connection pipes shall be PVC pipes with a minimum diameter of 150 mm.
d. The cleaning access pipes shall be PVC pipes with a minimum diameter of 150 mm.
e. No-fines porous concrete shall be used for embedment of the lateral drainage pipes and of the invert drainage pipe. No-fines porous concrete shall also be installed at the bottom of Regular Tunnel Cross Section Type as shown on the respective drawing. No-fines porous concrete shall be composed of ordinary Portland cement and single-sized aggregate of nominal size of 40 mm according to IS 383 (with a maximum grain size of 40 mm). The ratio of aggregate to cement shall be 8:1 by volume or 10:1 by mass.
f. Maintenance manholes as well as the drainage gutters shall be made of concrete grade M30 according to IS 456: 2000. (Reaffirmed 2011)
g. Inspection shafts that will be installed in the ballast less track of the Main Tunnel shall be constructed in accordance to the requirements of the BLT design and approved by the BLT engineer.

iii. Execution

a. The water appearing and/or collected during construction behind the waterproofing membrane shall be diverted permanently into the lateral drainage pipes installed at the bottom of each sidewall of the tunnel.
b. The lateral drainage pipes shall be covered and protected by no-fines porous concrete.

c. Inspection chamber shall be installed in the inner concrete lining for permanent maintenance (flushing) of the lateral drainage pipes as shown on the drawings.
d. The CONTRACTOR shall ensure that the permanent ground water drainage system is used only for the control of groundwater. Throughout the construction regular inspection and servicing shall be provided.
e. The CONTRACTOR shall protect and maintain the permanent ground water drainage system during construction phase so as not to compromise the effectiveness of the system during operation.
f. All pipes for control of the ground water shall be installed to line and grade as shown on the drawings.
g. No-fines porous concrete shall be mixed by machine or by hand to a uniform colour and consistency before placing. The quantity of water used shall not exceed that required to coat all of the aggregate particles without forming excess grout. The no-fines porous concrete shall be compacted by hand only.

# CHAPTER -5
# DEWATERING OF SURFACE CONSTRUCTION SITES

## 5.1 DEWATERING OF SURFACE CONSTRUCTION SITES

### 5.1.1 General

i. The Contractor shall perform all works necessary to drain the surface construction sites of rain, flood water, ground water and service water. The Work shall include, but not be limited to the following:

   a. Design and construction of drainage, ditches, pits, dykes/bunds and pump sumps.
   b. Design, furnishing, operation and maintenance of dewatering equipment.
   c. Relocation of dewatering facilities required for the performance of other Works.
   d. All auxiliary Works required for safe and continuous dewatering of the construction sites.

ii. Dewatering of surface construction Sites located near and above a river/stream shall be done up to the existing water level in the river / stream by gravity as directed by the Engineer. Suitable drainage shall be made joining the course downstream of the construction Site to provide required gradient to facilitate proper and efficient dewatering. Below the water level of the stream, dewatering shall be done by pumping water collected in the sumps and discharging the same into course of the river/stream downstream of the construction Site.

### 5.1.2 Requirements and Design

i. The Contractor shall design and install complete facilities at the surface construction Sites.

ii. The surface water dewatering systems shall be designed to accommodate, without undue disruption to the work, any rainfall event and considering the extent of the Sites to be dewatered and the dewatering arrangements proposed.

iii. Claims for extension of time due to delays caused by unfavorable weather conditions will not be considered.

iv. The contractor shall provide adequate pumping capacity, including standby units, to handle all water entering any of surface construction Sites. In addition, he shall provide sumps and pumps and or well points in the immediate vicinity of the structure foundations using such water conductors as are necessary to conduct the water away from the excavation and concrete placement operations in an approved manner, so that such operation shall be kept free from standing or running water.

v. Power for operating the dewatering system shall be arranged by the contractor from existing poling points. The contractor shall also make his own arrangement for enough standby power at his own cost to carry out the works during any interruption of power.

vi. The Contractor shall ensure that all drainage water is disposed off without causing interference to his own or other Contractors' operations elsewhere on the Site and that no drainage water runs into adjacent Works.

vii. The dewatering systems shall be designed and installed in such a way that modifications and extensions to the systems are possible while they are in full operation.

viii. All the components of the dewatering systems shall be installed and operated in accordance with the approved method and the construction time schedule, or approved modification thereof.

ix. The approval by the Engineer of the dewatering system shall not relieve the Contractor from being fully responsible for the design, construction, operation, maintenance, safety and removal of the facilities provided for the dewatering system and he shall be liable for any damage or delays caused by its failure. The Contractor shall indemnify the Employer against claims arising out of any such, failure made by a third party.

**5.1.3** Materials and Execution

i. Catch water drains shall be excavated along the top of excavated slopes and on the berms. Such drains shall be kept well back from the excavation edges in order to prevent saturating the upper part of the slopes. The drains shall be regularly cleaned out of all accumulated silt and other matter so that water may always flow freely .

ii. Where excavation is to be made below the ground water table, the Contractor shall lower the water table sufficiently below any working surface by means of properly screened wells and/or ditches to ensure that the foundation surfaces remain free of standing water and undamaged by the passage of construction traffic. All drains shall be outside the foundation areas. The water shall be collected and removed by pumping, if no outflow by gravity is possible.

iii. Where concrete is to be placed, the water table shall be maintained below the lowest part of the finished excavation for minimum one day following the raising of structure above the natural ground water table, and for such additional time as may be necessary to preclude damages to structure foundation.

iv. In trenches and foundations, the dewatering shall always enable to carry out the excavation Work in dry, and in a manner that will prevent loss of fines from the foundation.

v. Upon completion of dewatering, temporary pipes and pump sumps beneath permanent structures shall be closed off and filled with grout, mortar or concrete as required by the Engineer.

# CHAPTER -6
# EXPLOSIVE AND BLASTING

## 6.1 GENERAL

**6.1.1** The Specifications described herein under relate to supply transportation, handling, storage and use of explosives. All operations shall be carried out by the Contractor as per Indian Explosive Act, statutory requirements and regulations as applicable in India.

**6.1.2** Contractor may obtain license from statutory authority for procuring, transporting, storing and using explosives. The same may also be arranged through existing approved suppliers/license holders in the project area. The Contractor may also have his own magazine for the storage of explosive etc. In either case, no claim of contractor will be admissible on account of any delay in obtaining any mandatory permissions or in arranging the same for progress of the work.

**6.1.3** The contractor will be required to draw the explosives, transport to the site and keep it safely as per safety guidelines of Indian Explosive Act. He shall acquaint himself with all applicable latest laws and regulations concerning storing handling, safety and use of explosives. The Engineer may issue modifications, if required and the Contractor shall comply with the same without these being made a cause for claim whatsoever, against "EMPLOYER".

**6.1.4** Word "Explosives" would also mean the accessories related I similar substances for the purpose of safety unless otherwise specified.

## 6.2 SUBMITTALS

**6.2.1** At least 56 days prior to the commencement of the excavation works, the Contractor shall submit to the Engineer for approval, the details relating to transportation, storage and use of materials such as explosives, detonators, Detonating I safety fuse coils, Blasting Cables, Exploders, Loading Poles and tamping materials etc.

**6.2.2** The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.

## 6.3 STANDARDS

**6.3.1** Transportation, handling, storage and use of explosives shall be carried out under Indian explosive regulation, 1984 in a safe and efficient manner and shall also conform to the following Indian Standards or where not covered by these Standards, to equivalent International Standards.

Indian Explosive Act 1883 and Explosives regulations 1984 (Amended 2005)

IS 4081 Safety code for blasting and related drilling operation underground excavation in rock.

IS 6609 Methods of test for commercial blasting explosives and accessories.

IS 10081 Terms relating to commercial explosives, Pyrotechnics and blasting practices.

IS 15447(Part-I) Commercial blasting explosives specification- Nitroglycerin based.

IS 4863 Glossary of mining terms (drilling and blasting)

IS 7526 Detonating fumes.

IS 7632 detonators.

IS 5878(Part-II/Sec.I) Code of Practice for construction of tunnels

6.3.2 In case of conflict between the above standards and the Specifications given herein the specifications shall take precedence.

## 6.4 SUPERVISION

6.4.1 Before taking up blasting operation, contractor/Explosive manufacturer shall submit face wise blast pattern covering blasting pattern, minimum safe charge, vibration control / monitoring etc. for various class of rock mass likely to encounter during excavation to be approved by Engineer/institute of repute as approved by Engineer. Such study report shall have to be got updated improved periodically during the excavation period.

6.4.2 Design and excavation by blasting shall be permitted only under the supervision of competent and trained workmen who are fully experienced in the work and who have received adequate instructions. The Contractor shall make sure that his blasting crew is fully conversant with the rules and regulations concerning storing handling and use of explosives. The contractor shall submit blasting and monitoring design to engineer for approval. Engineer may arrange for proof checking of blasting design and vibration monitoring results at employer's cost from institution of repute like CIMFR/IIT Dhanbad/NIRM.

6.4.3 Blasting specifications should include detailed description of state-of-the-art detonators, explosives and blasting patterns as well as blasting expert services including training of actual site personnel to be provided on site at the start of the project.

## 6.5 TRANSPORTATION AND HANDLING

6.5.1 Explosive shall not be transported to the Site of operation except in suitable cases or containers, which are so made as to prevent any spillage of explosives during conveyance. No explosive shall be removed from such cases or containers except when it is to be used forthwith for the purpose of the work.

6.5.2 Suitable Explosive Vans, duly approved by the Engineer, shall be used for transportation of explosives and detonators. The following rules shall be observed for use of Explosive Van:

i. Vehicles shall have springs under the body. Tyre pressures shall be as per Indian Explosives Regulations.
ii. Detonators and igniters shall not be carried in the same vehicle with explosives.
iii. Beside the driver, only one helper shall be accommodated in the Explosive Van. The vehicle carrying the explosives shall not be used to transport workmen or other materials to workshops although there may be enough space for men or materials.
iv. Driver shall not leave the vehicle unattended while transporting explosives.
v. All vehicles transporting explosives shall be marked or placarded on both sides and with the word "EXPLOSIVES" in bold letters. All explosive boxes shall bear explosive's Batch details, Mfg. Date and specifications etc. clearly on them.
vi. A motor vehicle carrying explosive shall not be refueled except in emergencies and that too only when motor is stopped, and other precautions taken to prevent

accidents. Such vehicles shall invariably have at least two fire extinguishers placed at convenient points.

- **vii.** Use of Mobile phones shall be restricted while carrying detonators or while refueling takes place.
- **viii.** Explosives Vehicle should have the seat belt for driver and the use shall be mandatory for the driver.
- **ix.** Vehicles transporting explosives shall never be taken into a garage, repair shop parked in congested areas, or in a public garage or similar building.
- **x.** Explosives shall not be transported on a public highway during hours of darkness except in extreme emergency and that too only with the written approval of the Engineer.
- **xi.** Explosives shall not be transported in any form of trailer, nor shall any trailer be attached to a motor truck or vehicle hauling explosives.
- **xii.** No transfer of explosives from one vehicle to another shall be made on any highway except in case of emergency.
- **xiii.** Persons employed in the transport or handling of explosives shall not carry with them or in the vehicles, matches, loaded firearms, petrol or any flame-producing devices.
- **xiv.** All explosives shall be adequately protected against theft.
- **xv.** Smoking shall be prohibited during handling, transportation and use of explosives. The places of Explosives storage shall be clearly marked as "No Smoking".
- **xvi.** The speed of the vehicle shall not exceed 25 km per hour on rough roads and 40 km per hour elsewhere.
- **xvii.** The interior of the body of the vehicle shall not have any exposed metal parts except those of copper, brass and other non-Sparking metals and shall be preferably lined with wood.

**6.5.3** Motor vehicles used for transporting shall be carefully inspected daily to ensure that:

- **i.** No petrol driven vehicle shall be used.
- **ii.** Filled and serviceable extinguished are in position.
- **iii.** The electric wiring is well insulated and firmly secured.
- **iv.** Chassis, engine and body are clean and free from surplus oil and grease.
- **v.** Fuel tank and feed lines are not leaking.
- **vi.** Lights, brakes and steering mechanism are in good working order
- **vii.** Vehicle is in proper condition in all respects for the safe transportation of explosives.
- **viii.** Two nos of red flags shall be present at the left and right top front ends of the vehicle
- **ix.** Condition of Van doors and locking arrangement shall be checked to ensure that rainwater or moisture doesn't damage the explosives case.

**6.5.4** Boxes or explosives shall not be handled roughly or allowed to fall.

**6.5.5** Containers of explosives shall be opened only by means of non-sparking tools or instruments.

**6.5.6** After the loading of a blast is completed, all excess explosives and detonators shall be removed to a safe location or returned at once to the storage magazine, observing the same rules as when being conveyed to the blasting areas.

**6.5.7** Containers for detonators shall always be used for storing detonators only.

**6.5.8** Explosives and detonators shall be carried in separate containers and by separate persons to the loading face. Only non-electric detonators shall be used.

**6.5.9** The drivers of the vehicle carrying explosives shall be trained in use of fire extinguishers on his vehicle.

**6.5.10** If any fire occurs on a vehicle carrying explosives the driver shall take all practicable steps to ensure that all other traffic is stopped at least 300 m from the vehicle and that all persons in the vicinity are warned of the danger.

**6.5.11** Loadings, unloading and handling of explosives shall, be supervised by qualified personnel. At the time of loading or unloading of explosives no electric switch shall be operated.

**6.5.12** Explosives shall not be placed where these may be exposed to flame, excessive heat sparks or impact or hazards of similar nature.

**6.5.13** The covers of the explosives cases or packages shall be replaced every time after taking out part of the contents as long as any explosives are left in them.

**6.5.14** Explosives shall not be carried in any way other than as specified in The Explosives Act & The Explosives Rules.

**6.5.15** Contractor shall ensure no misuse or mishandling of explosives such as carrying the explosives material in the pockets or folds of clothing etc. by any person.

**6.5.16** Primers shall not be made up in advance. Priming shall be carried out only when charging of the face starts except emergency for which written approval from Engineer shall be required.

**6.5.17** Nothing shall be inserted in the open end of a blasting cap except fuses.

**6.5.18** No person shall strike, tamper with, or attempt to remove or investigate the contents of a blasting cap or an electric blasting cap or attempt to pullout the crimped safety fuse out of a blasting cap.

**6.5.19** No attempt shall be made to soften I harden explosives by any specific treatment such as heating over a fire or by rolling the explosive on the ground.

**6.5.20** The blasting powder, explosives, detonators, fuses, etc. shall be in good condition and not damaged due to damp moisture or any other cause. They shall be inspected before use and damaged articles shall be discarded totally and removed immediately.

**6.5.21** No attempt shall be made to reclaim or use fuses, blasting caps, electric blasting caps or any other explosives, which have been water, soaked, even if these have been dried out. The manufacturers shall be consulted for this.

**6.5.22** The Contractor shall make all necessary arrangements for the security of the explosives during transportation. However, the Engineer, upon a request by the Contractor, may arrange protection by the Govt. security forces for large quantities of explosives, and the corresponding cost shall be borne by the Contractor.

## 6.6 STORAGE

**6.6.1** The Contractor may either obtain necessary licenses and consents and provide secure storage facilities for all explosives and equipment in accordance with Indian explosive act and requirements of local administration and engineer or may arrange explosives from nay existing explosive supplier in the region. In either case, the contractor shall take approval of engineer and keep him initiated of the source of explosives. No claims on account of any delays will be admissible in this regard.

**6.6.2** If the Contractor has arranged the required licenses and decided to establish his own magazine for the storage of explosive etc. then: -

- **i.** The contractor will be required to draw the explosives, transport to the site and keep it safety as per safety guidelines of Indian Explosive Act and the Explosive Rules. The magazine shall always, be kept scrupulously clean.
- **ii.** All the explosives like dynamite shall be stored in a dry clean, well ventilated and fireproof building' constructed in accordance with Indian Explosives Act, on an isolated Site. The area around the magazine for 8 m shall be kept clear of all vegetation and combustible matter.
- **iii.** There shall be a barbed wire fencing and security lights around the magazine and security guards shall be posted around for 24 hours to prevent loss or theft of explosives.
- **iv.** Explosives, detonators and fuse coils shall be stored separately.
- **v.** The Contractor shall maintain a record of storage and withdrawal of all explosives. This record shall be made available to the Engineer on request. The Engineer shall be promptly notified of any loss or theft of explosives.
- **vi.** Explosives shall be stored and used chronologically to ensure that the ones received earlier are used first. There shall be enough space between the stacks.
- **vii.** A "preparation area" shall be identified close to the charging face prior to every blast for preparatory work by experienced men as required for the work. All safety measures shall be ensured in the "preparation area".
- **viii.** Unauthorized persons shall not be allowed at any time to enter the magazine.
- **ix.** The person-in-Charge of the magazine shall, always, ensure that the magazine is securely locked.
- **x.** Explosives shall be handled and used only by the Contractor's duly authorized personnel. The names and qualifications of such personnel shall be submitted to the Engineer in writing in advance of any possible use of explosives.
- **xi.** The magazine on no account is to be opened during or on the approach of a thunderstorm and no person shall remain in the vicinity of the magazine during such storm. Enough lightning conductors shall be provided on top of the magazine.
- **xii.** Magazine shoes, without nails, shall always be kept in the magazine, and a wood tub or cement trough, about 30 cms high and 45 cms in diameter filled with water shall be fixed near the doors of the magazine.
- **xiii.** Persons entering the magazine shall put on the magazine shoes provided for the purpose and be careful not to allow the magazine shoes to touch the ground outside the clean floor.
- **xiv.** Persons with bare feet shall before entering the magazine, dip their feet in water, and then step direct from the tub over the barrier (if there is one) on to the clean floor.

xv. A brush or broom shall be kept in the lobby of the magazine for cleaning the magazine on each occasion it is opened for the receipt, delivery or inspection of explosives.

xvi. No matches shall be allowed in a magazine.

xvii. No person having articles of steel or iron on him shall be allowed to enter a magazine.

xviii. Oily cotton rags, cotton waste and articles liable to spontaneous ignition, shall not be taken into a magazine.

xix. No tools or implements other than those of copper, brass, gun metal or wood shall be allowed inside the magazine. Tools shall only be used with great gentleness andcare.

xx. Boxes of explosives shall not be thrown down or dragged along the floor and shall be stacked on wooden trestles. Where there are white ants, the legs of the trestles shall rest in shallow, copper, lead or brass bowls, containing water.

xxi. Package containing explosives shall not be allowed to remain in the sun.

xxii. Empty boxes shall not be stored in the magazine nor let any packing material lie loose.

xxiii. Blasting caps and electric blasting caps shall never be stored in the same box, magazine or building with other explosives.

xxiv. The following shall be hung in the lobby of the magazine:

a. A copy of these rules;
b. Display of Magazine License No and the capacity
c. A statement showing the stock in the magazine and
d. Certificate showing the last date of testing of the conductor

xxv. Adequate firefighting equipment shall be provided in the magazine.

xxvi. Signboards reading "DANGER HIGH EXPLOSIVES" "PROTECTED AREA" "NO SMOKING etc. shall be conspicuously displayed in front of the magazine.

xxvii. No explosives shall be stored in the tunnel and adit except for the purpose of charging for an immediate blast. Such storage shall be close to the face and for the quantity limited to the immediate blast requirement. Primed cartridges shall be seated by even steady pressure only.

## 6.7 DISPOSAL OF DETERIORATED EXPLOSIVES

6.7.1 All deteriorated explosives shall be disposed off in an approved manner as per Explosive Regulation- 1984, The quantity of deteriorated explosives to be disposed off, shall be intimated to the Engineer prior to its disposal.

## 6.8 DRILLING

6.8.1 Preferably, Boomer automation software shall be used to finalize drill pattern, hole orientation, termination depth, sequence etc. The boomer shall be total station navigated before drilling holes. All holes should end at same depth. Manual mode shall not be resorted to. A report of the drill hole data (Measured while drilling) along with drilling report shall be generated and handed over to engineer after the drilling. Without affecting drilling quality, Engineer may allow other methods to finalize and execute drill pattern with permission of employer.

**6.8.2** The holes shall be drilled in automatic mode preferably, so that drilling accuracy is guaranteed. Drill pattern and drilling sequence created on PC through supported software shall be transferred to the drilling rig for this purpose. Without affecting drilling quality, Engineer may allow other methods for drilling of holes with permission of employer.

**6.8.3** Preferably parallel cut drilling pattern shall be adopted. The perimeter holes shall be located within 0.10m deviation from approved blasting plan and never within the design line of excavation. Lookout angle for perimeter holes shall not exceed 2o and drilling deviation of shall not exceed 5% of the borehole depth to a maximum of 250mm at the end of hole. Engineer, with permission of employer, may allow other type of cuts which do not increase the blast damage zone compared to specified type of cut.

**6.8.4** All holes shall be of greater diameter than the diameter of the cartridges of explosives used.

**6.8.5** Perimeter boreholes shall not be more than 0.6m apart. Distance between perimeter and next row of boreholes shall not be more than 0.9m, unless adoption of greater distance does not harm the rock outside design perimeter.

**6.8.6** Loading and drilling shall not be carried out with Electric detonators in the same tunnel simultaneously.

**6.8.7** Under no circumstances shall any holes be charged until completion of all drilling operations at the face.

**6.8.8** A drill or pole shall not be inserted in sockets of old holes even its examination fails to disclose explosives.

**6.8.9** Drilling shall not be resumed after-blasts had been fired until a thorough examination has been made to make sure that there are no misfires and sockets with explosives which the drills may strike.

**6.8.10** Drilling shall not be started until all remaining sockets of old holes are examined for unexploded charges.

**6.8.11** Drilling crew shall be provided with approved respirators in siliceous dusty atmosphere arising out of drilling operations.

**6.8.12** Blast design should cater to the changes in geology and/or geotechnical parameters for each face and shall be decided face wise on ground

## 6.9 LOADING AND CHARGING

**6.9.1** The holes shall be cleared of all debris before a cartridge is inserted.

**6.9.2** In loading the holes, tamping, if required shall be done with a wooden mallet having no exposed metal parts.

**6.9.3** Primed cartridges shall be first inserted and shall be seated by even steady pressure only.

**6.9.4** All loaded holes or charges shall be checked and located before firing.

**6.9.5** When holes are sprung ample time shall be left between spring shots for the hole to cool, and between the last springing shot and the loading of the main charge.

**6.9.6** When practicable, no more cartridges shall be primed those are required for a round of blasting.

**6.9.7** Detonators shall be inserted at the end of the primary cartridge facing the end of the drill hole, which is prepared specially for the purpose.

**6.9.8** Holes in cartridges for inserting the detonator shall be made with a sharpened wooden stick.

**6.9.9** When blasting on the surface the entire area to be blasted must be covered with blasting mats, in locations where surface structures are to be protected, from damage by flying rock fragments.

**6.9.10** Detonating cord shall be cut from supply reel before attaching to explosive or tamping in hole. Use of the short pieces of fuse shall be prohibited for detonation purposes.

**6.9.11** No welding shall be done inside the tunnel / cavity at the time or loading or charging of the face, till the blast has been taken.

**6.9.12** Naked flames and lamps shall be kept away at the time of the loading of holes.

**6.9.13** Before starting the charging/loading of holes all electrical lines must be disconnected.

**6.9.14** Contractor shall arrange visits of Explosive manufacturer's technical team to design and execute the blast, train the blasting crew and supervise the blasting crew as per the direction of the Engineer.

**6.9.15** A team from explosive manufacturer shall be arranged by contractor to remain at site until the definitive drilling patterns/blast plans are defined for each support class.

## 6.10 TYPE OF EXPLOSIVES & ACCESSORIES

**6.10.1** Explosives

i. **For enhancing safety of operations, saving in time and better control of blast quality, bulk type explosives shall be preferable**. However, packaged explosives may also be used.

ii. Explosives shall meet following criterion: -

| S | Parameter | Packages Explosive | Bulk Explosive |
|---|---|---|---|
| 1 | Density of explosive | 1.15±0.05 g/cc | 0.6-1.1 g/cc |
| 2 | Relative weight strength | 110 -120 % | 90 -110 % |
| 3 | Relative bulk strength | 155 -165 % | 110 -160 % |
| 4 | Velocity of Detonation | 4000±500 m/s | 3000 – 6000 m/s |

**These parameters shall be met before seeking Engineer's approval Additionally, Engineer may collect random samples during any charging cycle, in case of any suspicion.**

iii. Explosive as approved by competent statutory authorities shall only be used. These explosives shall be of safe to handle and use, exhibit excellent water resistance and liberate low volumes of noxious gases.

iv. Manual Mixing of chemicals to form any explosives shall not take place and such explosives shall not be used.

v. Any Explosives having shelf life less than 6 months shall not be used.

vi. Explosives being used shall be capable of performing in low temperatures.

**6.10.2** Detonators

i. Priming of the explosives shall be done only with Non - Electric detonators with shock tube containing fine spray of around 13-16 mg/m HMX/AL powder

ii. The detonators shall be truly Non-electric in nature.

iii. The shock lube shall be of the nature that the color of the tube gets changed post blast and can be located easily for misfires etc.

iv. Identification tag and J - hook shall be placed at the end of the tube for identification and easy connectivity respectively.

v. Ultrasonic seal shall be provided at the end of the tube to make it waterproof.

vi. Shelf life of the detonators shall be one year.

vii. Non - Electric detonators shall be safe against stray currents, static Electricity, Radio-frequency Energies and accidental initiation by impact, shock, friction and time as per the standards fixed by the appropriate authority.

viii. The delay range of detonators should comprise of a minimum 0 - 15 delays firing completely in not less than 8000 ms for long period detonators.

ix. Short delay series shall contain a nominal delay interval of 25 milli second (ms).

x. Electric detonators shall not be used except for the initiation of Detonating Fuse.

xi. Strict control over delay intervals will be required to control the blasting damage in first 50m of each tunnel portal or underground areas within 25m distance (Vertical/Horizontal) to ground surface/pre-existing underground structures. In such cases contractor shall use electronic detonators if required in opinion of Engineer in Charge. Payment shall be made to the contractor through extra items depending on type and specification of the required electronic detonator after subtracting cost of Nonelectric detonators.

**6.10.3** Detonating Fuse / Safety Fuse

i. Detonating Fuse shall be used for connecting Non-Electric detonators.

ii. Nominal Weight of PETN shall be 10 gm/m in detonating fuses (DF).

iii. Detonating Fuses shall be able to get initiated by No.6 electric detonators.

iv. Water resistance shall be excellent.

v. Detonating fuse shall be used only to initiate the plain detonators.

## 6.11 WIRING

**6.11.1** All detonators in a single blast shall be of the manufacture.

**6.11.2** Each electric blasting cap used for initiation of shot shall be tested with an approved galvanometer (circuit Tester) to determine whether it will carry the current. All testing shall be done away from the heading face. Testing of a single detonator at any time shall be avoided.

**6.11.3** After testing the leg wires of electric blasting caps, they shall be short circuited by twisting the 'bare ends together and shall remain so twisted until ready to be connected into the circuit prior to connection to the firing line.

**6.11.4** Unless, the power supply is heavy it is recommended that all electric blasting caps shall be wired in series and the firing line shall not be smaller than No; 14B and S-gauge copper wire.

**6.11.5** The number of electric blasting caps used in a circuit shall not exceed, the tested capacity of the blasting machine.

**6.11.6** The circuit including all caps shall be tested with a circuit tester or galvanometer, operating accurately before being connected to the firing line.

**6.11.7** In surface blasting the cartridges shall not be primed nor a hole during the approach of a thunderstorm or while it is in progress. If a charge has been primed or holes loaded, every person shall be ordered to a safe distance until the storm is over.

**6.11.8** Blasting circuit wires and/or detonators leg wires shall never touch other wires carrying electric current.

**6.11.9** Blasting operation control shall consist of two switches; a safety switch and a firing switch located at least 2 meters apart, the connection between the switches to be made by a "plug-in" jumper, which may be permanently attached to the safety switch. The plug-in jumper Is so made that it cannot be plugged into or connected to the firing switch until the firing switch is unlocked, and the jumper must be disconnected from the firing switch before the firing switch can be locked.

**6.11.10** Both the safety switch and the firing switch shall be of the locking, double pole, double throw type which, when opened and locked in downward position short circuit and ground the leading wires.

**6.11.11** Both the safety switch shall be locked immediately after firing the shot and before any person can return to the area. Keys to the switches shall always remain in the possession of the starter .

**6.12 FUSE BLASTING** will not be allowed.

## 6.13 FIRING

**6.13.1** Shots shall, so far as practicable is fired electrically and only apparatus especially designed for the purpose shall be used. Power lines shall not be tapped for the purpose. No shot shall, be fired except by a licentiate blaster authorized by the Engineer.

**6.13.2** The charge shall be fired successively and not simultaneously.

**6.13.3** Prior to the firing of a shot all persons in the blasting area shall be warned of the blast through audible warning and ordered to a safe distance from the area.

**6.13.4** Competent flagmen; equipped with red flags and whistles shall be posted to stop traffic at access points on each possible route of travel to the vicinity of the blasting area.

**6.13.5** Blasting shall be done at fixed hours approved by the Engineer and the blasting times shall be displayed on a Notice Board.

**6.13.6** Order to fire shall be given only by the Supervisor-in-Charge of the work after giving three warning signals to enable all the workmen to reach safe shelters.

**6.13.7** Blast shall not be fired until it is certain that every person has retreated to a safe distance.

**6.13.8** The person-in-Charge of blasting shall be the first one to leave the area to be blasted.

**6.13.9** A bugle or an electric buzzer with a distinctive note shall be used to give warning signals. This bugle shall not be used for any other purpose. All the labour shall be made acquainted with the sound of the bugle buzzer and shall be strictly warned to leave their

Site of Work immediately for safe shelters at the first warning signal and not to leave the shelters till all clear signal has been given.

**6.13.10** An all-clear signal shall be given when the blasting is over.

**6.13.11** Definite places of shelter, natural or artificially constructed, shall be assigned to the crew. Workers shall be made to go to these shelters rather than trust each other's judgment about a safe place.

**6.13.12** In special cases suitable extra precautions shall be taken. The Engineer may, however, permit blasting for underground excavation without restriction of fixed time provided he is satisfied those proper precautions are being taken and that the work of other agencies on the site is not unduly hampered.

**6.13.13** Only Supervisor-in-Charge shall be responsible for the safe custody of the firing apparatus.

**6.13.14** For blasts in series, only detonators of the same brand and same electrical resistance shall be used. All detonators shall be checked before use.

**6.13.15** The firing cables shall be with a proper insulating cover to avoid short-circuiting due to encountering water, metallic parts or rock.

**6.13.16** Use of earth, as a return line shall not be permitted.

**6.13.17** The firing cable shall be connected to the source of current only when nobody is in the area of blasting.

**6.13.18** Mats or rubber tyres tied together will rope shall be used as protection from flying debris to cover the charges where blasting may expose persons or Properly to injury or damage.

**6.13.19** Blasting shall be permitted only after adequate provisions have been made for the protection of persons, the works, and public and private property. The Engineer's approval of any of the Contractor's blasting operations shall not relieve the Contractor of his sale responsibility for the safety of persons and property. Any damage done to the works or property by blasting shall be repaired by the Contractor.

## 6.14 INSPECTION AFTER BLASTING (Misfire drill)

**6.14.1** Immediately after a blast has been fired, the firing line shall be disconnected from the blasting or other source of power.

**6.14.2** After each blasting operation the tunnel drive shall be sufficiently ventilated to remove any nitrous gases and the atmospheric conditions shall be constantly checked prior to personnel accessing the excavated face. No persons can enter the blasted area before 20 minutes after firing.

**6.14.3** After a blast has been fired, a careful inspection shall be made by the blaster to determine if all charges have been exploded. The blaster shall count the number of the exploding shots in blasting. Misfires in fuse blasting shall not be examined for a enough time after its failure to explode. Electric blasting misfires shall not be examined for at least 15 minutes after failure to explode. Other persons shall not be allowed to return to the area of blast until an "All Clear" signal is given.

**6.14.4** The shot-firer must keep a record of the number of shots fired, their time of firing, type and weights of explosives used per delay and total explosives used in the round and the type and number of detonators used, together with a record of the post-blast situation for each and every location. A copy of the record shall be available to the Engineer at the end of every shift on which shots are fired.

**6.14.5** All wires shall be carefully traced, and search made for any unexploded cartridges by the person-in-Charge of the blasting operation.

**6.14.6** Loose pieces of rock and other debris shall be scaled down from the sides of the face of excavation and the area made safe before proceeding with the work.

## 6.15 MISFIRES

**6.15.1** Misfired holes shall be placed in the charge of a competent person.

**6.15.2** If broken wires, faulty connections, or short circuits are determined as the cause of a misfire, proper repairs shall be made, the firing line reconnected; and the charge fired. This shall be done, however only after a careful inspection "has been made of burdens remaining in such' holes and no hole shall be fired when the burden has been dangerously weakened by other shots.

**6.15.3** The charge of explosives from a misfired hole shall not be drilled, bored or picked out.

**6.15.4** Misfired charges, tamped with solid material shall be detonated by the following method:

- **i.** Float out the stemming by use of a water or air jet from hose until hole has been opened to within 60 cm of charge;
- **ii.** Water shall be siphoned off or pumped out;
- **iii.** New charge shall be placed and detonated.
- **iv.** Whenever this method is not practicable; then a new parallel hole, not nearer than 60 cms, shall be drilled, loaded and detonated. A careful search shall be made of unexploded material in the debris of the second stage.

**6.15.5** If misfire has been found to be due to defective detonators or dynamite, whole quantity or box from which the defective article was taken must be withdrawn from the works site for return to the manufacturer or destruction as decided by the Engineer.

**6.15.6** The Contractor shall report, in writing, to the Engineer, all cases of misfire, causes of the same and steps taken in connection therewith.

## 6.16 BLASTING FOR UNDERGROUND TUNNEL

**6.16.1** General

- **i.** Blasting in tunnels and cavities shall be carried out with Non-Electric detonators only except for the cord initiation by electric detonators.
- **ii.** A separate circuit, independent of power and light circuits, shall be used for blasting.
- **iii.** No electrically energized circuit shall be installed on the same side of the tunnel, or cavity with the blasting circuits.
- **iv.** All electric lights or other energized circuits shall be disconnected for at least 70 meter from the point of loading.
- **v.** All tracks, airlines & vent pipes shall be kept properly grounded.
- **vi.** For loading purposes, the employees shall be equipped with permissible battery lamps.
- **vii.** The safety switch and the firing switch shall be placed on opposite sides of the tunnel / cavity.
- **viii.** Only explosives, which produce less than 0.005 $m^3$ of poisonous gas (carbon monoxide and hydrogen sulphide) per 1.25" X 8" (3.15 cm X 20 cm) cartridge shall be used for Underground Work.

ix. No fire, flame, smoking or open lights shall be allowed within 6 meters from any explosive except for the purpose of firing a charge.

x. Adequate warning notices shall be given to air persons employed indicating the period, or danger at the time or firing and it shall be the duty of the Contractor to provide adequate shelters or screens for protection of workers exposed to risk of injury from the explosion or from flying material.

xi. After the blast takes place in Underground Works the workmen shall not be allowed to go to the face till all the toxic gases are evacuated from the face.

xii. Under water Blasting

a. Only water-resistant blasting caps and detonating cord shall be used in underwater blasting operations.

b. Loading tubes and casings of dissimilar metals shall not be permitted because of possible electrical transient current from galvanic action.

c. When more than one charge is placed underwater a float device shall be attached to an element of each charge in such manner that it shall be released by the firing.

d. No drilling, digging or excavating shall be permitted until all misfires have detonated or the explosives are removed from the missed holes.

## 6.17 MONITORING OF BLAST

### 6.17.1 General

i. The Contractor shall supply and operate at least four approved Engineering Seismometer (Triaxial) or Seismograph to measure 3-components of ground vibration and air blast overpressure. The equipment shall have enough memory space to store at least 300 events and shall be equipped to measure wide range of ground vibration and air blast overpressure. It also shall be equipped with a microphone attachment, permanent paper trace output with built in strip chart printer, LCD display and PC retrieval attachment for data to be used as and where directed by ENGINEER" to monitor blasting work.

ii. Unless otherwise agreed in. writing by "ENGINEER" trial blasts, initial blasting in general, and initial blasts in new areas and blasts adjacent to complete concrete structures and sensitive areas shall be monitored. For structures in the proximity of blasting the peak particle velocity shall be' measured at the locations immediately adjacent to the structure nearest to the face being stated or another location where it is necessary to limit vibration as instructed by engineer. Apart from monitoring on its own the Contractor must provide supports for measurement to other agencies appointed by "EMPLOYER" in tunnel excavation, monitoring shall specially be undertaken with change in rock mass. in shallow cover zone and or as directed by Engineer.

iii. The measured vibration results shall be transmitted to "ENGINEER" together with all the useful information concerning the completed information (cut of the face / slope of the cutting face; particle size distribution of the excavated material etc.; drill marks; vibration wave form in three directions-radial, transverse & vertical; air overpressure waveform; print out of Peak Particle Velocity (PPV) and associated predominant frequency in each direction).

iv. Assistance shall be taken from blasting consultants / experts as specified in Quality Manual document.

v. In case the defined thresholds be exceeded, blasting operations shall be stopped in order to finalize the new blasting pattern or the choice of another methods of proceeding with the excavations.

vi. In general, the methods, parameters to be measured and equipment for measurement of vibration shall be in accordance with IS 14881 unless otherwise specified.

**6.17.2** Restriction of Blasting

i. All blasting works shall be completed before pouring the first structural concrete, unless otherwise specifically agreed by "ENGINEER" in writing. When excavation is carried out using explosives the Contractor shall arrange his excavation and concrete placing programmed so that as far as practicable it shall not be necessary to use explosives close to permanent construction. The Contractor shall be responsible for avoiding damage to adjacent structures from fly rock by erecting barricades and/or the use of blast mats or other means by installing shielding device acceptable to "ENGINEER". The maximum allowable limit of noise overpressure in blasting shall not exceed 110 dB (beyond 100m in any direction from blast) In surface blasts: It must be measured close to the structure to be protected from blasting. Ground vibration induced by blasting shall be measured in terms of the Maximum or Peak Particle Velocity (PPV) in mm/s and predominant frequency of the ground vibration.

ii. The measurement of peak particle velocity shall be obtained from instruments capable of measuring along three orthogonal axes, one of which shall be aligned parallel to the center line of the excavation and another shall be vertical. The Contractor is to provide supports for the measuring instrument if so, required by the manufacturer's instructions.

iii. The measurements of the particle velocities (PPV) shall be the responsibility of the Contractor. Copies of the readings in an agreed form shall be supplied to the Engineer.

iv. The following limit on peak particle velocity are given as a guide and may be modified by "ENGINEER" based on seismograph records and observations during the progress of works.

a. PPV shall not exceed 30mm/sec at 20m distance from the tunnel face.

b. For existing surface structures adjacent to excavation areas, including structures of following types.

- Not forming part of the contract,
- Belonging to Employer and
- Not belonging to Employer,

The frequency and peak particle velocity dependent safety criteria as per Director General of Mines Safety (DGMS) criteria shall be followed for protection of nearby structures in surface blasts.

- **v.** Where circumstances dictate, such as when blasting adjacent to partially cured concrete, the peak particle velocity permitted may be reduced by "ENGINEER"
- **vi.** For specific structures and if requested by "ENGINEER" the Contractor shall fulfill the following criteria:
  - a. At a 20 m radius of the blast, the interstitial velocity, for frequencies inferior to 100 Hertz, shall be limited to 4 cm per sec. (40 mm/sec.)
  - b. After blasting and scaling of blasted surface, 60% of the half bore holes (barrels) must be visible,
  - c. Smooth/control blasting is mandatory, in case of "Smooth blasting the spacing of perimeter holes should not exceed 40 cm c/c and the distance between perimeter row of holes and the buffer row of holes should not exceed 0.7 m.
  - d. Bores holes space is 45 cm maximum.
- **vii.** If necessary, "EMPLOYER" may require the Contractor to restore at his own expense any building, structure, masonry and equipment damaged by blasting, through direct or indirect effects.

**6.17.3** Recording blasting operations

- **i.** The Contractor shall keep records of all blasting carried out showing the time and location of each blast, the type and amount of explosive used, together with any other relevant data in an agreed format approved by "ENGINEER".
- **ii.** During the site works, as mentioned before each blasting pattern shall be submitted to "ENGINEER" for approval at least 24 hours before the blasting operation is due to begin. This shall be in the form of a presentation sheet setting out all the information concerning:
  - a. The type(s) of explosives to be used.
  - b. The x, y, z coordinates of each firing hole and the firing polygonal,
  - c. The diameter, depth, charge and the packing of each hole,
  - d. The method of ignition and the type of detonator for each charge,
  - e. If using a sequential exploder, the connection of the different lines and a plan showing the effective delays of the charges,
- **iii.** The total quantity explosives for the firing of the round: always, "ENGINEER" can interrupt the explosive operation or request the Contractor to modify to the blasting patterns and the cost on this account shall be borne by the Contractor.

# CHAPTER 7: INSTRUMENTATION MONITORING RECORDING AND THE CONTROL PROCESS OF UNDERGROUND WORKS

## 7.1 GENERAL

a) The Contractor shall submit to the Engineer for agreement a detailed method statement for instrumentation and monitoring, including instrumentation layout, trigger, design and allowable values and procedures for evaluating the monitored data.
b) The Contractor shall appoint within his site team an experienced Instrumentation & Monitoring Engineer who shall lead the Contractor's monitoring team. The Instrumentation & Monitoring Engineer shall present the results of the previous day's monitoring in the daily monitoring meeting with the Engineer where they shall be presented to the Engineer by the Instrumentation & Monitoring Engineer.
c) The frequency of such review meeting may be increased if requested by the Engineer.
d) The Contractor' Tunnel Construction Manager shall attend monitoring review meetings if requested by the Engineer.
e) The accuracy and precision of the measurement required will depend on the purpose of the monitoring.
f) Assessments shall be carried out to establish the zone of influence due to tunneling works and to determine the likely damage that will occur to existing above ground and subsurface infrastructure.
g) The outcome of the assessments shall determine the type and amount of monitoring that will be required.
h) Early preconstruction instrumentation requirements shall be determined so that baseline measurements can be taken for an appropriate period, to establish the stability of the monitoring system and any possible effects of any underlying environmental trends that could be attributed to the Works.

## 7.2 Ground Monitoring

a) Unless otherwise provided for in the contract, the Contractor shall monitor the effects of tunnel construction at the surface including all ground movements and the effects on all structures, including the Works. Where specifically requested, the subsurface effects, including movements of the water table, shall also be monitored.
b) Unless otherwise provided for in the contract, monitoring equipment and instruments shall be provided by the Contractor to enable the response of structures to be determined, Equipment and instruments shall be installed to the manufacturer's instructions and shall be calibrated and tested as appropriate. Monitoring pins and devices shall be securely fixed in position. Due regard shall be given to the construction of the structure to be monitored and the layout of its primary support.
c) Monitoring shall be referenced to stable survey stations located outside the zone of influence of the Works and not subject to ground movement. Such benchmarks and coordinated stations shall be established and agreed with the Engineer before any

ground is excavated and before any ground treatment or dewatering takes place. They shall be checked at intervals during the duration of the Works.

d) The Contractor shall observe, record and analyze the readings to establish trends in movement and reconcile movements measured with those predicted. He shall provide a copy of all recorded results to the Engineer. He shall make available results to the Engineer in accordance with an agreed programme: however, movement greater than predicted shall be reported to the Engineer immediately.
e) Prior to Construction Works commencing, a defect survey shall be carried out of all structures within the zone of influence and a schedule of defects shall be prepared. This schedule shall be agreed by the Contractor and the owner of the structure, or his representative, prior to the start of construction. Existing pipelines, tunnels and services shall be regarded as structures.
f) During the execution of the Works, defects which have been scheduled shall be inspected and monitored as necessary. Defects which arise during the course of the works shall be recorded. The Contractor shall keep records of such inspections and a copy shall be available to the Engineer.
g) Monitoring of settlement, scheduled defects and defects arising during the course of the works shall continue at agreed intervals for a period of at least 6 months after completion.

## 7.3 Monitoring of Tunnel Excavation

a) The Contractor shall survey, monitor and record tunnel and shaft construction as it proceeds, to form a record of the work. Monitoring shall generally be per unit of advance and include line, level, cross-sectional accuracy, shift advance, total advance.
b) Where grouting is carried out, the type, volume and pressure of grout shall be recorded.
c) All information recorded by the Contractor shall be provided to the Engineer on a daily basis unless another interval has been agreed.
d) Where the Contractor considers that any corrective actions he may take will exceed the tolerance in the contract he shall so inform the Engineer and obtain his agreement.
e) The strata exposed in the tunnel face shall be mapped and recorded where possible and the nature of the excavated material shall be noted in all cases.
f) All significant groundwater ingress shall be recorded and monitored.
g) All atmosphere testing shall be recorded and monitoring for all gases carried out in accordance with relevant code.
h) The Contractor shall keep copies of all recent face records at the workface for the information of supervisory personnel.

## 7.4 Daily Review Meeting (DRM)

a) The monitoring instrumentation shall be read on a regular basis- as per Drawings and monitoring plan and the record made available for a Daily Review Meeting (DRM) attended by the Senior members of the Contractor's and the Engineer's staff. Input into the meeting shall also include current Geotechnical Investigations, Measurement While Drilling (MWD) report, face logs, and any recent non-conformance reports relating to the tunnel construction.

b) This DRM shall be held daily during the excavation of the tunnels unless otherwise agreed by the Contractor and the Engineer.
c) At the meeting the Contractor shall present the current results of monitoring of the tunnels, together with records on these results and comparison with the deformation predicted by the calculations.
d) The outcome of the meeting shall be a report Required Excavation and Support Sheet (RESS) agreed by the Contractor and Engineer, which states that tunneling may continue as proposed or gives the requirements for modification to the tunneling (e.g. shorter advances, smaller heading).
e) If no agreed report is available by a specified time each day then the tunnel shall be made safe and tunneling be stopped.
f) All records from these meetings including face logging and monitoring results shall be kept and be available for inspection until the termination of the contract.

## 7.5 Key Performance Indicator (KPI)

a) A Key Performance Indicator (KPI) system shall be developed for monitoring movements so that action can be taken in a timely manner, thereby ensuring that damage to existing buildings and subsurface infrastructure is within calculated predictions.
b) The KPIs to be used to guide construction shall relate to specific monitoring activities.
   i. In-tunnel convergence monitoring (SCL)
   ii. Ground movement monitoring
   iii. Monitoring of adjacent and overlying structures.
c) The KPI values specified in the design documentation shall be used to indicate whether or not there is cause for concern during tunnel construction. To ensure that the response is appropriate for any specific concern, certain procedures shall be implemented when a KPI is exceeded. These are summarized below:
   i. A full review of the lining performance shall be conducted for the relevant tunnel section and checked against the KPI values. This includes checks on the ground/soil conditions, the quality of construction and the monitoring results provided by the Contractor.
   ii. A comprehensive review of the trends for monitoring data specific to the area of concern shall be carried out by the Contractor and the Engineer.
   iii. The Contractor shall assess the extent to which the deformations comply with the SCL serviceability and extreme limit conditions.
   iv. Together with the Engineer, the Contractor shall decide whether changes in the SCL excavation sequences are required. This is an interactive process that will determine whether it is safe to proceed with construction or, if there is reasonable cause for concern, the extent to which it is necessary to implement additional measures or emergency procedures. These measures will be included in a new RESS.
   v. The Contractor and Engineer shall implement the Action Plan, the emergency response to implement contingency measures. If there is reasonable cause for concern, it is emphasized that the response must be rapid.

vi. The performance of the tunnel is kept under continuous review until the monitoring data indicate that KPI trends show a stable condition.

a) At least three trigger values shall be established: a green, amber and red limit. The green limit marks the boundary of normal behaviors. The amber marks the boundary of serviceability while the red trigger should be set below the ultimate capacity of the lining. The Contractor's Action Plan should include pre-planned contingency measures that can be taken if a trigger value is exceeded.

b) If a trigger value is reached, first the site team should check that the reading is correct and consistent with the readings from other instruments. If the rigger has really been breached, then contingency measures will be investigated in accordance with a predefined Action Plan and as directed in the DRM. The contingency measures are designed to correct any anomalous behavior.

## 7.6 RESS- Required Excavation and Support Sheet

a) Based on the design and the evaluation of the result of monitoring, a RESS will be issued at the outcome of the Daily Review Meeting (DRM). In the absence of any approved changes the RESS will reflect exactly what is shown on the relevant design drawings.

b) The RESS shall be prepared and endorsed by the Contractor's Tunnel Construction Manager responsible for the tunneling works, the Designer (for specific issues) and the Engineer on site. Unless all the three signatures are obtained, the proposals indicated on the RESS shall not be implemented.

c) The RESS shall address, but not necessary be limited to the following matters:
   i. The tunnel section (chainages) to which the RESS is applicable
   ii. The support to be installed
   iii. The excavation sequence
   iv. The method of working related to ground support including staging of application of sprayed-concrete layers and lapping of reinforcement.
   v. Monitoring to be installed in the tunnel section in question
   vi. Measures to be taken during stoppage of works
   vii. Other instruction relevant to the tunnel section in question
   viii. Reference to relevant Design Drawings

d) A copy of the RESS will be given to the Head Foreman in charge of the work in the tunnel and shall be kept at the working face.

e) A RESS is required for every metre of the length of the tunnels.

f) If for any reason the approved design method of working is changed, then this will be reviewed prior to the DRM and subject to acceptance by the Engineer a new RESS will be issued.

## 7.7 Contingencies measures and Emergencies procedures

a) The Contractor shall determine contingency measures to deal with potential hazards that may affect the Works. The Contractor shall submit for approval to the Engineer an action plan which shall detail the actions, procedures and contingency measures to be followed in the event that the monitoring system shows unacceptable levels of deformation movement if potential hazards occur.

b) Hazards to be addressed include
   i. changing ground condition

ii. excessive movement of the linings
iii. Excessive ground movement
iv. Excessive settlement of the existing structures
v. Unplanned stoppages
vi. Mechanical excavation plant failure
vii. Insufficient labour resources
viii. Failure of services to underground work (air, light, power etc.)
ix. Incidents within underground works
x. Delay in supply of sprayed concrete (SCL)

c) In underground construction works, changes tend to be progressive with evidence of structure or ground behavior becoming apparent before failure occurs. For this situation a system of hierarchical trigger levels will be appropriate. This allows proportionate response to adverse indications from monitoring.

d) Trigger levels will be based on the results of assessments of at-risk infrastructure. If the assessment indicates that the at-risk infrastructure is unlikely to be able to tolerate the change due to the Works, then triggers will be set based on the levels of change that will be tolerable.

e) There may be some situations where change is less progressive and monitoring may simply be required to give a yes/no response. In these cases reporting is simple and systems of triggers are not appropriate.

# CHAPTER -8
# UNDERGROUND EXCAVATION

## 8.1 GENERAL

**8.1.1** The specifications described herein under relate to the excavation work for the underground structures and shall include all labour, materials, equipment all drilling and blasting, loading, transporting and disposal of materials in spoil or stockpile areas as well as the removal of all loose material and cleaning of excavated surfaces, to be carried out by the Contractor under this contract. In general, the excavation work shall be done by mechanical equipment or drill and blast (DBM) and in exceptional cases, by manual means.

**8.1.2** Excavation shall be made to the lines, grades and dimensions shown on the drawings or as otherwise directed by the Engineer, which shall be required to be backfilled with acceptable material and compacted by contractor in a manner acceptable to the engineer.

**8.1.3** Structural supports, structural steel support, rock bolts, shotcrete, grouting, concrete lining and dewatering works are covered in other chapters of Outline Construction Specifications.

**8.1.4** The contractor shall be required to perform surface exploratory drilling during excavation of the tunnel whenever required.

**8.1.5** The approval given by the Engineer to the Contractor's methods and equipment shall not relieve the Contractor of his full responsibility for proper and safe execution of underground excavations, or liability of injuries to or death of person or any obligations under this contract.

**8.1.6** The Contractor shall comply with all safety procedure and requirements as stipulated elsewhere in the tender documents.

**8.1.7** All excavations done inside ground with overlying material left in place shall be treated as underground excavation.

**8.1.8** **STANDARDS:**

The specifications, production, working etc. shall conform to the following latest Indian Standards or where not covered by these Standards, to the equivalent International Standards. The list is for guidance purpose only. The contractor shall abide by all codes/regulations/specifications as are deemed necessary for the satisfactory completion of work.

- **i.** IS: 4756: - 1978 – Safety Code for Tunnelling work
- **ii.** IS: 3764 –1966 – Safety Code for Excavation work
- **iii.** IS: 4081-1967 – Safety Code for Blasting and Related drilling operations
- **iv.** IS: 4138-1977 – Safety Code for Working on Compressed Air
- **v.** IS: 7293-1974 – Safety Code for Working with Construction Machinery
- **vi.** IS: 5878 (Various parts) – Codes of practices relating to tunnelling and underground excavations
- **vii.** Indian Explosive Act -1988
- **viii.** Indian Explosive Rules -1983

ix. IS: 823 -1964 – Code of procedure for manual metal Arc welding of mild steel

x. IS: 816-1969 – Code of practice for use of Metal Arc welding for General Construction in Mild steel.

## 8.2 SUBMITTALS

**8.2.1** At least 28 days prior to the commencement of underground excavation, the contractor shall submit details of his excavating methods and sequences for all underground works and portal excavation, including equipment, ventilation air cooling equipment, rock support, details of methods for drilling probe holes, grouting and safety measures. Contractor shall get approval for excavation and sequences from the Engineer.

**8.2.2** The description of drilling and blasting procedures shall include the following:

i. Diameter, spacing, depth, pattern and orientation of blast holes.

ii. Pattern of delays to be used per blast.

iii. Sequence of various activities of the excavation works in different. Heading faces with indication of corresponding time requirements.

iv. Excavation methodology shall include proposed exaction cycle time for each class of rock mass along with advance rock stabilization measures.

v. The details to be backed up by supporting calculations & details of trials.

**8.2.3** To enable the Engineer to verify all necessary setting out and elevations carried out by the Contractor, the latter, shall notify the Engineer in writing, giving at least 1 (One) week notice, of his intention to start excavation.

**8.2.4** During the advance of underground excavations, the Contractor shall record and submit weekly to the Engineer, 3 copies of the following:

i. Advance of each heading face and chainage of heading face before the blasting of each round.

ii. Amount, location, spacing, and type of steel support/Lagging installation in various zones, as defined hereafter.

iii. Surface area of shotcrete installed in various zones.

iv. Number, length, and type of rock bolts installed in various zones.

v. Occurrence of gas, if any.

vi. Water inflows at the heading face including its temperature.

vii. Personnel employed during various stages of the operation and their qualification.

viii. Unusual occurrences, all delays and the reason of delays.

ix. Type and number of drill holes, and length of each round.

x. Pattern of drill holes their diameter and length.

**8.2.5** The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.

**8.2.6** For geological overbreak and adverse geological occurrence Contractor shall be responsible for preparing geological plans and survey plot cross section at required intervals by tunnel profiler to allow for reasonably accurate assessment of the volumes and taking video / still photographs of overbreak in the presence of the representative of Engineer and providing copies of the same to "ENGINEER". The exact locations and / or chainage shall also be included therein. Such incidences shall be reported immediately to the ENGINEER. Detailed report on adverse geological occurrences shall also be prepared along with probable reasons and submitted to engineer as soon as possible. All cavity and voids formed due to geological overbreak shall be measured in situ, quantified and proposed by contractor for immediate approval of Engineer, If possible, before the excavation of the subsequent blast.

**8.2.7** The drilling parameters retrieved from the Jumbo machine will be submitted to the Engineer before every blast.

## 8.3 DEFINITIONS

**8.3.1** Conventional Excavation

i. Excavation performed underground by conventional methods using mechanical means (except TBM) or drilling and blasting and in exceptional cases, by manual means.

**8.3.2** Tunneling Face

i. The advance end of a tunnel at which the work is progressing.

**8.3.3** Heading Zone

i. Heading zone refer to tunnels (upstream and downstream headings) excavated by conventional method and is defined as a zone between the newly established face and 7m or equal to the excavated diameter of the tunnel behind the face, measured along the tunnel centerline.

**8.3.4** Rear Zone

i. Rear Zone is the whole length of tunnel between the heading zone and the portal.

**8.3.5** Excavation Rate per working day

i. The daily excavation rate is the average of daily rates calculated over a period of 1 month.

**8.3.6** Working Days (WD)

i. Working days are calendar days on which work is performed. When working days are mentioned in writing, they must be indicated with additional indices such as WD1, WD2 or WD3 in order to show whether on the day in question 1, 2 or 3 shifts will be working.

**8.3.7** Crown

i. Crown is the top arch of the tunnel above the spring line.

**8.3.8** Spring Line

i. The level at which overt and vertical I wall of the tunnel meet is called Spring level and horizontal line passing through the junction points of tunnel is called Springing Line.

**8.3.9** Round length (Pull): Maximum distance (along tunnel axis) between any two points on two successive tunneling faces by which the excavation is advanced from previous face to next face by conventional drill and blast or any other method in one go.

## 8.4 General

**8.4.1** The Contractor shall always be responsible for the safety and security of excavations during the execution of the Contract.

**8.4.2** Mechanized techniques for excavation shall be used.

**8.4.3** Excavation shall generally be full face, heading and benching or multi-drift as defined in the construction drawings.

**8.4.4** The Contractor shall provide details of his proposed methods for excavation support and spoil removal to the Engineer for agreement. No excavation shall take place until the Engineer's agreement has been obtained. Such agreement shall not relieve the Contractor of any of his obligations under the Contract.

**8.4.5** Excavation shall be carried out in a uniform and controlled manner and over-cutting shall be kept to a minimum consistent with the need to maintain the necessary clearance for construction of the Works.

**8.4.6** The invert of the tunnel shall be protected against damage and deterioration which may be caused by construction traffic. Any other surfaces which deteriorate or are damaged shall be made good to a standard agreed with the Engineer. After invert casting, tunneling muck will be filled, levelled and compacted over concrete invert.

**8.4.7** Excavation shall be carried out in sections limited to such lengths, depths and widths as may be safely executed having regard to all the circumstances and as appropriate to the ground conditions and the equipment and method of construction being used.

**8.4.8** In water-bearing strata the Contractor shall use such methods and take such steps as are necessary to control flows and maintain the stability of the excavation.

**8.4.9** Where necessary to ensure the safety and security of the Works, excavation shall be continuous by day and night.

**8.4.10** Weekends, general holidays and enforced stoppages will require the Works to be made safe and inspected by the Contractor at intervals agreed with the Engineer.

**8.4.11** Any voids formed during the excavation process by machine overcut slips, falls of material, overbreak and temporary works shall be filled either completely or partially in agreement with engineer, with grout, concrete, sprayed concrete or other approved durable material.

**8.4.12** Where the Contract specifies limits to surface settlement and/or protection in respect of existing services or structures, the Contractor shall provide calculations demonstrating that the method of excavation will result in compliance with those requirements. Details of the monitoring arrangements which are proposed for the recording of movements and the verification of the degree of any settlement or damage to services or structures shall be in accordance with the specified limits.

**8.4.13** Where agreed or required by the Engineer, temporary support shall be left in the Works. Generally, untreated timber shall not be left permanently in the Works.

**8.4.14** The volume of excavated material shall be measured and recorded as the Works proceed. The Contractor shall present to the Engineer after every 50m of advance, a Chainage wise reconciliation of volumetric advance of tunnel against volume of materials excavated and quantum of support installed (Bolts/Shotcrete), concrete placed, length of drilling of holes and grout injected.

**8.4.15** All excavation shall be carried out to a profile as close as possible to the specified minimum excavation line.

**8.4.16** The Contractor shall be constantly aware of the possibility of slips and ground movement which may be caused by his method or order of excavation. He shall maintain on-site material, and equipment, for use in ensuring the stability of the face.

**8.4.17** The proximity of other tunnels and excavations shall be considered when determining the method of excavation.

**8.4.18** Enlargement of tunnel cross section or excavation of bypass tunnel shall also be done as wherever required as per instruction of Engineer.

## 8.5 EXCAVATION LINES AND TOLERANCES

**8.5.1** Definitions:

- **i.** Theoretical excavation line: The excavation profiles as shown on the cross-section drawings refer to the theoretical excavation lines.
- **ii.**
- **iii.** "A" Line" – Depending on the quality of the rock, an appropriate enlargement of the theoretical excavation profile shall be made in order to provide enough space for the anticipated radial deformations. The "A" Line takes into consideration the anticipated radial deformations above the theoretical excavation line.
- **iv.**
- **v.** "B" Line – Line within which neither rock bolts nor sprayed concrete or any part of the primary support shall intersect except for bolt end hardware.
- **vi.**
- **vii.** "C" Line – A Line within which the final lining shall not protrude and be constructed within -0/+50mm radially (Negative value radially inward). The Contractor shall accommodate all his construction tolerances for excavation and support installation within this given allowance.

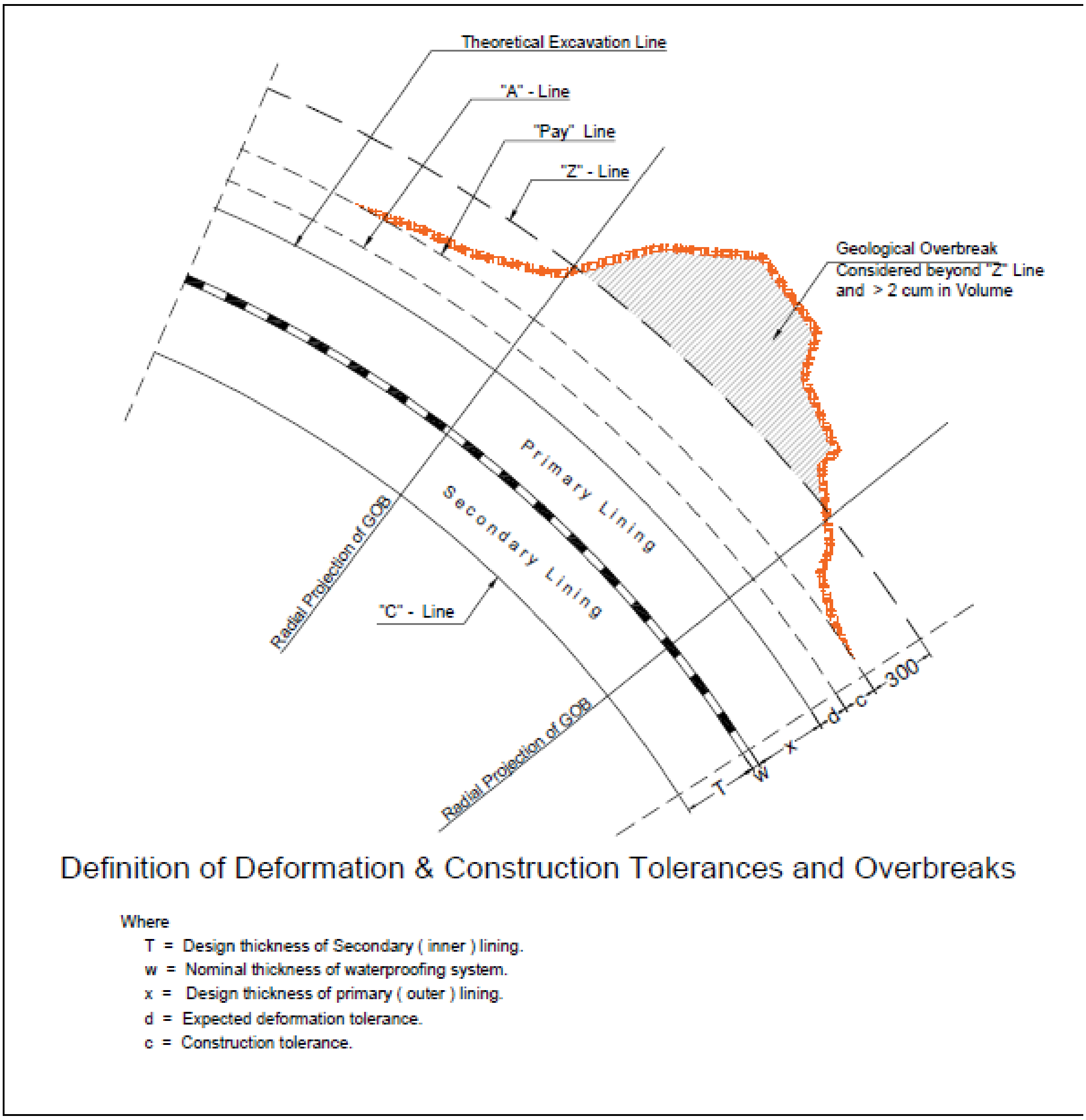



**Figure: 8.5.1: Definition**

Typical cross section, minimum excavation lines and dimensions of excavations will vary for different Support Section Types required to be installed. Radial Deformation tolerances (δ) as mentioned in drawings shall be adjusted by the engineer to suit actual deformations as experience is gradually gained during excavation. The "A" Line shall accordingly be modified, and the contractor shall be bound by all such adjustments.

### 8.5.2 Regulation for installation of Primary and Secondary Lining Support

I. **Primary Lining Support:** After scaling, entire excavated profile will be measured in situ with tunnel Profiler.

**For the support classes with shotcrete and bolts only,** the design thickness shall be applied directly on the excavated profile. Payment shall be made for the theoretical quantity increased by a thickness of 75mm only, based on the design drawings.

**For the support classes with lattice girders/steel ribs** the excavated profile shall be placed with Shotcrete upto the "A Line". Thereafter, Design thickness of shotcrete and other supports shall be applied below "A Line", as indicated in the drawings.

For the case of the support types with Steel Ribs or Lattice Girders, the application of the shotcrete should respect the design thickness after the A line and reach to the corresponding B Line. In between the steel ribs or lattice girders, the shotcrete application less than the B line can be allowed, upon approval by the Engineer, respecting the following two criteria:

A. Satisfy the shotcrete design thickness as per approved drawings

B. Satisfy the waterproofing membrane waviness criteria

The finished profile of shotcrete shall be checked with tunnel Profiler and shall meet the tolerance for surface finish requirements for installation of water proofing membrane (Sub Chapter 4.4.3 ix). Smoothening layer of shotcrete shall be applied as per drawings or as instructed by engineer.

**II. Secondary Lining Support:** Before application of water proofing membrane, Profile of existing shotcrete surface shall be recorded with tunnel Profiler to establish actual deformation occurred. Any eventual space between the shotcrete surface and "C" Line shall be filled with the inner lining concrete. This eventual space comprises of concrete volumes required on account of portion of radial deformation ($\delta$) which did not occur, added to the volume of theoretical lining thickness.

The actual occurred deformations before the installation of the Final lining will be measured with the convergence target at the closest monitoring cross-section of each support class.

**8.5.3** The drilling jumbo should be positioned as per precise survey reference points/lines and shall preferably be laser/total station navigated before it's usage in drilling etc.

**8.5.4** The Contractor shall measure the excavated profile by means of a 3 D laser tunnel profiler after each round or as per direction of Engineer.

**8.5.5** Excavation not shown on drawings, but which the Contractor considers necessary for his own purposes such as excavation from mucking pits, pump sumps, niche for vehicle parking/turning, drain ditches other than those shown on the drawings and specifications etc. for supply facilities shall only be carried out with the approval of the Engineer.

**8.5.6** In case of pipe roof umbrella, the excess of excavation below the steel pipes will be filled with Shotcrete/final lining concrete as instructed by Engineer.

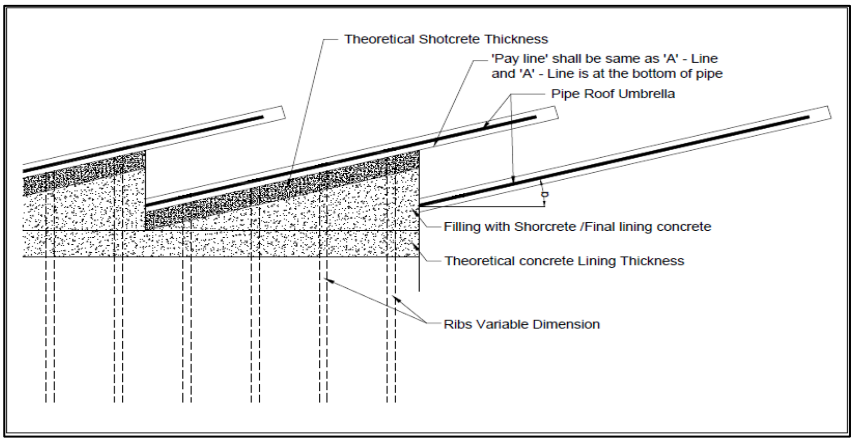



**Figure 8.5.7**

**8.5.7** Tolerances for Lining:

- **i.** Secondary Lining: Finished surface of Secondary Lining shall not protrude "C" Line and be constructed within tolerance of -0/+50mm radially (Negative value radially inward).
- **ii.** No reduction of the theoretical thickness of the inner lining is permitted unless approved by the Engineer. To achieve this requirement, no support elements such as primary shotcrete, rock bolts and steel ribs etc. shall penetrate the theoretical outer boundary of the inner lining.
- **iii.** In the area of the invert and the foundation beams, no rock parts or rock peaks shall protrude into the theoretical excavation line.

**8.5.8** Tolerance for Excavation level on invert:

- **i.** For tunnel sections with no concreted invert arch the Contractor shall excavate the bottom level of the invert with an accuracy of -0 to +100(Negative value radially inward) mm related to the theoretical excavation line of the invert.
- **ii.** If the bottom excavation level, after cleaning loose materials etc. is more than 100 mm below the designed theoretical excavation line, the Contractor shall backfill such areas up to the designed, theoretical level by means of sub-base material or as directed and approved by the Engineer.
- **iii.** For tunnel sections with a concrete invert arch no reduction of the designed, theoretical thickness of the concrete structure is permitted. Over excavation must be compensated with structural concrete/ shotcrete for the invert arch as specified. The inside face of a concrete invert arch may deviate not more than +/-50 mm in elevation from the theoretical cross section

## 8.6 PROFILE CONTROL

**8.6.1** Scope

- **i.** The Contractor is required to perform a careful and systematic checking of the final clearance of the primary tunnel lining in order to accommodate the designed nominal thickness of the secondary (inner) lining without interfering with the clearance requirements of the underground structure.

**8.6.2** Method of Profile Control

i. For profile control for the shotcrete lining see Chapter 11.
ii. It is the Contractor's responsibility to ensure that the minimum clearance for the final (inner) lining as shown on the drawings is provided. On approval, the Engineer will issue instructions regarding the systematic checking of the geometry of the template during profiling operations.
iii. The Contractor may prefer to use advance surveying techniques and data processing to establish the final clearance profile. In which case he shall define a method of marking out areas of deviation from the theoretical profile to be approved by the Engineer.

**8.6.3** Execution

i. The checking of the final clearance shall not proceed before the geotechnical measurements show that the radial displacements at any position of the tunnel have, in the opinion of the Engineer, largely stopped.
ii. The final clearance profile after the completion of support works of the tunnel and after deformation as per this Clause shall conform to the minimum clearance profile as indicated on the drawings. Final control is required before water proofing system is applied.
iii. In case of an existing under profile, the Contractor shall submit a proposal for the remedial works to the Engineer for approval.
iv. No reshaping (re-profiling) of the tunnel support shall be carried out without the approval of the Engineer.
v. Geotechnical measurements before, during and after the respective reshaping measures shall be carried out in compliance with the relevant design. The measurement points such as convergence bolts and/or extensometers shall be retained or substituted well in advance in order to establish "transfer - zero - readings".
vi. Geotechnical measurement stations shall not be removed and abandoned without the approval of the Engineer.

**8.6.4** Records

i. Records shall be kept for each stage of the remedial measures executed.
ii. The clearance profile i.e cross-sections of excavated profile shall be recorded at every meter of tunnel Chainage in longitudinal direction and at multiple points, 0.5 mtr apart along the periphery of the tunnel or as instructed by the Engineer. The clearance profile shall be recorded by non-contact method (by manually or automatically) i.e by means of a "Tunnel profiler". The checking of the clearance profile shall be done in presence of the Engineer.
iii. For the shotcrete lining, the final checking of the clearance profile after completion of re-profiling and surface preparation in compliance with this Specification shall be done in presence of the Engineer.

## 8.7 SUPPORT FOR UNDERGROUND EXCAVATION

**8.7.1** The provisional and permanent supports for the underground excavation shall principally consist of spot or pattern rock bolts and *I* or shotcrete and/or Structural steel and final concrete lining supports as approved by the Engineer.

**8.7.2** The Contractor shall install the support system as shown on the drawings or as directed by the Engineer in any part of the underground excavation based on rock conditions encountered during the work.

**8.7.3** The contractor shall employ a team of qualified geologists, who have adequate working experience in rock supporting work to act as support supervisor(s). The support supervisor(s) shall examine the rock conditions after each excavation advance and shall verify that the rock support system is installed as directed. The support supervisor(s) shall take necessary steps in consultation with Engineer in order to install additional supports or to stop further advance if, in his opinion, the conditions are unsafe. However, he shall have no right to cancel type or amount of rock supports previously directed by the Engineer. The support supervisor(s) shall be present at each heading face throughout the duration of underground excavation work.

**8.7.4** The required supports shall be installed concurrently without delay during the process of excavation within the heading zones. In the rear zones additional supports shall be installed immediately after it is observed by monitoring that the supporting system previously installed is not enough to prevent further loosening of the material surrounding the excavation.

**8.7.5** Shotcrete shall be applied, in accordance with the provision of relevant Sub Chapter of "Shotcrete". The Contractor shall consider in his construction planning, that placing of shotcrete protection will be required immediately after blasting a round in conventional method of drill and blast.

**8.7.6** The use of timber will not be permitted for tunnel supports in any form. However, the Engineer, in exceptional circumstances may permit use of timber for providing temporary supports, which shall be removed as early as practicable.

**8.7.7** The Contractor shall keep on the site all necessary construction plant and equipment for installing rock bolts and shotcrete, ready for operation in the excavation heading zones during the entire excavation period.

**8.7.8** The contractor shall bear the whole responsibility for the proper and safe excavation. With the prior approval of Engineer, extra supports and special protection for the personnel when the conditions so require can be provided.

## 8.8 CLASSIFICATION OF UNDERGROUND EXCAVATION

**8.8.1** Excavation

i. This section covers the description of rock mass types and rock classes relevant to the underground excavation with respect to the geotechnical properties of rock encountered and its behavior under the influence of tunnel construction. The terminology "rock" in this context shall also include soil conditions. The rock (ground) classes are derived not only from the rock parameters, but also from considerations of a number of external factors such as overburden, size of excavated section and length of round, driving sequence, ground water, water infiltration, results from geotechnical measurements, etc. which can essentially influence the classification.

According to Ö-NORM 2203 Classification, rock masses are divided into 3 main types which are A, B and C:

- A (Stable to over breaking): Stresses acting on rock mass do not cause major failures
- B (Friable): Disintegration due to structural weakness and/or lack of interlocking
- C (Squeezing): Strength of rock mass is exceeded to great depth; this type also includes rock bursts and swelling rock.

Type of support section required shall be based on based upon behavior of rock masses under load and monitoring the performance of underground excavations during construction.

**ii.** Rock (ground) classes are determined on the grounds of the appearance of the rock at the excavation face of the tunnel before the commencement of the respective excavation sequence. The results of geotechnical measurements under similar rock conditions shall be considered for prediction of deformations and for the determination of rock classes. The aforesaid classifications may not be applicable for a situation requiring multi drift excavation or locations encountering unexpected geological conditions requiring extra measures, for which the support system would be decided by the engineer depending upon the judgement of the rock type being encountered. In case of a drive subdivided into top heading - bench - invert excavation, the rock conditions of the top heading drive shall govern the classification. Following are the various types of Rock mass types and relevant rock mass behaviors.

| **Rock Mass Types** | **Rock Mass Behavior** |
|---|---|
| A1 (Stable) | Minor deformations that decline rapidly, no spalling |
| A2 (Over breaking) | Minor deformations that decline rapidly; some spalling at the crown due to discontinuities |
| B1 (Friable) | Minor deformations that decline rapidly; structural weakness and blasting operations lead to loosening and the separation of blocks in the crown and upper wall |
| B2 (Very Friable) | Deformations decline rapidly; poor structural strength, little interlocking, high mobility of rock mass and blasting operations lead to rapid and deep loosening where unsupported |
| B3 (Rolling) | Excavation even in small cross sections leads to inflow of rock material; lack of cohesion and interlocking are responsible for insufficient stability |
| C1 (Rock Bursting) | Sudden release of energy leads to explosive rock failure |

| **Rock Mass Types** | **Rock Mass Behavior** |
|---|---|
| C2 (Squeezing) | Pronounced deformations that take long to decline; development of failure zones and plastic zones in plastic, cohesive rock mass |
| C3 (Heavily Squeezing) | Large deformations, rapid at the beginning, taking long to decline; development of deep reaching failure zones and plastic zones |
| C4 (Flowing) | Very low cohesion, low friction, soft and plastic consistency of rock mass; material will flow into the tunnel even through very small unsupported areas |
| C5 (Swelling) | Rock mass with mineral content that increases in volume by absorbing water, e.g. swelling clay-minerals, salts, anhydrite |

**iii. SUPPORT SECTION TYPE**

a. **The Support Section Type classes are the Rock Support Type classes given in the Geotechnical Baseline Report (GBR) attached as Annexure-C to Section-5: Works Requirements.**
b. The selection of Support Section Type and its adjustment shall be according to NATM or any other Controlled Convergence Method with observational feedback through3D instrumentation and monitoring.
c. The defined Support Section Type classes reflect the excavation system, the round lengths of each advance and the support requirements under consideration of the behavior of the rock mass.
d. The defined Support Section Type classes are derived not only from the rock parameters, but also from considerations of a number of external factors such as overburden, size of excavated section and length of round, driving sequence, ground water, results from geotechnical measurements, etc. which can essentially influence the classification.
e. The Support Section Type to be applied must be determined on site through Tunnel Face Mapping, 3-D Geo-logging at the excavation face of the tunnel before/prior the commencement of the excavation sequence.
f. The Support Section Type at the face for each round shall be jointly agreed between the Contractor and the Engineer. In case of disagreement, the decision of the Engineer is binding.
g. The results of geotechnical measurements and monitoring during tunnel construction shall be considered for prediction of deformations and for the determination of Support Section Type to be applied for future excavations.
h. The behavior of the rock in a newly exposed round is time dependent, i.e. rock mass quality will decrease with the free span if no support is installed within a reasonable time. Accordingly, the maximum length of a round which can be excavated and supported in time is a criterion for the rock classification.

i. Advance probing shall be carried out during tunnel excavation as and when required, as per instruction of Engineer. During advance probing, joint measurements & collection of data with contractor and Engineer shall be carried out.

j. The selection of the Support Section Type shall be done jointly by Contractor and the Engineer in writing on agreed form-sheets. The classification record is a collection of all classification sheets, which shall be kept accessible for consultation and modification whenever excavation works are under progress/post construction phase. In case of disagreement, decision of the Engineer shall be binding.

k. Notwithstanding the duties of the Engineer, the Contractor is solely responsible for the safety of the works under construction.

iv. The contractor will adopt the round length for each blast as instructed by engineer. The engineer's decision to adopt a round length will depend on the behavior of rock mass in previous few rounds and the Support Section Type required to be installed in the round under consideration. Range of non-overlapping round lengths for various Support Section Types are mentioned in tender drawings.

v. **Variability for Each Support Section Type:** The defined Support Section Type includes some parameters variability (Round length, Support installations and locations) that should be managed during excavation using the parameters like Q Value, RMR Value and Behavior in last few rounds. During execution, the Round length, Support installations and locations may vary on upside or downside from the given values, however only the net effect of all such variations shall be considered.

vi. After each blast, support section required shall be decided by the Engineer and Contractor on the basis of recorded observations. Geological face mapping sheet and Geo-mechanical classification of the excavation which face shall be elaborated by the Contractor and validated by the Engineer. Required Excavation and Support Sheet (RESS) shall be used as detailed in Annexure to Sub- Chapter 6: Instrumentation

vii. Pull for next round will not be taken unless already excavated tunnel section in previous round has been supported to the satisfaction of Engineer.

viii. After each blast, fumes shall be ventilated immediately within 15 minutes and scaling shall be done subsequently to remove loose or hanging rock pieces. Contractor's geologist at the time of scaling shall prepare a tunnel geological map registering joint sets, foliation, joint, infill materials, weak zones etc.

ix. After completion of mucking, a period of 30 minutes and a man lift platform (Employer's half hour) shall be kept ready by the contractor at the excavated face for engineer to check for any loose scaling, visually inspection and checking of rock classification carried out by Contractor and to come to a mutual agreement of the support section to be adopted. In case of any dispute, decision of Engineer shall be final.

x. Immediately after decision on support section, supports shall be installed. The behavior of the rock in a newly exposed round will be time dependent, i.e. rock mass quality will decrease with the free span if no support is installed within a reasonable time. Therefore, contractor is required to respect the cycle time for timely support installation.

xi. The contractor shall document time taken for various activities, blast pattern adopted, charging of holes, blast sequence, geological mapping, scanning of tunnel profile before and after installation of support, actual support installed etc. in any excavation cycle on a shift basis and the record shall be got approved from engineer.

xii. Additional excavation tolerance has already been inbuilt which shall be further established through a system of well documented monitoring observations, during excavation.

xiii. The assignment of an individual support class shall always apply to the whole of the round length.

xiv. For mixed face conditions, applicable support system shall be guided by the conditions representative of more than 50% of the mixed face. Engineer may direct to adopt a different support class also in such conditions. In case of any dispute, decision of Engineer shall be final.

#### 8.8.2 Support System for Tunnels

i. The contractor shall understand and recognize the technical and design concepts of the NATM for the mined tunnels and shall appreciate the function and merits of each component of the tunnel support.

ii. The type and amount of tunnel support to be installed immediately after excavation is directly related to the rock classification as established. The initial support system associated with the established Rock mass types and relevant rock mass behaviors classification is shown on the Bid Drawings for reference. However, as a consequence of variations from the anticipated rock conditions the initial support system as shown on the drawing for each rock mass type may require modifications and adjustment during construction as per agreement between the representative of the Engineer and Contractor. Decision of the Engineer shall be final.

iii. The contractor shall ensure that support elements will be installed or applied is such a manner and sequence as to prevent disintegration and loosening of the rock mass in front and around of the excavated tunnel.

iv. Additional support types like pipe roof, face bolting etc. will be provided at the discretion of engineer in charge.

### 8.9 EXECUTION

#### 8.9.1 General

i. Prior to commencement of excavation, Tunnel portal, Tunnels, junction of tunnels with cross passages shall be strengthened as per construction drawings or as directed by Engineer.

ii. All rock material projecting inside the minimum excavation line shall be removed.

iii. All loose rock shall be removed from the underground construction sites and disposed off in the approved dump areas.

iv. The contractor shall constantly check the progress of excavation by means of Laser survey in order to avoid any substantial rectification of the already opened profile and eventual rearranging of the installed rock supports.

v. Where excessive inflows of water occur at the heading face, the contractor shall take all appropriate measures to execute the excavation work safely and properly including provision of extra supports and protection of workmen and any special equipment necessary for working in waterlogged conditions.

vi. When deemed necessary and ordered by the Engineer, the Contractor shall carry out long exploratory drilling >18 m (other than probe holes) with core recovery as described in Section of "Drilling and Grouting".

vii. The Geological Report, as a part of these documents, contains the results of Geological studies carried out on this component of the Project.

viii. The orientation of the tunnel as indicated on the drawings is subject to modification. It may be necessary to introduce slight shifting of the axes of the tunnel after additional information is available. The drawing showing the final orientation will be prepared by the Contractor prior to start of work and he shall be required to execute the Work as per drawings or as directed by the Engineer.

ix. Sheared or shattered rock zones, foliation shears, thick joints with gouge or other thick discontinuities may be encountered during excavation. Whenever shear zones and poor rock bands are encountered along the tunnel, Additional provisions of fore-poling, pipe roof, face bolting, etc. will be undertaken at once by the Contractor to avoid any cavity formation as shown on the drawings or as directed by the Engineer.

### 8.9.2 Method of Excavation

i. The Contractor shall establish by trial blast and use drilling and blasting techniques, which will produce a smooth final profile a minimum of Overbreak and a minimum of fracturing of the rock beyond the minimum excavation lines. The techniques used shall always be subject to the Engineer's approval, who may direct several blasting tests to be undertaken by the Contractor to substantiate his proposed blast design.

ii. Only controlled blasting techniques shall be used. It shall be performed as described below:

a. Pre splitting: Consists of drilling a single row of closely spaced holes along the final excavation perimeter. These holes are Lightly charged and simultaneously detonated before the main blast to produce a presplit crack, which limits the propagation of crack from the subsequent main blast, and in such a way, reduces damage in the rock beyond it. The blasting of the main excavation zone requires a reduced explosive charge in the line of hole nearest to the presplit line and a limit on the distance between the presplit line and the nearest line of main blast holes. The presplit holes shall be drilled deeper than the depth of the pull.

b. Smooth Blasting: Consist of drilling several closely spaced holes along the final excavation perimeter, placing light charges in the holes and detonating the charges simultaneously after the main blast. The outer line of drill holes for the main blast is set at an approved distance inside the final perimeter leaving an annulus of rock to be peeled off the damaged final excavation perimeter by the smooth blast The smooth blast holes are drilled, charged and blasted in the same tunneling cycle as the main blast.

c. Cushion Blasting: As special case blasting in which considerable air space of stemming surrounds charges in the holes and serves to reduce undesired blast effect on the final excavation perimeter.

iii. During the progress of excavation the drilling and blasting pattern specifically the number and depth of holes, quantity, quality and distribution of explosives, shall be varied as necessary to suit the rock conditions encountered taking into consideration the information obtained from the probe/exploratory holes, the actual drilling work (velocity, color of rinsing water, etc.,) as well as the previous blasting results.

iv. Only wet drilling will be permitted in order to reduce dust in the underground excavations.

v. Perimeter drill holes shall be placed such that the over excavation beyond the minimum excavation line is minimized. The Contractor shall pay utmost attention to obtain a smooth and uniform excavated surface.

vi. Should the entire length of most of the perimeter drill holes not be visible after each round of blasting, the contractor shall make an adequate adoption in the blasting pattern used and submit it to the Engineer for approval.

vii. The depth of a new round shall never exceed that which was determined and approved prior to commencement of basting. The Engineer may order reduction of the adopted round depth if the actual rock condition requires it.

viii. Blasting of new round will not be permitted if no, or insufficient, personnel are available to perform the mucking and subsequent support work afterwards. This applies to Work before holidays, non-working weekends etc.

ix. Blasting that may damage the rock beyond the required excavation lines or the tunnel installations will not be permitted. Any damage to, or displacement of the supports and any damage to, any part of the Works caused by blasting or any other of the Contractor's operations shall be repaired by the Contractor in a manner satisfactorily to the Engineer.

x. No new round shall be blasted until the supports required within the heading zone have been installed.

xi. All loosened material that is Iikely to fall shall be removed immediately following blasting, at frequent intervals during the progress of the Wonk, and finally during the clean-up prior to placing the final tunnel lining.

xii. After excavating, the Contractor shall adequately protect the tunnel invert, surface from damage caused by the construction traffic, should small grain or broken excavation material be used for such protection, it shall be removed prior to placing the final tunnel lining. No vehicular traffic will be permitted over tunnel invert after removal of the protective material.

### 8.9.3 Excavation of Shaft

i. The excavation for shaft if required shall be carried out by using raise borer or raise climber by using drilling and blasting method. Initially a pilot shaft of suitable size but not less than 4 Sq.m in cross section, shall be excavated and then the shaft shall be enlarged to the required size from top to bottom.

### 8.9.4 Cleaning of Excavation Surfaces

i. Even prior to the removal of the bulk of the material loosened by blasting, the contractor shall undertake scaling activities to clean the newly exposed rock surface from loose rock fragments, dust and debris to permit if required, the application of the first lay of shotcrete.

ii. Cleaning shall be done by directing a jet of water or air at the rock face. Compact washable rock shall be cleaned with compressed air water jets. Rock, which is prone to quick disintegration, swelling, heaving or is interspersed with clay filled fissures, shall be cleaned with compressed air only. The cleaning shall be done to the satisfaction of the Engineer.

iii. The cleaning is separate from the cleanup of excavated surface required immediately prior to placing of the final lining described in Section of "Cement Concrete".

### 8.9.5 Tunnel Maintenance

The Contractor shall be responsible for maintaining the completed underground works throughout the construction and contract period. As part of this maintenance, remedial work shall be carried out when repairs are required to the structural or other systems or when grouting is required to stop water inflow.

i. The Contractor shall monitor the tunnel support systems and record any damage to the support systems. If necessary, remedial action shall be taken with temporary propping, including evacuating the area and posting warning signs accordingly.

ii. The Contractor shall, in addition to monitoring the support system, carry out regular maintenance of the underground works, including but not limited to bench marks, 3D monitoring, drainage and pumping systems, light bulb replacement, cleaning, water removal, water pipe maintenance, ventilation system signalling system, communication system, toilets, containers and emergency equipment, and all cabling, transformers and pipes for different purposes and its maintenance, and cable maintenance. Maintenance shall include all repair work required to maintain all equipment in working order.

### 8.9.6 Site Traffic on Final excavation levels

i. (Formation level) for pavement construction shall be protected against any wear or deterioration of rock properties following site traffic by backfilling with rock material excavated in the tunnel or similar, to a minimum thickness of 0.5 meters. The access to the main drainage control shafts shall be possible at any time. These must be protected and marked on the side wall for later recovery.

ii. Pounding water and traffic through pounding water for vehicles or pedestrians shall not be allowed.

iii. Any deteriorated material shall be removed and replaced prior to pavement works as directed by the Engineer.

iv. The backfill material used for protection purposes shall be removed in the main tunnel only until immediately prior to pavement construction works

### 8.9.7 Site Traffic on Invert Support

i. To avoid damage to the Invert structures, these should be duly protected by giving a course constituted of excavated material and having an approximate average thickness of 0.5m. No site traffic shall be allowed to run on unprotected invert structures. Boulders larger than 100mm dia should not normally be used for this purpose.

## 8.10 DISPOSAL OF EXCAVATED MATERIALS

8.10.1 All materials from underground excavation suitable for use as fill concrete aggregates or for other purposes shall be stockpiled on the Site as directed or approved by the Engineer, if the immediate placement in the final location in permanent works is not possible.

8.10.2 Excavated materials, which are not suitable or are in excess of the permanent construction requirements, shall be disposed off as per extent regulations in force.

8.10.3 If additional areas are required for disposal of the excavated material, the contractor shall propose, such area for approval of the Engineer.

8.10.4 The Contractor shall ensure that no excavated materials are disposed off in the stream or at locations, where in the opinion of the Engineer these are liable to be washed away by the floods.

## 8.11 GEOLOGICAL MAPPING

8.11.1 The purpose of engineering geological mapping and follow-up is the documentation of rock and rock mass conditions as encountered during excavation. The documentation shall enable the verification of the suitability of the designed support and excavation measures, the prediction of rock mass conditions ahead as well as the interpretation of results of the geotechnical monitoring concerning ground deformations. After each blast, Mucking and scaling shall be done. After completion of scaling, a period of 30 minutes (Employer's half hour) shall be kept by the contractor for engineer to visually inspect and check the rock classification carried out by Contractor and to come to a mutual agreement. In case of any dispute, decision of Engineer shall be final.

8.11.2 If stand up time of unsupported tunnel is very less, then the mutual agreement on rock classification may be required to be arrived at during mucking and scaling activities for early installation of the required support.

**8.11.3** ENGINEER shall use mapping and related information along with the rock mechanics test and instrumentation monitoring results shall be used to optimize design of the final lining and rock reinforcement for the tunnel (s), shaft, cavern and chambers.

**8.11.4** The Contractor always shall provide adequate lighting, proper ventilation, reasonable access, cleaning and washing of the walls and crowns for checking correctness of mapping by "ENGINEER" representative.

**8.11.5** Documentation:

- **i.** The mapping and documentation of encountered geological conditions during the excavation shall be based on uniform legend and terminology for Rock Types / Rock Mass Types, Discontinuities, Jointing, Water seepage, Weathering, Rock Strength, Behavior of Rock Mass and other features which are needed to be described for complete record.
- **ii.** The documentation of the tunnels shall be based on the mapping of the face and the full periphery mapping method. The full periphery mapping method shall be applied for the permanent walls only. The frequency shall be adjusted to the variability of the encountered ground conditions. In case ground conditions are frequently changing within one round length each round shall be mapped. Each drive which is under construction shall be checked at least once a day.Support types will also be checked during periphery mapping studies.
- **iii.** Face mapping sheets: In general, the mapping shall be performed in a scale 1:100 and shall have a grid of 1 x 1 m for easier drafting, marked with "+". If necessary, details shall be mapped at other suitable scales. Using the uniform terminology, remarks can be stated directly on the mapping sheet or can be referred to the data sheet.
- **iv.** Data Sheets: The data sheet format shall be got pre-approved and shall consist of details like Tunnel, Location, Chainage, Excavation method, Name of mapping geologist, Date and Time, Rock Mass/Types, Discontinuities, Jointing, water, weathering, Behavior, General remarks etc.
- **v.** Vertical and Horizontal Sections: Based on the follow-up of mapping and data sheets, a vertical as well as a horizontal cross section shall be drawn, where the actual mapping results are incorporated continuously daily. The vertical section shall be located along the axis of the tunnel. The horizontal section must be fixed according to the chosen excavation cross section (full face, top heading - bench etc.). In case the tunnel is excavated by top heading - bench excavation the horizontal cross section shall be drawn on the level of the invert of the top heading. Horizontal and vertical scale shall be the same.
- **vi.** The position of the laser beams on the face as well as the steel rib connections may be marked as drafting guides.
- **vii.** Remarks can be stated directly on the mapping sheet or can be referred to the Face Mapping Sheet.

# CHAPTER - 9
# STRUCTURAL STEEL SUPPORT

## 9.1 GENERAL

**9.1.1** The specifications described herein under relate to the work which includes all labour, materials, equipment and services required for the supply, handling, fabrication and installation of structural steel supports consisting of steel ribs and lagging, Lattice girders and Lining stress controllers to be carried out by Contractor in the underground excavation to the shape and dimensions as shown on the drawings.

**9.1.2** Structural steel supports shall be installed either as complementary measure to the previously installed rockbolts and shotcrete when those prove to be insufficient to stabilize the excavation profile, or as immediate supports after excavation in the heading zone when the material encountered in the process of excavation requires such measures.

**9.1.3** Steel ribs shall be furnished complete with bracing, bolts, nuts, washers, plates, tie rods, and other accessories necessary for installation of the supports. Horizontal or bent bracing in the invert may be required in some reaches.

**9.1.4** Precast RCC or steel lagging shall be furnished separately for steel ribs.

**9.1.5** The Contractor, if he considers necessary, may install temporary supports for his convenience and safety of his workmen / equipment during execution.

**9.1.6** The supports shall be bent to the required shape by cold bending process only.

**9.1.7** Minimum buffer stock for one-month quantity as per agreed work's programme of Re-Bars for (size decided by engineer) Steel ribs and lattice girders.However, towards work closure, the contractor may use these quantities with prior approval of Engineer.

## 9.2 SUBMITTALS

**9.2.1** Within 4 (four) weeks from the commencement date but before procuring the equipment or mobilization to the site, the contractor shall submit to the Engineer, the description and drawings showing enough details of the layout, type and capacity of the equipment proposed for the fabrication of steel ribs.

**9.2.2** At least 8 (eight) weeks in advance of the excavation of underground works being carried out on the site, the Contactor shall submit to the Engineer the schedule for fabrication of ribs and the method statement for erection to the engineer for agreement.

**9.2.3** The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.

## 9.3 STANDARDS

**9.3.1** The fabrication and installation of structural steel support shall conform to the following latest Indian Standard or where not covered by these Standard to the equivalent International Standards:

i. IS: 5878 Code of practice for construction of tunnels conveying (Part-IV) water
ii. IS: 800 Code of Practice for general construction in steel.

- **iii.** IS: 814 Covered electrodes for manual metal arc welding of carbon and carbon manganese steel.
- **iv.** IS: 816 Code of practice for use of metal arc welding for general construction in mild steel.
- **v.** IS: 1786 Specification for High strength deformed steel base and wire for concrete reinforcement.
- **vi.** IS 2062 Hot Rolled Medium and High Tensile Structural Steel
- **vii.** IS: 2502 Code of Practice for Bending and Fixing of Bars for concrete Reinforcement.
- **viii.** IS: 2751 Code of Practice for welding of mild steel Plain & Deformed Bars for Reinforced concrete construction.

**9.3.2** In case of conflict between the above standards and the specifications given herein, the specifications shall take precedence.

## 9.4 NECESSITY & DETAILS OF STRUCTURAL STEEL SUPPORTS

### 9.4.1 GENERAL

- **i.** Steel support shall be installed to support crown and wall of underground excavation in all areas where, in the opinion of Engineer, alternative methods of rock supports like rock bolts and Shotcrete shall not provide adequate support either for construction safety or for permanent stability.
- **ii.** The exact requirement for steel supports in any area shall depend on actual conditions encountered as excavation progresses.
- **iii.** The design and details of the steel supports and steel supports accessories, precast RCC or steel lagging, including size, weight, spacing and method of installing in all parts of the excavation shall be subject to review / revision by the Engineer depending upon the rock conditions encountered.

### 9.4.2 STEEL RIBS

- **i.** The steel ribs shall comprise of I-beam or built up sections as shown on the drawings.
- **ii.** Rib splices shall be welded or made of bolted plates in such a manner as not to reduce the section moment of resistance.
- **iii.** Preferably one section size of steel rib profile shall be used for each portion of the Underground Works and the structural requirements due to rock conditions encountered shall be met by varying the spacing of the ribs as directed by the Engineer.

### 9.4.3 STEEL RIB ACCESSORIES

- **i.** Steel support accessories shall include, but not be limited to, collar braces, tie rods, spreaders, liner plates, cribbing, blocking wedges, foot blocks, sills and invert struts which are fabricated from steel plates or sections or other steel products. Steel support accessories shall be used exclusively in conjunction with the steel ribs in the underground excavations and shall be used elsewhere when required by the Engineer.

### 9.4.4 LAGGING

i. Laggings are the longitudinal supporting members placed behind the steel ribs where necessary to support the walls and crown of the underground excavation as indicated on the drawings.

ii. The precast RCC lagging shall generally be used. The RCC lagging shall be of grade M-20 and 150mm X 75mm section and of length to suit the spacing of the steel ribs as indicated in the drawing or as directed by the Engineer. The steel reinforcement in the R.C.C. lagging shall be provided as per drawings. Cutting, welding, placement and binding of the reinforcement steel shall conform to the relevant Indian Standards.

iii. Deleted.

### 9.4.5 Lattice girders

i. The lattice girders shall be installed in a similar manner as steel ribs. Lattice girder segments shall have butt plates and the method of installation shall ensure tight connection of all elements. The accessories of lattice girders like plates, bolts, nuts and washers etc. shall be like steel rib accessories. Lattice girders shall be fully encased in shotcrete. Under no circumstance shall lattice girders be installed under unsupported ground.

## 9.5 EXECUTION

9.5.1 Steel ribs shall be cold bent with an allowance of one percent to the shape as shown on the drawings. Re-shaping of the bent ribs at the place of installation may only be undertaken with Engineer's consent and only if the material properties would not be impaired.

9.5.2 Excavation of the underground works shall be completed true to the lines shown on the drawings before installation of steel ribs. The steel ribs shall be placed at the minimum excavation line and at spacing as shown on the drawings or as determined by the Engineer.

9.5.3 Concrete blocks or steel profiles shall be provided as footing for the steel ribs. Use of timber, as foot blocks shall be strictly prohibited. The footplates shall be of enough size and rigidity. If required, the legs of the ribs shall be anchored to the rock by the rockbolts. Where invert bracing is required, it shall be fixed securely to the lower legs of the rib in such a way that buckling is not induced in the steel rib by the presence of such bracing.In case of invert overbreak, the void between the rock and the lattice girder footing shall be filled with pre-cast concrete slabs / blocks.

9.5.4 Steel sections and plates shall be cut, welded, bolted or otherwise provided to the shapes and dimensions indicated on the drawing or as directed by the Engineer.

9.5.5 Immediately after placing the ribs in a correct position, they shall be interconnected and braced by mean of steel bars or beams in order to prevent any displacement and to maintain spacing. Use of timber spreaders shall be strictly prohibited.

9.5.6 Immediately prior to concreting, casting or spraying, the arches, ties and struts shall be rendered clean and free from deleterious matter.

**9.5.7** The space remaining between the outer flange of the steel rib and the rock surface shall be backfilled immediately, after the rib has been placed, with concrete or shotcrete over the entire circumference of the steel rib in order to provide uniform load distribution. In over excavation, the bulk of the void space may be filled with concrete / shotcrete.

**9.5.8** The Contractor shall duly record the position of all steel ribs installed in order to facilitate drilling operations later on for grouting/drainage purposes etc. Their position shall be marked on the finished concrete lining surface.

**9.5.9** Blocking and wedges used to set the steel may be steel, or concrete blocks.

**9.5.10** Structural steel supports be maintained in position by the Contractor after installation. Any steel ribs installed improperly or damaged by the Contractor's operations shall be adjusted, repaired or replaced as appropriate by the Contractor without delay after notification by the Engineer.

**9.5.11** In case of poor strata, Lagging shall be placed behind the steel ribs where necessary to support the crown and the sides of underground excavations. Where conditions require, it may, supported on the last steel rib, by pushed/pressing and/or hammering into the ground ahead to provide temporary overhead protection while installing the next rib. The space between the rock surface and the lagging shall be backfilled with M15 concrete.Backfilling between rock and lagging with rock spalls, bracing with timber and timber lagging shall be strictly prohibited.

**9.5.12** During work the contractor shall maintain a sufficient reserve of steel ribs complete with all accessories on each work site.

# CHAPTER -10
# ROCK BOLTS AND WIREMESH

## 10.1 GENERAL

**10.1.1** The specifications described herein under relate to the Work which includes all labour, material, equipment and services required for the supply, installation, testing and monitoring of rockbolts, pipe-roofs etc. and also the supply and installation of wire mesh and mesh anchors as specified herein or as shown on the drawings.

**10.1.2** Rockbolts, pipe roofs etc. shall be furnished complete with all accessories and other materials necessary for their installation, stressing and grouting.

**10.1.3** If directed or approved by the Engineer, the Contractor shall supply and install flat steel plates or rolled steel sections to connect together two or more rockbolts.

**10.1.4** The contractor shall maintain on site or have immediately available atleast one month buffer stock as per agreed work programme of any of the support element s i.e. Wiremesh, Self-Drilling bolts, Fiber glass bolts or any other specialised bolts required according to the rock mass classifications and as per drawings. However, towards work closure, the contractor may use these quantities with prior approval of Engineer.

**10.1.5** STANDARDS:

The specifications, production, working etc. shall conform to the following latest Indian Standards or where not covered by these Standards, to the equivalent International Standards. The list is for guidance purpose only. The contractor shall abide by all codes/regulations/ specifications as are deemed necessary for the satisfactory completion of work.

**i.** Indian Standards:

a. IS: 1786 – 1985 (Reaffirmed 2000), Specification for high strength deformed steel bars and wires for concrete reinforcement

**ii.** American Society for Testing and Materials (ASTM):

a. ASTM A36/A36M - Standard Specification for Carbon Structural Steel
b. ASTM C150 - Standard Specification for Portland Cement
c. ASTM C494 - Standard Specification for Chemical Admixtures for Concrete
d. ISRM - Doc.2, Part 1 "Suggested Method for Rock-bolt Testing".

## 10.2 SUBMITTALS.

**10.2.1** At least 8 (eight) weeks prior to the commencement of excavation works, the contractor shall submit, to the Engineer, the details of equipment to be used for testing and installation of Rock bolts / Pipe roofs / wire mesh etc.

**10.2.2** The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.

**10.2.3** Test reports of tensile strength tests and pull out tests, routine pullout tests (IS:11309) shall be submitted immediately within 3 hours after the test is carried out.

## 10.3 GENERAL

**10.3.1** For the sake of convenience, the terms used in the Chapter are defined as follows:

- **i.** Reinforcement Element is a general term of rockbolts, pipe roofs, wiremesh etc.
- **ii.** Rockbolt is a stressed (or tensioned) reinforcement element consisting of a rod, grouted anchorage, and plate and a nut for stressing by giving torque to the nut or for retaining tension applied by direct pull. It is synonymous with "active rock anchor".
- **iii.** Individual rock bolting refers to the installation of reinforcement elements in localized area of in stability or weakness as determined during excavation. It is synonymous with spot bolting.
- **iv.** Pattern Rock bolting refers to the installation of reinforcement elements in a regular pattern over the excavation surface.
- **v.** Water expandable bolts: High-pressure water shall be injected into the steel tube, which causes the steel tube to expand and to form it to the irregularities in the drilled hole.
- **vi.** The reinforcing bar steel used shall be from sources as indicated in the Section – Material for construction. Corroded steel bars shall not be used.

**10.3.2** The following types of reinforcing elements are proposed to be used:

- **i.** SN Bolts: Resin-grouted and cement grouted.
- **ii.** Water expandable bolts.
- **iii.** Self-Drilling anchors as Rock bolts or Fore Poles.
- **iv.** Pipe roofing umbrella.

**10.3.3** The type, length, diameter, inclination and pattern of the rockbolts shall be as shown on the drawings or as approved by the Engineer. The Contractor shall provide manufacturer's test certificate for all batches of rockbolts supplied. At least 5 samples shall have been tested for tensile strength until failure from each individual batch of rock bolts which is marked with the same manufacturer's identification number. All the results of the tensile test shall comply with the specified data of the manufacturer.

**10.3.4** Bearing plates shall conform to IS 2062 and be flat or dished steel plates having minimum dimensions suitable to carry take full load for Rock bolt is installed (Atleast 1 plate of 200x200x12 for 32mm dia bolts and 1 plate of 150x150x10mm for 25mm dia bolts). The washers to be used shall be bevel or hemispherical.

**10.3.5** All surfaces of the bearing plates, nuts, washers and wedges, and threads on the projecting ends of rockbolts shall be protected and lubricated with rust preventive compound.

**10.3.6** Corroded bolts or steel or other elements shall not be used.

**10.3.7** When rockbolts are used in conjunction with wire mesh, the mesh shall be connected firmly to the bolts by means of extra steel plates and nuts.

**10.3.8** Wire mesh shall not be placed between rock and the bearing plate of the rockbolts. Additional plates shall be provided for this purpose.

**10.3.9** Couplers may be required for the bolts. When coupler is used, the threading in the bar shall not reduce the effective diameter of bar. Coupler itself should be able to transfer at least 125 % of the yield load of the bar. Couplers shall not be permitted for rock bolts less than 4m in length.

**10.3.10** Minimum one PVC centralizer per rock bolt shall be provided. In long rock bolts, one centralizer at every 6m shall be provided along the length of the bolt.

## 10.4 TESTING AND MONITORING OF ROCKBOLTS / ROCK ANCHORS.

**10.4.1** The contractor shall furnish atleast two sets of testing equipment including hydraulic jacks, fixing device, hydraulic pump with pressure gauge / manometer, extensometer and all necessary accessories. The testing equipment shall be capable of stressing the largest diameter rockbolt to the yield stress of the bolt.

### 10.4.2 Proof Tests

i. A detailed test program set up on basis ofove-mentionabove-mentioned document shall be approved by the Engineer prior to all testing work.

ii. Specific deviations from the ISRM suggested method shall be approved by the Engineer.

iii. A test report shall be issued immediately after completion of the tests. It shall be submitted for approval to the Engineer.

iv. For each type of rock bolt submitted information shall comprise:

   A. type of bolts
   B. testing equipment
   C. location and installation records
   D. Applied testing loads and records of deformation
   E. Otherwise the evaluation of test results as specified in ISRM's document
   F. Interpretation and suggested action for failed pull-out tests

v. Proof tests shall be carried out for all types of bolts to be used for this project prior to the commencement of tunnelling to demonstrate the effect and the A service capacity of the bolts in the field.

vi. The tests shall be performed in similar geological ground conditions as expected during tunnel drive. The location of the bolts to be tested shall be selected by the Engineer.

vii. A minimum of five bolts of each type shall be tested. Depending on the testing procedure and the test results the Engineer may require further bolts to be tested.

viii. Adequate testing equipment, as specified in the above mentioned ISRM document shall be provided to record bolt elongation, movement of the bolts and tension forces.

ix. The maximum load to be applied shall be the bolt´s yield load or as otherwise approved by the Engineer.

### 10.4.3 Testing during Tunnel Driving:

The Engineer will select rock bolts for testing of production bolts. For each type of rock bolts five bolts will be selected from the first 100 bolts placed in the tunnel. From the remaining bolts five per 500 bolts will be selected for testing purpose. The testing force to be applied shall be equal to 80% of the rock bolt yield load.

- **i.** Bolts which fail the tests, or which are pulled out shall be replaced.
- **ii.** For each failure, the Engineer shall require further bolts to be tested inthe vicinity.
- **iii.** Otherwise as per relevant clause above.

**10.4.4** ***Grout mortar:***Prior to acceptance tests of rock bolts, tests with available cements and sands shall be carried out to determine an appropriate mix design to achieve the specified strength and a proper workability in association with the grouting equipment used. Additives will be used to improve workability. The grout mortar shall be tested on cubes 5x5x5 cm. The cubes shall be cured in water. Five numbers of cubes shall be prepared for each compressive strength test. The resultant strength is the average evaluated from the three remaining values after elimination of the highest and the lowest. During construction, cube sample shall be taken weekly at each five bolts drivage from the grouting hose at the nozzle. Preparation and evaluation shall follow the procedure as described above.

**10.4.5** If any rockbolt fails due to improper workmanship or defect in materials or due to any reason whatsoever, the Engineer may order a test on all adjacent rockbolts and all rockbolts so failing shall be rejected, replaced and retested.

**10.4.6** The bolts and anchors shall be checked for their straightness Tolerance with $\pm$ 1 mm.

**10.4.7** The pullout trials shall be conducted in conformity with IS: 11309.

**10.4.8** Further sampling and testing for quality control will be got done as directed by engineer at contractor's cost.

## 10.5 DRILLING HOLES & PREPARATION FOR INSTALLATION

**10.5.1** Holes for rockbolts shall be drilled as specified herein and in accordance with the provisions set out in Section of "Drilling and Grouting"

**10.5.2** The minimum diameter of each hole shall be as specified below or as directed by engineer:

- **i.** Rock Bolt of 25mm dia: Hole dia 45mm with coupler and 38mm without coupler
- **ii.** Rock Bolt of 32mm dia: Hole dia 64mm with coupler and 50mm without coupler

**10.5.3** The length of drill hole shall be such as to receive the specified rockbolt and to provide for its satisfactory anchorage.

**10.5.4** After drilling, each hole in compact, washable rock shall be washed out with clean water and cleaned by blowing out all drill cuttings and debris with compressed air. The holes in rock, which tend to swell or are interspersed with clay filled fissure shall be cleaned with compressed air only. The compressed air shall not contain any oil or other material preventing the bond.

**10.5.5** Prior to installing the rock bolts, which will be stressed, the rock surface adjacent to the hole shall be prepared for the bearing plate. Only bevel washers shall be used which shall be placed between the bearing plate and the nut, or dished bearing plate and hemispherical washer used to ensure uniform bearing.

**10.5.6** If a rock bolt is not installed immediately after drilling the hole, the hole shall be washed and cleaned as stipulated above, immediately prior to installing the rockbolt.

**10.5.7** Fresh holes, as directed by the Engineer, shall be drilled by the contractor at his expense to substitute such holes as have been drilled out of place or alignment.

**10.5.8** The rock surface around the drilled holes to receive the bearing plate shall be chipped smooth or be covered with a smooth quickset cement pad.

**10.5.9** All bolts within 10 m of a blasting operation shall be retightened to the specified torque within 4 hours after each blast. If it is found that any bolt does not take the required torque without anchorage slip, a new bolt shall be installed in the immediate vicinity of the unsatisfactory bolt.

## 10.6 Installation Records

Comprehensive records about details of the installation of rock bolts during drivage, such as grout consistency, drilling depth, length and type of rock bolts, deviations from the theoretical position, type and time of grouting, time of tightening, special observations, etc. shall be kept for each round by the Contractor and countersigned by the Engineer's supervisory personnel. Copies of these records shall be submitted to the Engineer.

## 10.7 ROCK BOLT RESIN-GROUTED (SN Bolt)

**10.7.1** Rockbolts shall consist of deformed steel bar of 25 mm or 32 mm Ø (Grade Fe-500D conforming to IS 1786). Each bolt shall have one end chamfered and the other end threaded with a coarse thread over a length of 200 mm.

**10.7.2** After the hole is drilled and cleaned, fast setting resin cartridges shall be placed in the fixed length of the drill hole at bottom as determined by the pull-out tests and slow setting resin cartridge in remaining length of drill hole. These cartridges shall be tamped with the bolt for proper packing. The rock bolt shall then be advanced and rotated steadily through the capsules at the rate recommended by the manufacturer by means of a pneumatic tool and a coupling attached to the threaded end of the bolt. The rotation shall be continued after the bolt has been fully inserted for a further 30 seconds. Bolt shall be stressed by torqueing/jacking, by means of an approved and regularly calibrated stressing device to the level as directed by Engineer. The bolt shall be stressed before setting time of slow setting resin cartridges as suggested by manufacturer. The Contractor shall demonstrate the resin cartridges used satisfy the specified strength requirements of the bolts to the satisfaction of Engineer, before use.

**10.7.3** Bolts shall be thoroughly cleaned before being placed in the drill hole.

**10.7.4** The minimum capsule diameter should be proposed for each drill bit dimension, considering that the hole must be fully filled with resin. The drill bit diameter should be defined by the manufacturer, however, as guidance, for a 32 mm resin capsule diameter, the drilling should not be more than 38 mm.

## 10.8 ROCK BOLTS CEMENT GROUTED (SN Bolt)

**10.8.1** Rockbolts shall consist of deformed steel bar of 25 mm or 32 mm Ø (Grade Fe-500D conforming to IS 1786). Each bolt shall have one end threaded with a coarse thread over a length of 200 mm.

**10.8.2** Anchor bars/anchor bolts shall be thoroughly cleaned before being placed in the drill hole. The hole shall be filled with grout constituting 1:1 cement/sand mix with low water cement ratio, by inserting the grout hose to the full depth of the hole and withdrawing as the grout is pumped in. The nozzle shall be kept buried in the grout as the pipe is withdrawn so that air is displaced as the hole is filled. The bolt is then pushed into the hole. Admixtures for fast setting and low shrinkage may also be required.

**10.8.3** In case of coupled rock bolts, partly collapsed boreholes, or major water- flow from the borehole, grouting may be done after installation of the bolt (post-grouting). The hole is then grouted by a special attachment which allows the mouth of the borehole to be sealed whilst the grout is pumped in. Air is displaced from the hole via a tube which is attached to the full length of the rock bolt as it is installed. Grout is then pumped in and the hole can be seen to be full, when grout escapes from the end of the tube.

**10.8.4** The nut of the grouted rock bolts shall be tightened not later than 12 hours after installation to achieve a force at the anchor plate of approx. 20 KN. This force shall be applied by a calibrated torque wrench.

## 10.9 SWELLEX TYPE WATER EXPANDABLE BOLTS

**10.9.1** Water expandable rock bolts shall be manufactured from a mechanically reshaped steel tube with bushing pressed onto the ends, sealed through welding. The bolt shall havean expansion pressure rating of 300 bar and wall thickness of minimum 3mm. The bolt shall have separate protective coating (zinc epoxy/bitumen/plastic/polymer) that isolates and actively protects the steel. The lower bushing shall have a flange to hold a face plate in place. High-pressure water (about 300 bars) shall be injected into the steel tube through a hole in the lower bushing. This causes the steel tube to expand and to form it to the irregularities in the drilled hole. A 200 mm long sleeve tube made of steel prevents the bar from swelling at the drill hole mount. As the swelling process occurs, the lower part of the steel tube shortens, pulling the face plate firmly against the rock face. The water pressure is released after installation and the water allowed draining out of the expanded steel tube. The drill hole diameter has to be adjusted to suit the size of rock bolt according to the Manufacture's recommendations. The water expandable rock bolts shall have characteristic minimum breaking load of more than 150 KN and shall undergo upto 10% minimum elongation before failure.

**10.9.2** All face plates, washers and other accessories used shall be from original manufacturer
of the bolt. Face plates shall be spherical dome type.

**10.9.3** The bolts shall be supplied, installed and tested as per recommended procedure of the manufacturer. Standard pull testing shall be done with pull tester along with it's other parts as manufactured by OEM. Additional bolt material testing, if required, shall be carried out as determined by Engineer in charge depending on site conditions.

## 10.10 SELF DRILLING ROCK BOLTS

**10.10.1** This is a high-grade (Yield load more than equal to 230KN) hollow core seamless steel bar with continuous threaded surface for mechanical coupling. In addition to hollow core seamless steel bar, other parts of the assembly consists of Hexagonal nut, bearing plate, extension couplings and sacrificial drill bit. Before and during installation, thread ends will be kept cleaned to allow hex nut and coupler threadability. Construction and drilling shall be as per manufacturers guidelines.

**10.10.2** SDA Bolts shall have outer dia of minimum 32mm and inner diameter less than equal to 18mm. Length of rod to be procured shall be decided in agreement with engineer.

**10.10.3** Bearing plates shall allow articulation of 5 to 7 degrees in all directions.

**10.10.4** Drill bit to be used shall be selected according to installed length of bolt, geology and size of bolt.

**10.10.5** Couplers and Nuts shall exceed the tensile strength of bars by minimum 20%.

**10.10.6** The bolt shall be grouted according to manufacturer's guideline (to a minimum pressure of 6 bars) with manufacturer's grout material supplied along with bolt. Alternatively, grout mix (M-35 grade) may be prepared using OPC 53 cement and sand having maximum particle size of less than 0.3mm. Grout mix shall have a water cement ratio less than 0.4 and shall contain PC based super plasticizer (Minimum 2%) and expanding plasticizer (allowing upto 3.5% expansion in neat cement) from reputed manufacturer. Admixtures containing chlorides and alkali shall not be used.Face of the Bolts shall be sealed off with GP2 or Similar rapid setting grout to prevent grout leakage during build-up of pressure.

**10.10.7** These bolts may also be used as forepoles.

**10.10.8** All accessories of self-drilling rock bolts shall be suited to the main anchor rod type and shall be procured from original manufacturer of the bolt.

## 10.11 WIRE MESH AND MESH ANCHORS

**10.11.1** WELDED WIRE MESH

**i.** Welded wire mesh shall be installed in surface and underground excavation as reinforcement for shotcrete, usually in combination with rockbolts. It may also be used with steel ribs, when it shall be laid over the outer flange of the rib and pinned or fixed to the excavated surface between the ribs where necessary.

**ii.** Welded wire mesh shall conform to the requirements of IS: 1566. The fabric shall have a minimum square mesh of 150x150x6 or 100x100x4, made of wires having a strength not less than 480 Mpa and diameter 3 to 5 mm or as directed by engineer.

iii. Where possible, the welded wire mesh shall be placed at the same time as rockbolts are installed. It shall not be placed between the rock surfaces and bearing plates of rockbolts but shall be placed over the heads of rockbolts and fastened to them by separate plates and nuts. Sufficient intermediate mesh anchors, or if directed by the Engineer, additional rockbolts, shall be placed to ensure that the mesh is drawn close to the excavated surface so that when shotcrete is applied subsequently, the mesh neither sags nor vibrates excessively and impairs the effectiveness of the shotcrete.

iv. In case the welded wire mesh is placed at such locations where rockbolts have not been provided, wire mesh anchors of a type acceptable to the Engineer shall be used to secure the edges of wire mesh tight to the rock surface to provide anchorage at overlaps and to provide intermediate support. The wire mesh anchors shall have a minimum length of 450 mm.

v. The use of wooden pegs and pins for fastening the wire mesh to the rock surface will not be permitted.

vi. Welded wire mesh shall be firmly stretched between the rockbolts. Care shall be taken to ensure that air pockets are not formed behind the wire mesh, when used as reinforcement for shotcrete. Overlaps in the wire mesh shall not be less than 300mm.

## 10.12 PRE-EXCAVATION SUPPORT MEASURES

**10.12.1** In general, all poor reaches shall be supported by regular supporting measures (Rock reinforcement, shotcrete, Steel Ribs, Lattice Girders, pre-injection grouting etc.) as specified in drawings. However, certain ground conditions may require tunnel support ahead of face before it's excavation. For such situations, **after completion of Pre-Excavation grouting ahead of face**, the advance support measures as described below shall be implemented if required at site as per direction of Engineer.

**10.12.2** Grouting of pre-excavation support measures (Forepoles, Piperoof and Fiber glass bolts):

i. OPC 53 / 53Scement shall be used for grouting.

ii. Cement grout shall attain minimum M20 strength.

iii. Viscosity of grout shall be such that it shall not leak down from vertical holes in the bolt/plate and adheres immediately to rock.

iv. Water cement ratio of cement grout shall be in the range 0.50 to 0.75 as decided by Engineer and 1.5% PC admixture shall be used to increase flowability of grout..

v. Admixture shall be added to achieve the workability required for the operation and prolong the initial set to minimum 1 hour.

vi. Starting pressure for grouting of cement grouted bolt and forepoles shall be 10 bars and grouting shall be continued till sufficient grout take has been accomplished throughout its length.

vii. Face of the Bolts/forepoles/pipes shall be sealed off with GP2 or similar grout to prevent grout leakage during build-up of pressure..

viii. Sufficient numbers of grouting packers shall be available at site to grout same stage of 6m in multiple pipe roofs. Packers will not be disturbed before final setting time of grout.

10.12.3 **FOREPOLING:** Fore poles shall be 25/32 mm diameter self-drilling anchor bars or SN bolts or pipes having outer dia less than 48mm of this sub chapter having length of 6 meters or more. The fore poles shall be placed along periphery of the tunnel inclined at angle and pipe spacing (mentioned in drawings), at the heading face and cement grouted in place as directed by the Engineer.

10.12.4 **PIPE ROOFING:** When ground conditions are such that face cannot be supported by forepoling, then pipe roofing shall be required to be implemented. Pipe roofing consists of high tensile seamless steel pipes(Having a minimum outer diameter of 76mm and a minimum yield load of 1200 KN) conforming to IS: 1611 (Maximum 24 m long) placed along periphery of the tunnel in one or two layers, each layer inclined at angle and pipe spacing (mentioned in drawings) at the heading face or as directed by the Engineer. Engineer may require use of Self drilling 76mm dia pipes. Other pipes of larger diashall be connected to each other by nipple coupling or squeezed connection or seamless butt-welded producing a leak proof connection. Standard threaded connection shall not be permitted. The cement (OPC 53 or other) grouting of pipes shall be done. In case of perforated pipes grouting shall take place in stages using packer in each stage and starting at deepest location first. Sacrificial ring bits should be used. AT-casing system (or similar) shall be used and orientation of drilling shall be guided by means of equipment installed on the jumbo boom.

## 10.13 FIBRE GLASS BOLTS

10.13.1 Fibre glass bolts shall be 32/15 configuration with load carrying capacity of more than 300 KN and shall be grouted immediately after installation.

10.13.2 Fibre glass bolts of other configuration or strength may be used by contractor with approval of engineer.

i. supply and installations.

# CHAPTER -11
# SHOTCRETE

## 11.1 SCOPE OF WORK

**11.1.1** The specifications described herein under related to the work, which includes all labour, materials, equipment and services required for the shotcrete work (plain and fiber reinforced) to be carried out by the contractor under this Contract.

**11.1.2** All shotcrete work shall be carried out in accordance with guidelines specified in this section. The shotcrete work shall be performed to the dimensions as shown on the drawings or as otherwise directed by the Engineer.

**11.1.3** ***Compressive strength of shotcrete shall be met by compression testing of cylindrical cores extracted from Tunnel wall. The sample prepared for testing shall have a 100mm length and 100mm diameter (Equivalent of a cube).***

**11.1.4** The approval given by the Engineer to the Contractor's equipment of their operation or of any construction methods shall not relieve the contractor of his full responsibility for the proper and safe execution of Shotcrete work or any obligations under this Contract.

## 11.2 SUBMITTALS

**11.2.1** Within 28 days from the commencement date, but before procuring or mobilizing to the site, the equipment, the Contractor shall submit to the Engineer, updated and detailed plans and descriptions, of the following:

- **i.** Batching and Mixing Equipment
  - a. Description and details of the equipment, which the Contractor intends to use to determine and control the quantity of shotcrete ingredients and mixing thereof into uniform mixture. This shall also include automatic dosing equipment for various admixtures and fibers. All equipments shall be capable of monitoring and recording the dosage during production process.
- **ii.** Placing Equipment
  - a. Full details, of the equipment to be used for placement of shotcrete (Robotic Shotcrete machine) and details of standby equipment.
- **iii.** Details of methods and equipment which the Contractor proposes to use to control the temperature of aggregates and water during extreme hot and cold weather conditions.

**11.2.2** At least 28 days in advance of any shotcrete work being carried out on the site, the contractor shall submit, to the Engineer the following:

- **i.** Notifications of any admixture and Pozzolana, which the contractor proposes to use, manufacturers thereof and information about the chemical names of the principal ingredients and the effect of under or over dosage.
- **ii.** Description and details of methods which the contractor proposes to adopt for Shotcrete.

**11.2.3** The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.

## 11.3 STANDARDS

**11.3.1** The Shotcrete materials, production, methods of application, testing and admixtures shall conform to the following latest Indian Standard or, where not covered by these standards, to the equivalent International Standards.

**11.3.2** Indian Standards

- **i.** IS: 456 Code of Practice for Plain & Reinforced concrete.
- **ii.** IS: 269 Specification for ordinary Portland cement.
- **iii.** IS: 383 Specification for coarse and fine Aggregates from natural source for concrete.
- **iv.** IS: 516 Method of test for Strength of concrete.
- **v.** IS: 9012 Recommended practice for Shotcrete.
- **vi.** IS: 2645 Specification for Integral cement water proofing compound.
- **vii.** IS: 9103 Concrete Admixtures.
- **viii.** IS: 12269 Specification for 53-grade ordinary Portland cement.
- **ix.** IS: 15388 Silica-Fumes.
- **x.** IS:7861 Code of practice of extreme weather concreting.
- **xi.** IS: 1199 Methods of Sampling and Analysis of Concrete.
- **xii.** IS: 5878 Code of Practice for Construction of Tunnels.

**11.3.3** International Standards have been mentioned at relevant locations in the section.

**11.3.4** In case of conflict between the above standards and the specifications given herein, the specifications shall take precedence.

## 11.4 General

**11.4.1** Shotcrete shall be applied by either the wet process to the circumstances. All aspects of the application of shotcrete shall be subject to the agreement of the Engineer. Particular emphasis shall be placed on the provision of adequate ventilation.

**11.4.2** The Contractor shall develop a shotcrete mix and a plan for its production and application. Specifications of constituent materials shall comply with those listed in this. Admixtures shall be compatible with each other and the mix.

**11.4.3** The shotcrete mix design shall, unless otherwise stated, comply with the characteristic strengths specified by the Designer for early-age and long-term loading.

**11.4.4** Contractor's shotcrete expert should be on site at all times to check that the materials and workmanship are consistent with the design intent, and to ensure that ground and groundwater conditions are in accordance with design assumptions. The Contractor shall establish a procedure to respond effectively to changes in ground and groundwater conditions from the design assumptions.

**11.4.5** The Contractor shall establish and maintain the instrumentation and monitoring required by the design. The Contractor shall establish a procedure that will enable prompt and regular review and effective response to the results from the instrumentation and monitoring. The Engineer shall be included in the monitoring review procedure.

## 11.5 DEFINITIONS

**11.5.1** Shotcrete: Shotcrete for the purpose of this work is defined as wet mix of cement concrete (plain) or fiber reinforced (SFR) applied from a spray nozzle by mean of compressed air. The Engineer may, in exceptional cases, allow use of dry mix for plain shotcrete. Shotcrete shall contain approved additives like Accelerator, Superplasticizer, retarder, stabilizer, Pumpability improving additive or curing agents suitable to attain desired properties as mentioned in these specifications and site conditions.

**11.5.2** Rebound: Rebound is defined as the portion of shotcrete mix or any of its constituents, which bounces away from a surface against which it is being projected.

## 11.6 MATERIAL FOR SHOTCRETE

**11.6.1** Material for shotcrete shall comprise cement, aggregates, fiber, water and approved admixtures, micro-silica/silica fume as specified herein.

**11.6.2** Cement:

- **i.** Cement used shall be ordinary Portland cement of 53/53S grade.
- **ii.** ***For M30 Grade Shotcrete: Minimum OPC 53/53S content will not be less than 385 Kg/cum. Minimum 15 Kg/cum Micro-silica/silica fume will be added to enhance mix durability and reduce life cycle cost of shotcrete.***
- **iii.** Preferably cement fineness shall not be less than 275 $m^2$/kg for OPC 53 and 370 $m^2$/kg for OPC 53S.
- **iv.** Maximum temperature of the cement in the mixing plant silos should be limited to 70°C and it should not exceed 50°C at the time of mixing. Cement should be preferably purchased in bulk and fresh cement shall be stored in a suitable silo.

**11.6.3** Aggregates:

- **i.** All fine and coarse aggregates to be used shall be supplied from approved sources, which shall not be changed without permission in writing from the ENGINEER Aggregates shall conform to the requirements of IS:383.
- **ii.** The aggregate shall be checked for chemical reactions, such as alkali–aggregate reaction, with latent hydraulic binders and admixtures, especially accelerators.
- **iii.** The aggregates size for shotcrete **shall not exceed 10 mm**. The proportion of aggregate larger than 8mm in size should not exceed 10%. The aggregate shall be well graded, and no fraction shall constitute more than 25 % of the total. The contents of the crushed and non-cubical material under 0.1mm shall not exceed 8 %.
- **iv.** Acceptance of source by Engineer shall not be construed as constituting the acceptance of all aggregates to be taken from that source or grading of aggregates to be in conformance with contract.
- **v.** It is the responsibility of the CONTRACTOR to choose the most suitable grading for the process and materials available from the range given in table below. The grain size distribution of aggregates shall be within ±2% for each sieve size as shown below:

| Standard Sieve | Sieve Size [mm] | Passing in % |
|---|---|---|
| IS | 10.0 | 100 |
| IS | 8.0 | 90-100 |
| IS | 4.0 | 73-100 |
| IS | 2.0 | 55-90 |
| IS | 1.0 | 37-72 |
| IS | 0.50 | 22-50 |
| IS | 0.25 | 11-26 |
| IS | 0.125 | 4-12 |

**11.6.4** Fibers: Macro Synthetic fibers shall be used which shall conform to specifications mentioned below.

**i.** The macro-synthetic fibers shall be in accordance with BS EN 14889-2. Fibers shall be dry and free from oil, grease and chlorides and shall be provided with arrangements to deliver anchorage properties. The fibers shall satisfy the following parameters:

| | |
|---|---|
| Class | Class-II (EN 14889-2) |
| Length of fibers | 45-55 mm. |
| Type of handling | Mulchable paper bags. |
| Geometric shape | Regular cross section (More than 0.30mm of equivalent Diameter) fully embossed. |
| Tolerances and sampling | In accordance with EN 14889-2. |
| Aspect Ratio (Length / Diameter) | ≥64 |
| Tensile strength | ≥550 MPa, when tested in accordance with EN 10002-1. |
| Modulus of Elasticity | ≥5 GPa. |
| Quantity of fibers | Maximum 5 Kg/ $M^3$ (E700)<br>Maximum 7 Kg/$M^3$ (E1000)<br>(Subject to mix design/field trials) |

**ii.** Mixing procedure adopted by the contractor should be such that there is no fiber balling.

**iii.** Storage: Fibers shall be stored, handled and dosed in accordance with the manufacturer's recommendations. Generally, this will require them to be stored in dry, sealed containers until ready for use and shall be free from oil, grease, chlorides and deleterious materials which may reduce the efficiency of mixing or spraying processes, or which may reduce bond between the fibers and the shotcrete.

**11.6.5** Air used for spraying shotcrete shall be clean and free of oil.

**11.6.6** Water used for mixing shall comply with IS-456. Water to cement ratio shall be less than 0.43.

**11.6.7** Admixtures: Admixtures conforming to IS:9103 shall be used to develop quick set and high early strength, to ensure good workability, low pumping pressure, adequate slump retention and low rebound as approved by the Engineer, conforming to the requirements of the relevant standards. The proportion of admixtures shall be kept less than 10-12% of the weight of cement or as determined by testing prior to any shotcrete work.

**i.** General

a. Technical criteria, approved documentation, test reports and test certificates shall be furnished to the ENGINEER for approval.
b. Admixtures shall be stored under the conditions specified and recommended by the manufacturers. The related storage Specifications and recommendations shall be presented to the ENGINEER before approval of such admixtures.
c. The manufacturer's safety instructions shall be observed Admixtures shall be free of chlorides such that the percentage of chlorides shall not exceed 0.1% by weight.
d. The required characteristic values and consistency of delivery to the site shall be agreed in writing with the manufacturer of each admixture before commencement of concrete spraying.
e. Written confirmation of the stability of admixtures with the mix water shall be provided prior to commencement of site trials.
f. The content of SO3 shall not exceed 4.8% by weight of total binder content.

**ii.** Accelerators

a. Accelerators are used to produce a fast set and to get sufficient early strength development. Accelerating admixtures shall be compatible with the cement used. The compatibility shall be tested in the laboratory by the Manufacturer and verified by the CONTRACTOR in field suitability tests to achieve the required properties for early and final strength.
b. The accelerator must mix with the concrete in the nozzle and begin the hardening immediately after the concrete hits the rock.
c. Only liquid alkali-free accelerators (pH 2.0 to 8.0 and having alkali content less than 1% by weight $Na_2O$ equivalent) shall be used. Additives based on Lingo sulphates (P agents) shall not be used due to retarding and reduced early strength.
d. The accelerators shall be added at the nozzle and only the minimum quantity of accelerator necessary shall be permitted in normal concrete spraying operations. The quantity shall be determined by site trials, subject to maximum dosage of 7% by weight of cementitious materials. Higher dosages of upto 8% accelerator can be considered subject to establishing the effect of the dosage rate on the medium and long-term strength development on the in-situ concrete. At no stage in the strength

development should the strength of the accelerated mix drop below 0.7 times the strength of the unaccelerated concrete mix.

e. Testing of accelerators and the base mix with respect to acceleration of setting, early strength and decrease of strength at a later age (28 days), shall take place in due time before commencement of concrete spraying.
f. Laboratory testing of the selected type(s) of accelerator shall be carried out at dosages as recommended by the manufacturer, to establish the variability of the above properties with dosage. Accelerators showing excessive variability with dosage will not be permitted.
g. Accelerators shall be selected so that, at the dosage chosen for use in the Works, the characteristic compressive strength of any shotcrete at an age of 28 days can be achieved. Compliance with this clause shall be demonstrated by site trials.
h. Accelerators delivered to site shall be tested at least once every two months for their reaction with the Portland cement used, with particular reference to the setting behavior and strength decrease after 28 days. The stability of accelerators during storage shall be visually inspected at similar intervals. Storage times and working temperature ranges shall be in accordance with the manufacturer's recommendations. The manufacturer's safety instructions shall be observed.

**iii.** Super Plasticizers and retarders

a. Used to reduce the quantity of the mixing water and to improve the pumpability of the concrete. The effects and optimum dosages shall be determined by site trials.
b. The above-mentioned desired properties shall only be attained through superplasticizers.
c. Shall be added at the batching plant to keep the shotcrete mix workable during transportation and to ensure good pumpability to an acceptable low water cement ratio.
d. The influence of the superplasticizers and retarders within the concrete mix shall be checked regularly for setting time, water reduction, and development of strength. These values shall be compared with the results from the pre-commencement trials.
e. Compatibility of superplasticizers and retarders with Portland cements, latent hydraulic binders and accelerators shall be verified by observation and site trials. Traditional retarders shall not be allowed.

**iv.** Hydration control admixtures

a. Hydration control admixtures may be used to control the hydration of the mix as appropriate to expedite construction of the Works. The effects and optimum dosages of hydration control admixtures shall be determined by site trials.
b. Compatibility of hydration control admixtures with Portland cements, latent hydraulic binders and accelerators shall be verified by observation

and site trials. Hydration control admixtures shall be used in accordance with the manufacturer's instructions.

**11.6.8** Additives: Micro-silica or silica fume

i. Micro-Silica or Silica fume shall conform to ASTM C1240 / IS-15388. Contractor shall submit MTC from original manufacturer. Manufacturer shall furnish evidence of factory production control systems.

ii. The performance of the shotcrete mix with optimum dosage of additives shall be determined by field suitability tests. Testing of Silica fume shall be carried out by contractor before or anytime during its usage at discretion of engineer.

iii. Micro Silica/ Silica fumes shall have a bulk density between 600-700 kg/m3. Micro Silica/ Silica fumes shall be added in the mix at the batching plant facilitating the mixing and distribution of fibers to reduce fiber rebound and improve bond between cement matrix and fibers. Dosage of Micro Silica/ Silica fumes shall be as per Mix design subject to minimum 15 Kg per cum of shotcrete mix.

**11.6.9** Curing agents

i. External curing agents and internal curing admixtures shall be allowed to maximize hydration of the cement by reducing uncontrolled water evaporation.

ii. The curing agent selected should not affect the bond of further layers/coatings or be easy to remove. Solvent based curing agents should be avoided

iii. External curing agents are sprayed onto the surface of the shotcrete shortly after it has been applied. When set accelerators are used, an external curing agent should be applied within 15 minutes after the end of spraying. When no accelerators are used it should be applied within 30 minutes.

iv. Internal curing admixtures are special admixtures added to the mix (see 4.6). Compatibility of curing agents with cements, hydraulic binders, accelerators and other admixtures should be verified in site trials. Particular care must be taken to ensure adequate mixing when used in the dry-mix process.

## 11.7 MIX DESIGN AND PROPORTIONING

**11.7.1** The type of shotcrete to be used in a particular location shall be as per drawings and as directed by the Engineer.

**11.7.2** The mix proportions of cement, aggregates, and permitted admixtures in each class shall be determined by the Contractor satisfying the requirements given in Table no. 1 below and shall be subject to the approval of the Engineer. The mixes shall be such as to permit placement without excessive rebound and segregation.

Table-1

| **28-day Characteristic compressive strength of** | **Aggregate size/grading** | **Cementations content, (C) kg/M$^3$** | **Water cement ratio** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| **Cylindrical cores (after applying a factor of 0.85 for In-Situ coring effects)** | | | |
| 30 MPa (Average of 4 consecutive non-overlapping tests) | Size grading: $D_{max}$≤10 mm, Aggregate flattening coefficient ≤20. | Refer para 11.6.2 | ≤0.43 |

**11.7.3** The water content of the mixes shall be limited to prevent sloughing. The water: cement ratio of fresh shotcrete in place shall be less than 0.43.

**11.7.4** Slump of mix shall be kept less than 200mm, as high value of slump will affect fiber distribution in the shotcrete.

**11.7.5** The Mixes shall be such that aggregate gradation and cement content after placing are as those obtained from samples taken from test panels produced from approved trial mixes. All constituents shall be uniformly dispersed throughout the mix.

**11.7.6** Proportioning of aggregates and cement shall be only by weigh batching.

**11.7.7** Moisture content of the combined aggregate at the time of mixing with cement shall not exceed 6 % (Six percent) by weight of the over dry aggregate.

**11.7.8** Mixed material shall be used within 90 minutes after addition of water to cement. This period may be extended by the use of hydration control admixtures, subject to the approval of engineer.

**11.7.9** The addition of fibers shall be at a stage in the mixing suitable for the sprayed concreting equipment. Fibers shall be added and mixed in a manner to avoid clumping and bending of fibers. Any fiber clumps in the mix shall be diverted and removed by means of a screen placed over the shotcrete hopper. Fibers shall be uniformly distributed throughout the mortar matrix without isolated concentrations.

**11.7.10** Approved mix proportions may have to be varied, during execution stage, to obtain required strength of shotcrete, to maintain rebound to the minimum and to meet other requirements of Contract. The Contractor shall notify to the Engineer of all variations to the mixes.

**11.7.11** The Contractor shall carry out all field tests before hand and then propose mix design for shotcrete to meet the requirements of the specifications for prior approval of the Engineer. The quantities of super plasticizers may be adjusted to compensate the slump loss because of fiber. The mix design shall provide the following details for one cubic meter of Shotcrete.

a. Ordinary Portland Cement Kg
b. Microsilica Kg
c. W/C Ratio
d. Aggregate
   i. Natural fine aggregate Size Kg
   ii. Natural coarse aggregate Size Kg
   iii. Crushed fine aggregate Size Kg

iv. Crushed coarse aggregate Size Kg
e. Super Plasticizer Agent Kg
f. Retarder or Stabiiser Kg
g. Internal curing Kg
h. Pumpability iimprover Kg
i. Alkali free Accelerator Kg
j. Fibre (Aspec Ratio/Length) Kg
k. Slump mm
l. Density (Wet) Kg/cum

## 11.8 Equipment

**11.8.1** Details of all equipment to be used shall be made available to the Engineer prior to commencement of site trials.

**11.8.2** The equipment selected and approved by the Engineer will be capable of maintaining the ratio of concrete and accelerator as selected from the trials and approved by the Engineer. The actual ratio of accelerator to concrete selected shall be identified at the nozzle and take into account the filling efficiency of the equipment and the efficiency of the accelerator dosage equipment to overcome the air and concrete pressure at the nozzle while spraying at typical outputs and air flows. ***Contractor shall provide shotcrete machine data in digital formatafter every cycle whenever required by Engineer.***

**11.8.3** Equipment shall be thoroughly cleaned at least once per shift. The spray nozzle shall be checked for wear and where necessary replaced.

**11.8.4** Transport pipes consisting of hoses and pipes shall be designed to convey the concrete efficiently and without leakage or blockage. The transport pipes shall have uniform diameter appropriate to the mix characteristics determined by site trials and be free of any dents or kinks between the shotcrete machine and the nozzle.

**11.8.5** Working area for sprayed concreting shall be well illuminated and ventilated. Dust pollution shall be minimized by choice of appropriate equipment and by means of additional ventilation, water sprays, and by maintaining equipment in good order. Protective clothing and dust masks shall be provided for and used by all persons present during spraying.

**11.8.6** The equipment shall allow for air and water in any combination to be available for preparation of surfaces and/or cleaning of finished work.

**11.8.7** **Recipe of mix shall be entered into PLC control prior to spraying.**

**11.8.8** A boom mounting or similar device shall be provided for the spray nozzle unless it can be demonstrated to the Engineer that the use of such equipment is impractical.

**11.8.9** In particular, the spray nozzle shall be kept as perpendicular as possible to the surface and care shall be taken to achieve a regular properly compacted coating of the correct thickness.

**11.8.10** The shotcrete shall emerge from the nozzle in a steady uninterrupted flow. Should the flow become intermittent for any cause, the nozzleman shall direct it away from the work until it again becomes constant.

**11.8.11** The thickness and position of the shotcrete shall be defined by screed boards, lattice arches, guide wires, depth pins, lasers or other means.

**11.8.12** The site trials shall employ the equipment which will be used in the Works and the constituent materials shall be fully representative of those to be used in the Works. A clean, dry mixer shall be used, and the first batch discarded.

**11.8.13** The equipment proposed for the application of concrete in the Works shall be used for the trial. The trial will establish whether the selected equipment is capable of efficiently mixing concrete, accelerator and air at the nozzle, and be capable of positioning the nozzle at a suitable distance and orientation to the surface geometry of the structure to which the concrete is to be applied.

**11.8.14** During the trials the Contractor will establish the volume of air required to give adequate compaction of the material using the nozzle and conveyance lines selected for the Works. If the delivery equipment or nozzles are to be changed during the course of the works, the volume of air required will need to be verified again. The equipment will be maintained adequately, to ensure that the required volume of air can be maintained while spraying. Air pressure can only be used as a control if the air delivery system is not altered from the original verification trial. No additional taps or restrictions will be permitted to be added into the system without repeating the verification trials.

**11.8.15** The static compressed air capacity measured at the shotcrete pump shall be according to the manufacturer's recommendations and generally as per EFNARC guidelines G 8.3.2 for wet process and G 8.3.3 for dry process.

## 11.9 QUAITY CONTROL AND TESTING

**11.9.1** The Contractor shall enable the Engineer access to the shotcrete Works at all times and shall allow the Engineer access to inspect the excavated ground surface prior to spraying if requested.

**11.9.2** The quality control and testing of shotcrete (Plain and SFR) shall be carried out by the contractor in the presence of Engineer. Tests for Field suitability (to determine mix design) and In-situ suitability (to control quality) shall be carried out separately. Field suitability tests shall be carried out on minimum three test panels for initial establishment of suitable range of accelerator/superplasticizer dosage (All types of Shotcrete), and fibre content of hardened concrete and Energy absorption class (SFR) for the required strength of shotcrete mix. The pressure at which the shotcrete shall be applied to the test panels shall be the same as will be used in actual works at the place of application. Mechanical rebound hammers shall not be used to obtain indirect compressive strength of shotcrete.

i. Control of Fresh shotcrete:

- **a.** Water/Cement ratio: Daily by calculation or test method.
- **b.** Aggregate gradation: Weekly by standard sieving.
- **c.** Accelerator/Superplasticizer: Daily through record of quantity added.

d. Slump: For Each batch separately, measured any time during application, at the pump and should conform within 25mm of the target slump range established earlier and approved by engineer.

e. Fibre content: For fresh shotcrete, one test every 100cum or 500m$^2$ (Whichever achieved first) of shotcrete applied in accordance with EN 14488-7. For hardened shotcrete, testing shall be done when testing energy abortion capacity.

f. Early (0-24hrs) strength development: Strength results shall conform to Class J2 as per EN-144887-1 unless specified otherwise in the design drawings. In-situ test shall be carried out every 250m$^2$ of shotcrete applied subject to minimum 2 test per month in accordance with EN 14488-2 (Strength up to 1.0 N/mm$^2$ shall be determined by Penetrometer and in the range between 1.0 and 16 N/mm$^2$shall be determined using the HILTI shot bolt method).

ii. Control of hardened shotcrete:

a. In-situ strength shall be carried out on shotcrete applied at the tunnel face and shall be determined by crushing of cylindrical shotcrete specimens. Samples shall be collected with core drilling equipment from In-situ shotcrete applied on tunnel wall/or from test panels as the case may be, after lapse of 1 day. Cores for strength testing shall be obtained from random locations. The cores will be visually inspected and the dimensions and comments regarding the quality of the cores will be recorded. The cores will be free from lamination. No sets of cores to be tested at any given age shall come from the same panel/In-situ location. Sets of cores to be tested at different age may come from the same panel/In-situ location. For each test at least one spare specimen shall be provided. The cores for determination of strength shall be cured in temperature-controlled water until 3 days before further testing. The specimens shall have a diameter of 100mm and be cut to a height of 100mm. Where the nominal required shotcrete thickness is less than 100 mm, the cores for the compressive strength testing shall be taken from areas where the actual thickness is greater than 100 mm. Alternatively additional shotcrete thickness shall be applied in selected areas agreed by the Engineer for subsequent coring of test specimens.

b. Further (1-7days) Strength Development: Average strength of 3 cores tested at 3 days and 7 days each shall exceed 12.5MPa and 70% of 28-day strength requirements respectively. The ENGINEER may also require the drilling of cores from the test panels perpendicular to the spraying direction.

c. Final strength: 3 cores shall be further tested at 28th day and at completion of 6 month each and the 28-day strength obtained shall exceed 28-day strength requirementsmentioned in Table-1 at 11.7.2. Strength results at 6 months shall not be less than 28-day results.

d. Energy absorption class for Fibre Reinforced Shotcrete: Field suitability tests shall be conducted to ascertain the fiber content required for different energy absorption classes. One test every 100cum or 500m2 (Whichever achieved first) of shotcrete applied in accordance with EN 14488-5. Two classes are required to be designed i.e. E700 and E1000. The design shall be considered satisfactory when each test result exceeds the required energy absorption value by a margin of 5% or more. Fibre content of hardened concrete shall also be measured in accordance with EN 14488-7. These tests shall be performed on site in contractor's field laboratory setup for this purpose. No extra cost on account of testing shall be payable to the contractor.

iii. Shotcrete thickness: In addition to recording tunnel wall profile before and after shotcrete by tunnel profiler etc., the contractor will be required to undertake confirmatory shotcrete thickness testing of the in-situ tunnel lining. The basic test shall consist of 4 nos. drill holes drilled on a $1m^2$ pattern. The average thickness of the 4 holes shall exceed the specified design thickness. If not, the ENGINEER shall propose remedial measures and/or further drill testing. All such drill holes shall be subsequently filled back by Non shrink mortar. Nothing extra shall be paid on this account.

iv. Bond Strength

Bond strength of shotcrete shall be tested every 1250m2 (in case of Ground strengthening) or min 3 tests (in other cases) of the shotcrete applied in accordance to EN 14488-4. Bond strength between plain shotcrete and fiber reinforced shotcrete shall also be established.

v. Contractor shall keep at site various testing tools like Penetrometer, HILTI shot bolt, Shotcrete core cutter, Test panels etc. along with all spares required as per standards and specification mentioned above. The frequency of testing, test type or the testing method will not be altered without approval of Engineer. Shotcrete from both the field suitability test panels and the In-situ quality control shall be tested by the Contractor in the presence of Engineer. Engineer may ask contractor to undertake further tests for examination purposes.

**11.9.3** Dimension, tolerances and sampling of fibers shall be in accordance with EN 14889-2. Criterion for Tensile strength, Ductility and Modulus of Elasticity have been specified earlier. Furnishing evidence of manufacturer's factory production control system meeting requirements of EN 14889-2 and EN ISO 9000 shall be mandatory and sufficient for QC of fiber, however the contractor shall be ready to demonstrate the same by carrying out initial type tests (EN 14889-2) in approved laboratories as required by engineer before or anytime during usage. No payments for conducting these tests shall be made by the employer.

**11.9.4** The Contractor shall propose to and agree with the Engineer trial mixes for the works at least 56 days before their commencement. Tunneling shall not be permitted to start until the Field suitability tests have been approved by the Engineer.

**11.9.5** The site trials shall be repeated if the source or quality of any of the materials, mix proportions or placing equipment is to be changed during the course of the Works.

**11.9.6** Where shotcrete does not comply with the required strength, the Contractor shall execute remedial work which may involve additional shotcrete or replacement in sections where it is safe to do so. The Contractor shall take into account any limits placed on the tunnel profile dimensions resulting from the Specification. The Contractor shall submit to the Engineer for agreement, a method statement, specification and calculations for remedial work. The Engineer shall, in the event of repeated failure in Quality Control, require the Contractor to adjust the mix to achieve the required strength.

**11.9.7** The Contractor shall keep a record in a form to be agreed with the Engineer of all tests on shotcrete, which shall be kept on site identifying the tests with the section of work to which they relate.

## 11.10 ROBOTIC SHOTCRETE MACHINE

**11.10.1** Shotcrete shall be carried out by Robotic shotcrete machine.

## 11.11 PLACING OF SHOTCRETE

**11.11.1** Rock or previously applied shotcrete surfaces to be shotcrete shall be carefully cleaned of all loose material, scale and other contaminations. It may be necessary to use compressed air and a water jet. The surface to receive shotcrete shall be damp but shall not exhibit free water.

**11.11.2** Where groundwater flow could interfere with the application of shotcrete or cause reduction in the quality of shotcrete the Contractor shall take all action necessary to control groundwater. Such action shall include the channeling of water by means of pipes and chases.

**11.11.3** The optimum distance between nozzle and surface of application is 1.5 to 2.0 meter. The nozzle shall be positioned at right angles to the surface of application.

**11.11.4** For vertical and near-vertical surfaces application shall commence at the bottom and the leading edge of the work shall be maintained at a slope. Downward spraying shall be avoided where possible. The nozzle may be inclined sufficiently to ensure reinforcement is properly embedded.

**11.11.5** If the design thickness must be applied in more than one layer, then the previous layer must have developed sufficient strength to support the additional layer(s). Lattice girders, roof ties, wire mesh and other reinforcement shall be embedded in shotcrete as shown on the drawings. The minimum cover of wire mesh and re-bars applied at the inner side of a tunnel lining shall be 2 cm or as shown on the drawings.

**11.11.6** Prior to continuation of spraying from a joint or leading-edge position or in any other circumstances where shotcrete has hardened beyond its initial set, loose material shall be removed by jetting with a compressed air lance. Any laitance which has been allowed to take final set shall be removed and cleaned by jetting with air and water.

**11.11.7** If more than one layer of reinforcement is used, the second layer shall not be positioned before the first one is embedded and covered with shotcrete. Exemptions are to be approved by the ENGINEER.

**11.11.8** The temperature of the mix before placing shall not be below $15^0$C and shall not exceed $35^0$C unless special provisions are made. Spraying shall not be undertaken when ambient temperature is below $15^0$C unless special measures can be taken to provide protection against frost until the shotcrete has developed a compressive strength of at least 5 MPa.

**11.11.9** A system of delivery notes shall be maintained to record the date, the time of mixing, mix design number, quantity, delivery point, time of delivery and completion of placing. The delivery notes shall be available to the ENGINEER for inspection.

**11.11.10** Rebound shall be removed immediately after finishing of each shotcrete application. In particular at horizontal shotcrete connections due to separate excavation sequences and at all construction joints the rebound shall be removed, if necessary, by pneumatic hammers, prior to further application of shotcrete.

**11.11.11** Under no circumstances rebound material shall be worked back into the construction. The work shall be continuously kept free of rebound material.

**11.11.12** Measures to establish the thickness of shotcrete shall be set up by the CONTRACTOR and approved by the ENGINEER. These may include visual guides installed prior to shotcrete, holes drilled after completion of shotcrete or a full control by laser scanning.

**11.11.13** Shotcrete shall be left in its natural finish without further working except as required to trim excess thickness where the shotcrete shall be allowed to stiffen sufficiently before being trimmed with an approved cutting screed.

**11.11.14** If deemed necessary by the ENGINEER, curing of the shotcrete shall be performed by water spraying or other appropriate measures subject to the approval of the ENGINEER in the first 48 hours after application.

**11.11.15** Major ground water seepages shall be drained off or sealed off by grouting prior to spraying or after application of a first sealing layer.

**11.11.16** Construction joints or stop joints shall be provided, as directed by the Engineer and shall be sloped at $45^0$ to the adjacent shotcrete surface in a clean, regular edge. Before placing the adjoining work, the sloped portion and adjacent shotcrete shall be prepared as specified in clauses above.

**11.11.17** Before a succeeding layer of shotcrete is placed, the preceding layer shall be checked for defects. Areas of work shall be properly compacted and bonded and free from honeycombing, laminations, dry or sandy patches, voids, sagged or slumped material, rebound, excessive cracking and overspray.

**11.11.18** Where defects occur, the Contractor shall agree with the Engineer proposals for the removal of the defective material and replacement by material without defect and the area to be replaced shall in any event be not less than 300mmx300mm at such locations.

**11.11.19** Gloves and necessary protective clothing shall be worn to protect against dermatitis.

# CHAPTER -12
# DRILLING AND GROUTING

## 12.1 SCOPE OF WORK

**12.1.1** The specifications described herein under relate to the Work of drilling and grouting, which includes all labour, materials, equipment, accessories and operations and required for the performance of drilling grout holes, holes for rock bolts/anchors and instrumentation, washing and water pressure testing of grout holes and supplying, transporting, storing, mixing and injecting grout materials and additives for consolidation and curtain grouting including void filling/contact grouting within the underground constriction sites and from surface, at locations shown on the drawings or where directed by the Engineer.

**12.1.2** Grouting operations shall include the following:

- **i.** Contact grouting: To fill voids between final concrete lining and primary support system applied to rock surface.
- **ii.** Consolidation grouting, of the rock surrounding the excavated hollow space, which shall commence after placing of the concrete lining/shotcrete and completion of contact Grouting.
- **iii.** Consolidation grouting in the heading zone during excavation to consolidate the heading face before further advance in zones of sheared and disturbed material and/or in zones of high-water inflow.
- **iv.** Fill grouting, ofkarstic cavities, drainage trench, conduits and sump pits, and of exploratory drill holes and drain holes.
- **v.** Crack grouting, to seal open cracks and joints in the structural concrete lining.
- **vi.** Chemical grouting in zones of fine sand and soils, and to control the water inflow and increase the stability and strength of the formations that are too tight to be grouted with a cement grout.
- **vii.** Compensation grouting: Pre-injection of grouting at a controlled pressure prior to tunneling permeate the area to avoid deformations due to tunneling activities

**12.1.3** The final number, length, location and inclination of the drill holes, as well as the composition and consistency of the grout mixes, grouting pressures pumping rates and sequence in which the holes are to be drilled and grouted shall be governed by actual conditions encountered on site and shall be at all times subject to approval by the Engineer.

**12.1.4** Contractor shall follow the grouting strategy as approved by Engineer.

**12.1.5** Contractor shall maintain one-month buffer stock of grout materials as per agreed programme or as directed by Engineer.

## 12.2 SUBMITTALS

**12.2.1** At least 14 days prior to the start of grouting works, The Contractor shall provide a grouting method statement for the Engineer's agreement. The proposals shall include details and location of the mixing plant and grout pump, mix design and constituents, pumping rates and pressures, injection points, methods of monitoring, recording and controlling the sequence, preventing grout leakage and reconciling the volume of grout placed with the theoretical volume required, including specifications of all equipment, tools and all grouting materials to be used, and qualification and experience of the proposed personnel.

**12.2.2** Grouting shall be carried out by operatives skilled in the work and notified in advance to the Engineer. They shall produce evidence of satisfactory performance on projects where the purpose of the work and extent was comparable. The skilled operatives shall further undergo training from OEM whose equipment is being proposed to be used at site.

**12.2.3** An overall drilling and grouting Program shall be drawn up jointly between the Contractor and the Engineer. Grouting mixes, pressures, pumping rates, and sequencing will be selected, subject to modifications, to meet local conditions encountered during the performance of the work. Grouting works shall be planned in such a manner that they can be carried out according to the approved plan concurrently with other activities.

**12.2.4** The Contractor shall decide and consult with the Engineer details of the proposed grouting scheme including:

- **i.** Information and case records to support the grouting proposed in respect of its ability to penetrate the strata and its ground enhancement effect.
- **ii.** Specific criteria to measure the adequacy, sufficiency or completeness of the ground treatment.
- **iii.** Details of the treatment zone and grout injection patterns with respect to the Works and adjacent structures.
- **iv.** Details of plant proposed.
- **v.** Method statement and programme including arrangements for storage of materials, mixing grout, Quality Control of grout, recording grouting pressures and grout take and tests to prove the efficacy of the grout in the ground, health aspects associated with the materials and grout proposed at all stages of the process and during excavation of treated ground, and means of protecting persons from any adverse effects
- **vi.** An assessment of the environmental impact of the materials and methods proposed.
- **vii.** An occupational health risk assessment, including methods of risk reduction on all aspects of the grouting operation.

**12.2.5** Contractor shall record grouting pressures and flows and produce ongoing assessments of the grout performance in relation to the requirements of grouting objectives.

**12.2.6** During the performance of the grouting works the contractor shall keep complete daily records of all grouting operation which shall include the following:

- **i.** Number and location of the drill holes.
- **ii.** Results of water pressure tests.
- **iii.** Grouting method.
- **iv.** Date and time of commencement and of each change in grouting operations.

v. Rate of pumping.
vi. Grouting pressures and gauge reference number.
vii. Water-cement ratio and its variations.
viii. Quantities of cement, sand, bentonite, fly ash, admixtures and chemicals used.
ix. Connections, if any, with other holes and cracks, as well as any surface leakage of water or grout. Location, how caulked and the success of caulking shall be described.
x. Number of holes and depth of holes left for re-drilling.
xi. Time of completion.
xii. Name of the Foreman in-charge.

**12.2.7** Grouting reports in an approved form shall be compiled from these records and submitted to the Engineer for approval. Results of water pressure tests and grout intakes shall be presented graphically. The above reports shall also cover the interpretation of the test results and the actions proposed to be taken by the Contractor for improving the quality of grouting pattern.

**12.2.8** The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.

## 12.3 STANDARDS

**12.3.1** Materials for grouting and performance of grouting works shall conform to the following Indian Standards or where not covered by these standards, to the equivalent International Standards:

i. IS: 12269 Specification for 53 grade ordinary Portland cement.
ii. IS: 383 Specification for coarse and fine Aggregates form natural source for concrete.
iii. IS: 5529(Part-II) Code of practice for in-situ permeability tests.
iv. IS: 5878 (Part-VII) Code of practice for construction of tunnels conveying water: Grouting
v. IS: 9103 Concrete Admixtures: Specification
vi. IS: 6066 Recommendations for pressure grouting of rock foundations in river valley projects.
vii. IS:10874 Portland Micro-Fine Cement Specification
viii. IS:14343 Choice of grouting materials for alluvial grouting

**12.3.2** In cases of conflict between the above standards and the specifications given herein, the Specifications shall take precedence.

## 12.4 DEFINITIONS

**12.4.1** Cement grout

i. Cement grout is defined as a mixture of cement and water with the addition of admixtures (sand and bentonite, if directed by engineer), which is forced under pressure into prepared holes or pipes in order to fill voids or consolidate the rock mass as a whole.
ii. Cement grouts are subdivided into stable and unstable mixtures:

a. Unstable mixtures are simple suspensions of cement in water. These suspensions are homogeneous as long as they are in movement and the sedimentations starts as soon as the movement is stopped.
b. Stable mixtures are colloidal suspension dissolved in water of which grain size is so small that no appreciable sedimentation occurs during the grouting operation. These suspensions are obtained by high speed mixing of cement with addition of bentonite.

**12.4.2** Chemical Grout is defined as mixture of two or more solutions which combine chemically and form a gel or a solid matter, the solutions may react either prior to pumping into, or within the void. The chemicals may be used in combination with cement or other grout as determined by testing and approved by the Engineer.

**12.4.3** Single-Stage Grouting is carried out by introducing the grout at either the collar of the hole through a nipple or by means of a grout supply pipe at the bottom of the hole. The entire length of the hole is grouted in one operation.

**12.4.4** Multiple Stage Grouting

i. Multiple stage grouting is carried out by introducing the grout into a predetermined section of the hole, which is blocked off by a packer. The grouting of the entire length of hole is performed in successive stages either in ascending or descending arrangement.
ii. The terms ascending or descending arrangement mean the sequence of the grouting stages, either from bottom to the collar of the hole or in reverse, irrespective of the effective direction of inclination of the hole.
iii. When grouting is done in ascending arrangement, the hole is drilled to its full depth, washed out, and the packer is set at the top of the deepest section to be grouted at the required pressure through the grout supply pipe. The packer is allowed to remain in place until there is no backpressure and then withdrawn to the top of the next section to be grouted. The water pressure testing and grouting is repeated successively, section by section, until the entire length of the hole is filled with grout.
iv. When grouting is done in descending arrangement, the work is accomplished in section from the collar of the hole. The hole is drilled to a limited depth, washed out and the packer is set just above the section to be grouted. The section is then water-pressure tested and grouted at the required pressure. The grout within the hole is removed before it takes a hard set while the grout surrounding the hole is allowed to obtain its initial set, before the holes is drilled to an additional depth. Repeating thus successively drilling, water-pressure testing, and grouting at various depths until the entire length of hole is completely drilled and grouted.

**12.4.5** Split spacing Grouting means the system of locating an additional grout hole approximately mid-way between two previously drilled and grouted holes.

**12.4.6** Water Cement Ratio is the proportion by weight of water to cement in a water-cement mixture.

## 12.5 GENERAL

**12.5.1** During drilling, grouting, washing and pressure testing operations, the Contractor shall keep concrete and rock surfaces free and clean of oil, grease, drill cuttings, grout, cement, excess of water or any kind of waste. At all times during the progress of Work pertaining to this item, contractor shall protect all open drill holes from becoming plugged or filled with oil, grease, drill cuttings, grout or waste. The contractor shall clean up and remove all waste in each area on completion of the work.

**12.5.2** Before starting the grouting, the contractor shall give due notice thereof to the Engineer, to enable him to be present during the grouting operations, which shall always be done in his presence.

**12.5.3** The grout mix that might flow out or otherwise get spilled on the concrete lined surface shall be removed expeditiously without allowing any time for the grout to set on the concrete surface.

**12.5.4** After finishing of grouting, each grout hole shall be re-drilled to ⅔rd of theoretical lining thickness and fitted with dry pack mortar.

## 12.6 SAMPLING AND TESTING

**12.6.1** The Contractor shall provide samples of materials and prepare trial mixes as directed by the Engineer and test in the presence of Engineer at least 30 days before the commencement of any grouting. The materials for use in grout mixes shall be tested with applicable requirements stipulated in these specifications.

**12.6.2** The Contractor shall carry out the following tests:

**i.** Laboratory Tests

a. Grain size distribution and moisture content of sand and bentonite, including aerometer analysis.
b. Atterberg limits.
c. Chemical analysis of water and solids.
d. Compressive strength.
e. Viscosity (by fan-viscosimeter and Marsh cone).
f. Density.
g. Decantation and setting time (by Vicat needle).
h. Shrinkage of grout.

**ii.** Field Tests.

a. Density by hydrometer or mud balance.
b. Viscosity by marsh cone.

**12.6.3** All Chemical grouts shall be tested in NABL approved laboratory under conditions identical to those to which they will be subjected in the field, in order to determine the suitability of various chemicals and proportion of the ingredients to satisfactorily complete the work.

**12.6.4** During the actual grouting operations, contractor in the presence of the Engineer will carry out tests on grout mixes at the same time as grouting, and will plot values of viscosity, sedimentation limits, compressive strength, and maximum viscosity possible for the grouting on a diagram. The frequency of testing will be once for each grouting jobsite or until acceptance criteria have been met.

However, if a significant change in the cement source occurs, sampling and testing shall be repeated.

**12.6.5** Further sampling, testing and quality assurance will be as per approved 'Quality Assurance programme submitted by the contractor.

## 12.7 GROUTING MATERIALS

**12.7.1** All grouting materials shall require approval of engineer before their application. Contractor shall arrange to carry out all testing required to the satisfaction of engineer before seeking any approvals.

**12.7.2** General

i. The following kinds of grout mixes shall be used:
   a. Cement grouts (OPC 53/53S and OPC based Micro/ultrafine cements).
   b. Mineral grouts (Colloidal silica or Polyurethane).
   c. Combination grouts: Combination of any of the above-mentioned grouts.
   d. Admixtures (like super plasticizer, accelerators, Micro silica/Silica fume etc.) shall be added in dosage required to achieve its benefits.
   e. Only PC based super plasticizers and alkali free liquid accelerators shall be used with OPC 53/53S, MFC, UFC etc.

ii. All cement based grouts shall use required dosage of super plasticizers (PC based and minimum 1.5% of cement weight), accelerators (1-2% if required), Micro silica/Silica fume (1-2% if required) and other additives and shall be tested on site to achieve following properties. The tests shall be performed both initially (for design approval) and subsequently just after preparing grout for injecting into strata (Once for each type of grout mix per shift):
   a. Marsh cone time of less than 35 seconds. (IS: 14343 Annex-A)
   b. Bleeding of less than 2% till 2 hours. (IS: 10874 Annex-C)
   c. Initial setting time of more than 120 minutes. (IS: 4031 (Part-5))
   d. Final setting time of less than 240 minutes. (IS: 4031 (Part-5))

iii. At few locations engineer may direct the contractor to adopt lesser setting times also. This will be achieved by increasing the dosage of accelerator.

iv. The use of toxic chemicals such as acrylamide/Poly-acrylates shall not be permitted for use in the works. Pre-blended cements shall not be permitted.

v. Cement (OPC 53/53S, MFC, UFC) shall not be older than 3 months/Manufacturer's specified shelf life at the time of usage.

**12.7.3** OPC 53/53S grade Cement

i. The cement shall conform to requirements of Section of "Materials for Construction" and relevant standards and shall be free from lumps. Any cement containing lumps and foreign matter detrimental to the results of grouting shall be rejected by the Engineer.

ii. Additionally, OPC 53 and OPC 53S used for grouting shall have Blaine value not less than 275 $m^2$/kg and 370 $m^2$/kg respectively.

**12.7.4** Micro Fine Cement (MFC) shall conform to IS:10874, additionally;

i. Micro fine cement should have specific surface (BET method IS: 15388) more than 600 $m^2/kg$ and $D_{95} < 15\mu$. Original MTC to be submitted for approval of engineer before usage. Contractor at his own cost shall get the same tested from 3rd party at direction of engineer.

**12.7.5** Ultra-Fine Cement (UFC) shall conform to IS:10874, additionally;

Ultra-Fine Cement should have specific surface (BET method IS: 15388) more than 900 $m^2/kg$ and $D_{95} < 12\mu$. Original MTC to be submitted for approval of engineer before usage. Contractor at his own cost shall get the same tested from 3rd party at direction of engineer.

**12.7.6** Colloidal Silica (CS):

i. Colloidal silica shall be environment friendly, highly stable and having ultralow viscosity of less than 6 mPA.s at $25^{o}$c.

ii. Gel time of Colloidal silica shall be adjustable from 60 minutes to 10 minutes by increasing the accelerator dosage.

**12.7.7** Water

i. Water shall not contain more than 2 parts per thousand of suspended colloidal solids and no particles larger in size than the cement particles. It shall not be aggressive. The chloride content shall be less than 50 mg per liter and the sulphate content less than 100 mg per liter.

ii. The temperature of water used for the preparation of grout shall not exceed $25^{0}$c.

**12.7.8** Admixtures

i. Admixtures shall be added to grout mixes to optimize the strength, viscosity, density, decantation, setting time and shrinkage.

ii. Only admixtures proved by testing prior to the start for grouting shall be used. Manufacturer's certificates or guarantees will not be accepted as relieving the contractor of his responsibility for the suitability of any admixture. Admixtures shall conform to the relevant IS code.

iii. Liquid accelerators shall be alkali free and if required shall be added only through dedicated nozzle into the grout line at the face (1-2% by weight of cement).

iv. Super plasticizers shall be PC based only (minimum 1.5% by weight of cement).

v. Micro silica/Silica fume shall be added 1-2% by weight of cement if required.

**12.7.9** Polyurethane (PU)

i. The products used in chemical grouting should be non-toxic, solvent free, eco-friendly and present low viscosity. Polyurethane foam resins, polyurethane resins and silicate foam resins can be used depending on the purpose and aim of the grouting.

ii. Polyurethane (combined systems) shall be used for consolidation of the sheared or disturbed rock, loose material, or for making the ground impermeable against water inflow even under high pressure. PU is two component system having high fire resistance, low flammability and extremely fast curing. The system should be capable of being designed to behave as foaming or non-foaming in the presence or absence of water.

iii. For consolidation grouting: A polyurethane resin with low viscosity, a large penetration factor and high compressive strength should be used. Foam factor should be less than 4 (4 times its original size).

iv. For waterproofing and control of high ingress of groundwater: A polyurethane foam resin with low viscosity and a large foam factor (approx. 40) with a fast reaction in contact with water should be used.

v. Accelerators should be used. The ratio accelerator/resin should be tested and calibrated in a trial test to optimize the penetration rate according to the needed depth of the treatment.

vi. It is advised to test the optimized mix for a situation where a weak sheared/fault zone is bearing high inflow and a quick stoppage of the water is required at the same time that a consolidation of the rock. A high foam factor reacts rapidly with the water but reduces compressive strength and decreases penetration capacity. Thus, a trial test should be carried out to define the best combination for each situation.

vii. The results of these tests should be confirmed with core drillings to evaluate the penetration capacity of the resins.

**12.7.10** Other Chemicals

i. When other chemicals are required or proposed, they shall be accompanied by the manufacturer's certificates that they have been commercially used with satisfactory service in the similar type of work. The storage, handling and usage shall be strictly with the manufacture's printed instructions.

## 12.8 GROUT MIXTURES

**12.8.1** The type of grout and proportions of various constituents in the grout mixtures shall be as directed by Engineer and shall be constantly adapted to the conditions on the site as the Engineer may direct.

**12.8.2** Any grout mixture not used within one hour after mixing shall be rejected.

## 12.9 DRILLING AND GROUTING EQUIPMENT

**12.9.1** General

i. Only modern, properly operating drilling and grouting equipment approved by the Engineer and operated by trained and experienced crew shall be used for the performance of the work.

ii. Drilling equipment of the rotary or percussion type shall be used to perform the drilling as specified herein and as required by the Engineer.

iii. Percussion type drilling equipment shall be equipped for continuous washing of holes during drilling.

iv. All Drill booms on jumbo shall be equipped with sensors to record measurements while drilling (MWD) to record the drilling data.

v. The washing and water pressure testing plant shall include pumps, gauges, valves and all other accessories necessary to complete the works as specified. The pumps shall be of the gear, centrifugal or other acceptable types and shall be capable of maintaining constant pressure. The contractor shall supply water storage tanks sufficient for the pumps in addition to flow meters and pressure gauges for calibration and checking purposes.The arrangement of injection equipment must include a return circuit, conveniently designed so that the grout or mortar can circulate continuously along the pipe, in order to avoid clogging and concurrently allowing an accurate pressure control into the hole. During grouting process, grout should always remain agitated. The distance between the injection pump and the injection hole should not be more than 50 meters. All the grout or mortar dosing and injection equipment must always be kept in optimal operating conditions and calibrated periodically. The entire circuit should be prepared to be washed in case of clogging by means of "T" fittings and water connections.

- **vi.** Grouting equipment shall consist of grout pumps, weighing scale for additives and cement, grout mixers water meters, agitator sumps, pressure gauges, packers, pipelines and fittings, and miscellaneous tools, and shall be specifically designed for grouting purposes.
- **vii.** Grouting equipment shall be capable of effectively mixing and stirring the grout and forcing it into the grout holes or grout convections in a continuous, uninterrupted flow at any specified pressure up to maximum of 100 bar, accurately measuring the grout intake, and maintaining the specified pressure for at least 5 minutes after the hole refuses to accept further grout. The equipment shall be capable of accurately controlling grout flows and pressures and shall be suitable for neat cement, cement sand, and chemical grouts.
- **viii.** Spare gauges, valves and fittings shall be kept available on the Site, and a two-way communication system between the mixing plant and place of grouting shall be provided if the distance exceeds 60 m.
- **ix.** Standby equipment, which can be activated immediately, shall be furnished to ensure continuity of work in the event of main equipment breakdown. The standby equipment shall be able to operate at pressures up to 100 bar.
- **x.** Prior to commencement of the work, during the work as specified or as requested by the Engineer, and at the end of the work, all pressure gauges, recorders and discharge meters shall be checked and calibrated.
- **xi.** The grouting equipment shall be maintained to the satisfaction of the Engineer in order to guarantee continued and efficient performance during grouting work.

**12.9.2** Deleted.

**12.9.3** Recording of data for grouting

- **i.** Recording of data shall be automatic through an electronic data logger (a PC), which shall have facility to actively control the entire process.
- **ii.** Control parameters such as maximum allowed injection pressure, maximum and minimum flow rate and maximum quantity of grout per injected hole shall be entered into the PC.

iii. PC shall then record the process automatically, and also stop the pump when any of the stop criteria have been reached. When injecting on several holes simultaneously (with one pump per line) this equipment is a great help in keeping things under control and receiving accurate recordings, without the need for more staff.

iv. It should be possible to see the cumulative grout volumes and grout material weights injected inside the hole under grouting operation.

v. Pressure transducer and an inductive flow meter shall be coupled into the grouting line.

vi. Print out of grouting rig log shall me submitted with grouting reports after each grouting operation.

**12.9.4** Grout Mixers and Agitator sumps

i. Grout mixers for mixing the stable mixtures shall be of the mechanically operated, high speed colloidal type of sufficient size, and operating at 1500 to 2000 rpm with electric or pneumatic drive to ensure complete dispersion and activation of the mix.

ii. Hand powered mixers or concrete mixers shall not be permitted for preparation of grout mixtures.

iii. Mix shall be weighing batched and mixers shall be provided with equipment for measuring weight and volume of mix components with an accuracy of 2 % and a water meter calibrated in liters with a reset switch for zeroing after each delivery.

iv. After mixing, the grout shall be discharged through a 5 mm mesh screen into an agitator sump equipped with stirring paddle to prevent settling and to remove any air bubbles from the mix. The stirring paddle shall be of such arrangement to guarantee a complete circulation of the entire sump content. The agitator sump shall have double the capacity as of the mixer so that one batch of grout can be pumped while the next batch is being mixed.

v. Grouting rig shall be equipped with computerized controls and automatic logging of entire grouting operations (volume of different recipies injected in each hole, pressure at which the injection took place, pressure build up/loss as the grout is run, start and stop time for different mixtures).

**12.9.5** Grout Pump

i. Grout pump should be able to inject grout at upto 80 bars steady pumping pressure for upto 20 L/min of constant flow, simultaneously into 2 holes at the same time.

ii. Pumps shall be of the duplex double acting piston type. The pump body shall be of high wear and shock resistant material. The plunger unit shall be of stainless steel, highly resistant to abrasion.

iii. The pump shall have hydraulic drive.

iv. The pumps shall be equipped with precise pressure and capacity control valves, which allow the setting of both, the maximum pressure and the flow independently. The pump shall automatically stop whenever the preset pressure is reached and shall maintain the pressure without fluctuation.

v. For works requiring a small volume of grout such as crack grouting or rock bolts grouting, the contractor may use hand operated grout pumps approved by the Engineer. These pumps shall be able to achieve a pressure of up to 25 bar.

**12.9.6** Pressure Gauges

i. The Contractor shall provide pressure gauges for both low and high-pressure ranges (0- 20 bar and 20 -100 bar). Two gauges of the appropriate range shall be provided in each grout line, one at the pump for the use of the pump operator, the other at the hook up connection directly at the collar of the hole. The required pressure for each particular hole shall be measured on the hook up pressure gauge, not at the pump.

ii. Pressure gauges shall have an accuracy of 3%. A minimum of two standardized pressure gauges for each range shall be calibrated and certified by an independent laboratory prior to the commencement of grouting works. One gauge for each range shall remain at the disposal of the Engineer, and the other shall be, used by the contractor for checking and calibration of working gauges. Working gauges shall be used for no longer than 2 shifts before being cleaned and recalibrated. All working gauges shall have reference number for identification, which shall be quoted in the grouting reports to be submitted to the Engineer.

**12.9.7** Connections to Grout Holes and Packers

i. Supply and return lines equipped with quick release couplings shall be able to withstand an internal pressure greater than the maximum produced by the pump. The internal diameter of the lines shall be such that no appreciable settlement of grout takes place when pumping at the minimum discharge capacity of the pump.

ii. Valves shall be provided at the pump, in supply line and at the collar of the hole being, grouted. Suitable screens shall be incorporated in the supply line for removing oversize particles and foreign matter before injection into the grout hole.

iii. Packers shall be the same as used for water pressure testing and shall be of the mechanical rubbing ring or pneumatically expandable rubber types. These shall be capable of sealing holes without leakage. These packers shall be capable of being used either single or double. Double packers shall be separated by up to 3 m of perforated pipe. The diameter of pipes used for separating and placing the packers in holes shall be the maximum possible for the size of the holes.

**12.9.8** Embedded Pipes and Fittings for Grouting

i. Whenever pipes are required to be installed, Standard mild steel pipes and fittings for grouting shall be set in the rock and concrete as directed by the Engineer. The pipes and fittings embedded in concrete shall be cleaned thoroughly of all dirt, grease, grout and mortar immediately before embedment and shall be firmly held in position and protected from damage of displacement while the concrete is being placed. The size of the pipes embedded in concrete lining for drilling holes for grouting shall be of a suitable internal diameter. A standard coupling and nipple wrapped to facilitate eventual removal shall be attached to the grout pipe where embedded in concrete. No portion of the pipe shall be allowed to remain within 50 mm of the concrete surface and the resulting recess, after removal of the pipe or fitting, shall be filled with dry pack mortar.

ii. Care shall be taken to avoid premature blockage of pipes. Any pipe that becomes blocked before completion of operations shall be cleaned in a satisfactory manner or replaced by the contractor

**12.9.9** Maintenance routine

i. Thorough cleanup must be performed to prevent cement from hardening in production apparatus and in the grouting rig. Such maintenance must be facilitated by ensuring that a high-pressure washer and a work bench are available in the vicinity of the grouting rig. Following is the advisory schedule which may be followed: -

| **Component** | **Maintenance frequency** | **Comments** |
|---|---|---|
| Hoppers | Feed screws should be checked regularly and cleaned when necessary. Hoppers must be emptied in the event a prolonged stoppage. | The screw can be checked when the hopper is run to empty. |
| High-speed mixer | Cleaning after each round of grouting. Impeller/paddles should be replaced every other year. | Thorough cleaning is vital. Inadequate cleaning may result in set cement falling into the cement being mixed and causing operating problems during grouting.<br>Impeller/paddles/knives will become worn and gradually give poorer mixing results. They should be replaced when they no longer give the same shear force in the mixing process. |
| Stirrer (agitator) | After each round of grouting. | Thorough cleaning will prevent a buildup of cement, also at the top of the mixer. All surfaces must be checked. |
| Grouting pump | After each round of grouting. | Must be dismantled, cleaned and lubricated internally with acid-free vaseline. |

| | | |
|---|---|---|
| | After each round of grouting. | Check of wear on connecting pieces, threads and split pins. |
| | After each round of grouting. | Check for wear and damage. Damaged hoses must be replaced. |
| Grouting rods | After each hole. | Thorough cleaning and lubrication of threads. |
| Packers | Check the packers that are going to be used before each round of grouting. | Check there are no production faults in the locking mechanism. |
| Taps/Ball valves | After each hole and during grouting. When grout takes are large, functionality should be checked by opening the tap. | Important to check functionality, particularly of pressure relief valves. |
| Grouting rig | Regular cleaning/lubrication, at a minimum after each round of grouting. | Anti-seize oil should be applied after rig has been washed. It is advantageous if the rig is equipped with a high-pressure washer for continuous cleaning during the grouting process. |
| Scales | Every other month, or after 200 tonne. | Measuring cells should be checked. |

## 12.10 DRILLING OF HOLES

**12.10.1** General

- **i.** The number of holes to be drilled, their location, sequence, orientation, inclination and the depth shall be as per approved methodology.
- **ii.** All holes shall be established within 0.10 m of the specified location. Maximum deviation for holes shall be $2^0$ (degree) from the proposed values.
- **iii.** If for any reason, the drill hole deviates in inclination or orientation in such a way that it does not satisfy the purpose for which it was intended, the contractor shall correct the deviation or shall drill another hole to the satisfaction of the Engineer.
- **iv.** Hole size for probing and consolidation grouting holes (Drilled in the face) shall be kept same.

**12.10.2** Drilling of Holes for Rock bolts, Exploration and Instrumentation and other than Grouting, etc.

- **i.** The minimum diameter of holes shall be 38 mm or as directed by the Engineer.
- **ii.** Holes shall be drilled either directly into the rock or through the concrete lining and then into rock as directed by the Engineer.

iii. The holes shall be drilled in a direction normal/inclined to the surface of the underground excavation / concrete lining as the case may be or as directed by the Engineer.

iv. While drilling the holes, utmost care shall be taken to ensure that the reinforcement or structural ribs, if any, in the concrete lining, shall not be cut through. The position of steel ribs shall be recorded and marked on the finished concrete lining. If the reinforcement or steel ribs are encountered during drilling of any holes in concrete, drilling shall be discontinued immediately, and a new hole shall be drilled nearby. The holes so abandoned shall be backfilled with concrete as direct by the Engineer and the surface of concrete shall be repaired.

v. Each hole shall be protected from becoming clogged or obstructed by a grout connection pipe fixed suitable into the holes and the holes shall be suitably capped or otherwise protected until these are grouted. Any hole that becomes obstructed before being grouted shall be cleaned out in a satisfactory manner.

vi. The use of rod dope, grease or other lubricants on drill rods shall not be permitted and no drilling water additives of any kind shall be used without the approval of the Engineer.

vii. Whenever the drilled water is lost or artesian flow is encountered, drilling operations shall be stopped, and the hole shall be grouted before drilling operations are resumed. The Contractor shall record the location, flow and the pressure of any artesian conditions encountered in any drill hole.

## 12.11 FLUSHING OF HOLES

**12.11.1** On completion of drilling, all holes shall be thoroughly flushed to remove any accumulation of fines, sludge, or foreign materials. Holes shall be flushed out by water at pressure of 10 bar, combined with some compressed air injected through a stiff plastic hose starting at the bottom of the holes. Contractor shall continue flushing for two minutes after the return water becomes clear.

**12.11.2** For grout holes, flushing will also be required immediately before water testing/high pressure grouting. A custom designed diesel-powered piece of equipment shall be used to provide a water jet pressure of upto 100 bar. The high-pressure water hose shall have nozzle arrangement so that some water jets pointing 45° back along the hose and others at 90° radially. With this configuration, the nozzle is self-propelled forward into the hole and can be removed by just pulling the flexible hose.

**12.11.3** If there are zones in the borehole that may collapse if soaked in water, or will be excavated by the flushing jet, or if the water yield from the hole is more than 10 l/min, the flushing may be omitted.

**12.11.4** Flushing of boreholes for grouting should be done as specified as a routine matter and any necessary deviations should be decided on and recorded by the supervisor, based on the borehole records.

## 12.12 GROUTING OPERATIONS

**12.12.1** General

- **i.** All pressure grouting operations shall be performed in the presence of the Engineer.
- **ii.** In the underground works, the grouting works, and other operations shall be carried out as per approved working methodology or directed by the Engineer.
  - a. Consolidation grouting and impermeabilization of the rock ahead and around the heading face as needed before further advance.
  - b. Fill grouting of exploratory and drain holes, which may be required during underground excavation, prior to placing of concrete lining.
  - c. Contact grouting in the crown of the tunnel and cavern after placing of concrete lining.
  - d. Fill grouting of drainage conduits and sump pits.
  - e. Depending on the rock conditions, the Engineer may direct to carry out Consolidation grouting.
  - f. Control grouting.
  - g. Installation of one-way checks valves.
  - h. Crack grouting as directed.
- **iii.** The above sequence is not exhaustive, and the Contractor shall plan his operations in such a way that he is flexible to adapt to the conditions encountered.
- **iv.** The utmost care and precautions shall be taken to ensure that the concrete does not get damaged during the grouting operations.
- **v.** If the Engineer considers necessary to carry out an additional grouting in any section of the works, the contractor shall reinstall the necessary equipment and perform the grouting to the satisfaction of the Engineer.

**12.12.2** Contact Grouting between Concrete and Rock where concrete lining is required to be installed

- **i.** Low pressure contact grouting shall be carried out between concrete and rock over the entire length of the tunnel to fill voids between the rock surface and the following:
  - a. Structural concrete in the crown of the tunnel and cavern and in the concrete plug in the tunnels.
  - b. Concrete in any other zones within the underground works where conditions so require and as the Engineer may direct.
- **ii.** Contact grouting shall normally be performed from holes drilled in the crown of the tunnel, shaft and cavern and shall be carried out in advance of consolidation grouting operation.
- **iii.** Contact grouting in the completed concrete plug in access and it shall be performed through the pipe system cast into the body of the plug as specified in Section of "Cement Concrete".
- **iv.** Water pressure testing will not be required prior to contact grouting.

v. In any section of the underground structure, the concrete lining within 100 m of that section shall have been in place for at least 21 days before grouting commences.

vi. Contact grouting shall be carried out at low pressure (not exceeding 5 kg/sq.cm) using a cement-sand grout and shall continue until all voids are filled. Vent pipes for the release of air and water during grouting shall be provided in locations as shown in the drawings, as directed or approved by the Engineer.

vii. After the grouting of any hole is completed, the pressure shall be maintained, by means of stopcock or other suitable device, until the grout has set.

viii. Control grouting shall be carried out, where directed by the Engineer, to verify that voids have been completely filled with grout. Grouting will be regarded as being satisfactory if the pressure can be maintained for at least 5 minutes without grout intake.

**12.12.3** Closure of Holes and Clean-up

i. Upon completion of grouting work, each hole shall be filled with thick grout and connections not embedded in the concrete shall be removed. The drilled holes in the concrete lining shall be reamed or redrilled to a depth corresponding to the ⅔ rd of theoretical concrete lining thickness and filled with dry pack mortar, as stipulated in Section of "Cement concrete", flush with the concrete surface.

**12.12.4** Crack Grouting

i. Crack grouting shall be performed to seal the cold joints, construction joints, shrinkage cracks, honeycombs, poorly closed grout holes etc., in the structural concrete lining of underground structure as directed by the Engineer and as stipulated in Section of "Cement Concrete".

ii. Crack grouting shall consist of injecting a stable, cement water mix with admixture through holes specially drilled into cracks or joints.

iii. Preventive measures shall be taken by plugging the joint with wooden wedges, cardboard; cement-gypsum mortar or other suitable mean to prevent the grout from flowing out of the crack.

**12.12.5** Curtain Grouting

i. Curtain grouting shall not be started until consolidation grouting has been completed within 60 m radius around the curtain holes to be grouted.

ii. Drill holes for curtain grouting shall be drilled and grouted in three stages consisting of Primary, Secondary and Tertiary holes. Primary holes shall be drilled, washed, subjected to water pressure testing, when required by the Engineer, and grouted before proceeding to execute the secondary holes. The depth of holes and spacing between them shall be as shown on the drawings or as approved by the Engineer.

iii. Unless otherwise specified by the Engineer, curtain grouting shall be done in stages of 5 m each.

iv. If grout absorption in any 5-meter stage, which is not caused by leakage at the surface, is found to be excessive in adjacent primary and secondary holes, the Engineer may require the contractor to drill and grout additional holes (tertiary holes) between the primary and secondary holes.

12.12.6 Water Pressure Testing

i. Water pressure tests with double packer apparatus having a perforated pipe not less than 1.5 m shall be carried out on the grout holes when directed by the Engineer. The actual spacing will be determined by the Engineer. Water pressure shall than be applied to the test section for a minimum period of 5 minutes.

ii. The maximum pressure for water testing shall correspond to the pressure specified for grouting. Water loss shall be measured in liters.

iii. Based on the results of the water pressure tests, the Engineer may require additional grouting. Such grouting shall be, carried out by the contractor at the pressure specified by the Engineer.

# Chapter 13
# Earthwork in Formation

## 13.1 FORMATION IN EMBANKMENT/CUTTING

Earthwork in formation and blanketing shall be carried out as per RDSO specification No. RDSO/2020/GE: IRS-004 September 2020 "Comprehensive Guidelines and Specifications for Railway Formation" and in accordance with the approved drawings.

The contractor shall arrange suitable borrow areas for balance earthwork (cut & fill) at his own cost and get them approved from the Engineer before using soil from such borrow areas.

Soils mentioned in Clause 3.7 (a) of the RDSO Guidelines shall not be used.

SQ-1 type of soils shall not be used in prepared subgrade and top layer of subgrade.

MDD in laboratory shall be determined by using Heavy Proctor test as per IS 2720 Part-16.

MDD achieved in the field compaction trial shall not be less than 98% of the MDD achieved in laboratory.

Degree of compaction of soil in prepared subgrade/top layer of subgrade shall not be less than 98% of MDD achieved in field as a result of Field Compaction Trial.

Degree of compaction of soil in lower layer of subgrade shall not be less than 97% of MDD achieved in field as a result of Field Compaction Trial

After completion of earthwork slope shall be dressed in final profile by cutting the extra earth and compacted with vibratory rollers of approved capacity and make as per RDSO guidelines.

Blanketing material shall be as per RDSO Guidelines.

The type of test, frequency and acceptance criteria for quality check of earthwork and blanketing shall be as given in Chapter 7 of RDSO Guidelines.

Before laying the coir netting for slope protection, the slope shall be levelled, fertilised and a dose of seed broadcasting of locally available suitable type of grasses shall be done. Thereafter, coir netting shall be laid on the prepared slope surface firmly in the direction of water flow and flushed to the ground ensuring that the runoff would flow over the nettings. The netting shall be secured against displacement by an overlapping of 5 cm to 8 cm and stitched or pegged down with 15 cm long steel nails about 1 .0 m apart. The top and bottom ends of the fully stretched coir netting shall be fixed/anchored in trenches of 50 cm depth. Afterwards, another dose of seed broadcasting or dibbling of locally available grasses 15 to 20 cm apart, in rows shall be carried out.

NP-4 pipe of 450mm diameter, conforming to IS 458, shall be provided at about 500m interval throughout the alignment in embankments having fill heights upto 5m. In embankments having fill heights more than 5m precast RCC box of 500mmx500mm clear size shall be provided for the purpose of future utilities. Installation conditions for the pipe shall be designed as per the IS-783, according to the fill height.

Precast retaining wall shall be manufactured from high strength reinforced concrete in factory under controlled environment and shall be steam cured. Dimensional tolerance shall be 0+/- 2 mm.

Boulder backing and backfill behind retaining wall shall be provided after completing the earthwork upto the height of retaining wall with mechanical compaction in layers and thereafter cutting the earthwork in required profile.

# Chapter 14
# BRIDGES

## 14.1 General

### 14.1.1 Scope of Specifications

This specification shall be applicable for carrying out bridge works.

### 14.1.2 Applicable Standards

The applicable standards shall be as follows:

a) Indian Railway Standard Codes and Specifications (IRS)

i. Bridge Rules
ii. Concrete Bridge Code
iii. Steel Bridge Code
iv. Well and Pile Foundation Code
v. Fabrication Specification No. B1-2001
vi. Specification No. B-2 for Steel Structures (other than Girder Bridges)- Part 3.
vii. Welded Bridge Code
viii. Bridge Sub-structure & Foundation Code
ix. Specification No.M-28, Classification, testing and approval of metal arc welding electrodes for use-Indian Railway
x. Specification No.M-29, Classification, testing and approval of submerged arc welding with flame combination
xi. Indian Railways Unified Standard Schedule of Rates - 2019
xii. Indian Railways Unified Standard Specification (Formation Works, Bridge Works & P.Way Works) - 2019
xiii. Indian Railways Permanent Way Manual (IRPWM)
xiv. Indian Railways Works Manual (IRWM)
xv. Indian Railways Bridge Manual (IRBM)
xvi. Indian Railways Engineering Code
xvii. Manual on the design and construction of Well and Pile foundations
xviii. Indian Railways Schedule of Dimensions (BG)
xix. IRS Seismic code for Earthquake Resistant Design of Railway bridges.

b) RDSO Guidelines

i. BS-113 Guidelines for providing Arrangements for Bridge Inspection
ii. Comprehensive Guidelines and Specifications for Railway Formation: RDSO/2020/GE: IRS 0004.
iii. Report No. GE: R-50: Transitional System on approaches of bridges

iv. Report No. BS-111: Guidelines for use of High Strength Friction Grip (HSFG) bolts on bridges on Indian Railways

v. Guidelines for design of Spherical and Cylindrical bearings (in case of Steel Bridges).- RDSO/CBS/Bearing dated 22-06-2011

vi. RDSO drawings for H-beam sleepers

vii. Report No. BS 115 : Guidelines for Composite Construction Including Stud Shear Connectors

c) Indian Standards Codes and Specifications (IS)

i. IS: 456 Plain and reinforced concrete - code of practice

ii. IS: 800 Code of practice for General Construction Steel

iii. IS: 875 Code of Practice for Design Loads Part 1, 2 3, 4& 5 (Other than Earthquake)

iv. IS: 1080 Design and construction of shallow foundations in soils (other than raft ring and shell)

v. IS: 1367 Technical Supply Conditions for Threaded Steel Fasteners

vi. IS: 13920 Ductile detailing of reinforced concrete structures subjected to seismic forces code of practice

vii. IS: 1489 Specification for Portland pozzolana cement (Fly ash based)

viii. IS: 1786 High strength deformed steel bars and wires for concrete reinforcement

ix. IS: 1904 Design and construction of Foundations in soils: general requirements.

x. IS: 2062 Specifications for weldable Structural steel

xi. IS: 2502 Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement

xii. IS: 2911 Design and Construction of Pile Foundation - Code of practice Part1 Concrete Pile- Section 2 Bored Cast-in-situ-piles

xiii. IS: 2911 Design and Construction of Pile Foundation- Code of practice Part1 Concrete Pile- Section 4 Precast Concrete Piles in Prebored Holes

xiv. IS 2911 Design and Construction of Pile Foundation- Code of practice Part 4 Load test on piles

xv. IS: 2950 Design and construction of raft foundations

xvi. IS: 3935 Code of Practice for Composite Construction

xvii. IS: 4923 Hollow steel sections for structural use -specification

xviii. IS: 1161 Steel Tubes for Structural Purposes- specifications

xix. IS: 8009 Calculation of settlements of shallow foundations

xx. IS: 269 Specifications of OPC cement

xxi. IS: 9103 Specifications of Concrete admixtures

xxii. IS: 12070 Code of practice for Design and construction of shallow foundation on Rocks

xxiii. IS: 14593 Design and Construction of Bored Cast-in-Situ Piles Founded on Rocks.

xxiv. IS 455 Specifications for portland slag cement

d) Other Standards

i. CPWD specifications, (Vol 1 & 2) -2019

ii. Delhi Schedule of Rates, (Vol 1 & 2) - 2021

iii. UIC Code 772-2 (R) Code for the use of rubber bearings for rail bridges

iv. IRC:83-2018 (Pt. II) - Standard Specifications and Code of Practice for Road Bridges (Section – IX) Bearings (Elastomeric Bearings)

v. IRC:83-2014 (Pt. IV) - Standard Specifications and Code of Practice for Road Bridges (Section – IX) Bearings (Spherical and Cylindrical)

vi. ISO 6892 – Tensile Testing of Metallic Materials

vii. ISO 13918-2008 – Welding- Studs and Ceramic Ferrules for Arc Stud Welding

## 14.2 Bridge Works: Substructure

### 14.2.1 GENERAL

a) Coverage

The Specifications given in this chapter deal with items pertaining to all types of foundations for bridges and bridge superstructure viz., Piers, abutments, wing walls, bed blocks and ballast walls / dirt walls.

### 14.2.2 Setting out for foundations

a) Setting out for Minor Bridges and Culverts

Shall be carried out by a competent / qualified engineer, employed by the Contractor and checked by the Engineer’s representative for all bridges and culverts. Contractor shall provide necessary instruments, linear tapes, pegs etc.

The setting out for foundations and sub-structure shall be carried out with a theodolite and steel tapes / Invar tapes in case of works not involving deep foundations or standing water. All levels will be measured using a precise levelling instrument. Errors in location of piers / abutments and fixing levels shall be within following limits.

| | |
|---|---|
| Linear Measurements | ±5 mm |
| Levels | ±3 mm |

b) Setting out for Major Bridges

i. Locations of piers and abutments along with the centre line of the bridge should be accurately laid out by establishing one or more base lines as directed and a system of pegs and posts. Also sufficient reference pegs and pillars should be established for checking the positions with ease during progress of work. Reference Bench Marks for levelling should be established nearby on a permanent structure or on a pillar to be built up in vicinity.

ii. The principal reference lines and level pegs should be established at easily accessible locations. They include-

1) Longitudinal Centre line
2) Transverse Centre lines of abutments and piers
3) Tangent points of the curve at either end, if alignment is on a curve.

iii. For Bridge Works involving deep excavations, pile driving or well sinking and / or where there is standing water, use of base line is obligatory. They should be preferably at right angle to centre line of bridge, with one on either end on high bank in case of long bridges or on one side bank of bridge for shorter ones.

iv. In case of bridges of length exceeding 1000 Metres, base lines and reference towers will have to be established. Provision of all assistance in form of measuring instruments, linear tapes as may be required by the surveyor, technical and skilled staff and labour required to assist them, fixing pegs, pillars and towers including all building materials and maintaining and guarding them including supply of all materials, tools and plant shall be done by the Contractor at his cost. Nothing extra will be payable to them on this account. Important points to be observed in this activity are:

1) Linear Measurement shall be carried out with invar tape or electronic distance measuring instruments
2) Spring balances shall be used for giving specified tension to the tape. Tape readings shall be corrected for tension, temperature and slope.
3) Concrete pillars with steel plates fixed over them shall be located at intermediate points (at tape lengths) and ends.
4) Reference pillars at pier and abutment position along centre lines and reference pillars on base lines shall be to standards to be prescribed by the Engineer. During construction, since centre line pillars at abutment / pier locations will be disturbed, reference pillars and lines shall be fixed around each structure by the Contractor under Site Engineer's supervision. Reference diagrams at Annexures 4/1 and 4/2 and Clause 401 of IRBM shall be referred to for more details.

### 14.3 Soil Exploration

Soil exploration and test shall be carried out conforming to Indian Railways Codes and Specifications according to soil type, foundation type and site requirement.

### 14.4 Earthwork in excavation

Excavation shall be made only to the exact depth as shown on the drawings. In the event of excavation having been made deeper than that shown on the drawing or as ordered by the Engineer, the extra depth shall be made up with M10 concrete in case of foundation resting on soil and with concrete of the same grade as that of the foundation, in case of foundation resting on rock.

### 14.5 Method Statement

The Contractor shall submit Method Statement for carrying out the work of excavation in foundations and flooring etc. suiting to local ground conditions and safety measures conforming to IS: 3764 (Excavation Work- Code of Safety) to the Engineer for approval.

The work shall be carried out strictly in accordance with the approved Method Statement and drawings.

### 14.6 Site Clearance

Site clearance shall be done as per the Contract.

#### 14.6.1 Setting Out

After the site has been cleared, the limits of excavation shall be set out true to lines, curves, slopes, grades and sections as shown on the drawings or as directed by the Engineer. The Contractor shall be responsible for the setting out of works and the establishment and maintenance of benchmarks, other marks & stakes as long as in the opinion of the Engineer, they are required for the work.

a) Excavation shall be carried out in all types of soil encountered at site and to the lines, levels and profiles shown on the drawings that have NONO from the Engineer. The Work shall be carried out by the Contractor in such a way as to avoid soil erosion and groundwater pollution, accidents in habitational or frequented places, disturbance to the surrounding ground or structures, accident to workmen and any other untoward incident. Fencing, caution signages with red lights and other safety measures shall be employed to avoid accidents. Where necessary, signal men shall be employed to guide the movement of people, vehicles and equipment.

b) The work shall be carried out in a careful manner to ensure that the exposed surfaces are as sound as the nature of the material permits and that no point shall protrude inside the lines shown on the Drawings.

c) The Contractor shall be responsible for the safety and stability of all excavations performed by him or under his control. In case of any slips or blows in the excavation, the same shall be cleared by the Contractor at his own cost.

d) The Contractor shall notify the Engineer without delay of any permeable strata, joints, faults, fissures or unusual ground conditions encountered during excavation and any excavation instability and/or collapse.

e) The Contractor shall ensure that no air pollution takes place during excavation, storage and transportation of earth/spoil by providing suitable measures such as appropriate cover and the like.

f) The Contractor shall carry out ground stabilization measures without delay before and/or after excavation, if required.

g) The Contractor shall make provision for all shoring, de-watering, dredging, bailing out or draining water whether subsoil or rain or other water and the excavation shall be kept free of water while concrete work is in progress until the Engineer considers the work well set. The sides of trenches shall be kept vertical and the bottom level throughout or properly stepped as directed by the Engineer. No extra payment shall be made on this account.

h) De-watering shall be carried out by suitable means with adequate stand-by arrangements as may be approved by the Engineer. The Contractor shall be deemed to have satisfied himself with regard to feasibility of all aspects of de-watering including site constraints due to existing structures. Though the method of de-watering is left to the Contractor, he shall be required to submit method statement of de-watering scheme including requisite justifications to obtain approval from the Engineer.

i) Approval of the Engineer, however, shall not relieve the Contractor of the responsibility of adequacy and appropriateness of de-watering and protection arrangements for the quality and safety of the work.

j) The Contractor shall erect and maintain during progress of works temporary fences/ barricading around the work area with all safety measures as shown in Reference Information/Reports. The excavations near habitations, public movement areas and all works along the roads shall be provided with proper caution signs and marked with red lights, reflectors at night to avoid accidents. The Contractor shall take all adequate protective measures to see that excavation operations do not affect or damage adjoining structures.

k) Disposal of muck: The surplus excavated material (that cannot be used in the Works), shall be treated as contractor's property. The contractor shall be free to take away and make use of this surplus excavated material in the manner he wishes to, including disposal in spoil dumps or elsewhere as approved by the Engineer/concerned parties and regulating authorities. The employer takes no responsibility for the arrangement of dumping areas and these will have to be arranged by the Contractor at his own cost. The Contractor is required to carry out detailed survey to identify dumping areas, clearances required, leads involved etc. The quoted rates shall be deemed to have taken all these factors into account. The excavated material that can be used in the Works, shall be temporarily stockpiled, if required, in a dump site as proposed by the contractor and agreed by the Engineer and the concerned regulating authorities. Any royalty, if to be paid to local authorities on the excavated material, is to be borne by the Contractor at his own cost irrespective of whether the excavated material is used for the Works or being used for any other purpose or being disposed off as surplus. Truck drivers shall be trained and educated by the Contractor to follow the traffic rules.

l) The Contractor shall ensure that traffic management on roads and railways is carried out in accordance with Sub-Division 6070 of the General Specifications.

### 14.6.2 Excavation beyond True Lines and Levels

If due to any cause whatsoever excavations are carried out beyond their true line and level, the Contractor shall make good excavation at his own cost to the required line and level with the appropriate grade of filling or with concrete subject to the NONO from the Engineer.

### 14.6.3 Backfill to Structures

a) Prior to commencement of backfill, the Contractor shall submit Method Statement for carrying out work such that the optimum use may be made of excavated material and obtain approval from the Engineer. The proposals shall include details of the compaction plant and methods for adjusting the moisture content of the material.

b) No filling shall commence until approval has been received from the Engineer.

c) The Contractor shall not backfill around structures until the structural elements have attained adequate strength.

d) The backfill material shall be selected excavated material, thoroughly compacted mechanically in layers not exceeding 300mm loose thickness to achieve a density of at least 90% of the maximum dry density.

### 14.6.4 Tolerance

Permissible Tolerance for excavation

| Item | Standard value (mm) |
|---|---|
| Finished depth of excavation | ±25 |
| length/width | 0 to +50 |

## 14.7 Bored cast in-situ Piling

Piling shall be carried out by hydraulic piling rig.

### 14.7.1 Method Statement

The Contractor shall submit Method Statement for carrying out the work of piling. The work shall be carried out strictly in accordance with the approved Method Statement, Manual on the design and construction of Well and Pile foundations, the Specification and the Drawings.

### 14.7.2 Materials

a) **Concrete**

Piles shall be constructed in accordance with the details shown in the drawings using the grade of concrete indicated, produced and placed in accordance with provisions of Annexure OCS-1 of these specifications.

b) **Reinforcement Steel**

Reinforcement steel shall comply with the provisions of Annexure OCS-2 of these specifications.

c) **Temporary Casings**

Temporary casings, as approved by the Engineer, shall be used to maintain the stability of pile bore hole. Temporary casings shall be free of distortion and shall be of uniform cross-section throughout each continuous length. During concreting, they shall be free of internal projections and encrusted concrete which may prevent proper formation of the pile.

d) **Stabilizing Material**

The stabilizing material to maintain the sides of pile bores shall preferably be natural drilling mud. If natural mud is not available, then stabilizing fluid having bentonite, controlled with a polymer like CMC (Carboxyl Methyl Cellulose), shall be used. The stabilizing material shall be approved by the Engineer. Bentonite, when used, shall conform to IS 2911 (Part 1/ Section 4).

### 14.7.3 Pile Installation

a) **General**

i. Bored cast-in-situ concrete piles shall conform to IS 2911 (Part 1/ Section 2), where not contravening to the following provisions. Based on borehole reports and drawings, installation of piles shall be carried out as per pile layout drawings, installation criteria, approved Method Statement and instructions of the Engineer. Any changes to the pile design, based on test-piles results, bore-hole data or soil conditions encountered during boring, shall be as instructed by the Engineer.

ii. The equipment and accessories for installation of piles shall be selected giving the due consideration to the sub-soil conditions, ground water conditions and type of founding material. These shall be of standard type and shall have been approved by the Engineer.

iii. Before installing the initial test pile, the Contractor shall finalise the pile testing arrangement and obtain approval of the Engineer.

iv. It is envisaged that the working piles shall be installed after the successful completion of the initial pile load test.

v. In case the Contractor desires to install the working pile, pending successful completion of initial pile load test, he may be permitted to do so, provided he gives undertaking to the Engineer to bear all associated risks and costs involved to make up for the short falls in the pile capacity, in the event of the failure of the initial pile load tests to establish specified 'Design Ultimate Load' carrying capacity of initial test pile.

vi. The Engineer reserves the right to reject any pile which in his opinion is defective on account of less carrying capacity, structural integrity, position, alignment, concrete quality etc. Piles that are defective shall be pulled out or left in place as judged convenient by the Engineer, without affecting the performance of adjacent piles. The Contractor shall install additional piles to substitute the defective piles, as per the directions of the Engineer, at no additional cost to the Employer. Further, the cost of additional piles and increase in the pile cap size, if any, on account of additional piles, shall be borne by the Contractor.

vii. Each pile shall be identified with a reference number and shall be as shown in the Drawings. The convenience of installation may be considered while scheduling the sequence of piling in a group.

viii. In a pile group, the sequence of installation of piles shall normally be from the center to the periphery of the group or from one side to the other.

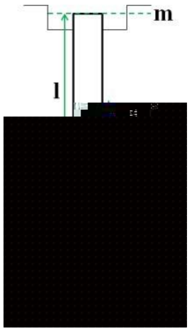
ix. Level marks shall be accurately painted on each pile immediately after its installation. Subsequently, if any pile displays any tendency to heave up due to installation of other piles or due to any other reasons, the same shall be reinstalled firmly as per the directions of the Engineer without any additional cost.

x. The Contractor shall record all the information during installation of piles, including pile-bore observations before concreting each pile. The data sheet for recording pile data shall be as approved by the Engineer. On completion of each pile installation, pile record shall be submitted to the Engineer within two days of completion of concreting of the pile.

b) **Control of Position and Alignment**

Piles shall be installed as accurately vertical as possible. The permissible tolerances with respect to position and inclination/alignment are as shown below:

**Tolerances**

| No | Item | Permissible | Figure |
|---|---|---|---|
| 1 | Level of top i.e. Cut-off-Level (m) | -25mm to 25mm |  |
| 2 | Position of the head in plan at Cut-off-Level (d) | 75mm or less | |
| 3 | Embedded depth in bearing stratum (l) | Design value or more | |
| 4 | Diameter of the pile (D) | Design value or more | |
| 5 | Variation from vertical at Cut-off-Level (v) | 1.5% or less | |

c) **Pile Boring**

**i. Boring Operation:**

- Boring operations shall be done by rotary hydraulic feed drilling rigs with reverse mud circulation or other suitable boring methods that have been approved by the Engineer. The boring or drilling equipment shall have suitable and adequate accessories for boring or drilling through all types of strata expected at site.
- The size of cutting tools shall not be less than the diameter of the pile by more than 75 mm. However, the pile bore shall be of the specified size.
- The boring centre shall be aligned with the pile centre and the boring machine shall be installed so as not to move or incline. The sides of the bore-hole shall be stable throughout.
- Working level shall be above the Cut-off-Level. After the initial boring of about 1.0 m, temporary guide casing of suitable length shall be lowered in the pile bore for vertical pile. The diameter of guide casing shall be such as to give the necessary finished diameter of the concrete pile. The centre line of the guide casing shall be checked before continuing further boring. Guide casing shall be minimum of 1.0 m length. Additional length of casing may be used depending on the condition of the strata, ground water level etc.
- The temporary guide casing (if provided) shall be withdrawn cautiously, after concreting is done up to the required level. While withdrawing the casing, concrete shall not be disturbed.
- For providing permanent MS liner, Clause 709.1.4 of IRC:78 shall be complied with. Whenever stricter provision has been given in the drawings, the same shall be followed.
- If boring operation becomes difficult before reaching the predetermined depth, further plan of action shall be submitted by the Contractor and

approval shall be obtained from the Engineer for the same. The piles shall be founded on rock or other suitable strata as approved by the Engineer.

**ii. Maintaining the** bore **hole:**

- For maintaining bore hole wall while boring, a stabilizing material, according to the soil shall be used and the level of the stabilizing fluid shall be maintained at not less than 2.0 m above the ground water level or at such other level as will ensure that the fluid pressure is at all times in excess of pressures exerted by the soils and external groundwater. The stabilizing fluid shall be under constant circulation till start of concreting. The level of stabilizing fluid for all piles shall be recorded by the Contractor and reported to the Engineer, including the confirmation of the bore-hole wall shape after boring. Where temporary casings or an alternative method for maintaining stability of a boring are used, these shall be subject to the Engineer's approval.
- Consistency of the stabilizing material suspension shall be controlled throughout concreting operations in order to keep the bore stabilized, as well as to prevent concrete getting mixed up with the thicker suspension of the mud.
- When the boring is done by rotary drilling rigs, the verticality of Kelly bar shall always be maintained. In the soil layer such as sandy soil layer where the bore hole tends to collapse, care shall be taken to ensure the drilling bucket does not hit the hole wall. While boring in the founding soil layer, the drilling bucket shall be raised at appropriate speed to prevent loosening of the soil by suction.

**iii. Stabilizing material management:**

In addition to the requirements that are already stated, the following shall be considered:

- The stabilizing material shall be controlled so as to prevent pile-bore wall collapse and ensure the quality and shape of the concrete.
- While boring, the Contractor shall periodically check the properties of the stabilizing material and control the management items (specific gravity, marsh funnel viscosity, pH, etc.) to be within the values set in the Method Statement that has been approved by the Engineer.
- Stabilizing fluid shall comprise of bentonite, complying with the specifications of IS 2720, IS 2911 (Part 1/ Sec2; ANNEX D) or otherwise approved by the Engineer, thoroughly mixed with clean fresh water along with the required Polymer like CMC, to form a suspension meeting the specification requirements as submitted to and consented by the Engineer.
- The Contractor shall obtain manufacturers' certificates of the bentonite powder consigned to the Site giving properties of each consignment and shall submit them to the Engineer prior to commencing the work and whenever required.
- The frequency of testing stabilizing material and the method and procedure of sampling shall be proposed by the Contractor and approved

by the Engineer prior to the commencement of piling work. Such control tests on the bentonite suspension as required or as approved by the Engineer shall be carried out during the piling work.

- Prior to concreting a pile, the Contractor shall take measures to remove any heavily contaminated stabilizing material which could impair the free flow of concrete from the tremie pipe. Placing of concrete shall proceed only with due modification as per consent of the Engineer.
- All reasonable steps shall be taken to prevent the spillage of bentonite suspension in the Site in areas outside the immediate vicinity of boring.

**iv. Confirmation of bearing stratum for termination level:**

- Confirmation of the support layer shall be carried out by boring depth and comparing excavated soil and soil survey material. Also, the pile designated as per approved Method Statement or by the Engineer shall receive necessary confirmation.
- The boring depth shall be measured at two or more places to the bottom of the hole immediately after completion of boring operations. The results shall be reported promptly.
- A protocol shall be maintained regarding the strata at the founding level, Standard Penetration Test (SPT) value, percent core recovery, Unconfined Compressive Strength (UCS) from the nearest borehole, socketing horizon, flushing of pile bore, time interval between end of boring and start of concreting, bentonite density prior to the commencement of concreting.

**v. Cleaning of pile bore just after boring:**

- After completion of the pile bore up to the required depth, the pile bore shall be cleaned of loose, disturbed or re-moulded soil from the base of the pile.
- The cleaning shall preferably be achieved by three stages flushing of slurry using airlift technique, as per approved Method Statement. The bottom of the pile bore shall be thoroughly cleaned by airlift technique. Cleaning shall ensure that the pile bore is completely free of sludge or bored material, debris of rock or boulder etc. Necessary checks shall be made to ensure the thorough cleaning of the pile bore.
- Concreting operations shall not proceed if the contaminated stabilizing material at the bottom of the pile bore possesses a density of more than 1.12 g/ml. The stabilizing material sample shall be collected from the bottom of pile bore. For this a solid cone shall be lowered by a string to the bottom of pile bore. A sampler tube closed at top with a central hole (hollow cylinder) is lowered over the cone, then a top cover shall be lowered over the cylinder. Care shall be taken for proper fittings of assembly to minimise the leakage, while lifting the cone assembly to the ground surface. The slurry collected in the sampler tube shall be tested for density and sand content.
- When the boring is done by rotary drilling rigs, cleaning-bucket attached to the Kelly shall be used for cleaning the bore. Wherever stabilizing

material is used, after using the cleaning-bucket, the bore shall be flushed with fresh slurry.

- The Contractor shall measure the final depth after this cleaning and confirm its effect by comparing with the depth at the end of boring.

**vi. Cleaning of pile bore just before concreting:**

- Pile bore shall be cleaned by fresh stabilizing material through tremie pipe or as specified in the Method Statement, before (in case delay in concreting after the completion of bore) and after placing the reinforcement cage and just before the start of concreting. Pile boring shall be inspected and approved by the Engineer, in accordance with approved Method Statement, before concreting.
- The Contractor shall measure the final depth after this cleaning, when there is a delay in concreting after completion of the bore, for knowing the casting pile length, and confirm its effect by comparing with the depth at the end of boring.

**vii. Other relevant considerations for pile boring:**

- Care shall be taken not to harm a recently concreted pile due to driving the casing nearby before the concrete has sufficiently set in that pile. The danger of doing harm is greater in compact soils than in loose soils.
- For bored holes, the finishing and cleaning of the bore, lowering of reinforcement cage and concreting of the pile for full height must be accomplished in one continuous operation without any stoppage.
- Pumping from a boring shall not be permitted unless approval has been issued by the Engineer.
- A pile excavation shall be backfilled without delay where a rapid loss of drilling fluid occurs and no further excavation at the location of that pile shall be carried out until the Engineer's approval is obtained.
- After each pile has been cast, any empty bore which may remain shall be protected and carefully backfilled as soon as possible to the satisfaction of the Engineer.
- Carriage and Disposal: The bored spoil material and contaminated mud and bentonite slurry shall be disposed at the designated areas identified by the Contractor and as per the procedure approved by the Engineer and as mandated by other relevant Contract provisions.

d) **Concreting**

i. Cast-in-Situ pile concreting shall conform to provisions of Annexure OCS-1 of these Specifications and the relevant provisions of IS 2911 (Part 1/ Sec 2), where not in contravention to the following provisions.

ii. Concreting shall not be done until the Engineer is satisfied that the termination level of pile, is as per the installation criteria and the Method Statement that has been approved by the Engineer.

iii. Concrete in the pile shall be coherent, rich in cement with high slump and restricted water cement ratio. The slump of concrete shall vary between 150 mm to 180 mm for bored piles. For long or large diameter piles, use of retarding plasticiser in concrete is desirable.

iv. The time interval between the completion of boring and placement of concrete in pile bore shall not exceed 6 hours. In case the time interval exceeds 6 hours, the pile bore shall be abandoned. However, the Engineer may allow concreting provided the Contractor extends the pile bore by 0.5 m beyond the termination level and clean the pile bore. The entire cost of all operation and materials for this extra length shall be borne by the Contractor.

v. The concrete shall be properly graded, self-compacting and shall not get mixed with soil, excess water, or other extraneous matter. Special care shall be taken in silty clays and other soils which have the tendency to squeeze into the newly deposited concrete and cause necking. Adequate head of green concrete shall be maintained to prevent inflow of soil or water into the concrete.

vi. Concreting shall be done by tremie method. The operation of tremie concreting shall be governed by IS 2911 (Part 1/ Sec 2). Stabilizing material shall be maintained sufficiently above the ground water level, as specified elsewhere in this Specifications.

vii. Concreting by tremie shall continue to allow the initial pours of concrete, mixed with stabilizing fluid, sludge and cut spoils from the bore to overflow and the consistency and quality of the overflowing concrete is comparable to that of design mix. The length of overflow shall be decided by the Engineer.

viii. It shall be ensured that the volume of concrete poured is at least equal to the theoretically computed volume of the pile shaft being cast.

ix. The tremie shall have uniform and smooth cross-section inside. The tremie shall be water-tight throughout its length and have a hopper attached at its head by a water-tight connection. All tremie tubes shall be scrupulously cleaned before and after use.

x. While concreting the tremie shall be withdrawn slowly ensuring adequate height of concrete outside the tremie pipe at all stages of withdrawal.

xi. An adequate quantity of concrete within the pipe shall be maintained at all times to ensure that the pressure from it exceeds that from the water or drilling fluid.

xii. The tremie pipe shall be lowered to the bottom of the bore-hole, allowing water or stabilizing material to rise inside it before pouring concrete. The tip of the tremie pipe shall not be separated from the bottom of the hole more than necessary (when plunger is used, it is about 0.2 m or less from the hole bottom)

xiii. The tremie pipe shall always be kept full of concrete and shall penetrate well into the concrete in the borehole, at least 2 m or more, with adequate margin of safety against accidental withdrawal if the pipe is surged to discharge the concrete.

xiv. During concreting, the cycle time of concreting, concreting volume, concrete placement height and the height of the tremie pipe tip in concrete shall be checked for all the piles and reported in a format that has been approved by the Engineer.

xv. To prevent the reinforcement cage from floating during placement of concrete, appropriate countermeasures shall be made in advance, as per the Method Statement that has been approved by the Engineer. The same shall be monitored for all piles and reported.

xvi. Temporary casings, when used, shall be extracted carefully to the satisfaction of the Engineer, whilst the concrete is sufficiently workable to ensure it is not disturbed or lifted, and the reinforcement cage does not get disturbed. During extraction, sufficient quantity of concrete shall be maintained inside the casing to overcome the pressure from external water, soil or stabilizing material and to ensure that no reduction in section by way of necking or shearing of concrete and contamination of the pile takes place.

xvii. Segregation of the ingredients shall be prevented. The displacement or distortion of reinforcement during concreting shall be avoided. If the concrete is placed inside precast concrete tubes or consists of precast sections, subject to the approval of the Engineer, these shall be free of cracks or other damage before being installed.

xviii. While concreting uncased piles, voids in concrete shall be avoided and adequate head of concrete shall be maintained to prevent inflow of soil or water into the concrete. It is also necessary to take precautions during concreting to minimise the softening of the soil by excess water. Uncased cast- in-situ piles shall not be allowed where mudflow conditions exist.

xix. Where concrete is placed in dry borings, measures, subject to approval of the Engineer, shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in grout.

xx. Where enlarged bases are required, as per site conditions and as approved by the Engineer, these shall be mechanically formed and shall be concentric with the pile shaft within a tolerance of 10% of the shaft diameter and shall not be smaller than the required dimension. The sloping surface of the frustum forming the enlargement shall make an angle of not less than 55° to the horizontal.

xxi. Grouting at base of pile shall be done wherever the results of proof coring (in case of rock), sonic logging and/or loading test etc. confirm that there is a void/ sludge at the pile base. The grouting shall be done with cement slurry under suitable pressure after concrete in the pile attains the desired strength, if required by the Engineer. For this purpose, conduit pipes with easily removable plugs at the bottom end shall be placed in the bore along with reinforcement cage before concreting

### 14.7.4 Top of Concrete in Pile, Cut-off-Level (COL):

a) Cut-off-Level of piles shall be as indicated in the drawings.

b) The top of concrete in pile cast shall be above the Cut-off-Level by 1.0 m (minimum) and as per the Method Statement, to remove all laitance and weak concrete and to ensure good concrete at Cut-off-Level, for the proper embedment into the pile cap. Any exceptions, due to contingent situation, will be subject to the approval of the Engineer.

c) Preparation of pile head: The area surrounding the piles shall be excavated up to the bottom of the pile caps. After seven days of concreting of pile, the exposed part of concrete above the COL shall be removed or chipped off and made rough at COL. In case a part of extra-pile concrete before curing is handled, the Contractor shall obtain prior approval from the Engineer. The projected reinforcement above COL shall be properly cleaned and bent carefully, only where required, to the required shape and level to be anchored into the pile cap as per the drawing. While finishing the pile head, care shall be taken to ensure no harmful damage, such as cracks, occurs in the concrete. The pile top shall be embedded into the pile cap by 150 mm as per the Drawings and as agreed by the Engineer. All loose material on the top of pile head after chipping to the desired level shall be removed and disposed as per contractual procedure and as directed by the Engineer.

### 14.7.5 Reinforcement Steel

a) Reinforcement steel, along with its inspection and testing shall conform to Annexure – OCS-2 of these Specifications, along with IS 2911 (Part 1/ Sec 2) and used as per the drawings.

b) The reinforcement shall be assembled before placing in the moulds and all hoops and links shall be of uniform length firmly wired into position. Ends of helical reinforcement, if used, shall be firmly secured. Diagonal fork spacers shall be of a pattern that has been approved by the Engineer.

c) Lap joints in main longitudinal bars will be permitted only when, in the opinion of the Engineer, each bar cannot be supplied in one complete length. Where permitted, joints shall be provided at agreed centres, designed to develop the full strength of the bar across the joint, provided with adequate links or stirrups and staggered in position from those of adjacent longitudinal bars or as indicated in the drawings, subject to the approval of the Engineer.

d) The 'L' bends in the reinforcements at the bottom of the piles shall not be provided to avoid the formation of soft toe.

e) Jointing of Reinforcement Steel for Piles: Only lap joints shall be provided as shown in the drawings.

f) Lowering of the reinforcement cage:

    i. The reinforcement cage shall be properly aligned with the pile core and kept vertical without collapsing the hole wall. In lowering of the reinforcement cage, it shall avoid deformations, damages, etc. by using reinforcing material as necessary. In the lap joint part of the reinforcement cage, the upper and lower cages shall be in a straight line, with the joints tightly bound.

    ii. Proper cover to reinforcement and central placement of the reinforcement cage in the pile bore shall be ensured by use of suitable concrete spacers or rollers cast specifically for the purpose, as directed by the Engineer. The longitudinal reinforcement shall project above Cut-off-Level as indicated in the drawings.

iii. After lowering of the reinforcement cage, the height of the top end of the reinforcement shall be measured and reported. The axes of the reinforcement cage and the pile core shall be matched, checked and reported.

### 14.7.6 Breaking off of Piles

If any pile already cast requires breaking due to subsequent change of Cut-off-Level, then the same shall be carried out, not before seven days of casting without affecting the quality of existing pile, such as loosening, cracking etc., and to the satisfaction of the Engineer.

### 14.7.7 **Pile** Caps

The ground shall be excavated, levelled, prepared and then layers of coarse aggregate and blinding concrete shall be constructed below pile cap. The pile cap shall then be cast as per the Drawings and conforming to Annexure OCS-1 and Annexure OCS-2 of these Specifications, subject to tolerances mentioned therein.

### 14.7.8 Tests on Piles

**a) General**

When preparing for conducting a pile test, the Contractor shall follow the requirements of the various acts, orders, regulations and other statutory instruments that are applicable to the work for the provision and maintenance of safe working conditions, and shall in addition make such other provision as may be necessary to safeguard against any hazards that are involved in the testing or preparations for testing.

**b) Load Test on Piles**

i. These Specifications covers the requirements for initial vertical load and routine vertical load tests on reinforced concrete single vertical piles of specified diameter to assess their vertical load carrying capacities. All pile load testing shall conform IS 2911 (Part 1/ Sec 4)

ii. Full details of the equipment proposed to be used, the test setup and pile testing scheme along with detailed design, drawings shall be submitted to the Engineer, before making arrangements to carry out the tests, for obtaining his approval. Approval of the Engineer shall also be obtained after the test setup is complete, prior to commencement of loading.

iii. The work shall include mobilization of all necessary equipment, kentledge, anchor piles and rock anchors, or combination of kentledge and anchor piles and rock anchors, providing necessary engineering supervision and technical personnel, skilled and unskilled labour as required, to carry out the complete pile testing and submission of test reports.

iv. In all cases, the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the pile head the whole system will be stable up to the maximum load to be applied.

v. Necessary means shall be provided to enable dial gauges to be read from a position clear of the kentledge stack or test frame in conditions where failure in any part of the system due to overloading, buckling, loss of hydraulic pressure and so on might constitute a hazard to personnel.

vi. The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable of withstanding a test pressure of one and a half times the maximum working pressure without leaking.

vii. The maximum test load or test pressure expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

viii. Where kentledge is used, the Contractor shall construct the foundations for the kentledge and any cribwork, beams or other supporting structures in such a manner that there will not be differential settlement, bending or deflection of an amount that constitutes a hazard to safety or impairs the efficiency of the operation. The kentledge shall be adequately bonded, tied or otherwise held together to prevent it falling apart, or becoming unstable because of deflection of the supports. The weight of kentledge shall be greater than the maximum test load and if the weight is estimated from the density and volume of the constituent materials, an adequate factor of safety against error shall be allowed.

ix. It is essential that all the equipment and instruments are properly calibrated both at the commencement and immediately after the completion of tests, so that they represent true values. If the Engineer desires, the Contractor at his own cost shall arrange for calibration of the instruments in presence of the Engineer, at a laboratory having Engineer's approval, and the test report and calibration certificate shall be submitted to the Engineer.

x. The complete jacking system including the hydraulic jack, hydraulic pump and pressure gauge shall be calibrated as single unit. The complete unit shall be calibrated over its complete range of travel for increasing and decreasing loads same as that of test loads. The calibration certificate shall be submitted to the Engineer.

xi. The reaction load to be made available for the test shall be at least 25% greater than the maximum jacking force. The reaction system as relevant shall be designed for the total reaction load. All reaction loads shall be stable and balanced during all operations of testing. During testing, stability of reaction system shall be ensured.

xii. The vertical displacement of pile shall be measured using dial gauges having a least count of 0.01 mm.

xiii. Load test shall be conducted at pile Cut-off-Level (COL). If the water table is above the COL, the test pit shall be kept dry throughout the test period by suitable dewatering methods.

xiv. In case of initial vertical load test, where the water table level is higher than the COL, the Contractor may use anchor piles and rock anchors for testing purposes. The Engineer, at his discretion, may decide to raise the COL above water table.

xv. All operations in connection with pile load test shall be carried out in a safe manner to prevent exposure of the people to hazard and also to ensure the safety of manpower and material.

xvi. Test record and report for pile load tests shall be as per IS 2911 (Part 1/ Sec 2) and as approved by the Engineer. The reports shall be submitted to the

Engineer immediately on completion of each test.

xvii. Two fixed independent benchmarks shall be established as reference points at least 15 m from the test pile to monitor the settlements.

xviii. If any initial pile load test gets abandoned and is not successfully completed, then the Contractor shall install another test pile and repeat the initial test after correcting the fault, at his own cost.

xix. On completion of a test all equipment and measuring devices shall be dismantled, checked and either stored so that they are available for use in further tests or removed from the Site.

**c) Test Pile Installation**

i. Piles shall be installed as per Sub-Clause 3.5.3 herein above.

ii. Pile installation data as applicable shall be furnished along with the load test results to the Engineer.

**d) Types of Tests**

i. Initial vertical (compression) load test and lateral load test shall be carried out on test piles, which are not to be incorporated in the work, to assess the 'Ultimate Load Capacity of Pile' before the commencement of the installation of working piles.

ii. The test piles shall have the same design details as of the working piles typically adopted in the predominant soil profile in that area.

iii. Routine vertical (compression) load test and lateral load test shall be conducted to verify the load carrying capacity of working pile.

iv. Pile integrity test shall be carried out on each pile by The Low Strain Method as per IS 14893 to verify the structural integrity, shape and continuity of pile

**e) Number of Tests:**

i. **Initial pile-load tests:** The number of load tests shall be as per IS 2911 (Part 4) depending upon the total number of piles but not less than two (2). Wherever the soil strata are erratic or there is change in structure type (such as river bridge, rigid frame), additional tests shall be required as directed by the Engineer.

ii. **Routine pile-load tests:** The number of tests may generally be 0.5 percent of the total number of piles required, but not less than one (1). The number may be increased up to 2% depending upon the nature, type of structure and sub-strata condition.

iii. Initial and routine tests may be suitably increased for important structures or cases with large variation in the subsurface strata as directed by the Engineer.

iv. Pile load tests shall be carried as per IS 2911 (Part 4).

**f) Testing-Piles**

i. The testing-piles for routine load test shall be identified by the Engineer. For initial load test, testing-pile shall be installed as a test-pile, separate from working piles, as directed by the Engineer.

ii. A minimum time period of four weeks shall be allowed between the time of pile casting and testing. Testing-pile head shall be prepared for testing purposes only, one week after casting the pile.

iii. Testing-piles shall be cut off at the proper level and provided with a proper cap, to provide a plane bearing surface for the test plate and for proper arrangements for seating of the jack and dial gauges.

**g) Static Vertical Load Test**

i. The tests shall conform to IS 2911 (Part 4).

ii. Equipment and Test Setup

- A steel plate of adequate thickness and not less than 50 mm shall be centered on the pile cap to prevent it from getting crushed under applied load. The size of the circular test plate shall not be less than the pile size nor less than the area covered by the base of the hydraulic jack(s).
- The datum bars shall be supported on immovable supports, preferably of concrete pedestals or steel sections, placed sufficiently far away from the test pile. The distance shall not be less than 3 times the diameter of testing-pile and in no case less than 2 metres from the edge of testing-pile. These supports shall be placed at an adequate depth below ground to be unaffected by ground movements.

iii. Loading System

The test load on pile shall be applied by means of hydraulic jack(s) which obtain reaction in one of the ways mentioned in Cl.7.1.3 of IS 2911 (Part 4).

The measurement of strains for load monitoring may also be done by load cell connected to a digital read out unit.

iv. Test Procedure

- Application of Load:- The test should be carried out by applying a series of vertical downward incremental load each increment being of about 20 percent of safe load on the pile. For testing of raker piles it is essential that loading is along the axis.
- This is applicable for both initial and routine test. In this method application of increment of test load and taking of measurement or displacement in each stage of loading is maintained till rate of movement of the pile top is not more than 0.2mm/h or until 2 h has elapsed, whichever is earlier subject to a minimum of 1 h. The test load shall be maintained for 24 h.
- Duration of vertical loading shall be as per Cl. 7.2 of IS 2911 (Part 4)
- Settlement:- Settlement shall be recorded as per Cl. 7.1.4 of IS 2911 (Part 4).
- The safe vertical load on single pile for the initial test shall be as per Cl. 7.1.5 of IS 2911 (Part 4).
- Items to be measured:

The following items shall be measured:

- Time;
- Applied pressure;
- Applied load;
- Displacement at the pile head;
- Movement of reaction devices;
- Others, as decided by the Engineer.

- Commencement, interruption and completion of the test:
  - The test shall be commenced after ensuring the conditions surrounding the site, preparations of all equipment and the suitability of the weather condition.
  - If any abnormal conditions are noticed during the test, the test shall be interrupted promptly. The test can only be resumed when the cause of the abnormal condition has been detected and rectified.
  - The test shall be completed when the objectives of the test shall have been achieved, or when it is judged that abnormal conditions make it impossible to continue the test.
- Loading on the pile shall be continued till as given in IS 2911 (Part 4).

h) **Lateral load tests –** Lateral load tests shall be carried out on test pile as well as on working pile safe load capacity determined as per Clause 8 of IS 2911 (Part 4).

i) **Pile Integrity Test on Working Piles (other than piles subjected to routine load test):**

i. Pile integrity test shall be carried out on each pile by The Low Strain Method as per IS 14893:2001. In case of large diameter piles, the tests shall be conducted at 5-6 places to cover the entire section of the pile.

ii. The tests shall be conducted on piles whose length is correctly recorded or on test piles where available, to determine the value of stress wave velocity and characteristic or reference signal for comparing the signals for testing subsequent piles.

iii. The area surrounding the pile should be free from standing water and kept dewatered during the tests. The pile head should be accessible.

iv. Testing should be free of work likely to cause disturbance. The cast-in-situ piles should not be tested normally before 14 days of casting.

v. The test piles, if available at site, can be used to determine the pulse velocity and characteristic or reference signal generated. Where no test pile is available information can be obtained from cast piles whose length is accurately recorded.

vi. Methodology for Low Strain Integrity test:

- This is a system of assessing the integrity of piles by the use of low stress wave imparted to the pile shaft and is also known as Sonic Integrity or Sonic Echo Test. A small metal/hard rubber hammer is used to produce a light tap on top of the pile. The shock traveling down the length of the pile is reflected back from the toe of the pile and recorded through a suitable transducer/accelerometre (also held on top of the pile close to the point of impact) in a computer disk or diskette for subsequent analysis. The primary shock wave which travels down the length of the shaft is reflected from the toe by the change in density between the concrete and sub-strata. However, if the pile has any imperfections or discontinuities within its length these will set up secondary reflections which will be added to the return signal.

- The reflected stress wave can be monitored using either processing technique, the observed signals are amplified and converted into digital display as velocity versus length or frequency versus mobility records, providing information on structural integrity of piles. The stress wave velocity and approximate pile lengths are provided as input for the integrity testing. The stress wave velocity is dependent on the Young's modulus and mass density of pile concrete. This value generally lies between 3000-4000 metre per second depending on the grade of concrete used (M15-M25).

**j) Sampling, Testing, Inspection, and Acceptance Criteria Including Construction Tolerances of Piles**

i. Frequency of sampling, testing and quality assurance including the method of conducting the tests, acceptance criteria and construction tolerances shall be as mentioned herein above and included in the Method Statement that has been approved by the Engineer. The tests shall be performed and reported as per the Method Statement that has been approved by the Engineer.

ii. Forcible corrections for any deviations shall not be made to concrete piles.

iii. Data Reporting and processing

- The assessment of structural integrity is based on two equally important aspects:
  - Quality of signals, and
  - Accurate analysis and interpretation of signal.
- Piles requiring remedial measures should be so marked immediately on completion of the field integrity testing and rectification measures selected.
- The final report should include signals of each integrity test and structural condition of piles.

iv. Submission of Results: Immediately after testing, a signed copy of all the raw data of a pile shall be given to the Engineer. A test report shall be submitted to the Engineer within 3 days after testing.

### 14.7.9 Safety

The Contractor shall adopt appropriate method and practice conforming to IS 5121 (Piling and other deep foundation - Code of Safety) suiting to local ground characteristics.

## 14.8 Formwork

Form work for bridge foundations, sub structure and superstructures shall be as per IS-3696, IS-4014 and Annexure OCS-1. It includes all temporary or permanent forms required for forming the concrete of the shape, dimensions and surface finish as shown on the drawing or as directed by the Engineer, together with all props, staging, centering, scaffolding and temporary construction required for their support.

## 14.9 Substructure

### 14.9.1 Piers and Abutments

a) Concrete and reinforcement for piers and abutments shall conform to relevant sections of these specifications and drawings. In case of concrete piers, minimum grade will be M 20 unless otherwise specified / approved. The number of horizontal construction joints shall be kept to minimum. Construction joints shall be avoided in splash zones unless specifically permitted by the Engineer and provided they are treated in accordance with special provisions. No vertical construction joint shall be provided. Shear connectors in the form of vertical plumbs, dowels, bond bars or rail cut pieces shall be provided at all horizontal joints as directed by Engineer. The work shall conform strictly to the drawings or as directed by the Engineer.

b) In case of tall piers and abutments, use of slipform shall be preferred. The design, erection and raising of slip form shall be subject to special specifications which will be furnished by the Contractor. The concrete shall also be of higher grade and subject to additional specifications as necessary. All specifications and arrangements shall be subject to the approval of the Engineer.

c) The surface of foundation / well cap / pile cap shall be scraped with wire brush and all loose materials removed. In case reinforcing bars projecting from foundations are coated with cement slurry, the same shall be removed by tapping, hammering or wire brushing. Care shall be taken to remove all loose materials around reinforcements. Just before commencing masonry or concrete work, the surface shall be thoroughly wetted.

d) In case of solid (non-spill through type) abutments, weep holes as shown on the drawings or as directed by the Engineer, shall be provided.

e) The surface finish shall be smooth, except the earth face of abutments which shall be rough finished or left as form finished.

f) In case of abutments likely to experience considerable movement on account of backfill of approaches and settlement of foundations, the construction of the abutment shall be followed by filling up of embankment in layers simultaneously with filter backing behind to the full height to allow for the anticipated movement during construction period before casting of superstructure.

### 14.9.2 Pier Cap and Abutment Cap (Bed Blocks)

a) Form work, Concrete and reinforcement shall conform to relevant paras of Concrete work & RCC of these specifications and the Drawings. Unless otherwise specified, minimum grade of concrete mix shall be M 35.

b) The locations and levels of pier cap / abutment cap / pedestals and bolts for fixing bearings shall be checked carefully to ensure alignment in accordance with the drawings of the bridge.

c) The surface of cap shall be finished smooth and shall have a slope for draining of water as shown on the drawings or as directed by the Engineer. For short span slab bridges with continuous support on pier caps, the surface shall be cast horizontal. The top surface of the pedestal on which bearings are to be placed shall also be cast horizontal.

d) The surface on which elastomeric bearings are to be placed shall be wood float finished to a level plane which shall not vary more than 1.5mm from straight edge placed in any direction across the area. The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25mm below the bottom level of bearings and as indicated on the drawings. Specified rich levelling mortar shall be provided over this at the time of placing of bearing.

### 14.9.3 Dirt / Ballast Wall, Return Wall and Wing wall

a) Dirt / ballast walls ,return wall & wing walls shall be in RCC. Minimum grade of concrete will be M35 unless otherwise specified. In case of cantilever return walls, no construction joint shall generally be permitted. Wherever feasible, the concreting in cantilever return walls shall be carried out in continuation of the ballast wall.

b) For concrete return and wing wall, the surface of foundation shall be prepared in the same manner as prescribed for construction of abutment. No horizontal construction joint shall be provided. If shown on drawing or directed by the Engineer, vertical construction joint may be provided. Vertical expansion gap of 20mm shall be provided in return wall / wing wall at every 10 metre intervals or as directed by the Engineer. Weep holes shall be provided as prescribed for abutments or as shown on the drawings.

c) Form work, reinforcement and concrete in dirt / ballast wall shall conform to relevant sections of these specifications.

d) The finish of the surface on the earth side shall be rough/form finish while the front face shall be smooth finished.

e) Architectural coping for wing wall / return wall in brick masonry shall conform to Drawings.

### 14.9.4 Tests and Standards of Acceptance

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria.

The work shall conform to these specifications and shall meet the prescribed standards of acceptance.

### 14.9.5 Tolerances in Concrete elements

a) Variation in cross-sectional dimensions: + 10mm, -5mm

b) Misplacement from specified position in plan: 10mm

c) Variation of levels at the top: + 10mm

d) Variations of reduced levels of bearing areas: + 5mm

e) Variations from plumb over full height: + 10mm

f) Surface irregularities measured with 3m straight edge

- All surfaces except bearing areas: 5mm

- Bearing areas: 3 mm

**14.9.6** For construction of Br Nos. 150 and 153 temporary diversion of existing roads will be required first. Then existing roads will be lowered by about 1.90 m at the site of the bridges and regraded to join the existing roads. Thereafter Br Nos. 150 and 153 will be constructed.

## 14.10 Bridge Work : Superstructure

### 14.10.1 GENERAL

a) Coverage

This chapter covers specifications for the following types of superstructures:

i. RCC Box

ii. Prestressed concrete girders and slabs

iii. Steel- Open Web Girders (OWG) and Composite Girders

### 14.10.2 RCC BOX

All concrete works for RCC box shall conform to Annexue OCS-1 & 2.

### 14.10.3 STEEL Open Web Girders (OWG) and Composite Girders

Fabrication and erection of steel girders shall conform to Annexure OCS-3.

Concrete and reinforcement for composite girders shall conform to Annexue OCS-1 & 2.

### 14.10.4 PRE-STRESSED CONCRETE GIRDERS AND SLABS

All prestressed works for bridges shall be carried out in accordance with Annexure OCS-1 to 4. PSC slabs of 12.2 m span shall be cast on a prepared casting bed and shall thereafter be launched in position after prestressing using suitable capacity crane.

### 14.10.5 Linking of Track on Open Web Girder (OWG)

Galvanised H-beam bridge sleepers shall be as per RDSO Drawing No. B-1636/4/R, 5 & 9. Zero toe load fastening shall be as per RDSO Drawing No. T-8759 to T-8765 for 60kg running rail and 52 kg guard rail. Both H-beam bridge sleepers and track fittings/fastenings shall be procured from RDSO approved source. Inspection of material shall be done by the Engineer at factory premises before dispatch. The Contractor shall arrange for necessary inspection/testing of material at factory premises.

Linking of track on H-beam sleeper with 60 kg running rail and 52 kg guard rail shall include bending of guard rail, drilling of holes, cutting of rails, providing wooden wedge at the end of guard rail, provision of gang pathway of 6 mm thick MS chequered plate as per RDSO Drawing No. B-1636 /5 on H-beam sleeper and making track fit for normal sectional speed.

# Chapter 15

# BALLASTLESS TRACK

## 15.1 GENERAL

a) BLT in tunnel has to be laid over the tunnel in the tunnel invert concrete base.
b) Electrical Interface: The plinth electrical continuity is essential, for which purpose the contractor shall supply and install suitable connection.
c) The opposite electrical continuity between rail bases shall be checked by means of a low resistance continuity apparatus (10V-100 amp) in presence of the Engineer.
d) Detailed specification for RCC to be used for slab track etc. shall be as per

## 15.2 BALLASTLESS TRACK INSTALLATION

### 15.2.1 GENERAL

i. The track gauge throughout shall be 1673 mm (nominal) measured between the running edge gauge point of each rail and normal to the Centre line of the track 14 mm below top of rail.
ii. All main line track shall be laid with 1:20 inward rail slope.

### 15.2.2 RAIL JOINTING

i. All rail joints throughout the main lines glued insulated joints, switch expansion joints etc. shall be welded.
ii. The welding of nominal rail lengths into long welded rail panels for main lines shall be done with Mobile Flash butt welding machine approved by RDSO. Wherever the Mobile Flash Butt welding is practically not possible the Alumino-thermit welding can be done in accordance with RDSO specification.

### 15.2.3 RAIL EXPANSION JOINTS

i. Particular attention shall be given to ensure that rail expansion joints are assembled and installed in accordance with the Drawings and correctly located with relation to the type of Rail Expansion joint and the direction of traffic.
ii. Immediately prior to completion of a section, all sliding surfaces of rail expansion joint shall be cleaned and greased.

### 15.2.4 RAIL TEMPERATURE

Rail temperatures shall be measured using appropriate dial type magnetic thermometers placed on the web of the rail on the shaded side. A minimum number of thermometers required to be used per rail for measuring average rail temperature of a segment of track shall have the prior approval of Engineer.

### 15.2.5 CLEANING OF TRACK

The track from structure (including the rail surface) as installed shall be thoroughly cleaned to an acceptable standard as approval by the Engineer immediately after installation and as required thereafter maintaining the standard until the arrangement of service trails so as to provide adequate levels of electric insulation and rail surface quality for correct performance of train control and signaling equipment under prevailing climate and environment conditions.

### 15.2.6 RAIL INSULATION

The track as installed shall be thoroughly cleaned immediately after insulation. This shall be necessary to provide adequate levels of electrical insulation for the correct performance of the signaling and traction equipment under the prevailing climatic and environment condition.

### 15.2.7 CUTTING OF RAILS

i. Rails shall only be cut by using abrasive rail cutting machines. The proposed method and equipment for the cutting of rails shall have the prior approval of the Engineer.
ii. Rails required to be cut shall be cold sawn square and vertical across the rail. A deviation from square or vertical of more than 0.5mm measured about the rail head, shall not be permitted. All burrs shall be removed from the rail ends.
iii. Quality of cutting shall be such as to ensure tolerances in Alumino-thermit welding manual.

### 15.2.8 STAGES OF REQUEST FOR INSPECTION DURING CONSTRUCTION OF SLAB TRACK.

The ballastless track system consists of:

i. Support structure done as a part of tunnel civil works
ii. Reinforced concrete slab track
iii. Rail fastening system (design and drawing shall be submitted by the bidder/contractor for approval).

"Request for inspection" shall be submitted to the Engineer, Complete with all necessary information to allow assessment, after the following activities and approval must be received prior to the commencement of any follow-on activity.

a) Acceptance of support structure including specified surface treatment
b) Acceptance of the slab track reinforcement
c) Acceptance of temporary/false works shuttering, jigs, fixtures and supporting arrangements
d) Acceptance of the track for concreting
e) Acceptance of the track for the movement of construction of plant equipments and machinery
f) Acceptance of the track for in-situ welding
g) Acceptance of the track for destressing

### 15.2.9 REINFORCED CONCRETE SLAB TRACK

a) The ballastless tracks shall be laid with reinforced concrete slab track on supporting structures.
b) The ballastless track shall be constructed by Top down method of construction. The laying tolerance for various parameters for the installed Ballastless track shall be strictly achieved in accordance with the relevant clauses in these specifications. For achieving these tolerances the tenderer may propose the method/scheme of construction of ballastless track along with the tender submission. However, the sole responsibility of achieving the stipulated track laying tolerances lies with the contractor.
c) The contractor shall be responsible to calculate the height of the slab track at each location to maintain the desired rail level as shown in the relevant drawings and submit the same for the approval of the Engineer. The reinforced concrete slab track shall be laid on the tunnel invert duly making the provision for cant and vertical curves.

d) Suitable construction joints shall be provided for the slab track in tunnel. Location of the joints shall be in conformity with the location of other joints in the tunnel structure.

e) The handling and transport arrangement of rails shall ensure no damage to the rails.

f) Resilient pads placed under the metal base plates shall be coated with silicon or any suitable product, on their underside and lateral side, to stop them adhering to the slab track concrete, as approved by Engineer.

g) During the concreting phase, the track fastening device, the running rails and the expansion joints templates shall be protected by movable covers against possible splattering of concrete.

h) Conduits required for crossing of signaling wires shall be have to be provided before concreting as directed by the Engineer.

i) Immediately after concreting of slab track the assembly consisting of the rails and the plinth segments shall be covered by wet cloths to prevent damage due to rise in temperature.

j) These cloths shall be damped constantly for 8 hours from the time of pouring the concrete.

k) The rail fastening between the metal base plates and running rails base shall then be removed to authorize differential movement in the longitudinal direction between the rails and structures.

l) Twenty-four (24) hours after pouring of the slab track concrete, the formwork shall be removed.

m) The concreted surfaces of the slab track below the base plates shall be smooth, devoid of any inclusions, roughness cracks and without showing any aggregate at the surface.

n) Temporary rails shall not be used for constructions, slab track shall be constructed using the permanent rail to be finally fastened.

## 15.3 TEST FOR RAIL FASTENING SYSTEM COMPONENTS

The following tests are required to be conducted for fastening system-

a) Pull out strength test of anchor bolts.

b) Longitudinal creep resistance test of rail seat assembly.

c) Fatigue test of tension clamp.

d) Fatigue test of helical spring.

e) Stiffness test (static & dynamic) of elastic base plate pad & the ratio of dynamic to static stiffness at various frequencies.

f) Fatigue tests of assembly as a whole. These tests shall cover as minimum heat generated in pads in terms of temperature, records of gauge, rotation of rail head, slippage of rail foot, and lateral & vertical movement of base plate and vertical deflection of rail head.

g) Installation procedure tests.

## 15.4 RAIL INSULATION TO EARTH TEST

i. All track work shall be subjected to a rail insulation to earth test. The track shall have a minimum rail to earth value of 40 Ω/km of single track for ballastless tracks.

ii. The rail to earth test shall be undertaken after the track has been completed and cleaned but before it is finally formed into a continuously welded system and before all the bonding is installed.

iii. Junctions shall be isolated and tested prior to their final connection into the track.

iv. The test shall be undertaken on rail lengths up to maximum lengths of 1000 m. The tracks shall not be finally formed into a continuous length, nor shall the junctions be joined to the adjacent tracks, until the rail insulation to earth tests have been undertaken and approved.

### 15.5 BALLASTLESS TRACK BASE RESISTANCE TESTS

i. A ballastless track base resistance test shall be undertaken on all track lengths over 50 meters as a check of the leakage of current through the track base and rail fastening system from one rail to the other.

ii. The ballastless track base resistance test shall be undertaken after the track has been complete and cleaned but before it is finally formed into a continuous length and all the bonds are attached.

iii. The testing procedure and the minimum resistance shall comply with the requirements proposed by the engineer.

### 15.6 RAIL INCLINATION INSPECTION

i. Both rails of all ballastless running line tracks shall be checked, at maximum 10m intervals, for inclination using an approved equipment/method in the presence of the engineer.

ii. Should any reading show the inclination to be outside the specification limits every alternate fastening assembly shall be further checked either side of the non-compliant reading until compliant readings are consistently obtained.

### 15.7 RAIL WELDING:

i. The main line track shall be welded into LWR/CWR using mobile flash butt welding machine approved by RDSO. Wherever the mobile flash butt welding is practically not possible the Alumino-thermit SKV process welding shall be done with the approval of the Engineer through agencies approved by RDSO and as per provision of manual for fusion welding of rails by the Alumino-thermit process supply of portion must be and procurement is from sources approved by RDSO.

ii. Welding shall be supervised by trained welding supervisor and carried out by trained welder having competency certificate from RDSO/Lucknow in his possession.

iii. The preparation of rail ends to be ensured before welding.

iv. The contractor shall arrange for test welds and their testing done as per manual.

v. The welds shall be finished to final profile by grinding and the finished weld shall be within the specified tolerance.

vi. Each joint shall have distinctive marks as per details in the manual.

vii. Weld collar shall be painted against corrosion as per specification given in manual.

viii. All the recorded welds shall meet the acceptance tests including ultra-sonic test.

ix. Rail joints welded by the contractor shall be guaranteed against failure for a period of 2 years from date of welding the joints in track or from date such welded joints made in cess are inserted in the track. Any such welded joint which fails within guarantee, the joints shall be rewelded free of cost.

x. In case of failure of sample test joint, the period of guarantee for 100 joints represented by the sample joint shall be extended for a further period of 1 year. In case of failure of joints exhibiting sign of failure by cracking within extended period of guarantee, the joints shall be rewelded free of cost.

xi. When one bad joint is required to be replaced by two new joints, the entire cost of both the joints shall be borne by the contractor.

xii. Drilling of holes in the 60kg rails is strictly not permitted.

## 15.8 DESTRESSING OF CWR:

i. Destressing must be done as per provisions of Indian Railway Permanent Way Manual.

ii. Destressing of rails shall not be undertaken until it has been demonstrated to Engineer's satisfaction that the track has been completed to the specified standard specifications and the method of working for destressing of the relevant track has been approved by the Engineer.

iii. Destressing must be done in accordance with temperature conditions stated in the Railway Manual.

iv. The stress free temperature condition of LWR shall be achieved naturally or artificially by the use of hydraulic rail tensors as approved by the Engineer.

## 15.9 CONSTRUCTION PROCESS

Tenderers are advised to visit local sites location as specified in tender to get familiar with typical local environment like drainage system/extent of tunnel and water flooding during monsoon period in tunnel area etc.

Procedure of construction process of BLT should be mentioned in details suitable to local site conditions including necessary ground improvement. Removal of earth to required level followed by filling of coarse grained material in layer along with COMPACTION by vibratory process & system offered should be easy in construction suitable to condition prevailing on specified tunnel section in tender, clearly demonstrating how it can be constructed & installed within a reasonable time frame.

## 15.10 MAINTENANCE AND PERFORMANCE MONITORING

a) The defect liability period will be for 3 years from the date opening of traffic.

b) After Construction of Ballastless track, HRIDC will monitor the performance jointly with the contractor on quarterly basis & for 3 years. The performance monitoring will be based broadly upon following parameters:

c) Efficacy of fastening: Fastening system should be able to maintain track geometry (gauge, cross level, loose fitting etc.) at all times within track tolerances during service without any components breakage, excessive wear & tear.

d) Track tolerances to be maintained at the time of construction & during trial/services should be as per Section VII-5 Outline Design Specification (ODS) - Civil.

e) Any track settlement which impairs the functionality of ballastless track.

f) Any visible crack of width more than 0.1 mm in concrete/RCC portion of slab which impairs the functionality of ballastless track.

g) Efficacy of drainage system e.g. the slope and drains constructed should function properly during Monsoon period.

h) Any special observation.

i) The decision of HRIDC about performance of the ballastless track after monitoring period shall be final.

# Annexure OCS-1
# PLAIN AND REINFORCED CEMENT CONCRETE

## 1 MATERIALS

a. Before bringing to the site, all materials for concrete shall be approved by the Engineer. All approved samples shall be deposited in the office of the Engineer before placing orders for the materials with suppliers. The materials brought on to the works shall conform in every respect to their approved samples.

b. Fresh samples shall be deposited with Engineer whenever type or source of any material changes. The contractor shall check fresh consignment of materials as it is brought on to the works to ensure that they conform to the specifications and/or approved samples.

c. The Engineer shall have the option to have any of the materials tested to find whether they are in accordance with specifications at the contractor's expense. All bills vouchers and test certificates which in the opinion of the Engineer are necessary to convince him as to the quality of materials or their suitability shall be produced for his inspection when required.

d. If fly ash is used in concrete, the contractor shall demonstrate the quality control procedure including source of fly ash, its properties, handling as per the relevant IS & international codes etc. and shall use in slabs and walls only after "no objection" to the same has been obtained from the Engineer.

e. Any materials which have not been found to conform to the specifications and not approved by the Engineer shall be rejected forthwith and shall be removed from the site by the contractor at his own cost within the time stipulated by the Engineer. The Engineer shall have the powers to cause the contractors to purchase and use materials from any particular source, as may in his opinion be necessary for the proper execution of work.

f. Contractor shall also ensure that all constituents of exposed concrete shall be taken from same sources to achieve a uniform colour and texture.

g. Approved list of Manufacturer's/Suppliers is given in Section VII- 8,Tender Drawings and Documents. In case the Contractor desired to procure the material from any other supplier, it shall be got approved by the Engineer.

## 2 CEMENT

### 2.1 Product and Materials for Cement

a. Cement to be used in the works shall conform to 53-grade OPC (IS 269:2015) or blended cement such as Portland Pozzolana Cement (IS 1489:2015) or Portland Slag Cement (IS 455:2015).

b. The Contractor shall submit to the Engineer the Manufacturer's Certificate to affirm that the cement complies with the relevant standards.

c. Samples of the proposed cement shall be taken and forwarded to an independent laboratory for analysis before the source is approved.

d. Prior to ordering cement, the Contractor shall submit details of the proposed supplier or manufacturer and information on the proposed methods of transport, storage and certification for the Engineer's approval and show that the quantity and quality required can be attained and maintained throughout the construction period. In exposed concrete elements, the cement used in the concrete for entire element shall preferably be from a single manufacturer to ensure uniform colour.

e. Subsequent to obtaining the Engineer's approval, the Contractor shall not change the agreed arrangements without the prior approval from the Engineer. Each delivery of cement shall be accompanied by a certificate which shall be submitted to the Engineer immediately after the delivery showing the place of manufacture and the results of standard tests carried out by the manufacturer.

## 2.2 Testing for Cement

a. Samples shall be tested from every batch of cement delivered on site or once for every 1000 bags whichever is more frequent. The sampling from bulker shall be increased as decided by the Engineer.

b. Samples shall be taken immediately on receipt of cement at site. The methods and procedures for sampling shall be in accordance with IS: 3535.

c. Tests shall be carried out as per IS4031 for physical analysis as fineness, initial and final setting time and compressive strength and results approved by the Engineer before use. The contractor shall provide complete facilities at site for carrying out the following tests:

  i. Setting time by vicat's apparatus as per IS:5513 and IS:4031.

  ii. Compressive strength of cement as per IS: 4031, IS:650, IS:10080.

d. The Engineer may require any other form of sampling and tests including chemical analysis. Total chloride content in cement and total sulphur content calculated shall in no case exceed the requirements of Table 2 of IS 269. In case the cement supplied is of doubtful quality, tests shall be done in accordance with IS 4032. The costs of such additional tests shall be borne by the Contractor.

# 3 AGGREGATES

## 3.1 General

Aggregates shall conform to the provisions specified in IS 383:2016. The contractor shall submit to the Engineer certificates of grading and compliance for all consignments of aggregate. In addition, at site from time to time, the contractor shall allow for carrying out tests and for supplying test records to the Engineer. Prior to commencing any concrete work, the Contractor shall obtain the Engineer's approval of the proposed types and sources of aggregate.

For fair faced concrete, the contractor shall ensure that aggregates are free from iron pyrites and impurities, which may cause discoloration. Aggregates shall be stored on paved areas in different compartments according to their nominal size.

Sampling of aggregates shall be as per IS 2430.

## 3.2 Fine Aggregates (Sand)

a. The grading of the sand shall conform to IS:2386(Part1). The grading of fine aggregate shall be within the grading zones I, II, III. Sand, if found too coarse, shall be suitably blended with finer sand obtained from approved sources to obtain the desired grading. The provision of two types of sand, their separate stacking and their mixing in the specified proportions shall be at the Contractor's own cost.

b. The sand shall not contain silt, shale, clay and other weak particles for more than a total of 3% by weight. In case of sand containing excess silt, clay and chlorides, the sand shall be washed in screw type mechanical washers in potable water to remove the same. The screening and washing of sand shall be completed at least one day before using it in concrete. The washed sand shall be stored on a sloping platform while ensuring that contamination is avoided.

c. Water absorption shall be less than 3% by weight (ASTM C 117)

d. The sand shall be screened on a 4.75 mm size screen to eliminate oversized particles. The Contractor shall carry out the following tests at Site and ensure that the appropriate provisions of Indian or other standards, as may be applicable, are complied with:

i. Proportion of clay, silt and fine dust by sedimentation method as per IS 383:2016 and IS 2386 (Part II)

ii. Moisture content in fine aggregate as per IS 2386(Part III)

iii. Water absorption shall be worked out as per IS 2386(Part III)

iv. Bulk Density or bulkage as per IS 2386(Part III)

v. Grading of fine aggregate asper IS 383:2016 and IS 2386(Part I)

**3.3 Coarse Aggregates**

a. All coarse aggregate shall conform to IS: 383 and tests for conformity shall be carried out as per IS: 2386, Parts I to VIII.

b. The maximum size of coarse aggregate shall be such that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of formwork. The grading of coarse aggregate shall be such that not more than 5% shall be larger than the maximum size and not more than 10% shall be smaller than the smallest size. Between these sizes the coarse aggregate shall be well graded. Unless otherwise permitted by the Engineer the nominal maximum size shall not exceed 20 mm.

c. Water absorption shall be less than 3% by weight (ASTM C 117)

d. Coarse aggregates used for the Works shall be crushed stone conforming to IS 383, obtained from approved sources by the Engineer. Only quarries having jaw crushers with choke feeding arrangements producing aggregates of nearly cubical shape shall be applied.

e. Coarse aggregate containing flat or flaky pieces or mica shall be rejected.

f. The Contractor shall carry out the following tests at site and ensure that the appropriate provisions of following Indian standards as may be applicable are complied with:

i. Moisture content in coarse aggregate asper IS 2386(Part III)

ii. Water absorption shall be worked out as per IS 2386(Part III)

iii. Bulk density and voids asper IS 2386(Part III)

iv. Grading of coarse aggregate as per IS 383:2016 and IS 2386(Part I)

**4 Water**

Water used in the works shall be potable water and free from deleterious materials. Water used for mixing and curing concrete as well as for cooling and/or washing aggregate shall be fresh and clean free from injurious amounts of oil, salts, acids, alkali, sugar other chemicals and organic matter. Mixing and curing with seawater shall not be permitted.

Water shall be from the source approved by the Engineer and shall be in accordance with IRS: CBC(Cl.4.3), IS: 456 (Cl. 5.4) and/or BS 3148.

Water samples from the intended source of supply shall be taken for analysis before any concrete work commences, and at regular intervals throughout the duration of the Works, as approved by the Engineer. Whenever the source of water changes, the water shall be tested for its chemical and other properties or impurities to ascertain its suitability for use in concrete, subject to the approval of the Engineer. No water shall be used until tested and found satisfactory. Cost of all such tests shall be borne by the Contractor.

**5 Chloride Content**

The chloride content of aggregates shall be within the recommended limits stated in IS: 383 or BS 882 and the chloride content of the concrete mix shall be within the recommended limit of IS: 456 or BS 8110. Chloride levels shall be determined daily in accordance with the methods described in BS 812.

**6 Alkali-Silica Reactivity**

If aggregates contain any materials which are reactive with alkalis in any of the constituents of the concrete, or in water which will be in contact with the finished work, then the Contractor shall take samples of these materials every week. The Contractor shall ensure that the concrete mix complies with the requirements of this Specification regarding "Minimising risk of alkali-silica reaction in concrete". The results of the Contractor's weekly monitoring tests shall be submitted in writing to the Engineer-in-charge.

**7 Sulphate Content**

The total acid soluble sulphate content of the concrete mix, expressed as SO3, shall not exceed the recommended limit in IS: 456 or BS 8110.

**8 Reinforcement Steel**

The Contractor shall refer to Annexure - C of these Technical Specifications.

**9 Binding Wire**

GI wires of 1.6mm diameter shall be used for binding of reinforcements. It shall conform to the provisions laid down in IS 280.

**10 Concrete Admixtures**

a. Admixtures shall conform to the provision laid down in IRS: CBC (Cl. 4.4).

b. Concrete admixtures are proprietary items of the manufacturer and shall be obtained only from established manufacturers with proven track record, quality assurance and full- fledged laboratory facilities for the manufacture and testing of concrete. Naphthalene or melamine-based admixtures that are approved by the Engineer only shall be used in the Works. The admixture shall be non-air entraining type.

The Contractor shall provide the following information concerning each admixture after obtaining the same from the manufacturer:

i. Normal dosage and detrimental effects, if any, of under dosage and over dosage.

ii. The chemical names of the main ingredients in the admixtures.

iii. The chloride content, if any, expressed as a percentage by weight of the admixture.

iv. Values of dry material content, ash content and relative density of the admixture which can be used for uniformity tests.

v. Whether or not the admixture leads to the entrainment of air when used as per the manufacturer's recommended dosage, and if so, to what extent.

vi. Where two or more admixtures are proposed to be used in any one mix, confirmation of their compatibility.

vii. Whether or not there would be an increase in risk of corrosion of the reinforcement or other embodiments as a result of using the admixture.

viii. Retardation achieved in initial setting time.

c. Physical and chemical requirements of admixtures shall conform to IS 9103. In addition, the following conditions shall be satisfied:

i. Plasticizers and superplasticizers shall meet the requirements indicated for "Water reducing Admixture".

ii. The air content of freshly mixed concrete, in accordance with the pressure method given in IS 1199, shall not be more than 1% higher than that of the corresponding control mix.

iii. There shall be no chloride content in admixture when tested in accordance with IS 6925.

iv. Uniformity tests on the admixtures are essential to compare qualitatively the composition of different samples taken from batch to batch or from the same batch at different times.

v. All tests relating to the concrete admixtures shall be conducted periodically at an independent laboratory and compared with the data given by the manufacturer.

vi. While qualifying the admixture, the infrared spectrograph plot shall be given. Each batch of the supply shall be tested for IR spectrograph and prove the consistency of supply.

## 11 Minimising the Risk of Alkali-Silica Reaction (ASR) in Concrete

a) Precautions against ASR in Concrete

Concrete mixes for use in the Permanent Works shall comply with one of the Subsections (b), (c) or (d). The Contractor shall notify the Engineer of his proposals for complying with this requirement.

b) The cementitious material shall have a reactive alkali content not exceeding a maximum value of 0.6% by mass when defined and tested in accordance with

Subsections 3.3.1 ((e) to (k) inclusive).

To combat the ASR, Microsilica shall be used in minimum 5% cement and shall not exceed 10% by the wt of cement in order to bind free alkalis early in plastic concrete and to reduce the permeability of concrete to prevent the moisture and external alkalis penetration.

OR

c) The total mass of reactive alkali in the concrete mix shall not exceed 3.0 kg/m$^3$ of concrete when defined, tested and calculated in accordance with Subsections 3.3.1 ((e) to (k) inclusive) and 3.3.1 ((l) to (o) inclusive).

OR

d) The aggregate shall be classed as non-reactive in accordance with the definition in Subsection (n).

e) Cementitious Material (Hydraulic and Latent Hydraulic Binders):

f) The term alkali refers to the alkali metals sodium and potassium expressed as their oxides. The reactive alkali content of Portland cements shall be defined as the percentage by mass of equivalent sodium oxide ($Na_2O$) calculated from:- % equivalent $Na_2O$ = % acid soluble $Na_2O$ + 0.658 x (% acid soluble $K_2O$)

g) The method used in determining the acid soluble alkali content of the materials shall be in accordance with BS 4550: Part 2: Subsection 16.2.

h) The Contractor shall make available the certified average acid soluble alkali content of Portland cement on a weekly basis.

i) The Contractor shall give immediate notice of any change which may increase the certified average acid soluble alkali content above the level used in the mix design for the concrete. A revised mix design for any concrete which would be affected by the increased alkali content shall be submitted for consent with notification of the change.

j) Minimising the Risk by Using Cementitious material Containing less than 0.6% Reactive Alkali

The requirements of Subsection (b) will be met by Subsection (k) provided that the contribution of alkalis from other sources does not exceed 0.2 kg/m3 (see Subsections and (u)). Where alkalis exceed 0.2 kg/m3 the requirements of Subsections (l) to (o) shall apply.

k) The cementitious material shall be Portland cement complying with Indian Standard and shall have additionally a certified maximum acid soluble alkali content not exceeding 0.6%.

l) The Contractor shall provide on request weekly certificates which name the source of the cement and confirm compliance with the Specification.

Minimising the Risk by Limiting the ReactiveAlkali content of the concrete to 3.0 kg/m3. The requirements of Subsection (c) will be met provided that Subsections (m), (n) and are satisfied.

m) The reactive alkali content of the concrete contributed by the Portland cement to the concrete shall be calculated from:

Portland cement

A = C x a, 100

Where,

A = reactive alkali content of the concrete to the nearest 0.1 (kg/m3) C = target mean Portland cement content of the concrete (kg/m3)

a = certified average acid soluble alkali content of the Portland cement (%).

n) Where reactive alkalis in excess of 0.2kg/$m^3$ are contributed to the concrete from sources other than the cementitious material the limit of 3.0 kg/$m^3$ from the cementitious material shall be reduced by the total amount so contributed.

The reactive alkali contributed by sodium chloride contamination of aggregates shall be calculated from:

H = 0.76x (NFxMF)+(NCxMC) (kg/m3)

100

Where H = equivalent alkali contribution made to the concrete by the sodium chloride

NF = chloride ion content of the fine aggregate as a percentage by mass of dry aggregates and measured according to BS 812: Part 4

MF = fine aggregate content (kg/m3)

NC = chloride ion content of the coarse aggregate as a percentage by mass of dry aggregate and measured according to BS 812: Part 4: 1976 (now in draft as Part 117)

MC = coarse aggregate content (kg/m3).

The factor 0.76 is obtained from a consideration of the composition of sea water.

The chloride ion content of aggregate sources containing 0.01% of chloride ion by mass or more shall be determined weekly in accordance with BS 812 or another approved method. When the chloride ion level is less than 0.01% it shall be regarded as nil.

o) The Contractor shall provide certificates on request confirming compliance with the Specification and stating:

i. The target mean cementitious material content of the concrete.

ii. The names of the works manufacturing the cement.

iii. A weekly report of the cement alkali determinations in accordance with Subsection (f).

iv. The certified average acid soluble alkali content of the Portland cement.

p) Minimising the Risk by Using Selected Aggregates

Fine and coarse aggregate material shall comply with the requirements of IS:383 (and/or AASHTO Standard Specifications M6 and M80 respectively) to be taken out to conform to 512(2).

q) Water

r) Water for use in the manufacture of concrete shall be obtained from a public utility undertaking supply or from a source approved by Engineer and shall be of potable quality, and comply with the requirement of IS:456 and or BS 3148

s) Where a potable mains supply is not available the Contractor shall obtain confirmation of the quality and reliability of the proposed source from the appropriate water authority and shall thereafter seek consent from the Engineer to use the proposed source.

t) Water other than from a public utility undertaking supply shall be sampled at a frequency to be determined by the Engineer and tested in accordance with the relevant provisions of IS:3025 or BS 3148. The sodium oxide and potassium oxide content shall be declared and expressed as equivalent $Na_2O$ and shall be taken into account when calculating the total reactive alkali content of the concrete mix.

u) Admixtures and Pigments

Admixtures and pigments shall comply with the requirements of IS 9103 and IS:6925 or BS 5075 and BS 1014. The manufacturer's declared equivalent acid soluble alkali content and the dosage rate of any admixture or pigment to be incorporated shall be included with details of all concrete mixes submitted for consent.

v) The alkali content of admixtures shall be taken into account when determining the total equivalent alkali content of the concrete mix.

w) Microsilica (silica fume) shall be used in 5% by the weight of cement and shall not exceed 15% by the weight of cement.

## 12 Storage of Materials

### 12.1 General

a. Handling and storage of all material shall be as per IS 4082.

b. All materials shall be stored at proper places to prevent their deterioration or intrusion by foreign matter and to ensure their satisfactory quality and fitness for the work. The storage space shall also permit easy inspection, removal and restoring of the materials. All such materials even though stored in approved storage places, will be subjected to acceptance test prior to their immediate use.

c. The procedures to be adopted for transportation and storage of the materials shall obtain prior approval from the Engineer.

### 12.2 Cement

a. Cement shall be transported, handled and stored on the site in such a manner as to avoid deterioration or contamination. Cement shall be stored above ground level in perfectly dry and watertight sheds and shall be stacked not more than eight bags high. Wherever bulk storage containers are used, it shall be ensured that their capacity is adequate to cater to the requirement at Site and they are cleaned at least once every 3 months. Cement older than 3 months from the date of manufacture shall not be used.

b. Each consignment shall be stored separately so that it may be readily identified and inspected, and cement shall be used in the sequence in which it is delivered at Site. Any consignment or part of a consignment of cement which had deteriorated of any sort during storage, shall not be used in the Works and shall be removed from the Site by the Contractor, without adding any costs to the Employer.

c. The Contractor shall prepare and maintain proper records on site regarding delivery, handling, storage and use of cement. These records shall be available for inspection by the Engineer at all times.

d. The Contractor shall make a monthly return to the Engineer on the date corresponding to the interim certificate date, showing the quantities of cement received and issued during the month and in stock at the end of the month.

**12.3 Aggregates**

a. Storage areas for aggregates have to be covered, protected against any kind of contamination, avoid the possibility of mix among aggregates and protected also against any water inflow. The floor of the storage for aggregates has to be in concrete and has to be drained. Storage areas for different size of aggregates have to be independent to avoid any possibility of mix.

b. During rainy and cold weather periods, the aggregates shall be stored undercover for at least 48 hours before being used and kept sufficiently dry.

c. The stockpiling of the processed aggregate and drawl there from shall be such as to ensure that the variation in the free moisture in the aggregate during anyone shift of working, does not exceed 1 percent.

d. The coarse aggregates shall, be stored as per the procedure of relevant IS: codes.

e. Care shall be taken in screening and stocking of the coarse aggregates so as to avoid intermixture of different gauge materials and inclusion of any foreign materials.

f. The stockpiles shall be built up in horizontal or gently sloping layers.

g. Trucks and bulldozers shall be kept off the stockpiles to prevent breakage and impairing the cleanliness of aggregate.

h. A hard base shall be provided to prevent contamination from underlying materials in storage areas in continuous use.

i. Overlap of different sizes of materials shall be prevented with suitable walls or by ample distance between storage piles.

j. Arrangement shall be made to store natural and manufactured sand in a way that shall protect it from being contaminated with dust, organic matter or other deleterious substances.

**13 Design Mix Concrete**

**13.1 General**

a. For all items of concrete, only design mix shall be used. Prior to the commencement of construction, the Contractor shall design the mix and submit the proportions of materials, including admixtures to be used to the Engineer for obtaining approval. Suitable water reducing admixtures or super-plasticizing admixtures shall be used for achieving desired workability and strength of the concrete only after obtaining prior approval from the Engineer. No extra payment shall be made for such admixtures.

b. Mix design shall conform to the provisions under IRS: CBC (Cl. 5.5 and 8.7) and IS 10262.

c. Drying shrinkage of concrete shall be 0.03% or less. Drying shrinkage of concrete shall be tested in accordance with IS 1199.

d. When non-bleeding high flow concrete is used, it shall be confirmed that no bleeding occurs under Concrete Bleeding Test specified in IS 9103. The Contractor shall submit the test results to the Engineer prior to the commencement of concrete works for obtaining approval.

e. Mix design, once approved, must not be altered without obtaining prior approval of the Engineer. However, if the Contractor anticipates any change in quality and/or change in source of future supply of materials than that used for earlier mix design, the Contractor shall inform the Engineer well in advance and bring fresh samples sufficiently in advance, to carry out fresh trial mixes.

f. The total chloride content of all constituents of concrete in mix shall be limited to 0.43 kg/m3 for reinforced concrete works and prestressed concrete works as per IS:14959.

### 13.2 Workability of Concrete

a. The mix shall have the consistency which allows proper placement and consolidation in the required position. It shall be ensured that uniform consistency is maintained.

b. Workability of concrete shall conform to the provisions of IRS: CBC(Cl.5.3).

### 13.3 Durability of Concrete

a. Maximum water cement ratio for design mix shall conform to IRS: CBC(Clause5.4.3) as follows:

| **Plain Concrete** | **Reinforced Concrete** |
|---|---|
| 0.45 | 0.40 |

b. Minimum grade of concrete shall conform to IRS: CBC(Clause5.4.4) as follows:

| **Plain Concrete** | **Reinforced Concrete** |
|---|---|
| M-20 | M-35 |

c. Maximum and minimum permissible cementitious material shall conform to IRS: CBC (Clause5.4.5) as follows:

| **Minimum(kg/cum)** | | **Max** |
|---|---|---|
| **Plain Concrete** | **Reinforced Concrete** | |
| 250 | 350 | 500 |

### 13.4 Trial Mixes

a. The Contractor is entirely responsible for the design of the concrete mixes. However, the design shall have approval from the Engineer. At least 8 weeks before commencing any concreting in the Works, the Contractor shall make trial mixes using samples of coarse aggregates, sand, water, super plasticiser and cement, typical of those to be used in the Works, and which have been tested in an approved laboratory. A clean dry mixer shall be used, and the first batch shall be discarded.

b. The mix shall be designed to produce the grade of concrete having the required workability, durability and a characteristic strength not less than appropriate value given in IRS: CBC (CL. 5.1, 5.3 & 5.4). Trial mixes shall be prepared under full-scale site conditions and tested in accordance with IS 10262.

c. Whenever there is a significant change in the quality of any of the ingredients for concrete, the Engineer, at his discretion, may order the carrying out of fresh trial mixes. All costs for trial mixes and tests shall be borne by the Contractor's and held to be included in the rates quoted in the priced Bill of Quantities.

d. Before commencing the Works, the Contractor shall submit full details of the preliminary trial mixes and tests to the Engineer for approval.

### 13.5 Size of Coarse Aggregate

The nominal size of coarse aggregates for concrete shall be as per the Drawings. The proportions of the various individual size of aggregates shall be so adjusted that the grading produces densest mix and the grading curve corresponds to the maximum nominal size adopted for the concrete mix.

### 13.6 Mixing Concrete

#### 13.6.1 General

a. Production and control of concrete shall conform to IRS: CBC(Cl.5.6).

b. Concrete shall be mixed in an automatic batching and mixing plant as per this Technical Specifications. Hand mixing shall not be permitted. The mixer or the plant shall be at an approved location that shall be selected considering the properties of the mixes and the transportation arrangements available with the Contractor. The mixer or the plant shall be approved by the Engineer. Unless permitted by the Engineer, all concrete shall be produced in computerised automatic weigh batching plant having printing facilities to printout records of each batch and installed at the Site.

c. Mixingshallbecontinuedtillmaterialsareuniformlydistributedandauniform colour of the entire mass is obtained, and each individual particle of the coarse aggregate shows complete coating of mortar containing its proportionate amount of cement.

d. Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before putting in a new batch. Unless otherwise agreed by the Engineer, the first batch of concrete from the mixer shall contain only two thirds of the normal quantity of coarse aggregate for cleaning purpose only, and the same shall not be used for concreting purpose. Mixing plant shall be thoroughly cleaned before changing from one type of mix to another.

### 13.6.2 Batching on site

a. Batching of concrete shall conform to the provision of IRS: CBC (Cl. 5.6.2) and IS 4925.

b. All weighing and measuring equipment shall be tested and calibrated as per IS 4926.The results of these tests and calibration shall be submitted to the Engineer.

c. Addition of water to compensate for slump loss shall not be resorted to nor shall the design maximum water content and maximum water-cement ratio be exceeded. If permitted by the Engineer, additional dose of retarder shall be used to compensate the loss of slump at the Contractor's cost. Re-tempering water shall not be allowed to be added to mixed batches to obtain desired slump.

### 13.6.3 Ready Mixed Concrete

The Contractor can use RMC, if approved by the Engineer. The source batching plant of RMC shall not change during the course of work. If RMC is used, it shall conform to the provisions laid down in IRS: CBC (CL. 5.7).

**a. Transporting, Placing and Compaction of Concrete**

Transporting, placing, compacting and curing of concrete shall be in accordance with IRS: CBC(Cl.8), IS 456 and IS 5892.

**i. Transporting**

The method of transporting and placing concrete shall have approval from the Engineer. Transportation of concrete shall conform to IRS: CBC (Cl. 8.1, 5.7), if not in contravention to the following provisions.

The mix shall be transported by agitating transit mixers, buckets, pumps etc. or asper approval by the Engineer, without causing segregation and loss of cement slurry and without altering its desired properties with respect to water content, water cement ratio, slump, air content, cohesion and homogeneity.

1m$^3$ of each mix shall be supplied to Site before it is required in the Works to enable the Contractor to carry out workability tests. Under no circumstances shall extra water be added to the concrete after the original mixing is completed.

**ii.Pumping**

Pumping of concrete shall conform to IRS: CBC (Cl.8.9), if not in contravention to the following provisions.

a) The type of concrete pump, the diameter of transporting pipe, the route of piping etc. shall be determined considering the pumpability of the concrete to obtain the required quality of concrete after pumping.

b) The type and the number of concrete pumps shall be determined in consideration of the pumping pressure, the discharge amount, the pumping rate per hour, the environmental conditions of construction site etc.

c) Prior to pumping design mix concrete, pumping of mortar with the same proportion as of design mix concrete shall be done to prevent loss of mortar in pump due to adherence.

d) The mortar pumped prior to the concrete pumping shall not discharge into the formwork.

### iii.Placing

#### a) Placing General

- Placing of concrete shall conform to the provisions laid down in IRS: CBC(Cl.8.2).
- Prior to concreting, detailed planning on the placing system, the arrangement and the number of pumping cars, the position of the inlet for concrete pump, lighting equipment and arrangements for power supply, the sequence and rate of placing, time interval between concrete lifts etc. shall be specified in the Method Statement and the same shall be submitted to the Engineer for approval. Due allowance shall be made to secure enough clear spacing of reinforcement bars which enables concrete to flow through the spaces between reinforcement bars.
- Concrete shall be transported by means which prevent contamination (by dust, rain etc.) segregation or loss of ingredients, and shall be transported and placed without delay.
- Concrete shall be placed directly in its final position without segregation or displacement of the reinforcement, embedded items and formwork. Concrete shall not be placed in water, except as specified. Concrete shall not be dropped through a height greater than 1.5 metres..
- All formwork shall be thoroughly cleaned to remove debris etc. before concreting. In addition, the Engineer shall inspect that there is no debris etc. in the formwork before concrete is cast. It shall be examined that there is no abnormality in the formwork and falsework before and during concreting.
- No concrete shall be placed in any part of the structure until approval of the Engineer has been obtained. If concreting did not commence within 24 hours of issuance of approval, then it shall be obtained again from the Engineer. Concreting then shall proceed continuously over the area between the construction joints.
- Except where otherwise agreed by the Engineer, concrete shall be deposited in horizontal layers to a compacted depth of not more than 300 mm.
- Concrete when delivered in the works shall be maintained at a temperature of not more than 35°C as far as possible.
- Clear spacing between reinforcements shall be secured adequately and lighting equipment shall be arranged adequately in order to visually check the position of inlet of the concrete pump and the filling situation of the concrete during concreting works. In addition, suitable measures shall be taken so that the reinforcement bars do not move and clear cover to the reinforcement bars does not change.
- The clear cover shall be uniform and as per the Drawings. Concrete cover blocks used shall be of the same concrete mix as the member and shall contain the binding wire to secure it to the reinforcement. All ends of binding wire shall be carefully turned inside so that they do not project out of concrete cover. Reinforcement bars shall be adequately secured by chairs/ties/hangers so that it maintains its position during casting and

vibrating concrete. Ends of the wires used to tie bars shall be bent into the member.

- In case of concreting the horizontal member immediately after the concreting of vertical member is finished, the horizontal member shall be cast after any settlement of concrete of the vertical member ceases in order to prevent settling cracks.
- If bleeding water is present on the surface of concrete during concreting, the bleeding water shall be removed before the following concrete is placed.
- The Contractor shall ensure that the place where concreting is to be done shall be free of water.

**b) Extent of Pours**

For piers and pier heads, portal columns the concreting is to be carried out in single stage i.e. in first stage concreting will be from kicker to just below pier head bottom and second stage of concreting will be pier head including shear key and cross girder (in station zone stages as given in drawings for all heights by using tremie/ pumps at the rate not more than 1.5m / hr or as approved by the Engineer.

Floors, roofs and ground slabs shall be placed in a sequence of pours to the approval of the Designer and the consent of the Engineer.

If the use of slip-forms or paving trains is permitted, these limits may be revised. The sequence of pours shall be arranged to minimise thermal and shrinkage strains.

**c) Placing Equipment**

Concrete shall generally be placed without segregation by pumping or bottom-opening skips. If chutes are used their slopes shall not cause segregation and spouts or baffles shall be provided.

**d) Time for Placing**

Concrete and mortar must be placed and compacted within 30 minutes of water being added to the mix or otherwise included via damp aggregates, unless admixtures are in use. Partially-set concrete shall not be used in the Works.

**e) Continuity of Placing**

Placing in each section of work shall be continuous between construction joints. The Contractor shall make provision for standby equipment. If the placing of concrete is delayed due to breakdown then the Contractor shall erect vertical stop-ends and form a construction joint or remove the concrete already placed and restart after repair of the breakdown, as directed.

**f) Placing in Inclement Weather**

Placing shall not take place in the open during storms or heavy rains. If such conditions are likely to occur the Contractor shall provide protection for the materials, plant and formwork so that work may proceed. If strong winds are prevalent protection from driving rain and dust shall be provided.

**g) Placing in High Temperature and Low Temperature**

The temperature of concrete shall not exceed 32° nor below 5°C or the temperature stated in the table of Mixes whichever is the lower at the time of placing concrete. Also the maximum concrete temperature after placing shall not exceed temperature 50 ° C or 30 ° C above the concrete temperature at the time of placing whichever is the lower.

"Concrete in hot countries" published by FIP congress at New Delhi 1986 shall be complied with. The procedures the Contractor wishes to employ shall be subject to the Engineer consent

The Contractor shall supply suitable maximum/minimum thermometers and record the shade and sun temperatures at locations where concrete is being placed. Recommendations for cold weather concrete can be had from IS: 7861 (Part 2).

**h) Placing at Night**

If consent has been given for placing at night or in dark interiors, adequate lighting shall be provided where mixing, transportation and placing are in progress.

**i) Placing Under Water**

Underwater concrete shall be placed with minimum disturbance of the water. Running water and wave wash shall be controlled. The specified concrete grade shall be used and the mix design shall provide for good flowing ability.

Tremie pipes, bottom-dump skips or other approved placing equipment shall be used. Segregation shall be avoided.

Placing shall be commenced in approved sections and continued to completion.

The tremie pipe shall be buried in the concrete for at least 1.5m and the pipe must not be emptied until the pour is complete. If a bottom-dump skip is used, the contents shall be covered by canvas or similar before lowering into the water. The doors shall be opened when the skip is resting on the bottom with no tension in the support cable, and the skip shall be lifted gradually so that the concrete flows out steadily.

**j) Preparation Before Placing**

Before placing concrete for reinforced work on the ground, the formation shall be compacted as specified and a screed of blinding concrete shall be applied to form a surface for construction.

Before placing concrete on or against rock, masonry, brickwork or old concrete, loose material shall be removed and the surface washed down; water seepage shall be stopped or channelled away from the work.

**iv. Compaction**

**1** Compaction of concrete shall conform to the provisions laid down in IRS: CBC (Cl.8.3).

Additional vibrators in serviceable condition shall be kept at site so that they can be used in the event of breakdowns. Concrete shall be compacted before setting commences and shall not be subsequently disturbed.

**2** Internal (needle) and surface (screed board) vibrators of approved make shall be used for compaction of concrete. Internal vibrators shall be inserted in an orderly manner. The distance between insertions shall be 500 mm or less. The vibrator shall be made to operate at a regular pattern of spacing. The effective radii of action will overlap approximately half a radius to ensure complete compaction.

**3** Internal vibrators shall be used for compaction of concrete in foundations, columns, buttresses arch section, slabs etc, and if required surface vibrators shall also be used. Depending on the thickness of layer to be compacted, 25 mm, 40 mm, 60 mm and 75 mm dia internal vibrators will be used. The concrete shall be compacted by use of appropriate diameter vibrator by holding the vibrator in position until:

a) Air bubbles cease to come to surface.

b) Resumption of steady frequency of vibrator after the initial short period of drop in the frequency, when the vibrator is first inserted.

The vibration shall be done till the tone of the vibrated concrete becomes uniform. To achieve an even and dense surface free of aggregate pockets, vibration shall be supplemented by tamping or rodding by hand in the corners of forms and along the form surfaces while the concrete is plastic.

c) Flattened, glistening surface, with coarse aggregates particles blended into it appears on the surface.

d) Use of curing compounds may be permitted with specific approval of Engineer.

**4** After the compaction is completed, the vibrator should be withdrawn slowly from the concrete so that concrete can flow in to the space previously occupied by the vibrator. To avoid segregation during vibration the vibrator shall not be dragged through the concrete nor used to spread the concrete. The vibrator shall be made to penetrate, into the layer of fresh concrete below if any for a depth of about 150mm. The vibrator shall be made to operate at a regular pattern of spacing. The effective radii of action will overlap approximately half a radius to ensure complete compaction.

a) To secure even and dense surfaces free from aggregate pockets, vibration shall be supplemented by tamping or rodding by hand in the corners of forms and along the form surfaces while the concrete is plastic.

b) A sufficient number of spare vibrators shall be kept readily accessible to the place of deposition of concrete to assure adequate vibration in case of breakdown of those in use.

c) Form vibrators whenever used shall be clamped to the sides of formwork and shall not be fixed more than 450 mm above the base of the new formwork and concrete shall be filled not higher than 230mm above the vibrator. The formwork must be made specially strong and watertight where this type of vibrator is used.

Care must be taken to guard against over vibration especially where the workability of the concrete mix is high since this will encourage segregation of the concrete.

a) Plain concrete in foundations shall be placed in direct contact with the bottom of the excavation, the concrete being deposited in such a manner as not to be mixed with the earth. Plain concrete also shall be vibrated to achieve full compaction.

**14 Construction Joints**

a. Construction joints shall be avoided as far as possible and in no case the locations of such joints shall be changed or increased from those shown in the drawings, unless otherwise approved by the Engineer.

b. Where provision of construction joint is unavoidable, the location, direction and construction method of construction joint shall be determined in consideration of the structural strength, durability and appearance of the structure. Concreting shall be carried out continuously upto the construction joints. Construction joints shall conform to the provisions laid down in IRS: CBC (Cl. 8.5 and Annexure - B). The Contractor shall submit Method Statement on the construction joints which shall be subject to the consent of the Engineer prior to concreting works.

c. The location of the construction joints and their arrangement, procedure for surface preparation of construction joint and sequence of concreting shall be subject to the consent of the Engineer. Construction joints shall be located at locations where the shear force is minimum. The joints shall be provided in a direction perpendicular to the member axis. Sequencing of concrete placement shall be organized in such a way that cold joints are totally eliminated. Properly designed reinforcement shall be provided prior to casting of the next lift for transfer of full tensile stress across the joints.

**15 Expansion, Contraction and Movement Joints**

a. Expansion, contraction and other movement joints shall be incorporated in the works as shown on the Drawings.

b. Where shown on the Drawings approved, expansion joint fillers shall be supplied and installed. Filler material shall be stored flat on a dry surface adequately protected from rain or moisture in such a way that the material does not deteriorate. Filler material which has been damaged or has started to deteriorate shall not be incorporated in the works.

c. Movement joints shall be sealed with an approved sealant applied in strict accordance with the manufacturer's instructions to the dimensions shown on the Drawings. The surface of the concrete to which the sealant is to adhere shall be straight and cleaned of all filler material, dirt, oil, grease and other matter. The sealant shall be applied by methods recommended by the manufacturer so that the sealant is brought flush to the surface of structure and a smooth surface is achieved. Excess material and spillage shall be properly cleaned off and removed.

d. Dowel bars shall be installed and cast in across the movement joint where shown on the Drawings. The bars shall be straight with clean cut ends of the diameters and lengths as

e. shown on the Drawings or in the Schedules. Cutting and cleaning of the dowel bars shall comply with the requirements of this Specification.

f. The bars shall be firmly supported in the positions shown on the Drawings so that they remain accurately parallel and are not displaced during the casting of the concrete in the first part of the structure. After the concrete has hardened and the formwork removed, the projecting ends shall be cleaned of all concrete spillage and painted with two coats of an approved bituminous paint and caps shall be fitted to the free ends of the bars. Dowel bar end caps shall be of cardboard or other material, of correct diameter for the dowel bar and of sufficient length to allow the specified movement of the two adjacent concrete structures. They shall be manufactured expressly for this purpose by an approved manufacturer.

g. The Contractor shall take care to protect the projecting ends of dowel bars from bending or other damage prior to concreting the succeeding bay. The bituminous paint shall be applied as soon as practicable, but end caps shall not be fitted until immediately prior to the succeeding concreting operations.

## 16 Bolts, Inserts and Openings

h. All fixing blocks, brackets, built in bolts, holes, chases, etc., shall be accurately set out and formed and carefully sealed prior to the concrete being placed. No cutting away of concrete for any of these items shall be done without the permission of the Engineer-in- Charge.

i. Bolts and other inserts to be cast into the concrete shall be securely fixed to the formwork in such a way that they are not displaced during the concreting operations, and that there is no loss of materials from the wet concrete through holes in the formwork.

j. Unless shown otherwise on the Drawings or the Engineer has given consent, reinforcement shall be locally moved so that the minimum specified cover is maintained at the locations of inserts, holes, chases, etc.

k. Temporary plugs shall be removed and the threads of cast in bolts shall be proved to be free and shall be greased before handing over any part of the Works. Construction joints in all concrete work shall be made as directed by the Engineer. Where vertical joints are required, these shall be shuttered as directed and not allowed to take the natural slope of the concrete.

## 17 Concreting under Special Conditions

Concreting under special conditions shall conform to the provisions laid down in IRS: CBC.

### 17.1 Concreting in Extreme Weather Conditions

Concreting in extreme weather conditions shall conform to the provisions laid down in IRS: CBC (Cl. 8.6.1).

### 17.2 Concreting under Water

a. Concreting underwater and seawater shall conform to the provisions laid down in IRS: CBC (Cl. 8.6.2 and Cl. 8.6.3), where not contravening to the following provisions.

b. When it is necessary to deposit concrete under water, the methods, equipment, materials and proportions of mix to be used shall obtain approval of the Engineer, prior to the commencement of any work.

c. Concrete shall not be placed in water having a temperature below 5°C. The temperature of the concrete, when deposited, shall neither be less than 16 °C nor more than 35°C.

d. All underwater concreting shall be carried out by tremie method as described in IRS: CBC (CL.8.6.2) only, using tremie of appropriate diameter. The number and spacing of the tremie shall be worked out to ensure proper concreting. The tremie concreting when started shall continue without interruption for the full height of the member being concreted. The concrete production and placement equipment shall be adequate to enable the underwater concrete to be completed uninterrupted within the stipulated time. Necessary standby equipment shall be available for emergency situation.

e. In case of withdrawal of tremie out of the concrete either accidentally or to remove a choke in the tremie with the approval of the Engineer, the tremie shall be reintroduced in the following manner to prevent impregnation of laitance or scum lying on top of the concrete deposited in the bore. The tremie shall be gently lowered on to the old concrete with very little penetration initially. A vermiculite plug shall be introduced in the tremie. Fresh concrete of slump between 150 mm and 175 mm shall be filled in the tremie which will push the plug forward and will emerge out of the tremie displacing the laitance or scum. The tremie shall be pushed further in steps making fresh concrete sweep away the laitance or scum in its way. When tremie is buried in for about 0.60m to1.0 m, concreting may be resumed.

f. In case of concreting through tremie or such pipes which are subsequently withdrawn, the concrete shall be placed in adequate quantity to ensure that during withdrawal of the tube, a sufficient head of concrete is maintained to prevent the inflow of soil and water or bentonite slurry.

g. No concrete shall be allowed to come in contact with seawater within 72 hours of casting.

### 17.3 Concreting under Aggressive Soils and Water

Concreting under aggressive soils and water shall conform to the provisions laid down in IRS: CBC (Cl. 8.6.4).

## 18 Curing of Concrete

### 18.1 General

a. Concreting operations shall not commence until adequate arrangements for curing of concrete have been made by the Contractor. Curing and protection of concrete shall commence after the concrete has set hard enough, to with stand stresses due to curing work and does not get damaged, in order to protect it from the following:

   i. Premature drying out, particularly by solar radiation and wind.

   ii. High internal thermal gradients.

   iii. Leaching out by rain and flowing water.

iv. Rapid cooling during the first few days after placing.

v. Low temperature.

vi. Vibration and impact which may disrupt the concrete and interfere with its bond to there in forcement.

b. Where members are of considerable size and length, with high cement content, accelerated curing methods may be applied, as approved by the Engineer.

**18.2 Curing Procedure**

a. In order to ensure the required quality of concrete in terms of parametres such as strength, durability and permeability, concrete shall be cured adequately, being kept at a temperature and humidity necessary to be hardened within a certain period of time after concreting, in order not to be affected by harmful effects such as low or high temperature, rapid temperature change, drying, loading and impact loading.

b. Curing of concrete shall conform to the provisions laid down in IRS: CBC (Cl.8.4). Approved curing compounds shall be used in lieu of moist curing, with the approval of the Engineer, particularly for all vertical faces and inaccessible areas, conforming to IRS: CBC (CL. 8.4.2).

**18.3 Finishing**

Finishing shall conform to the provisions laid down in IRS: CBC (Cl. 6.2.4), if not in contravention to the following provisions:

a. Immediately after removal of forms, exposed bars or bolt, if any, shall be cut inside the concrete member to a depth of at least 50 mm below the surface of the concrete and the resulting holes shall be filled with cement mortar of dry pack consistency.

b. All construction and expansion joints in the completed work shall be left carefully tooled and free of any mortar and concrete. Expansion joint filler shall be left exposed for its full length with clean and true edges.

c. The finished surfaces of concrete after removal of form work shall be such that no touching up is required. All finsca used by form joints, if any, shall be ground using electric sur face grinder.

d. Immediate Lyon removal of forms, before any defects are rectified, the concrete work shall be examined by the Engineer.

i. Exposed concrete surfaces shall be smooth and even, originally as stripped, without any finishing or rendering. The Contractor shall exercise special care and supervision of formwork and concreting to ensure that the cast members are made true to their sizes, shapes and positions. The work that has sagged or contains honeycombing to an extent which is detrimental to structural safety or architectural appearance shall be rejected. Honeycombed parts of the concrete, including other surface defects in the concrete, shall be removed by the Contractor as per the methods which do not affect the strength of adjoining concrete and as per approval of the Engineer. In the final finish, no honeycombing is allowed.

ii. Part of defective concrete thus removed shall be recast using fresh concrete of same grade, as approved by the Engineer without any additional cost. For that purpose, the Contractor shall prepare a comprehensive work procedure and obtain approval of the Engineer. No additional payment shall be made for repair of the concrete. The Contractor shall ensure that no air bubbles are formed on the exposed surface. Concrete pouring sequence, vibration methodology etc. shall be planned to ensure that air bubbles are not formed. All materials, sizes and layouts of formwork including the locations for their joints shall have approval from the Engineer prior to the commencement of the works.

iii. After the finishing works, cracks which occurred in the surface of concrete until the concrete starts to set shall be removed by refinishing or tamping.

e. The top face of a slab intended to be surfaced with other material shall be left with a spaded finish.

f. Chemical surface retarders, if approved by the Engineer, shall be used to produce an exposed aggregate finish, provided the Contractor demonstrates that the durability of the concrete surface is not reduced.

**19 Inspection, Tests and Standards of Acceptance**

a. The Contractor shall submit test certificates from the manufacturer or supplier of materials along with each batch of material(s) delivered to site.

b. The Contractor shall set up a field laboratory with necessary equipment for testing of all materials & finished products to be used in the construction. The laboratory must have riffle divider of adequate capacity as approved by the Engineer for preparation of lab sample for sieve analysis of aggregates.

c. The test in go falls the materials shall be carried out by the Contractor at the field laboratory or from the laboratory approved by the Engineer and in the presence of the Engineer. The Contractor shall make all the necessary arrangements and bear the entire cost for the same.

d. Tests which cannot be carried out in the field laboratory shall be done at the Contractor's cost at any recognized laboratory or testing establishments having NABL certification and duly approved by the Engineer.

e. If materials are brought from abroad, the cost of sampling or testing, whether in India or abroad, shall be borne by the Contractor. The Contractor shall provide and maintain on site, until the works are completed, at all times the equipment and staff required for carrying out these tests.

**20 Quality Control of Concrete**

a. The Contractor shall carry out the following tests for concrete, at the site of placing, and ensure that they comply with appropriate provisions of Indian and/or other standards, as may be applicable:

i. Slump test for concrete: The frequency of slump test shall be as follows:

ii. Case 1: If the site of placing is at the same area as the concrete plant installed, then it shall be conducted once in every hour, as per IS1199(Cl. 5.0) and IS7320.

iii. Case2: Other than Case1, it shall be conducted once in each delivery of transit mixer, asper IS 1199 (CL. 5.0) and IS 7320.

iv. Tolerance for slump shall conform to IS4926(Cl.6.2.1).

v. Compressive and Flexural strength of concrete: Sampling, Strength tests and Acceptance criteria of concrete shall conform to IRS: CBC (Cl. 8.7) according to the type of concrete grade.

vi. Chloride ion content test: It shall be conducted as per IS:15949 once a week. Chloride ion content shall be0.43kg/m3 or less.

vii. Relative Density and pH value of plasticizer (if used): The test shall conform to IS9103(Cl.7.1, Cl.10.0, Annexure-E) and the tolerances shall be as specified in IS9103(Cl. 9.0, Table-2).

viii. Temperature of concrete shall be verified once in each slump test.

ix. The concrete shall be verified for permeability and the test procedure along with tolerances shall conform to IRS: CBC (Cl. 5.4.2, Appendix - G). The frequency of test shall depend up on the change in design mix or change in source of material used in the work. However, the Engineer shall select random batches of concrete for examination at his discretion, and any time during concreting. Sampling shall generally be done at the point of discharge from the mixer and at placing point. The concrete shall pass the permeability test if it is properly compacted and the water penetration depth in the broken core is less than 25mm.

b. It is the complete responsibility of the Contractor to redesign the concrete mixes as per the standard methods that have been approved and to produce there in forced concrete conforming to the specifications. The Contractor shall have competent staff to carry out this work.

c. After the completion of the quality control checks of concrete, the Contractor shall immediately report the test results to the Engineer by submitting quality control records of the concrete.

**21 Inspection of Concrete**

a. Inspection shall be carried out by the Contractor, after the removal of form work. Also, additional inspection shall be carried out if instructed by the Engineer.

b. Inspection shall be carried out as per approval of the Engineer for the Method Statement, incorporating the test procedures specified in Table below:

**Table: Inspection of Concrete Surface Condition**

| Measurement Items | Inspection Method | Place to be Inspected |
|---|---|---|
| Presence or absence of honey combing, cold joint, discoloration, and cracking | Visual inspection at point-blank range | All parts |
| Presence or absence of cavity, float, and cracking | Hammering Inspection | As per approved Method Statement, and as directed by the Engineer |
| Clear cover to the outermost reinforcement | Non-destructive test using a probe | |

c. Additional non-destructive tests (NDT) on the hardened concrete in the structure as a whole or any finished part of the structure where necessary, or directed by the Engineer, shall be carried out as laid down in IRS: CBC (CL. 18.3).

d. The Contractor shall report the inspection results along with the location to the Engineer immediately after the inspection. The forms generated from the probes during the inspection shall be attached to the records.

e. If defects such as deleterious cracking, spalling, deformation and finishing defects or damages caused by the Contractor are noticed from the results of the inspection, no repair work shall be commenced without prior permission taken from the Engineer.

f. Counter measures against the defects shall be subject to approval of the Engineer. In this case, "repair work" refers to all actions which make alterations to the surface of concrete after the removal of formwork (including plastering etc.). If repair work is required, the Contract or shall submit Method Statement on the repair work and shall obtain approval of the Engineer for the same, prior to the commencement of repair work. During the repair work, the Contractor shall record about the work, and shall report to the Engineer on the results of the work immediately after the repair work has finished.

g. If cracks develop in concrete construction, which in the opinion of the Engineer may be detrimental to the strength of the construction, the Contractor, at his own cost, shall dismantle the construction, carry away the debris, replace the construction and carry out all consequential work thereto.

h. If any cracks develop in the concrete construction, which in the opinion of the Engineer, are not detrimental to the stability of the construction, the Engineer shall decide whether such cracks are required to be grouted. The Contractor shall grout such cracks as decided by the Engineer with polymer cement grout of approved quality at his own risk and cost.

i. External crack width shall be restricted to 0.2mm or less on all concrete structures, unless otherwise specified in the Drawings/Design.

**ADDITIONAL TESTS FOR CONCRETE:**

As frequently as the Engineer may require, additional testing shall be carried out for concreting in addition to mandatory test specified in CPWD specifications 1996/2002 / relevant IS Code / MOST/MORTH Specifications.

## 22 Non-Destructive tests for concrete

**1. Ultrasonic pulse velocity test**

**2. Rebound hammer test**

In order to determine the following properties of concrete, non-destructive tests for concrete (ultra-sonic pulse velocity test and rebound hammer test) in accordance with IS 13311(Part 1 and Part 2) shall be carried out.

i. the homogeneity of concrete

ii. the presence of cracks, voids and other imperfections

iii. changes in the structure of the concrete which may occur with time

iv. the quality of the concrete in relation to the standard requirements

v. the quality of one element of concrete in relation to the another, and

vi. the values of dynamic elastic modulus of the concrete

In view of the limitations of each method of the non destructive testing of the concrete, it is essential that the results of tests obtained by one method should be complemented by other tests and each method should be adopted very carefully.

**23 Permeability test for Concrete:**

The concrete will be verified for permeability by the following procedure and shall confirm to IS: 3085-1965 – „Permeability of Cement Mortar & Concrete‟, Section 1717.7..5 of MOST Specification and DIN 1048.

a) The Engineer shall select random batches of concrete for examination at his discretion and sampling will generally be done at the point of discharge from the mixer and at placing point.

b) From the batches thus selected two concrete cylinders shall be made in accordance DIN 1048.

c) All cylinders shall be made, cured, stored, transported and tested in accordance with clause 1717.7..5 of MOST Specifications. The tests shall be carried out in a laboratory approved by the Engineer.

d) At least two cylinders shall be made on each day‟s concreting until 60 cylinders have been made for each grade of concrete. The cylinders will be tested as per the procedure, given in Clause (e) next.

e) Test Procedure:

The permeability of concrete will be verified by the following procedure:

i. Prepare a cylindrical test specimen 150 mm dia and 160mm high.

ii. After 28 days of curing, test specimen will be fitted in a machine such that the specimen can be placed in water under pressure up to 7 bars. The typical machine shall be similar to one shown in Appendix 1700/II of MOST.

iii. At first a pressure of one bar is applied for 48 hours, followed by 3 bars for 24 hours and 7 bars for next 24 hours.

iv. After the passage of the above period, the specimen is taken out and split in the middle by compression applied on two round bars on opposite sides above and below.

v. The water penetration in the broken core is measured with scale and the depth of penetration assessed in mm (max permissible limit 25 mm).

f) Acceptability Criteria:

The concrete shall pass the permeability test if it is properly compacted and is not considered permeable when tested as per DIN, and the water penetration in the broken core is less than 25mm.

No extra payment shall be made for this test and cost of the same will be included in his rate for concrete work.

## 24 Chlorides in Concrete

The levels of equivalent acid-soluble chlorides as NaCl (Cl x 1.65 = NaCl) in the constituents of concrete as stated elsewhere are indicative and are subject to the over- riding limits for the mixes.

The total estimated content as a percentage by weight of the cement in the mix shall not exceed the following limits: -

(a) For reinforced concrete

0.5% if made with Ordinary Portland Cement (OPC)

0.1 % if made with Sulphate Resistant Portland Cement (SRPC)

0.2 For mass concrete 1.0% if made with OPC% if made with SRPC

The Contractor shall test the constituents of the concrete to establish these contents as provided for elsewhere in this Specification.

In addition, regular tests to BS 1881: Part 6 for chloride content shall be made on the hardened concrete. The following values are acceptable: -

(i) For reinforced concrete made with OPC

95% of the test results less than 0.40% NaCl by weight of cement and no result greater than 0.50% NaCl by weight of cement.

(ii) For reinforced concrete made with SRPC

95% of the test results less than 0.1% NaCl by weight of cement and no result greater than 0.14% NaCl by weight of cement.

(iii) For mass concrete made with OPC

95% of the test results less than 1.0% NaCl by weight of cement, and no result greater than 1.30% NaCl by weight of cement.

(iv) For mass concrete made with SRPC

95% of the test results less than 0.2% NaCl by weight of cement and no result greater than 0.25% NaCl by weight of cement.

In the event that the SRPC used contains a proportion by weight of tri-calcium aluminate which approaches 4 - 8%, then consent may be sought for an appropriate adjustment of the relevant chloride content limits.

## 25 Sulphates in Concrete

The level of acid-soluble sulphates ($SO_3$) in the mix shall be no greater than: Coarse aggregate 0.4% by weight

Fine aggregate 0.4% by weight Water500 mg/l

The total estimated sulphate content ($SO_3$) of the mix including that present in the cement shall not exceed 3.7% by weight of cement in the mix.

In addition, regular tests to BS 1881: Part 6 shall be made on the hardened concrete to determine the total sulphate content, which shall not exceed 4% by weight of cement in the mix.

**Permissible Level of Chloride and Sulphates**

The permissible level of chlorides and sulphates quoted in the above Subsections shall not be considered as mean values for the whole of the Works, but shall apply to any concrete.

Concrete for water-retaining structures shall in addition be as per IS: 3370.

## 26 CRACKS:

If cracks, which in the opinion of the Engineer may be detrimental to the strength of the construction, develop in concrete construction, the Contractor at his own expense shall test the structure as specified in "Loading Tests" of these Specifications.

If under such test loads the cracks develop further, the Contractor shall dismantle the construction, carry away the debris, replace the construction and carry out all consequential work thereto.

If any cracks develop in the concrete construction, which in the opinion of the Engineer- in-Charge, are not detrimental to the stability of the construction, the Contractor at his own expense shall grout the cracks with neat cement grout or with other composition as directed by Engineer-in-Charge and also at his own expense and risk shall make good to the satisfaction of the Engineer all other works such as plaster, moulding, surface finish, which in the opinion of the Engineer have suffered damage either in appearance or stability owing to such cracks. The Engineer's decision as to the extent of the liability of the Contractor in the above matter shall be final and binding.

External crack width shall be as per IRS: CBC with latest addendums.

## 27 DEFECTIVE CONCRETE:

Should any concrete be found honeycombed or in any way defective, such concrete shall be cut out partially or wholly by the Contractor and made good at his own expense. If Engineer feels that repaired structure will not be having same strength or shape or uniformity with other exposed surface as original desired structure / original structure, the same shall be rejected by Engineer and required to be dismantled and disposed by contractor at his own cost as instructed by Engineer-in-Charge. Decision of the Engineer shall be final and binding in this regard.

## 28 EXPOSED FACES, HOLES AND FIXTURES:

On no account shall concrete surfaces be patched or covered up or damaged concrete rectified or replaced until the Engineer or his representative has inspected the works and issued written instructions for rectification. Failure to observe this procedure will render that portion of the works liable to rejection.

Holes for foundation or other bolts or for any other purposes shall be moulded, and steel angles, holdfasts or other fixtures shall be embedded, according to the drawing or as instructed by the Engineer.

## 29 FINISHES:

Unless otherwise instructed the face of exposed concrete placed against formwork shall be rubbed down immediately on removal of the formwork to remove irregularities. The face of concrete for which formwork is not provided other than slabs shall be smoothed with a float to give a finish equal to that of the rubbed down face, where formwork is provided. The top face of a slab which is not intended to be covered with other materials shall be leveled and floated to a smooth finish at the levels or falls shown on the drawings or as directed. The floating shall be done so as not to bring an excess of mortar to the surface of the concrete. The top face of a slab intended to be surfaced with other material shall be left with a spaded finish. Faces of concrete intended to be plastered shall be roughened by approved means to form key.

## 30 CONCRETE FOR FLOORING ON GRADE:

Concrete for flooring on grade shall be placed in alternate bays not exceeding more than 4m x 6m or as specified in the drawings including forming the joints or adjacent bays. The stiff mix shall be thoroughly vibrated and finished to receive the floor finish.

## 31 GROUTING OF BASE PLATES & BOLT HOLES:

a) **Mixing :**

Dry grout should be mixed in a mechanical mixer: the conventional 200/400-litre capacity concrete mixer can be used to mix four bags of dry grout; alternatively, paddle type mortar mixers can be used. The quantity of grout to be mixed at one time should not exceed that amount which can be placed in approximately 10 to 15 minutes.

b) **Batching :**

Batching of grout by fraction of a bag is not allowed. The quantity of mixing water should be the minimum commensurate with workability, compaction, and filling of the grout in all corners and crevices. Mixing should be done for a minimum of three minutes to obtain a fluid grout of uniform consistency.

c) **Cleaning and preparation of the surface :**

The base concrete should be clean and strong, and its surface should be properly hacked; all dust should be removed suction or compressed air. The surface should be thoroughly wetted with water for several hours. Before the grout is poured, all free water should be removed and the flat surfaces coated with a thin cement slurry.

d) **Restraint :**

Heavy back-up blocks of timber or concrete should be fixed on all sided of the base plate to prevent escape of the grout, when poured through the openings provided in the base plate. Adequate restraint must be ensured on all the sides for a period of 7 days to obtain effective expansion and shrinkage compensation.

e) **Curing :**

The grout should not dry out where external restraint is provided in the form of form- work, the top opening and all stray openings should be covered with wet sack for at least 7 days.

f) **Placing and Compaction :**

The grout should be placed quickly and continuously either through the holes in the base plates or from one side only to ensure complete filling without entrapment of air. Grout should be properly spread and compacted by rodding. Excessive vibration should be avoided.

Below the bed plates the grout should be compacted using long pieces of doubled-over flexible steel strapping or chains. The forward and backward movement of the strap or chain will assist in the flow of the grout into place. Steps must be taken to keep the grout in full contact with the underside of the bedplate until the grout sets; maintaining a small head of fresh grout in the forms.

g) **Shrinkage Compensated Grout:**

Shrinkage compensated grout or non-shrinkable grout of Associated Cement Companies Limited or any other approved manufacturer (Fosroc, Roff, Sikka) should be used. The batching shall be as per the manufacturer's specifications, other procedures being as above.

## 32 Tolerance

Tolerances for the finished concrete structures shall be as specified in the Contract.

## 33 Precast Concrete

### 33.1 Manufacture Off-Site

a. Casting of members shall not begin until a NONO has been given by the Engineer to the shop drawings, required computation and method of manufacture.

b. When the drawings and method of manufacture have been noticed, no changes shall be made without NONO from the Engineer

c. The Contract or shall in form the Engineer in advance of the date of commencement of manufacture and casting of each type of member.

d. Concrete reinforcement and work man ship shall be asper IS: 456.

e. A copy of all cube test results for the precast concrete works shall be sent to the Engineer as soon as these are available.

f. No members to which the tests relate shall be dispatched to the Site until the tests have been satisfactorily completed and noticed by the Engineer.

### 33.2 Forms

The design and fabrication of the forms and false work as well as their construction shall be the responsibility of the Contractor. Forms shall be inspected prior to authorizing casting operations. Details shown on the Drawings shall be built into the forms. Worn, damaged, or otherwise unacceptable forms shall be repaired be forecasting of any member is authorized. The forms may be made either of steel or of plywood. If the Contractor elects to use plywood forms, it shall be high quality plywood, 19mm minimum thickness marine grade subject to NONO from the Engineer. Forms shall be structurally adequate to support the members within permissible tolerances. Forms shall be coated with a noticed form-release agent prior to use. Anchor devices may be cast into the concrete for later use in supporting forms provided the arrangement has Notice from the Engineer. Bottom/base should be true level without offsets and kinks of designed supports and sutterings over required PCC base with proper drainage arrangement for proper working and curing.

**33.3 Curing**

a) Steam curing with approved methodology can be adopted if required, for precast components subject to the approval of Engineer-in-Charge. No extra payment will be made for adopting steam curing. Before concrete products are subjected to any accelerated method of curing, the cement to be used shall be tested in accordance with accepted standards (relevant IS codes) especially for soundness, setting time and suitability for steam curing. In the case of elements manufactured by accelerated curing methods, concrete admixtures to reduce the water content may be allowed to be as permitted by applicable codes of practice subject to the approval of the Engineer-in- Charge. The normal aeration agents used to increase the workability of concrete shall not be allowed. The steam curing of concrete products shall take place under hoods, under chambers or in tunnels. Use of insulated tarpaulin may be permitted. The steam shall have a uniform quality throughout the length of the member. The precast elements shall be stacked with sufficient clearance between each other and the bounding enclosure, so as to allow proper circulation of steam. The surrounding walls, the top cover and the floor of steam curing chamber or tunnel or hood shall be so designed as not to allow more than 1 kcal/m2/h/ deg C. The inside face of the steam curing chamber, tunnel or hood shall have a damp-proof layer to maintain the humidity of steam. Moreover, proper slope shall be given to the floor and the roof to allow the condensed water to be easily drained away. At first, when steam is let into the curing chambers, the air inside shall be allowed to go out through openings provided in the hoods or side walls which shall be closed soon after moist steam is seen jetting out. Preferably, steam should be let in at the top of the chamber through perforated pipelines to allow uniform entry of steam throughout the chamber. In no case shall steam impinge directly on concrete products. The fresh concrete in the moulds shall be allowed to get the initial set before allowing the concrete to come into contact with steam. The regular heating up of fresh concrete product from 20 °C to 35 °C shall start only after a waiting period ranging from 2 to 5 hours depending on the setting time of cement used. The second stage in steam curing process shall be to heat up the concrete elements, moulds and the surroundings in the chamber. The air-space around the member shall be heated up to a temperature maximum to 70°C at a gradual rate, not faster than 10° per hour. This process shall continue 1 1/2 to 2 1/2 hours depending upon the outside temperature. The third stage of steam curing shall be to maintain the uniform temperature and pressure for a duration depending upon thickness of the section. This may vary from 3 to 5 1/2 hours. The fourth stage of steam curing shall be the gradual cooling down of concrete products and surroundings in the chamber and normalization of the pressure to bring it at par with the outside air. The maximum cooling rate, which is dependent on the thickness of the member, shall not exceed 30° per hour. In all these cases, the difference between the temperature of the concrete product and the outside temperature shall not be more than 60°C for concrete up to M 30 and 75°C for concrete greater than M 45. In the case of light weight concrete, the difference in temperature shall not be more than 60°C for concrete less than M 25. For concrete greater than M 50, the temperature differences may go up to 75°C. After the steam curing is completed, the elements shall be further water cured for about 3 to 7 days.

The curing shall be carried out as per approved Method Statement.

**33.4 Storage**

When members are stored, they shall be firmly supported only at the points specified.

a. The accumulation of trapped water and deleterious matter in the units shall be prevented.

b. Care shall be taken to avoid rust staining and efflorescence.

c. The area intended for the storage of pre-cast units should be surfaced in such a way that no unequal settlement can occur.

d. To prevent deformation of slender units, they should be provided with supports at fairly close intervals and should also be safeguarded against tilting. Lifting and hand ling positions should conform to the Engineer's directions and drawings. In addition, location and orientation marks shall be put on the members, as and where necessary.

**33.5 Handling and Transport**

a. Members shall be lifted or supported only at points specified or otherwise given a NONO from the Engineer and shall be handled and placed without impact.

b. The Contractor shall define the method of lifting, the type of equipment and transport to be used, and the minimum age of the members to be handled and shall submit to obtain approval from the Engineer.

**33.6 Protection**

At all stages of construction, pre-cast concrete units and other concrete associated there with shall be properly protected to prevent damage to permanently exposed concrete surfaces, specially arises and decorative features.

## 34 Falsework and Formwork

**1 General**

Falsework and formwork shall conform to the provisions laid down in IRS: CBC (CL. 6.1 to6.4) and IRC: 87, if not in contravention to the following provisions.

a. Falsework shall be designed in consideration of appropriate raising (camber) against sinking and deformation due to the weight of the concrete during construction and after completion. Furthermore, the Contractor shall submit the plan of the camber to the Engineer prior to the commencement of works for obtaining approval.

b. Ties shall not be welded to the reinforcement bars. Clear cover to the end of the ties shall not be less than 25mm. Filling of tie locations after removal of form work shall be carried out with dry pack cement mortar.

c. The form work shall be of steel plates of proper thickness to give good finish.

**34.1 Design of Formwork**

a. The Contractor shall submit the design and drawing of complete formwork (i.e. the forms as well as their supports) to the Engineer, before any erection work commences. If proprietary system of formwork is used, the Contractor shall furnish detailed information to the Engineer. However, the Contractor shall be entirely responsible for the adequacy and safety for formwork.

b. The foundation of all supports shall be designed to suit the bearing capacity of soil to support the designed loads without settlement.

c. The Contractor shall prepare detailed shop drawing showing the arrangement of form work for structural members including shoring system, horizontal and diagonal bracing system, details of foundation etc. The sizes of individual members shall be as per the design calculations.

**34.2 Finishing of Formwork**

a. Finishing shall conform to IRS: CBC (Cl.6.2.4 and Cl.6.2.5).

b. Formwork shall be made to produce a finished concrete true to shape, line, levels and dimensions.

c. Chamfers shall be provided at all angles of the formwork to avoid sharp corners. The chamfers, bevelled edges and mouldings shall be made in the form work itself, conforming to the Drawings.

**34.3 Cleaning and Treatment of Forms**

Cleaning and treatment of forms shall conform to IRS: CBC(Cl.6.3).

**34.4 Specialized Formwork**

a. Specialized form work shall conform to the provisions laid down in IRC:87(Cl.10).

b. Specialized formwork may be required in the case of slip formwork, underwater concreting etc. Such specialized formwork shall be designed and detailed by competent agencies and a set of complete working drawings and installation instructions shall be supplied to the Engineer. The site personnel shall be trained in the erection and dismantling as well as operation of such specialized formwork. If proprietary equipment is used, the supplier shall supply drawings, details, installation instructions, etc. in the form of manuals along with the formwork. Where specialized formwork is used, close coordination with the design of permanent structure is necessary.

c. For slip form, the rate of slipping the formwork shall be designed for each individual case considering various parametres including the grade of concrete, concrete strength, concrete temperature, ambient temperature and concreted mixtures.

d. In order to verify the time and sequence of striking or removal of specialized formwork, routine field tests for the consistency of concrete and strength development are mandatory and shall be carried out before adoption.

**34.5 Inspection of Formwork**

a. The Contractor shall inspect the formwork and shall submit inspection results by "Formwork Assembly Inspection Record" prior to concreting works.

   "Formwork Assembly Inspection Record" describes the results of verification of inspection results of the formwork with design documents in which the shape and dimensions of the formwork, clear cover to the outermost reinforcement, effective height etc. are verified. The proposed form of "Formwork Assembly Inspection Record" shall be submitted by the Contractor for approval of the Engineer.

b. Concreting shall not be allowed unless approved for the formwork by the Engineer.

**34.6 Stripping and Removal of Formwork**

a. Stripping time shall conform to the provisions laid down in IRS: CBC(Cl.6.4).

b. The scheme for removal of formwork (i.e., de-shuttering and decentring) shall be planned in advance and submitted to the Engineer for scrutiny and approval. No form work or any part there of shall be removed without prior approval of the Engineer.

c. The formwork shall be removed in such a manner that does not cause any damage to concrete. Centring shall be gradually and uniformly lowered in such a manner that it permits the concrete to take stresses due to its own weight uniformly and gradually to avoid any shock or vibration.

d. Where the rear ere- entrant angles in the concrete sections, the formwork shall be removed at these sections as soon as possible after the concrete has set to avoid cracking due to shrinkage of concrete.

**34.7 Reuse of Forms**

The Contractor shall not be permitted reuse of timber facing formwork brought new on the works for more than 5 times for exposed concrete formwork and 8 times for ordinary formwork.5 or 8 uses shall be permitted only if forms are properly cared for, stored and repaired after each use. Use of different quality boards or the use of old and new boards in the same form work shall not be allowed. If any other type of special or proprietary form work is used, the number of times they can be used shall begiven a NONO from the Engineer.

# Annexure OCS-2
# REINFORCEMENT STEEL

## 1. General

a) High strength deformed steel bars for concrete reinforcement used in the works shall be Fe 500D TMT, conforming to IS 1786 and manufactured by SAIL/TATA STEEL /JSW STEEL/RINL/IISCO. No rerolled steel shall be used. The Contractor shall produce copy of original challan or voucher as a proof of having purchased the steel reinforcement from manufacturers or their authorized distributors having approval of the Engineer. Reinforcement steel shall be stored as per IS 4082.

b) Any steel specified for reinforcement shall conform in every respect to the latest relevant Indian Standard Specifications and shall be of tested quality under the ISI Certification Scheme.

c) All reinforcement work shall be executed in conformity with the drawings supplied and instructions given by the Engineer and shall generally be carried out in accordance with the relevant Indian Standard Specifications IS: 2502- Bending and Fixing of Bars for Concrete Reinforcement.

d) No work shall be commenced without the Engineer's approval for reinforcement bar bending schedule. The reinforcement bars shall be bent to conform to the dimensions and shape shown in the Drawings in a manner that will not damage the parent material. Bars shall be bent cold. Any reinforcement, which is bent, shall not be re-bent. However, when it is unavoidable to re-bend the reinforcement, the same shall have approval from the Engineer.

e) Placement of reinforcement shall conform to the provisions laid down in IRS: CBC (Cl. 7.1.3). Cover and spacing of steel shall be uniform and as specified in the specifications and as shown in the Drawings.

f) Uncoated reinforcement steel shall be protected from rusting or chloride contamination. Reinforcements shall be free of rust, mortar, loose mill scale, grease, oil or paint.

g) Procurement of reinforcement steel shall be so phased by the Contractor that the storage period before its actual use in the works is limited to the bare minimum as directed by the Engineer.

## 2. Transportation and Storage

a) Transportation and Storage shall be undertaken in such a manner that no damage is done to the steel.

b) Reinforcement steel shall be stored off the ground in separate groups according to size and length. Reinforcement steel, which has been cut and bent according to the schedules provided by the contractor, shall be marked with bar number, as shown in the schedule, by using weatherproof tag or by placing in marked bins and shall be stored in such a manner as to be readily accessible when required and to facilitate inspection.

c) A hard base of PCC M 20 shall be provided for stacking of steel to avoid corrosion.

## 3. Inspection and Testing

a) Manufacturer's test certificate shall be submitted for each lot of supply brought at the Site by the Contractor. Physical tests shall conform to IS1387, IS1599, IS1608 and IS1786. Independent test on quality of steel from each lot shall be carried out as per IRS: CBC (Cl.4.5.2).

b) The frequency of tests on reinforcement consignments delivered at site from one manufacturer should be as per IS 1786:2008 (Cl. 11.1).

c) Specimens required for three tensile tests for each of the different size of bar for each consignment delivered shall be sampled and tested by the Contractor before use at Site. Test results shall be duly supported by graph with respect to stress and strain. If first test of three test samples does not give the specified results, two additional tests shall be carried out. Both retests shall conform to the requirements as specified in IS 1786. The steel shall be rejected otherwise.

d) Reinforcement steel shall be inspected prior to the commencement of works and assembly on Site. Defective, brittle, excessively rusted or burnt bar shall be discarded. Cracked ends of bars shall be cut out. All reinforcement steel shall be free of loose small scales, rust and coats of paint, oil, mud etc.

e) The Contractor shall inspect the reinforcement works and submit inspection results by "Reinforcement Assembly Inspection Record". "Reinforcement Assembly Inspection Record" describes the results of verification of inspection results of the reinforcement work with the Drawing in which the diameter, number and length of the reinforcements, position of splices and joints, position and interval of the bent reinforcement bar, type and disposition of cover blocks are verified. The form of "Reinforcement Assembly Inspection Record" shall be proposed by the Contractor for approval of the Engineer.

f) The Contractor shall obtain approval of the Engineer for reinforcement work prior to the commencement of concrete work.

## 4. Tolerances and Criteria

a) Unless otherwise specified by the engineer, reinforcement shall be placed within the following tolerances:

   i. For overall depth 200 mm or less : ±10mm

   ii. For overall depth more than 200mm : ±15mm

   The cover shall, in no case, be reduced by more than one third of specified cover or 5mm whichever is less.

## 5. Lapping and Joints

a) Lapped Splices: No splicing of bars shall be permitted without prior approval of the Engineer. Lengths of splice, wherever required, shall be as indicated on the drawings and approved by the Engineer. Lapped splices shall be staggered and located at points along the span where shear stresses are low.

b) Mechanical Joints: Mechanical coupler shall be used for jointing of reinforcement bars of diameter 25 mm and above. Mechanical coupler shall conform to laid down specification given in Clause 6 below. Mechanical couplers of threaded type with enlargement at connection by cold forging may be used at appropriate locations after prior approval of the Engineer.

c) Welded Joints : Not permitted

## 6. Coupler Specifications

a) **Introduction**

Only cold-forged, parallel threaded mechanical coupler system shall be used. All mechanical couplers shall be of Type 2 (or Class H as specified in IS-16172) and should be simple to install and which can be confirmed by quick visual inspection to have been correctly installed and to have achieved the required full strength connection. Any other types of mechanical coupler systems are not permitted.

The couplers shall be of standard parallel thread type. Ends of the reinforcement bars, which are to be joined, shall be enlarged by cold forging, threaded in such a way that root thread diameter is not lesser than the parent bar to be joined. The coupler shall be of TYPE – II and qualified/Certified as per UK CARES, IS code 16172:2014, ACI 318, ASME, Section III, and Div.2, Caltrans.

Couplers installed shall be strictly in accordance with the manufacturer's recommendations. Couplers shall be located away from high stress zones in the various structural elements and shall be staggered and shall conform to provision of IRS: CBC

All the couplers shall be manufactured in a factory which is ISO 9001:2008 (or higher revision) certified for "Manufacturing of Mechanical Steel Rebar Couplers & Accessories" and also be certified for "Site Management of Threading & Processing of Rebar including Sales and Distribution". All the couplers shall undergo quality checks on uniformity of threads, dimensional accuracy etc. Each coupler shall be clearly stamped indicating batch number and diameter. This number shall be traceable to the original cast. The relevant material mill certificate shall be submitted with supply of a particular lot. The certificate shall give salient material properties. The coupler manufacturer shall operate at least an ISO 9000 approved quality assurance programme or equivalent for the manufacture of couplers.

**b). Threading of ends of the reinforcing bars:**

The threading activity shall preferably be done at Site. The various stages involved in threading are as given below:

i. **Cutting (Rebar End Preparation):**

The ends of reinforcement bars shall be cut by mechanical means to get a perfect plane surface perpendicular to the axis of the bar.

ii. **Cold forging & threading:**

After cutting the ends of the bar shall be enlarged by cold forging such that the area of cross section after threading shall not be less than the area of cross section of the parent bar. The length of cold forging shall be adequate for proposed thread length as per manufacturer's design. Threading shall be done on threading machine. The threads shall be square parallel type to suit the couplers. The thread length and depth shall be as per manufacturer's design. After threading is completed, the threaded length of the bars shall be protected by providing plastic end caps before taking the bars out of the shop.

a) **Quality control in making of threads:**

Double forging of bars is not permitted. In case of improper cold forging the forged of the bar shall be square cut and fresh cold forging shall be undertaken. 100% threading at threaded rebars shall be checked with 'go' and 'no go' gauges for the correctness of the thread profile on the rebar. A proper record for same shall be maintained at site.

b) **Qualification tests**

The coupler shall be qualified as per IS code 16172:2014, ACI 318, ASME - Section III, and Div.2, Caltrans and must have conducted & qualified for the following tests:

i. **Static tensile test**

Mechanical connections shall be tested for all reinforcing rebar sizes. For each rebar size, a minimum of three connections (3 joints + 1 Parent bar) in each load direction shall be tested in accordance with ASTM A370 test method to meet code requirement. A tensile test on an unsliced specimen from the same bar used for the spliced specimens shall be performed to establish actual tensile strength. The tensile strength of an individual splice system shall not be less than the 125% of the specified minimum yield strength (fy of rebar) of the spliced bar.

ii. **Cyclic tension and compression test**

Mechanical connections shall be tested in all reinforcing rebar sizes. For each rebar size, a minimum of three connections shall be tested for cyclic tension & compression test. Each specimen shall withstand cycles of stress variation of the specified minimum yield strength of the reinforcing bar. The test should be carried out as per the table mentioned below:

**Loading Stages and Cycles per stage for cyclic load test**

| Stage | Tension | Compression | Cycles |
|---|---|---|---|
| 1 | 0.95 fy | 0.5 fy | 20cycles |
| 2 | 2 εy | 0.5 fy | 4cycles |
| 3 | 5 εy | 0.5 fy | 4cycles |

**Note:**

fy is specified yield strength of the reinforcing bar.

εy is the strength of reinforcing bar at actual yield stress

iii. **Cyclic tensile test**

Mechanical connections shall be tested in all reinforcing rebar sizes. For each rebar size, a minimum of three connections shall be tested for low cyclic tensile test. Each specimen shall withstand 100 cycles of stress variation from 5% to 90% of the specified minimum yield strength (fy) of the reinforcing bar. One cycle is defined as an increase from the lower load to the higher load & return.

**iv. Low cycle fatigue test (for 10,000 cycles)**

Fatigue test shall be conducted on splice sample from +173 Mpa to -173 Mpa for 10,000 cycles. A sine wave form @ 0.5 Hz shall be followed for bar dia 36 mm & above and 0.35 Hz shall be followed for bar dia less than 36 mm. Test shall be conducted confirming to IS 16172:2014 & Caltrans specifications. Past certificates for low cycle fatigue test shall be accepted. However these should not be more than 3 years old.

**v. High cycle fatigue test (for 2,000,000 cycles)**

In high cycle fatigue test, the test specimen is subjected to an axial tensile load which varies cyclically according to the sinusoidal wave form of constant frequency in the elastic range, as accordance with IS-16172. Past certificates for high cycle fatigue test shall be accepted. However these should not be more than 3 years old.

**vi. Slip test**

Slip Test Shall be performed on each diameter coupler specimen as per ASTM A 370 section 10. Test shall be conducted conforming to IS 16172:2014 & Caltrans specifications. Total slip shall not exceed the max value of 0.1 mm.

**vii. Proof loading test**

Every cold-forged, threaded bar end shall undergo a proof load test prior to leaving system supplier's workshop. Every threaded bar must be subjected to proof load testing to a minimum test loading of 75% of the characteristic strength (theoretical fy). The system supplier shall essentially install a proof load tester equipment within its threading workshop premises and ensure to test each and every threaded bar. A positive indication shall be marked on the rebar to indicate that this operation has been carried out.

Note: All three steps involved in the preparation of mechanical joints i.e end cutting of reinforcement, cold forging and threading shall be performed by the coupler manufacturer either at site or at supplier's workshop. Proof load testing of each threaded bar end shall also be performed by the manufacturer at a NABL approved lab which will be witnessed by the Engineers Representative. Contractor shall submit the test certificates of joint strength issued by the manufacturer.

## 7. INSTALLATION OF COUPLERS IN THE FIELD:

The installation of couplers in the field, for joining reinforcing bars shall be undertaken by trained manpower and as per manufacturer's instructions. Threads of both the couplers and the bars shall be thoroughly cleaned just before installation.Where couplers are cast-in the concrete, but connection is not to be completed immediately, the couplers shall be internally greased and plastic capped to a protection detail acceptable to the engineer. This cap shall be removed only when next bar is to be attached, then the same to be cleaned before joining the next bar.

The contractor shall arrange for a suitably qualified manufacturer's representative experienced in mechanically connecting reinforcement to be present at site before the start of work for initial training of personnel, and also to demonstrate the equipment and techniques as necessary. The threading workshop is to be fully supervised by the manufacturer's representative.

The contractor shall submit to the Engineer, for his approval a method statement duly approved by the manufacturer for mechanically connecting the reinforcement and for the installation and verification in the field. All activities of manufacture of mechanical joint i.e. cutting, forging and threading shall be carried out under the overall guidance of the manufacturer at the rebar yard with necessary machines and equipment supplied by the manufacturer. The Contractor shall also submit certificate for satisfactory performance of the mechanical joint from the manufacturer for all the coupled bars. This shall take into account any special requirements for horizontal, vertical and inclined couplers and shall include a rectification procedure, if the connection is incorrectly made. It shall also cover the correct methodology for handling of tools and equipment for mechanical connection on site. The following information shall also be included:

1 Requirements for cleanliness

2 Equipment for threading bars

3 Method of locking the connections on both rebars

4 Method of verification of final rebars alignment and coupler integrity

Each coupler shall be visually examined prior to use to ensure the absence of rust and of any foreign material on the inside surface. All completed couplers shall be inspected and verified in accordance with the approved QAP. The Contractor shall ensure the acceptance of the Engineer for a procedure for documenting the inspection of the couplers. The contractor shall retain inspection records and shall submit copies to the Engineer-in-Charge within 7 days. The Couplers that do not meet the acceptance shall be completely removed and the bars re-connected as required.

**6. BAR BENDING AND BAR BENDING SCHEDULE:**

All bars will be carefully and accurately bent by approved means in accordance with IS: 2502, and relevant drawings. It shall be ensured that depth of crank is correct as per the bar cutting and bending schedule and bent bars are not straightened for use in any manner that will injure the material.

Prior to starting bar bending work, the Contractor shall prepare bar bending schedule from the structural drawings supplied to him and get the same approved by Engineer. Any discrepancies and inaccuracies found by the Contractor in the drawings shall be immediately reported to the Engineer whose interpretation and decision there to, shall be accepted.

**7. SPACING, SUPPORTING AND CLEANING:**

a) All reinforcement shall be placed and maintained in the positions shown on the drawings to be prepared by contractor.

b) The Contractor shall provide approved types of supports for maintaining the bars in position and ensuring required spacing and correct cover of concrete to the reinforcement as specified on the drawings. Cover blocks of required shape and size, Chairs and spacer bars shall be used to ensure accurate positioning of reinforcement. Spacers or chairs should be placed at a maximum spacing of 1m and closer spacing sometime be necessary. Cover blocks of approved proprietary should be pre-packaged free flowing mortars (Conbextra HF of Fosroc or equivalent). Cover blocks of concrete (not sand cement mortar) should be of the same strength as that of the surrounding concrete and properly compacted and vibrated on a vibrating table. They shall be cured for a minimum period of 14days before they are used in the works. The cost of cover block shall be deemed to have been included in the rates.

c) Cover blocks shall be firmly placed at appropriate intervals to maintain specified concrete cover to the reinforcement. The number of cover blocks to be provided shall generally be about 4 pieces per m2 for the bottom surface of the member and about 2-4 pieces per m2 for the side surface of the member. Cover blocks shall be made of concrete or mortar having quality equal to or higher than that of the parent concrete.

d) Bars must be cleaned, before concreting commences, of all scale, rust or partially set concrete which may have been deposited there during placing of previous lift of concrete. On no account shall the bars be oiled or painted nor shall mould oil used on the formwork be allowed to come in contact with the bars. Cement wash to bars will not be permitted.

e) Only Fe500D TMT bars complying to IS:1786 shall be provided.

f) 1.6mm dia. G.I. wire shall be used for binding reinforcement.

## Annexure OCS-3
## FABRICATION AND ERECTION OF STEEL BRIDGE GIRDER

**1. General**

Fabrication of all Steel Bridge Girders shall be performed within the plants and by fabricators having the experience, knowledge, trained manpower, quality controls, equipment and other facilities required to produce the steel work to desired quality. The plants where fabrication works are proposed to be performed shall be duly approved by RDSO for fabrication of OWG. The tenderer shall submit complete details of the plants along with his tender for the approval of the Engineer. Inspection and passing of fabricated elements/girder shall be done by the RDSO/Employer as per codal provisions and specifications.

Fabrication and erection of steel girder bridges shall be in accordance with IRS fabrication specifications (B1).

**2. Material**

a. Steel: Mild steel for welded/riveted bridge girders subjected to railway loading shall conform to IS: 2062, Quality "B0" Grade Designation E250, fully killed and with normalizing/ normalizing rolling/ controlled rolling. Plates less than 12mm thick need not be with normalizing/ normalizing rolling/ controlled rolling.

b. In case Rolled Steel Standard Sections conforming to IS:2062 Quality "B0" are not available in market, Engineer may permit use of steel conforming to IS:2062 Quality "BR" / "A" on case to case basis.

c. Steel shall have smooth and uniform finish and shall be free from rolling defects such as cracks, flaws, seams, laps, imperfect edges etc. and other defects such as loose mill scale, rust, pitting, or other defects affecting its strength and durability.

d. High Strength Friction Grip (HSFG) (DTI)washers shall conform to EN: 14399 series.

e. All the steel sections used in the fabrication must have mill test certificate clearly indicating the specification to which the steel conforms and whether steel is killed and normalized.

f. The materials, on receipt, shall be carefully unloaded, examined for defects, checked, sorted, and stacked securely on a level bed, out of danger from flood or tide and out of contact with water or ground moisture. They will be supported on timber or concrete plinths so that they do not touch the ground.

**3. Fabrication of steel work**

a. The records of fabrication shall be maintained in the registers as per the formats given in the Appendix I of IRS: B1-2001.

b. The greatest accuracy shall be observed in the design, fabrication, and erection of every part of the work to ensure that all parts will fit accurately together on erection. Components of all the spans shall be fully interchangeable. Same jigs and assembly fixtures duly approved shall be used. The tolerances in manufacture shall be in accordance with as shown in Appendix II of IRS: B1-2001.

c. There should be level, finished concrete floor of sufficient dimensions in the fabrication yard, on which the fabricator will precisely set out the outline of the structure (to full scale) as per drawings for the purpose of preparing templates. Only steel tapes shall be used for all measurements, and they will be held tight and level on the floor while measuring or marking.

d. Steel tapes used for marking out the work shall be calibrated at a temperature of 20° C.

e. The templates throughout the work shall be of steel bushed.

**i. Flattening and straightening**

All steel materials, plates, bars and rolled sections shall have straight edges, flat surfaces and be free from twist. If necessary, they shall be cold straightened or flattened by pressure before being worked or assembled unless they are required to be of curvilinear form.

**ii. Cutting of Steel**

Cutting of steel for fabrication may be done by shearing, sawing, or by gas using mechanically controlled torch/torches. All flame cut edges shall be ground to obtain reasonably clean square and true edges. Plasma-arc cutting method may also be employed. This process offers less heat input causing less distortion.

**iii. Making of Holes**

Marking and drilling of holes in members shall preferably be done with the use of templates/jigs. All bolt holes in members built up by welding shall be drilled after welding.

Holes for turned bolts, should be 1mm under drilled in shop and should be reamed at site to suit the diameter of turned bolt. Jigs shall be periodically checked for tolerances from master plates.

**iv. Welding**

Welded construction work shall be carried out generally in accordance with the provisions of Indian Railway Standard Welded Bridge Code and subject to further specifications as given below:

i. All welds shall be done by submerged arc welding process in shop. Site welding should not be undertaken except in special circumstances with the approval of the Engineer. Site welding should be confined to connections having low stresses, secondary members, bracings etc.

ii. Suitable jigs and fixtures shall be used to avoid distortion during welding. Components which are mass fabricated in the shop should be proved in master templates.

iii. Class and size of electrode for welding shall conform to IRS Specification M-28. For fabrication of steel bridge girder following class of electrode shall be used-

| **Class of Electrode as per IRS Specification No. M.28.66** | **Type of work to be welded** | **I.S. Specification No.** | **Code (as per IS:815-66)** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Class B2 (Moderately high ductility) | For welding of mild steel to IS:2062-1962 (Fusion welding quality) or equivalent, for service conditions where the weldment is rigid and subjected to relatively high dynamic stresses | 814-63 | M 110 to M 997-H, J, K<br>or P. |

Brand and make of electrode on approved list of M&C wing of RDSO should be used.

a) No welding operator shall be employed on the work until he has, in the presence of the Engineer, passed the appropriate tests laid down in relevant codes.

b) All main butt welds shall have complete penetration and shall comply with the requirements of IRS Welded Bridge Code. They shall be made between prepared fusion faces. Where possible they shall be welded from both sides. The ends of the welds shall have full throat thickness. This shall be obtained on all main welds by the use of extension pieces adequately secured on either side of the main plates. Additional metal remaining after the removal of the extension pieces shall be removed by machining, or by other approved means and the ends and surfaces of the welds shall be smoothly finished.

c) In the fabrication of built-up assemblies all butt welds in the component parts shall be complete before the final assembly.

d) A record of butt welds shall be kept to enable it to be identified with the welders responsible for the work but material shall not be marked by hard stamping for this purpose.

The welding techniques and sequence, quality, size of electrodes, voltage and current required shall be as prescribed by manufacturers of the material and welding equipment. The Contractor shall submit full details of welding procedure in proforma given at Appendix V of IRS: B1-2001 for approval of the Engineer.

**v. Welding of Stud Shear Connectors:**

a) The welding of stud shear connectors shall be done by "DRAWN ARC STUD WELDING WITH CERAMIC FERRULE" technique. The shear stud and ceramic ferrules shall conform to type SD1/UF as per BS EN ISO 13918-2008.

b) The stud and the surface to which studs are welded shall be free from scale, moisture, rust and other foreign material. The stud base shall not be painted, galvanized or cadmium plated prior to welding. Welding shall not be carried out when temperature is below 10 degrees Celsius or surface is wet or during periods of strong winds unless the work and the welder are adequately protected. The welds shall be visually free from cracks and shall be capable of developing at least the nominal ultimate strength of studs. The procedural trial for welding the stud shall be carried out when specified by the Engineer.

**vi. Testing of Stud Shear Connectors:**

**a) Appearance Test**

1) The weld to a shear stud connector should form a complete collar around the shank and free from cracks, excessive splashes of weld

material, free from injurious laps, fins, seams, twist, bends or other injurious defects.

2) Weld material should have a 'steel blue' appearance.

**b) Test to check the fixing of shear studs**

1) Ring Test: Involves striking the side of the head of stud with a 2 kg hammer. A ringing tone achieved after striking indicates good fusion whereas dull tone indicates a lack of fusion (BS 5400-6) All studs shall be checked by Ring test.

2) Bend Test: Test requires the head of a stud to be displaced laterally by approximate 25% of its height using 6kg hammer.

* The weld should then be checked for sign of cracking or lack of fusion.

* Stud should not be bent as back as this is likely to damage the weld.

* The testing rate should be 1 in 50 (BS 5400-6).

**vii. Making of Joints**

a) Joints shall normally be made by filling not less than 50 per cent of holes with service bolts and barrel drifts in the ratio 4:1. Only barrel drifts shall be used in erection. Drifts may be used for drawing light members in position; but their use on heavy members shall be restricted to securing them in their correct position. Any error in the shop fabrication or deformation resulting from handling and transportation which prevents proper assembling and fitting up of parts shall be reported immediately to the Engineer. No reaming shall be undertaken without the written authority of the Engineer.

b) The erection of OWG shall be done in accordance with Appendix III of IRS: B1-2001. However, if the Contractor desires to adopt any other method of erection, they shall submit the scheme and obtain the approval of the Engineer. It shall be ensured that when in position, the girder has the camber as per drawing.

**viii. High Strength Friction Grip (HSFG) bolting assembly**

The HSFG bolting assembly shall conform to EN 14399 Series (High strength structural bolting assemblies for preloading):

a) EN 14399-1:2015- General requirements.

b) EN 14399-2:2015- Suitability for preloading.

c) EN 14399-3:2015- System HR- Hexagonal bolt and nut assemblies.

d) EN 14399-5:2015- Plain washers.

e) EN 14399-6:2015- Plain chamfered washers.

f) EN 14399-9:2009- Direct Tension Indicator for bolt and nut assembly.

HSFG bolting assemblies are very sensitive to differences in manufacture and lubrication. Therefore, complete HSFG bolting assembly (i.e. bolt, nut, washers & DTI) including galvanizing shall be procured from single manufacturer. Use of Direct Tension Indicator (DTI) washers shall be mandatory in the HSFG bolting assemblies.

Grade and size of bolts shall be as per the Drawings. The surface preparation, tightening procedures and other details for HSFG bolts shall be as per RDSO standard Drawing No. RDSO/B-11760/R1.

**Table: Composition of high strength structural bolting assembly and its component marking**

| Type of bolting assembly | | System HR | |
|---|---|---|---|
| General requirements | | EN 14399-1 | |
| Suitability for preloading | | EN 14399--2 and, if any, additional testing specified in the product standard | |
| Bolt & Nut | | EN 14399-3 | |
| Marking | Bolt | HR8.8 | HR10.9 |
| | Nut | HR8 or HR10 | HR10 |
| Washers | | EN 14399-5[a] or EN 14399-6 | |
| Marking | | H or HR[b] | |
| Direct tension indicator and nut face washer or bolt face washer | | EN 14399-9 | |
| Marking | Direct Tension Indicator | H8 | H10 |
| | Nut Face Washer | HN | |
| | Bolt Face Washer | HB | |
| [a] EN 14399–5 can only be used under the nut.<br>[b] At the choice of the manufacturer. | | | |

The bolt length shall be chosen such that after tightening the following requirements are met for bolt end protrusion beyond the nut face and the thread length:

- the length of protrusion shall be at least the length of one thread pitch measured from the outer face of the nut to the end of bolt
- at least four full threads (in addition to the thread run out) shall remain clear between the bearing surface of the nut and unthreaded part of the shank.

**Holes for HSFG bolts-** The holes shall be made by drilling only. The actual diameter of hole shall be 1.5 mm more than the bolt diameter for less than 25mm diameter bolts and 2mm more than nominal diameters of HSFG bolts for diameters 25mm and above.

**Surface preparation of steel interface before providing HSFG bolts**–Wherever property class 8.8 bolts are used these should be hot dip galvanized as per ISO: 10684(latest version). Property class 10.9 bolts should not be hot dip galvanized since this may cause hydrogen embrittlement. So these bolts should be coated with zinc flakes as per ISO: 10683 (latest version). However, depending on the site conditions, locations of these bolts in the structure and corrosion proneness, use of zinc flake spray coating as per ISO: 10683(latest version) can be adopted even for property class 8.8 bolts as well.

**Installation of HSFG bolting assembly-** Installation /tightening of preloaded bolting assemblies shall be carried out as per clause 8.3 & 8.5 of EN 1090-2 and clause 5.2 of EN 14399-9. The following steps shall be followed for tightening of bolts:

i. The holes shall be brought in alignment by using drifts etc. such that bolt threads are not damaged/enlarged during insertion of bolts.

ii. The members being joined shall be held in position by insertion of few HSFG bolts (tightened to first stage only i.e. snug tight condition).

iii. After the alignment/geometry of members is verified to be correct as per drawings, balance bolts shall be inserted and tightened upto first stage of tightening. The drifts inserted as above shall also be replaced by HSFG bolts one by one.

iv. After first stage of tightening, the joint shall be checked to see if the plies are in close contact and clearances are not exceeded.

v. Second stage tightening shall be done with torque wrench. Bolts shall be tightened until indentation on the DTI indicate full tightening. In order to minimize loosening of already tight bolts, tightening in both the stages shall be done starting from the stiffest part to free edges.

vi. 100% bolts shall be checked for proper tightening using feeler gauge of 0.4/0.25 mm.

vii. Fully tensioned bolt, opened for any reason whatsoever, shall be rejected and removed from the site of work along with washers, nut and DTI.

**1. Bearing and Expansion Gear**

All bearings and expansion gears shall be procured from a reputed and experienced manufacturer qualified to undertake precision fabrication of this type and shall be approved by the Engineer.

**2. Trial Shop erection**

Trial shop erection shall be done in accordance with Cl.614 of IRBM.

**3. Field erection**

Field erection shall be done in accordance with Cl.616 of IRBM.

**4. Erection in contractor's Works**

The whole of the work shall be completely interchangeable. First span (of each type) shall be temporarily erected complete at the Contractor's Works for inspection by the Inspecting Officer to test the accuracy of the templates. Further spans or part span assemblies built from parts selected at random by the Inspecting Officer shall be erected from time to time to check the accuracy of the work as the Inspecting Officer may require.

**5. Track work for OWG:**

Track work for open web girder bridge on H-beam sleepers shall be done as per IRPWM, relevant RDSO drawings and codal provisions.

**6. Camber**

In order to eliminate secondary stresses in a span under loaded condition, the nominal length (i.e. the lengths which will give no camber) of member shall be increased or decreased by the amount shown on the camber diagram supplied by the Employer. Frequent checks shall be made of the camber of girders during erection and care taken to see that the camber as per drawing is obtained when the girder is completely assembled. When span is supported on ends and intermediate supports are removed the dead load camber shall be recorded and entered in bridge register. This will provide the reference to compare the camber checked during technical inspection to ascertain the loss of camber.

**7. Test certificates & testing**

All materials for the work shall pass Mechanical test, Charpy test, Chemical Analysis, etc. prescribed by the relevant IS specifications or such other equivalent specifications.

For all materials including HSFG bolts, the contractor shall furnish copies of test certificates from the manufacturers including proof sheets, mill test certificates, etc. showing that the materials have been tested in accordance with the requirements of various specifications and codal provisions.

If any further testing of materials is required by Engineer in respect of these and other items, it shall be arranged for by the contractor at a reputed laboratory/National test house as approved by Engineer. For this, nothing extra shall be payable.

Even satisfactory outcome of such tests or analysis shall in no way limit, dilute or interfere with the absolute right of the Engineer to reject the whole or part of such materials supplied, which in the judgement of the inspecting authority does not comply with the conditions of the contract. The decision of the Engineer in this regard shall be final, binding and conclusive for all purposes.

The Engineer shall be empowered, at his/her discretion to make or have made under the supervision, any of the tests specified in the specifications mentioned herein in addition to such other tests as he/she may consider necessary, at any time up to the completion of the contract and to such an extent as he/she may think necessary to determine the quality of all materials used therein. In doing so, he/she shall be at liberty under any reasonable procedure, he/she may think fit to select, identify, have cut-off and take possession of test pieces from the material either before, during or after its being worked up into the finished product.

The Engineer shall also be empowered to call for a duly authenticated series of mechanical tests to be obtained from the maker for this materials used in the work and to accept the same in lieu of other tests to the extent he/she deems fit. The Contractor shall supply the material for the test pieces and shall also prepare the test pieces necessary.

The test shall be carried out by the Contractor, for which Contractor shall provide all facilities including supply of labour and plant. Engineer may at his/her discretion direct the Contractor to despatch such tests pieces as he/she may require to the National Test House or elsewhere as he/she may think fit for such testing purposes. The Engineer may at his/her discretion, check test results obtained at Contractor's work by independent tests at National Test House.

The Engineer shall at all times be empowered to examine and check the working of the Contractor's plant before and after using it. Should the Contractor's plant be found, in the Engineer's opinion, unreliable, he/she is empowered to cancel any tests already carried out in this contract and have these tests carried out at any National Test House or elsewhere, as he/she may think fit.

**8. Fabrication drawings**

The contractor shall prepare detailed shop drawings including drawing office dispatch lists (DODL's) on the basis of design drawings supplied by Engineer in such size and in such details as may be specified by Engineer. The shop drawings shall be submitted to Engineer in triplicate.

No work of fabrication will be started without such approval being obtained. Contractor has to arrange the proof checking of the working fabrication drawings from the nominated Institution / Consultant. The cost will be borne by the contractor.

## 9. Painting

a. Fabricated steel work shall not be painted over except to the extent specified in para (b) until it has been inspected and passed by the Engineer or his representative and any defect, pointed out by him has been rectified.

b. All surfaces which shall be in permanent contact and any others which will not be accessible for painting later on shall be cleaned thoroughly and given one coat of Zinc Chrome Red Oxide Priming to IS 2074 or other approved composition in the prescribed number of coats immediately prior to assembly.

c. Steel girders (including all components) shall be provided with protective coating by metalizing with sprayed aluminum as given in the Appendix-VII of IRS: B1-2001, followed by painting as per painting schedule given below-

    i. One coat of etch primer to IS:5666

    ii. One coat of zinc chrome primer to IS: 104 with the additional proviso that zinc chrome to be used in the manufacture of primer shall conform to type 2 of IS:51.

    iii. Two coats of aluminum paint to IS: 2339 brushing or spraying as required. One coat shall be applied before the fabricated steel work leaves the shop. After the steel work is erected at site, the second finishing coat shall be applied after touching up the primer and the finishing coat if damaged in transit.

# Annexure OCS-4
# PRESTRESSING

## 1. GENERAL

The work shall be carried out in accordance with the drawing and these specifications or as approved by the Engineer.

Concrete and un-tensioned steel for the construction of prestressed concrete members shall conform to the requirements of respective sections so far as the requirements of these Sections apply and are not specifically modified by requirements set forth herein.

Contractor shall ensure that different components of prestressing such as jacks, bearing plates, wedges, anchorages, strands, and HDPE ducts etc. are compatible to each other and the same shall be exchanged in between all the suppliers to ensure the same.

## 2. MATERIALS

### a. Sheathing

i. The sheathing ducts shall be of the spiral corrugated type. Unless otherwise specified, the material shall be Cold Rolled Cold Annealed (CRCA) Mild Steel conforming to IS: 513 intended for mechanical treatment and surface refining but not for quench hardening or tempering.

ii. The material shall normally be bright finished. However, where specified, as in case of use in aggressive environment, galvanized or lead-coated mild steel strips shall be used. The thickness of sheathing shall be as shown on the drawing, but shall nevertheless not be less than 0.3mm, 0.4mm and 0.5mm for sheathing ducts having internal diameter of 50mm, 75mm and 90 mm respectively. For larger diameter of ducts, thickness of sheathing shall be based on recommendations of prestressing system supplier or as directed by the Engineer.

iii. For major projects, the sheathing ducts should preferably be manufactured at the project site utilising appropriate machines. With such an arrangement, long lengths of sheathing ducts may be used with consequent reduction in the number of joints and couplers. Where sheathing duct joints are unavoidable, such joints shall be made slurry tight by the use of corrugated threaded sleeve couplers which may be tightly screwed onto the outer side of the sheathing ducts.

iv. The length of the coupler should not be less than 150mm but should be increased upto 200mm wherever practicable. The joints between the ends of the coupler and the duct shall be sealed with adhesive sealing tape to prevent penetration of cement slurry during concreting. The couplers of adjacent ducts should be staggered wherever practicable. As far as possible, couplers should not be located in curved zones. The corrugated sleeve couplers are being conveniently manufactured using the sheath making machine with the next higher size of die set.

v. The internal diameter of the sheathing duct shall be in accordance with the recommendations of the system manufacturer and shall be about three times the area of the tendons. In case of 6T13, 12T13 and 19T13 sizes of tendons comprising 12/13mm dia strands, the inner diameter of the sheathing shall not be less than 50mm, 75mm and 90mm respectively or those shown in the drawing, whichever is greater.

### b. Anchorages

i. Anchorages shall be procured from authorized manufacturers only. Anchorages shall conform to BS 4447. Test certificates from a laboratory fully equipped to carry out the tests shall be furnished to the Engineer. Such test certificates shall not be more than 12 months old at the time of making the proposal for adoption of a particular system for the project.

ii. No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times. Threaded parts shall be protected by greased wrappings and tapped holes shall be protected by suitable plugs until used. The anchorage components shall be kept free from mortar and loose rust and any other deleterious coating.

iii. Swages of prestressing strand and button heads of prestressing wire, where provided shall develop a strength of at least 95 per cent of the specified breaking load of the strand or wire as the case may be. Where swaging / button-heading is envisaged, the Contractor shall furnish details of his methodology and obtain approval of the Engineer, prior to his taking up the work.

**c. Prestressing Steel**

i. 12.7mm nominal dia stress relieved low relaxation high tensile steel strand (CLASS-II) conforming to IS: 14268 with ultimate tensile strength 1861 N/mm2 shall be used. Various test as recommended in IS: 14268 shall be conducted before transporting the lot to site. Apart from 1000 hrs relaxation test conducted by manufacturer, at least two such tests are required to be conducted by independent agency in the beginning of project.

**d. Prestressing strands/Wires storage**

i. All high tensile steel for prestressing work shall be stored about 30cm above the ground in a suitably covered and closed space to protect it from dampness. It shall also be invariably wrapped in gunny cloth or tar paper or any other suitable materials, as per approval of Engineer. Even if it is to be stored in an area at the site for short time during transit it shall be suitably covered. Protection during storage and repacking or application of washable protective coating to the H.T. steel shall be given by the contractor at no extra cost if the packing of H. T. Strand/wire during unloading and storage / handling in the stores gets damaged.

ii. Stock piling of H. T. Steel on the work site shall not be allowed any time, especially before and during the monsoon.

iii. The Engineer or his authorized representative shall always have an easy access to the store-yard for inspecting the H. T. Wire/strands/Bars and satisfying themselves regarding the condition thereof. Any modifications regarding storage suggested by the Engineer shall scrupulously be followed by the contractor. During monsoon days, H.T wires/strands shall be kept in reasonable airtight store, if required by the Engineer, at no extra cost.

**e. Testing of Prestressing steel and Anchorages**

i. All materials specified for testing shall be furnished free of cost and shall be delivered in time for tests to be made well in advance of anticipated time of use.

ii. All wire, strand or bars to be shipped to the site shall be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be shipped shall be like-wise identified.

iii. All samples submitted shall be representative of the lot to be furnished and in the case of wire or strand, shall be taken from the same master roll. The Contractor shall furnish samples of at least 5.0m length selected from each lot for testing. Also, two anchorage assemblies, complete with distribution plates of each size or types to be used, shall be furnished along with short lengths of strands as required.

## 3. WORKMANSHIP

### a. Cleaning

i. Tendons shall be free from loose rust, oil, grease, tar, paint, mud or any other deleterious substance.

ii. Cleaning of the steel may be carried out by immersion in suitable solvent solutions, wire brushing or passing through a pressure box containing carborandum powder. However, the tendons shall not be brought to a polished condition.

### b. Straightening

i. High tensile steel wire and strand shall be supplied in coils of sufficiently large diameter such that tendons shall retain their physical properties and shall be straight as it unwinds from the coil. Tendons of any type that are damaged, kinked or bent shall not be used.

ii. The packing of prestressing wire / strand shall be removed only just prior to making of cable for placement. Suitable stands shall be provided to facilitate uncoiling of wires / strands without damage to steel. Care shall be taken to avoid the possibility of steel coming into contact with the ground.

### c. Positioning

**i. Post-Tensioning**

Prestressing tendons shall be accurately located and maintained in position, both vertically and horizontally, as per drawings.

Tendons shall be so arranged that they have a smooth profile without sudden bends or kinks.

The location of prestressed cables shall be such as to facilitate easy placement and vibration of concrete in between the tendons.

Sheathing shall be placed in correct position and profile by providing suitable ladders and spacers. Such ladders may be provided at intervals of approximately 1.0 m. Sheathing shall be tied rigidly with such ladders/spacer bars so that they do not get disturbed during concreting.

The method of supporting and fixing shall be such that profile of cables is not disturbed during vibrations, by pressure of wet concrete, by workmen or by construction traffic.

- Each anchorage device shall be set square to the line of action of the corresponding prestressing tendon and shall be positioned securely to prevent movement during concreting.
- The anchorage devices shall be cleaned to the satisfaction of the Engineer prior to the placing of concrete. After concreting, any mortar or concrete which adheres to bearing or wedging surfaces shall be removed immediately.

### d. Cutting

i. Cutting and trimming of wires or strands shall be done by suitable mechanical or flame cutters. When a flame cutter is used, care shall be taken to ensure that the flame does not come in contract with other stressed steel. The location of flame cutting of wire or strand shall be kept beyond 75mm of where the tendon will be gripped by the anchorage or jacks.

ii. In post-tensioning the ends of prestressing steel projecting beyond the anchorages, shall be cut after the grout has set.

**e. Protection of Prestressing steel**

i. Prestressing steel shall be continuously protected against corrosion, until grouted. The corrosion protector shall have no deleterious effect on the steel or concrete or on the bond strength of steel to concrete. Grouting shall conform to these specifications or as directed by the Engineer or specified in Contract Specifications.

**f. Sheathing Joints and Couplings**

i. Joints in sheathing shall, if so, instructed be sealed with a heat shrink tape.
ii. Special attention should be paid to its junction at the anchorage. It should tightly fit on the trumpet end of anchorage and the junction should be sealed, preferably, with heat shrink tape.
iii. The heat shrink tape is supplied in the form of bandage rolls which can be used for all diameters of sheathing ducts. The bandage is coated on the underside with a heat sensitive adhesive so that after heating the bandage material shrinks on the sheathing duct and ensures formation of a leak-proof joint. The heating is affected by means of a soft gas flame.
iv. The sheathing and all joints shall be watertight. Any temporary opening in the sheathing shall be satisfactorily plugged and all joints between sheathing and any other part of the prestressing system shall be effectively sealed to prevent entry of mortar, dust, water or other deleterious matter. Sheathing shall be neatly fitted at joints without internal projection or reduction of diameter.
v. Enlarged portions of the sheathing at couplings or anchorages shall be of sufficient length to provide for the extension of the tendons.

**g. Grout Vents**

i. Grout vents of atleast 20mm diameter shall be provided at both ends of the sheathing and at all valleys and crests along its length. Additional vents with plugs shall also be provided along the length of sheathing such that the spacings of consecutive vents do not exceed 20m. Each of the grout vents shall be provided with a plug or similar device capable of withstanding a pressure of 1.0MPa without the loss of water, air pressure or grout.

**h. Anchorages**

i. All bearing surfaces of the anchorages shall be cleaned prior to concreting and tensioning. Anchor cones, blocks and plates shall be securely positioned and maintained during concreting such that the centre line of the duct passes axially through the anchorage assembly.
ii. The anchorages shall be recessed from the concrete surface as per drawings.
iii. After the prestressing operations are completed and prestressing strands are cut, the surface shall be painted with two coats of epoxy of suitable formulation having a dry film thickness of 80 microns per coat and entire recess shall be filled with concrete or non-shrink/pre-packaged mortar or epoxy concrete.

**i. Handling and Storage**

i. Care shall be taken to avoid mechanically damaging, work-hardening or heating prestressing tendons while handling. All prestressing tendons shall be stored clear of the ground and protected from the weather, from splashes from any other materials, and from splashes from the cutting operation of an oxy-acetylene torch, or arc-welding processes in the vicinity.

ii. In no circumstances shall prestressing tendons after manufacture be subjected to any welding operation, or 'on-site' heat treatment or metallic coating such as galvanizing. This does not preclude cutting as specified.

iii. All wires, strands or bars stressed in one operation shall be taken, where possible, from the same parcel. Each cable shall be tagged with its number from which the coil numbers of the steel used can be identified. Cables shall not be kinked or twisted. Individual wires and strands for which extensions are to be measured shall be readily identifiable at each end of the member. No strand that has become unraveled shall be used.

**j. Supervision**

i. All prestressing and grouting operations shall be undertaken by trained personnel only. A representative of supplier of the prestressing system shall be present during all tensioning and grouting operations and shall ensure, monitor and certify their correctness.

**4. Tensioning Equipment**

All tensioning equipment shall be procured from authorized manufacturers only and be approved by the Engineer prior to use. Where hydraulic jacks are used, they shall be power driven unless otherwise approved by the Engineer. The tensioning equipment shall satisfy the following requirements:

a. The means of attachments of the prestressing steel to the jack or any other tensioning apparatus shall be safe and secure.

b. Where two or more wires / strands constitute a tendon, a single multiple stressing jack shall be used which is capable of tensioning simultaneously all the wires / strands of the tendon. Suitable facilities for handling and attaching the multi-pull jack to the tendons shall be provided.

c. The tensioning equipment shall be such that it can apply controlled total force gradually on the concrete without inducing dangerous secondary stresses in steel, anchorage or concrete; and

d. Means shall be provided for direct measurement of the force by use of dynamometres or pressure gauges fitted in the hydraulic system itself to determine the pressure in the jacks. Facilities shall also be provided for the linear measurement of the extension of prestressing steel to the nearest mm and of any slip of the gripping devices at transfer.

e. Any indication in the loss of strength in tendons during the tensioning operation shall be brought to the attention of the Engineer. Any corrective measures which may be required in procedures and/or material shall be approved by the Engineer.

f. When friction must be reduced, water soluble oil may be used subject to the approval of the Engineer. This oil may be flushed from the duct as soon as possible after stressing is completed by use of water pressure. These ducts shall be flushed again just prior to the grouting operations. Each time the ducts are flushed, they shall be immediately blown dry with oil-free air.

**5. Testing by the Contractor**

For the purpose of accurately determining the tendon elongations while stressing, the Contractor shall bench test two samples of each size and type of strand tendon to determine the modulus of elasticity prior to stressing the initial tendon. The bench should be at least 6metres long, with concrete anchorage blocks having a constant area end section of at least four times that of the anchorage assembly area. The tendon shall be straight and centered on the cross-sectional area of the bench. The test procedure shall consist of stressing the tendon at an anchor assembly with the dead end consisting of a load cell. The test specimen shall be tensioned to 80 percent of ultimate in 10 increments. For each increment, the gauge pressure, elongation and load cell force shall be recorded. The data shall be furnished to the Engineer. The theoretical elongations shown on the post-tensioning working drawings shall be re-evaluated by the Contractor using the results of the tests and corrected as necessary. Revisions to the theoretical elongations shall be submitted to the Engineer for approval.

Apparatus and methods used to perform the tests shall be proposed by the Contractor and be subject to the approval of the Engineer. After the initial testing, five more tests shall be performed. These tests shall be spaced evenly throughout the duration of the Contract.

**a. Post Tensioning Procedure**

i. Tensioning force shall be applied in gradual and steady steps and carried out in such a manner that the applied tensions and elongations can be measured at all times. The sequence of stressing applied tensions and elongations shall be in accordance with the approved drawing or as directed by the Engineer.

ii. It shall be ensured that in no case, the load is applied to the concrete before it attains the strength specified on the drawing or as stipulated by the prestressing system supplier, whichever is more.

iii. After prestressing steel has been anchored, the force exerted by the tensioning equipment shall be decreased gradually and steadily so as to avoid shock to the prestressing steel or anchorage.

iv. The tensioning force applied to any tendon shall be determined by direct reading of the pressure gauges or dynamo metres and by comparison of the measured elongation with the calculated elongation. The calculated elongation shall be invariably adjusted with respect to the modulus of elasticity of steel for the particular lot as given by the manufacturer.

v. The difference between calculated and observed tension and elongation during prestressing operations shall be regulated.

vi. **Grouting of Prestressed Tendons:** Grouting shall conform to provisions in **Annexure D** of "IRS Concrete Bridge Code: 1997". A record of grouting operations shall be maintained in a format given by Engineer.

**6. Safety Precautions during Tensioning**

These are applicable for both pre-tensioning and post tensioning operations.

a. Care shall be taken during tensioning to ensure the safety of all persons in the vicinity.

b. Jacks shall be secured in such a manner that they will be held in position, should they lose their grip on the tendons.

c. No person shall be allowed to stand behind the jacks or close to the line of the tendons while tensioning is in progress.

d. The operations of the jacks and the measurement of the elongation and associated operations shall be carried out in such a manner and from such a position that the safety of all concerned is ensured.

e. A safety barrier shall be provided at both ends to prevent any tendon, which might become loose from recoiling unchecked.

f. During actual tensioning operation, warning sign shall be displayed at both ends of the tendon. No person will stand behind in line with jacks while tendon / wire are being stressed.

g. After prestressing, concrete shall neither be drilled nor any portion cut nor chipped away nor disturbed, without express approval of the Engineer.

h. No welding shall be permitted on or near tendons nor shall any heat be applied to tendons. Any tendon which has been affected by welding, weld spatter or heat shall be rejected.

**7. Transportation and Storage of Units**

a. Precast girders or elements shall be transported in an upright position. Points of support and the direction of reactions with respect to the girder shall approximately be the same during transportation, and storage as when the girder is placed in final position.

b. When members are to be stacked, they shall be firmly supported at such bearing positions as will ensure that the stresses induced in them are always less than the permissible design stresses. Further, inclined side supports shall be provided at the ends and along the length of a precast girder to prevent lateral movements or instability.

c. Care shall be taken during storage, hoisting and handling of the precast units to prevent their cracking or being otherwise damaged. Units worked or damaged by improper storing or handling or transport shall be replaced by the Contractor at his expense.

**8. Tolerances**

a. Permissible tolerances for positional deviation of prestressing tendons shall be limited to the following:

| | | |
|---|---|---|
| i. | Variation from the specified horizontal profile: | 5 mm |
| ii. | Variation from the specified vertical profile: | 5 mm |
| iii. | Variation from the specified position in member: | 5 mm |

# Annexure OCS-5
# FORMWORK

## 1. MATERIALS

Forms shall be timber, steel or other approved material, except that the sheeting for all exposed surfaces, where form lining is not specified shall, be of tongue and groove timber of uniform width unless otherwise by the Engineer.

All materials used in formwork construction shall be of adequate strength and quality for their intended purpose and shall be satisfactory to the Engineer.

Timber shall be sound, straight, free from warp, decay and loose knots, and shall be dressed smooth.

Where plywood is used, it shall be non-wrinkling and manufactured with special water proof glues. Plywood sheets shall be of uniform width and length.

The surface of steel or steel lined forms shall be smooth. Forms with dents, buckled areas or other surface irregularities shall not be used.

Reuse of forms and form lumber shall be allowed only if they are thoroughly cleaned and repaired and capable of producing the finish required for the concrete. Timber or plywood forms required with metal patches shall not be used unless permitted by the Engineer.

Damaged forms or forms which have deteriorated through usage shall not be used.

Form oil used on surfaces of timber or plywood forms shall be a straight, paraffin base refined, pale, mineral oil. The oil used on the surface of steel forms shall be specially compounded petroleum oil and other oils of animal or vegetable origin and gums or resins which are heavier in body and frequently darker than straight petroleum oils shall be used in the case of steel lining forms. The Contractor may use any other material also for coating of the formwork with the approval of the Engineer.

Forms of like character shall be used for similar exposed surface in order to produce a uniform appearance.

The type, size, shape, quality and strength of all materials from which forms are made shall be the sole responsibility of the Contractor but subject to the approval of the Engineer.

In general, forms for permanently exposed surface shall consist of or shall be lined with matched or dressed edge grain timber of appropriate thickness, free from loose or cracked knots.

Metal forms or metal-lined forms shall be permitted for permanently exposed surfaces only when an entire surface is to be built completely with such forms.

## 2. DESIGN, FABRICATION, ERECTION AND MAINTENANCE OF FORMWORK

Forms and falsework shall be designed, fabricated, erected and removed in accordance with the applicable provisions of the Recommended practice for concrete formwork of IS:456-2000 as required by the Engineer and as specified herein.

All falsework shall be designed to withstand safely all live and dead loads, necessary pressures, ramming and vibrations without significant deflection from the prescribed lines, which might be applied to the falsework during all stages of construction, service and removal.

The Contractor shall be solely responsible for the design, construction and maintenance of all formwork and falsework required in the work.

Detailed drawings of shoring and falsework shall be prepared by the Contractor. The calculations and drawings shall show the size and specification of the falsework, including the type and grade of all materials used in the construction, design load on falsework supports, horizontal forces imposed on the falsework and used for design purpose, and details of splices and connections, including nails, spikes and other fasteners. If mechanical equipment such as concrete buggies, screening machines, etc., are to be used, this information shall be shown on the drawings.

Falsework shall be constructed only after the falsework drawings have been approved by the Engineer.

The approval by the Engineer of Contractor's drawings shall not relieve the Contractor of his responsibility for the adequacy of form and falsework, or for the successful completion of the work.

The Contractor shall construct the falsework strictly in accordance with the approved falsework drawings, one set of which shall be kept on the site at all times, and no changes shall be allowed without prior written acceptance of such changes by the Engineer.

Forms shall be designed to permit the concrete to be deposited, as nearly as is practicable, directly in its final position, and to allow inspection, checking and clean up of the formwork and reinforcement to be completed without delay.

Formwork and falsework shall be designed, constructed, erected and maintained such as to confine the concrete without loss of mortar and produce finished surface which are within the tolerances specified.

Forms for concrete against which backfill is to be placed or which shall not be exposed to view, may be constructed of smooth tight boards not less than 25 mm nominal thickness.

Forms for concrete exposed to flow of water or exposed to view shall be constructed of steel or ply wood which is smooth and free from defects with matched and sanded joints to give a symmetrical pattern over the entire area. Chamfer strips, 40 mm by 40 mm, shall be use don all exposed corners, unless otherwise specified or required by the Engineer.Form ties, supports, anchors, braces, spreaders and other similar devices which shall be embedded in the concrete for holding the forms shall incorporate threaded metal bars to facilitate removal of forms. Wood spreaders shall not be left in the forms. Any metal remaining embedded in the concrete shall be at least 50 mm from the surface of concrete. Holes left in the concrete by removal of parts of form ties or similar devices shall be well filled with cement mortar and neatly finished to match the adjacent concrete.

Form inserts or other similar permanently embedded items shall be accurately located and securely fastened in place. The number and location of form ties and bolts shall be such as to ensure that forms fit tightly against the concrete previously placed and remain in tight contact during operations.

Forms shall be set and maintained within the specified tolerance limits such that the complete concrete surfaces are within these limits.

All form surfaces shall be thoroughly cleaned before erection and shall be lubricated with a non-staining mineral oil. All excess oil shall be wiped off the forms prior to placement of concrete. Oil shall not be allowed to come into contact with reinforcing steel or other embedded items. For use of timber forms, the oil shall be capable of penetrating the timber and keeping it sufficiently oily to eliminate sticking and preventing absorption of water and consequent warping.

The oils shall be applied by brush, spray or swab and the forms shall be covered fully and evenly without excess or drip. Care shall be taken to prevent oil from getting in the surface of construction joints. Special care shall be taken to oil thoroughly the form strips for narrow groove seats.

Immediately before concrete is placed, all forms shall be inspected to ensure that they are properly placed, sufficiently rigid, clean, tight and properly surface treated and free from encrustations of mortar, grout or other foreign materials. No concrete shall be placed until formwork has been inspected and accepted by the Engineer. Where forms of continuous surfaces are placed in successive units, the forms shall fit tightly over the surface so as to prevent leakage of mortar from the concrete and to maintain accurate alignment of the surface.

The formwork for the gate groove areas shall be accurately drilled to be held with first stage anchor couplings/plates to be embedded in primary concrete, Both shall be fixed through formwork into the first stage anchor couplings/plates to ensure that the couplings/plates remain flush with primary concrete face and the couplings do not get plugged.

Where timber forms are used, the laying shall be in the direction which will blend architecturally into the lines of the structures, as decided by the Engineer.

Curved and special forms shall be such that these will result in smooth concrete surfaces. They shall be designed and constructed so that they will not warp or spring up during erection or placing concrete.

When metal sheets are used for lining forms, the sheets shall be placed and maintained on the form with the minimum amount of wrinkles, humps or other imperfections. The use of sheet metal to cover imperfections in the lining of timber faced forms for surfaces that shall be permanently exposed to view, shall not be permitted.

Where plywood or hardboard is used for form lining, the joints between the sheets shall be smooth and as perfect as practicable and no patching of the plywood or hardboard shall be permitted for permanently exposed surfaces. Minor imperfections in the ply wood may be corrected by the use of plastic wood secured firmly in place and sand papered smooth.

Wire ties shall be permitted for the forms when specially approved by the Engineer and shall be cut off flush with the surface of concrete, after the forms are removed. Wire ties shall not be used when permanently exposed finished surfaces are required.

Forms shall be so constructed that the finished concrete surfaces shall be of uniform texture in accordance with the type of finish specified for concrete surfaces in these Specifications.

The erection of formwork in position shall be rapid enough, rigid and strong to withstand concreting operations and maintain the alignment. Panels of similar shape shall be identical and inter-changeable.

For special section/shapes, timber/steel form shall be used, as approved by the Engineer.

The Contractor shall strengthen or modify the formwork, whenever required by the Engineer.

Unless authorised, suitable mouldings shall be placed to level all exposed edges, at construction joints, and any other edges shown on the drawings, or as required by the Engineer. The final detailed drawings shall show any formed recesses, slots, blockouts and similar construction details, which have to be kept into account in fixing the formwork.

Forms shall be maintained, at all times, in good condition, particularly as to size, shape, strength, rigidity, tightness and smoothness of surface.

The Engineer will, at any time, have the right to reject formwork which he considers to be no longer fit for use.

## 3. REMOVAL OF FORMWORK

Forms shall not be removed until the concrete has hardened and has attained a crushing strength of at least twice the stress which the concrete may be subjected to at the time of removal of forms.

Duration for which the forms shall remain in place shall be decided by the Engineer, with reference to weather condition, shape, position of the structure or structural members and the nature and magnitude of dead and live loads. The forms shall not be removed without the permission of the Engineer.The following minimum intervals of time shall generally, be allowed between completion of placing of concrete and removal of forms but the period shall increased in case of wet or cold weather and also at the option of the Engineer.

Structure Period in days with Normal Portland Cement

| | | |
|---|---|---|
| (a) | Beam sides, walls columns (Unloaded) | 3 |
| (b) | Slabs and arches (Props left under) | 4 |
| (c) | Props to slabs and arches | 10 |
| (d) | Beam soffits (Props left under) | 8 |
| (e) | Props to beams | 21 |
| (f) | Mass concrete | 2 |

The above minimum periods are only recommendatory. The Contractor, may, where he so desires, extend the above to longer intervals. This shall not, however, constitute any reason for any claim for extension of time or damage to concrete etc.

If the Contractor desires to remove the forms earlier than the period stated above by addition of cement and/or suitable admixtures in the concrete, so as to gain carely strength without affecting long term strengths, the matter shall be examined by the Engineer in each case and his decision in the matter shall be final and binding.

Heavy live loads shall not be permitted until after the concrete has reached its design strength.

The forms shall be removed with great caution and without jarring the structure or throwing heavy forms upon the floor. In order to achieve this end, wedges and clamps shall be used whenever practicable instead of nails.

In order to avoid excessive stress in the concrete that might result from swelling of the forms, wood forms for wall opening shall be loosened as soon as this can be accomplished without damage to the concrete. Forms for the opening shall be constructed so as to facilitate such loosening.

The Contractor shall be solely responsible for any damage that may be caused by negligence, lack of proper precautions or hastiness etc. in the matter of removal of forms and shall make the same good to the satisfaction of the Engineer.

# Section VII: Employer's Requirements

## Section VII-7: General Electrical Services

# CHAPTER –1 SCOPE OF WORK

## 1.1 GENERAL

A general description of the broad scope of work, relating to works covered in this Tender under Schedule A, is given below. It shall, however, be clearly understood that the description is for the purpose of general guidance only and is not exhaustive. For complete appreciation of the Scope, the specifications, drawings and other relevant paragraphs of the Tender documents shall be referred to.

### 1.1.1 ITEMS OF WORK

The jobs **Tunnel** to be carried out by the Contractor under this contract comprises of but not limited to the following: -

| Sr. No. | Description of Work | Tunnel-1 | Tunnel -2 | Total Qty |
|---|---|---|---|---|
| 1 | Design, Supply, Erection, Testing & Commissioning of (11/.433) kV Sub-station complete in all respect along with all protection system including 11kVA GIC HT Panel Board, (2x2000) kVA Dry Type Transformers( 02 Nos transformer for each substation), 3 ways 11 kV Ring Main Unit (RMU) comprising of 2 Nos load break switch, Battery Charger, APFC Panel, LT Distribution Panel, other necessary switchgears, Complete Earthing system & all associated works as per specification. GIS panels shall be operated and monitored through SCADA.This includes construction of sub-stations building complete in all respect as per specification and drawing. | 1. Sub-station-1 (SS-1) at Centre of Tunnel - **01 Job**<br>2. Sub-station-2 (SS-2) at North Portal of Tunnel - **01 Job** | | **02 Job** |
| 2. | Design, Supply, Testing & Commissioning of 11 kV HT/LT fire survival Copper cable (Power and Control) Network of adequate sizes including laying of cables in Air/HDPE pipe/DWC Pipe/ Trench of size 0.5 mts wide x 1.2 mts deep/ stainless steel cable tray/ cable ladders/ Stainless steel conduit on wall inside/outside of the tunnel as per site requirement, specification and standard. | 1. Main HT Supply (Incoming supply) for SS-1 and SS-2 = 3x120 Sqmm Cu cable.<br>2. HT supply between SS-1 and SS-2 for Ring main system = 3x95 Sqmm Cu cable.<br>3. LT Distribution Network from SS-1 and SS-2 = 4x50,4x25 Sqmm And other size of copper cable as per specification. | | **01 Job** |

| Sr. No. | Description of Work | Tunnel-1 | Tunnel -2 | Total Qty |
|---|---|---|---|---|
| | | **Note: - EPC Contractor shall ensure laying of spare cables of same size for each feeder as per Railway Board/RDSO Guidelines.** | | |
| 3 | Supply, Erection, Testing & Commissioning of 900 kVA / 910 kVA Advantage prime rating diesel generating set (11000 Volts Alternator) along with powder coated acoustic enclosure suitable for outdoor application including AMF panel, Auto synchronizing panels, silencers, Earthing system, all civil work & associated arrangement as per CPCB norms and as per specification. | 1. DG of 900 kVA /910kVA capacity including all accessories, foundation work at SS-1 - **01 Job**<br><br>2. DG of 900 kVA /910kVA capacity including all accessories, foundation work at SS-2 - **01 Job** | | **02 Job** |
| 4 | Design, Supply, Erection, Testing and Commissioning of tunnel lighting system and its associated works by using of 4x25/4x16/4x10,4x6/4x4 sqmm copper cable, energy efficient 20 Watt LED fixtures, Lighting DB's, Lighting Panel, Junction Box with complete wiring of multi core 1.5/2.5/4/6 sqmm Cu conductor cable laying in stainless steel conduit of dia 12.5/25mm, necessary switch gears and surge protection equipments complete in all respect as per site requirement, standard and specification. | **01 Job** | **01 Job** | **02 Job** |
| 5 | Design, Supply, Installation, Testing and commissioning of Maintenance Power socket (1 Phase- 16/20 Amp, 3P and 3 Phase-16/20 Amp, 5P) system including MCB's, all accessories and Maintenance DB's with IP 65 protection complete in all respect as per site requirement, standard and specification. | **01 Job** | **01 Job** | **02 Job** |
| 6 | Design, Supply, Installation, Testing & Commissioning of Emergency power supply system including online UPS 10/20/80 kVA capacity with Sealed Maintenance Free Heavy duty lead acid Batteries for 120 min backup along with UPS lighting DB's and other accessories, powder coated steel racks for placing | 1. At SS-1 – **01 Job**<br>2. At SS-2 – **01 Job** | | **02 Job** |

| Sr. No. | Description of Work | Tunnel-1 | Tunnel -2 | Total Qty |
|---|---|---|---|---|
| | batteries, interconnecting Copper PVC sleeved bus bars complete in all respect as per site requirement specification and standard. UPS Power Supply to be designed through DG set for providing Level-I illumination in the tunnel as per specification. | | | |
| 7 | Design, Supply, Installation, Testing and Commissioning of Programmable Illuminated Escape Route Orientation sign board, Programmable non Illuminated Escape Route Orientation sign board controlled by SCADA and Fire Extinguisher glow signage board, other required Signage board, as per decision of Engineer and Visibility Sensors at adequate distance controlled & monitored through SCADA, complete in all respect as per site requirement, standard and specification. | **01 Job** | **01 Job** | **02 Job** |
| 8 | Supply, Installation, Testing and Commissioning of Stainless steel cable Trays of size 150x50x2mm thickness ladder and Perforated type as per specification made of material no. 1.4404, throughout the tunnel, for HT/LT and lighting etc. Cu. Cable, wall mounted on hot dip galvanized heavy duty steel structure, continuously connected including horizontal and vertical bends, reducers, tees, coupling plate and high grade stainless steel anchor fasteners of material no. 1.4401 complete in all respect and as per site required. | **01 Job** | **01 Job** | **02 Job** |
| 9 | Electrification of Sub-station and other service Building/Rooms with allied facilities including LED luminaries (Indore & 150-watt flood light fitting with all accessories, 1.5-ton capacity split Ac 5-star rating for control room, 150 ltrs water cooler and all other electrical accessories in C4 package area as per site requirement specification and guide line issued by RDSO/Railway Board. | **01 Job** | | **01 Job** |

| Sr. No. | Description of Work | Tunnel-1 | Tunnel -2 | Total Qty |
|---|---|---|---|---|
| 10 | Extension/Augmentation of Electrical Power Supply (3 phase, 11 kV) for both sub-stations of tunnel and associated works including all liaison work from state electricity board. Total Sanctioned load/connected load of each sub-station will be decided by the EPC contractor after load calculation of each tunnel. | **01 Job** | **01 Job** | **02 Job** |
| 11 | **Design, Supply, Installation, Testing and Commissioning of Earthing System of following type: -** | **01 Job** | **01 Job** | **02 Job** |
| 11 (a) | Supply, Installation, Testing and Commissioning of Earthing system with 3-meter-long, 50 mm dia, G.I. pipe class 'B' earth electrode, adding of charcoal or coke and salt, providing masonry enclosure and cover plate with lifting arrangement etc. including connections with 8 SWG G.I wire from earth electrode as per specification. | | | |
| 11 (b) | Supply, Installation, Testing and Commissioning of Maintenance Free Earthing (chemical Earthing) as per specification | | | |
| 11 (c) | Supply, Installation, testing & Commissioning of Copper Bonded Steel Earth Rod of 3-meter length, 17.2 mm dia with Exothermically welded busbar along with 50 kg Earth Enhancement Compound in each pit. pit covers made up of Poly Plastic and SITC of 10 mm Copper Clad Steel Round Conductor laid at 600mm below the ground, as per specification, requirement and code of practice. | | | |
| 11 (d) | Supply & Installation of Earth Grid for 11/0.433 KV Substations. It shall have a Copper Bonded steel rod & conductor of diameter 17.2 mm / 3 meters length. An earth rod shall have an earth enhancement compound 50 kg per pit. All the joints shall be exothermically welded. Dedicated riser of 50x6 & 25 x 6 mm copper coated steel strip shall be provided for Neutral & Body respectively with RCC Chambers. With Copper MET's | | | |

| Sr. No. | Description of Work | Tunnel-1 | Tunnel -2 | Total Qty |
|---|---|---|---|---|
| | shall be provided PC enclosure. An Isolation spark gap shall be provided for equipotential bonding as per IEC 62561-3 & as per requirement and specification. | | | |
| 12 | **Design, Supply, Installation, Testing and Commissioning of Earthing and Potential equalization system for Inside throughout the tunnel with crossings by following material: -** | | | |
| 12 (a) | Providing, excavating & laying of Stainless steel main potential equalization 150 sq mm to be laid inside the tunnel on both walls of the tunnel. It shall be available in a drum roll of minimum 1000 meters. Inclusive exothermic welded joints at the required intervals for connections to other elements of the earthing network and straight through joints. | **01 Job** | **01 Job** | **02 Job** |
| 12 (b) | Providing & laying of Stainless steel main potential equalization 25 sq. mm for all required earth connections to MET to be laid at every crossing to interconnect busbar to the other equipments for equi-potential bonding along with all required fixing arrangements. | | | |
| 12(c ) | Providing & fixing of Isolation Spark Gaps for Equipotential Bonding as per IEC 62561- 3 | | | |
| 12 (d) | Providing & Fixing of Stainless steel potential equalization Bus bar of size 500x50x6 mm with 8 holes drilled on it provided on both sides of the tunnel at every 250 m along with all accessories. It shall be enclosed in an enclosure PC box with transparent front cover and fixed to the wall with insulated supports such as Bakelite or equivalent material. | | | |

**NOTE: -**

1) All the quantity, type ,rating and size of equipments/material (Transformer, DG and HT/LT Panels etc.) in above table is indicative only. It may vary as per EPC contractor design, various guidelines & standard issued by RDSO/Railway Board and site condition.
2) The capacity of HT/LT panels, Transformers & DG's and size of power/control cable (Fire survival cable) and other equipments will be decided by EPC contractor as per voltage drop calculation, dimension, and installation to suit site requirements.
3) The Contractor shall arrange the approval of Sample of all required item and lay out plan of Complete HT/LT power supply arrangement of each tunnel from Engineer before commissioning of work.

XXXXXX

# CHAPTER 2 — DESIGN AND PERFORMANCE REQUIREMENTS

## 2.1 General

**2.1.1** The design, supply, installation, testing and commissioning of General Services work including Power supply system and construction of sub-station buildings etc. shall meet the design and performance requirements within the design environments specified in this PS.

### 2.1.2 Design Environment

Adequate Margin shall be built in Design, particularly to take care of Climate Conditions/Operating Environment. Wherever the equipment is installed in open at the surface level or inside service buildings at surface level, the same shall be designed for working in the tropical conditions existing here and the ambient temperature and humidity levels pertaining to HORC Project area.

Tunnel walls may be wet and seepage water will normally be present in the invert. The system design shall, therefore, take into consideration the effect of seepage and continue to operate in such wet and humid conditions.

## 2.2 Basic Design Philosophy and Requirements

### 2.2.1 Proven Design

The Contractor shall develop the design based on specification and on proven and reliable Engineering Practices. The design details shall be submitted with technical data and calculations to the Engineer for review.

The contractor shall submit drawings in such a form as the Engineer will require them for approval, copies as required of all drawings, diagrams and details of all equipment in part or in whole. The contractor shall make any drawings available to the Engineer at all reasonable times. Wiring diagrams and other drawings as the Engineer deems shall not be finally settled until satisfactory installation and testing has been made, this shall be approved in principle.

The contractor shall submit a schematic block diagram of the equipment showing the manner, in which the functional requirements of this specification shall work together. The contractor shall submit a schedule including details of numbering, categories and drawing registers / indexes for the production, submission and approval during the period of the contract of drawings and also of any information, required for the Engineer in connection with the design of the contract works.

This schedule shall be suited to the requirements of manufacture, delivery and installation of the contract works to meet the requirements of the contract and shall allow reasonable time (approx. 8 weeks) for study and approval by the Engineer of all drawings, calculations and graphics submitted (and, as necessary, resubmitted) by the contractor.

No approval by the Engineer of any drawing shall relieve the contractor of any of his obligations of liabilities under the contract or of his responsibility for ensuring that the work is satisfactory done and that all operational requirements shall be met.

The contractor shall provide final drawings without undue delay, and in any case within twelve weeks of the award of the contract, these drawings shall include dimensions, capacity of equipments and complete power supply & lightning arrangements of tunnels with all associated items.

### 2.2.2 The design philosophy should meet the following criteria:

a) Application of state-of-the-art Technology
b) Service proven design
c) Design life 30 years
d) Minimum life cycle cost
e) Low maintenance cost
f) Use of interchangeable, modular components
g) Extensive and prominent labelling of parts, cables and wires
h) High reliability
i) Low energy loss
j) System safety
k) Adequate redundancy in system
l) Fire and smoke protection
m) Use of fire retardant materials and fire survivals cables
n) Environment friendly
o) Adherence to operational performance requirements
p) Maximum utilization of indigenous materials and skills, subject to quality conformity.

Adequate margin shall be built into the design particularly to take care of the higher ambient temperatures, dusty conditions, and high seasonal humidity, etc. prevailing in HORC Project area.

## 2.3 AS-BUILT DRAWINGS

Preparation of the as-built drawings shall be part of these specifications. As-built drawings will be Final Design Drawings of the project showing the actual work done. The contractor shall provide the as-built drawings in one original and one reproducible negative produced from the original, with the names of the signature authorities of the Engineer and the contractor. After they are signed for approval, prints shall be taken from the signed original of each drawing. Also, DVDs with all as-built drawings shall be handed to the Engineer. Together with the as-built drawings, the contractor shall provide reduced size (e.g. A3 size) booklets of the as-built drawings as per the Engineer requirement.

All details, dimensions, texts, etc., on the reduced size drawings shall be clearly recognizable and readable. The contractor shall complete and obtain the Engineer's approval on the as-built drawings and make the final submission of the as-built drawings together with the A3 size booklets latest within three months following the date of the Certificate of Completion. All costs associated with the provisions mentioned above shall be deemed to be included in the contract price.

As-built drawings shall cover in general (but not limited to):

**a) For mechanical equipment**:

i. Construction drawings,
ii. Instruction drawings,
iii. Functional block diagrams with set-point range of process parameters depicted

thereon.

**b) For electrical installation:**

i. Installation drawings with circuit numbers and exact type-assignation of all installed equipment,
ii. Distribution diagrams with circuit numbers,
iii. Fault analysis and protection co-ordination settings the of protection system,
iv. Power consumption,
v. Precise type numbering
vi. Earthing systems

**c) For distribution panels:**

i. Construction drawings,
ii. Circuit drawings as operating diagrams,
iii. Additional current flow-charts where required,
iv. Accurate lists of any installed equipment with precise description of this equipment,
v. Adjustment tolerances of circuit-breakers, switches, etc.

**d) For equipment:**

i. Construction drawings,
ii. Circuit diagrams,
iii. Functional block diagrams with set-point range of process
iv. parameters depicted thereon,
v. List of quantities with detailed break-down of the bill of materials comprising the equipment.

**e) For cabling:**

i. Diagrams with dimensions, type of cables and power requirements with regular cross- section area and measured cable values shall be used for these diagrams.

**2.4 System Requirements :**

**2.4.1 Conformity with Governing Specifications and other Statutory Requirements: -**

The work shall be carried out in accordance with the following governing specifications and other statutory rules:

i. CEA Regulations 2010
ii. Indian Electricity Act 2003 with latest amendments.
iii. Central Safety regulations, 2010
iv. Regulations laid down by Chief Electrical Inspector to the government.
v. Regulations laid down by EIG Indian Railways.
vi. Rules and Regulations prescribed by local authorities as applicable.
vii. Relevant, Indian Standards, IEC Standards, CENELEC, British Standards, Tunnel draft Manual of Indian Railways (as applicable) and other National/ International

standards as applicable.

viii. The Contractor shall furnish information asked for by a statutory body (e.g., Government of India, Ministry of Railways, Commissioner of Railway Safety, Government of Haryana etc.) in particular format as directed by Engineer. Any documents, studies, test reports, compliances required for getting safety clearances from any authority shall be submitted by the contractor

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# CHAPTER –3 INSTALLATION AND CONSTRUCTION

## 3.1 REQUIREMENTS

### 3.1.1 General Requirements

i. The Contractor shall comply with all Enactments in executing the Works, including but not limited to all statutory provisions on occupational health and safety.

ii. The Contractor shall co-ordinate with Other Contractors in the execution of the Works.

iii. The Contractor shall also co-operate with all Relevant Authorities in the execution of the Works.

iv. The installation of all equipment shall be undertaken at all times by suitably trained and competent employees of the Contractor, to the satisfaction of the Engineer.

v. Only appropriate tools, plant, equipment and vehicles shall be used.

vi. Installation of all equipment shall be in accordance with the Construction and Installation Plan described in the drawing/plans as approved by Engineer before commissioning of work.

vii. Installation of all equipment shall conform to the best industry practices.

viii. Precautions shall be undertaken to ensure the safety of personnel and equipment for all installation works.

ix. The Contractor shall, prior to starting any installation and construction work, identify any possible hazards, and implement measures of eliminating and/or controlling such potential hazards, in line with safe working practices.

x. The Contractor shall ensure that all areas of work are sufficiently illuminated for the works to be undertaken and that a safe system of work is employed for all activities.

xi. The Contractor shall operate a robust system for the control of persons entering or working upon the site.

xii. The Contractor shall co-operate, always, with the Engineer and Other Contractors to ensure that the Site is protected from unauthorised admission, either wilfully or otherwise.

xiii. The Contractor shall make due provision for the safe access and egress to the Site of Works for its staff and subcontractors.

xiv. This access shall be maintained such that it is free of all hazards and is in a safe condition throughout the duration of the Works.

**xv. The EPC contractor shall set up at least one main store/ depot for receiving and storing materials & other equipment at his own cost.**

### 3.1.2 Specific Requirements

The installation and construction work pertaining to this Contract shall include, but not be limited to the following: -

i. Finalisation of the Construction and Installation Programme provided by EPC contractor and duly approved by Engineer.

ii. Survey on Site and review the technical requirements shown in this Specification and the Engineer's Drawings (if any).

iii. Production of the calculation sheets and installation drawings for Site installation.
iv. Production of specific site designs and drawings based on typical designs and drawings supplied.
v. Installation in accordance with the finalised installation drawings.
vi. Co-ordination with Other Contractors;
vii. Submission of the installation reports and records.
viii. Testing and commissioning, as per finalised protocol and programme.

## 3.2 Construction and Installation Plan

The Contractor shall undertake installation work in stages as shown in the detailed installation programme. Installation, testing and commissioning of later stages shall not impact revenue operation of earlier stages.

As a minimum, the detailed Construction and Installation Plan shall include but not be limited to all the activities, installation details and methods of all activities, equipment and tools to be used for installation, safety issues, supervision, temporary land occupation needed and the vehicles to be used for installation.

### 3.2.1 Manual Handling

To facilitate handling of equipment during installation and maintenance thereafter, the Contractor shall closely co-ordinate and interface with other contractors travelling hoists and unloading jib cranes for sub-stations. The entire material handling plan for movement of bulky item such as Transformers, Panels, DG sets, and cables etc. shall be carefully planned. Crane of adequate capacity with a jib of requisite length will be arranged by the EPC Contractor at his own cost. Road crane for handling heavy materials at the contractor's depot for loading and unloading of material will be arranged by the contractor who will also arrange his own crew for its operation and maintenance. All charges including pay and allowances of the crew and all running expenditure will be borne by the contractor.

## 3.3 Site Supervision/ Deployment of Technical Staff: -

**3.3.1 The Contractor shall set up a Site supervision system, which shall be part of the overall safety, system assurance and quality management system.**

i. The Contractor shall provide sufficient number of experienced Engineer, Supervisors and skilled workers to ensure progress and quality of the work at Site and in the Contractor's workshops( if any), are maintained to the satisfaction of the Engineer. The minimum number of Engineers required to be deployed is shown in table below: -

| No | Post | Minimum Eligibility | Minimum Requirements in nos. |
|---|---|---|---|
| 1 | Sr. Engineer (Overall in charge of all type of General Services work) | Graduate in Electrical Engineering with 10 or more- year experience in Electrical and E&M System. | 1 |

| No | Post | Minimum Eligibility | Minimum Requirements in nos. |
|---|---|---|---|
| 2 | Electrical Engineer (Site Engineer) | Graduate in Electrical Engineering with 7 or more-year experience in HT & LT works.<br>**Or**<br>Diploma in Electrical Engineer with 10 or more years experience in HT & LT works. | 1 |
| 3 | E&M Engineer (Site Engineer) | Graduate in Electrical /Mechanical Engineering with 3 or more-year experience in E&M system.<br>**Or**<br>Diploma in Electrical/ Mechanical Engineer with 5 or more-year experience in E&M system. | 1 |

ii. The contractor shall submit to the Engineer, not later than 60 days from the date of award of contract, the organization chart showing following key positions, and CV's of the incumbents and the brief job descriptions. The Engineer shall issue Notice of "No-objection" or otherwise for the appointment of "key positions" within stipulated working days of such submission.

iii. The performance of personnel shall be under observation by Engineer. In case the performance of any personnel is not up to the mark, as decided by Engineer. In case replacement is required, contractor shall be responsible for replacement of such personnel.

iv. In case the contractor fails to employ the technical staff as aforesaid to the satisfaction of the Engineer-in-charge, the recovery shall be as mentioned below per each calendar month or part thereof of default.

| Sl. No. | Post | Amount to be recovered per person per each calendar month or part thereof of default. (Rs) |
|---|---|---|
| 1 | Sr. Engineer | 1.0 Lakhs |
| 2 | Electrical Engineer | 50,000 /- |
| 3 | E&M Engineer | 50,000/- |

v. Contractor is to abide by the provisions of Payment of Wages act & Minimum wage act.

vi. The Contractor's supervision system shall be responsible not only for the supervision of the concerned system installation but also for the supervision of the installation of the primary fixing system, earth mats and systems, etc. The supervisors shall work on a full-time basis during the entire installation process.

vii. The Contractor shall maintain a set of drawings at each system which accurately reflect the current status of field changes. The Contractor shall obtain letter of no objection from the Engineer for any such changes. The Contractor shall prepare final drawings showing the as built configuration. These drawings shall be developed in a logical format to facilitate routine system maintenance and troubleshooting. All drawings and details shall be endorsed by the Contractor.

viii. The Engineer reserves the right to undertake, at any time, checks on the proficiency of the Contractors staff, licensing and all associated documentation. If any of the Contractors staff be found incompetent or unlicensed he shall be removed from the site until their Competency has been established.

### 3.4 Workmanship

All the installation shall be carried out according to the instructions shown in these specifications and Drawings (as approved).

All assemblies of equipment and their components and parts shall be completely interchangeable if they are of similar type

The style and procedure of the workmanship shall be consistent throughout the Works.

Unless otherwise specified, the Engineer shall decide the final colours for all paint work and other finishes to be applied to any part of the Works.

All parts, which are subject to, wear or damage by dust, shall be completely enclosed in dust proof housings.

#### 3.4.1 Installation of Cables

The Contractor shall co-ordinate with the Civil Contractors wherever necessary, for the installation of cables in cable galleries, trenches, ducts, trays, risers and other locations.

The cable system shall, during installation, be fully protected from mechanical damage and be generally accessible at all points for inspection along its entire route. Suitable cable markers shall be provided for covered cables upon completion of installation Should it prove necessary to cut any cable during installation, all cut ends shall be properly sealed.

The maximum pulling force of any cable during installation shall not exceed the design force of cables.

All cables shall be installed in the formed cable trenches, shafts, hangers, trays and brackets. The minimum recommended bending radius of the cables shall be adhered to during installation.

All materials used for termination, jointing and installation of cables in confined spaces shall have flame retardant, low smoke, halogen free characteristics.

## CHAPTER – 4 TESTING AND COMISSIONING

### 4.1 TESTING

This Chapter describes the testing & commissioning related to the Various General Services works in conformity with the requirements of RDSO/Railway Board Standards and standard Railway practices.

Testing constitutes an essential obligation to satisfy the Railway System.

### 4.2 Testing Conditions and Equipment Acceptance

The Contractor will have to carry out all the tests and checks required guaranteeing the Engineer of the good construction and the satisfactory operation of all power supply installation.

Also, the contractor shall co-ordinate & arranges testing equipment etc. required for testing facilities.

The various high, medium and low voltage equipment will be subjected to all the tests required under equipment test sheets, (lists are not exhaustive) as per the relevant IEC or other standards mentioned in the technical specification of each equipment or otherwise.

It is reminded that the contractor is totally entrusted with full responsibility of assembly and installation of all pieces of equipment mentioned in this specification, with supplying the maintenance equipment and the special tooling which shall be delivered as soon as equipment installation will be completed and with the various duties he is bound to regarding witnessing of tests at commissioning and supervision after energising.

4.2.1 **In-plant testing**: -

In plant testing concern type, routine tests and factory acceptance test.

i. Type tests are tests performed on one or two of an equipment series
ii. Routine test are tests performed on each equipment
iii. Factory acceptance tests are tests on a sample size as per standards.
iv. These tests will enable checking the quality of the equipment and its compliance with the specifications.
v. Following equipment, if desired by the Engineer shall be tested at third-party (duly approved by the Engineer)/ RITES during Factory Acceptance Test.:
    1. DG sets
    2. Transformer of any capacity
    3. Switch gears
    4. Different size of cables (LT/HT)
    5. LED light fittings
    6. Different types of HT/LT panels, RMU and APFC panel etc.
    7. Earthing material

Once the equipment will have passed the in-plant acceptance tests, it shall be delivered and installed under the contractor responsibility.

Concerning some type tests, test certificates issued by recognised agencies will be able to be supplied if the contractor cannot carry out these tests himself and if the test certificates are related to a similar equipment of same capacity and design.

The final factory tests will be carried out on the fully assembled equipment as specified.

Thereafter, if required and permitted by the technical features of the equipment, the equipment may be dis-assembled for transportation purposes. The dis-assembly should not, however, cause any deterioration of the technical performance of the equipment.

**These tests will be carried out by the contractor, under his responsibility and in the presence of the Engineer and of the consulting Engineer. The cost of Factory Inspection/Site Inspection/Lab Test/Documentations will be borne by contractor.**

Each of these tests will be subjected to a certificate. Provisional acceptance will be granted only after execution of the both sets of tests.

**NOTE: For type tests, the contractor can provide test reports performed according to the corresponding IEC standard, on similar equipment of same capacity and design.**

### 4.2.2 Third Party Tests

i. During execution stage Engineer may conduct the Test on any type of equipment from third party independent lab at its own cost, to ensure the quality of material supplies. If any of the samples fail in the test, the cost of the Test along with the complete replacement of whole lot shall be borne by the Contractor.

ii. If contractor represents, two random samples from the failed Lot shall be collected by the contractor in the presence of Engineer duly sealing the samples and send to two different NABL accredited labs (as approved by Engineer) for conducting all those tests, which were conducted on the failed sample. Cost of the testing including the collection of sample and transportation of sample will be borne by the contractor.

iii. If both the samples pass all the Tests, the Lot will be deemed as accepted by HRIDC, but in the case of failure of any of the samples collected by the contractor, complete Lot will be deemed as rejected and contractor will replace the whole Lot.

iv. The delay, if any for the procurement of the material due to failure, shall be considered as non-compliance and applicable penalty shall be imposed on the contractor.

### 4.2.3 System Acceptance Tests

At least six weeks in advance of any particular site testing, the contractor shall submit details of tests and details for the teste equipment the proposes to use for that testing to the Engineer for his approval.

All tests for statutory requirements and insurances including arrangements for such tests, inspections by Authorized bodies, persons or insurers, as necessary and the provision of certificates in the prescribed and approved forms necessary to enable plant and equipment to be put into service, shall be made by the contractor.

If each section of plant is installed, commissioning tests for each section shall be carried out on site. At least six weeks in advance of any particular site testing, the contractor shall submit details of tests and details for the test equipment he proposes to use for that testing to the Engineer for his approval. As installation proceeds, the insulation resistance of cables shall be checked and recorded.

The identification of the cores shall be confirmed from end to end of each cable end, in the case of communication, alarm- and control-cabling, from end to end of each circuit. Tests on cables shall be completed and accepted by the Engineer before the testing of the associated equipment starts.

All tests for statutory requirements and insurances including arrangements for such tests, inspections by authorized bodies, persons or insurers, as necessary and the provision of certificates in the prescribed and approved forms necessary to enable plant and equipment to be put into service, shall be made by the contractor.

**4.2.3.1 On-site commissioning tests being subject of acceptance by the Engineer shall include**:

a) All equipment, cabling, distribution etc. is electrically and mechanically safe.
b) All interlocks, isolators and door and cover securing mechanisms shall be properly fitted and adjusted.
c) All exposed metal work is properly bonded and grounded and that all connections and points required to be grounded for a safe and satisfactory operation shall be properly grounded in accordance with the manufacturer's requirements.
d) All cables, cores and terminations shall be secure, properly fitted and correctly identified and coloured.
e) All phases, polarities, neutral and common connections shall be correctly switched / connected as required, so that the power is correctly available at all points and that the voltage and frequency at all equipment is correct and in accordance with the requirements for correct work.
f) All supplies shall be properly fused or otherwise protected, to give successfully discrimination and safe disconnection under fault conditions.
g) All contacts shall be properly aligned / adjusted and not subject to excessive wear or corrosion.
h) Batteries shall be correctly installed, connected and fitted and checked that the battery chargers are working correctly.
i) The insulation-resistance of all cabling and equipment shall not be less than specified.
j) During the commissioning of major item like GIS panel, Transformer, DG sets etc. the contractor shall arrange expert Engineer of OEM of such item at respective sites. The expenditure for charges for the same including transport, lodging, shall be borne by the contractor at no extra cost.
k) All instruments and meters shall be energized with correct polarity and working properly.
l) All fault indications and alarms shall be working correctly.
m) In addition to all operational tests, required for a successful hand-over, the operation of all interlocks, sequences and protections which are not utilized in normal operations shall be subject of acceptance by the engineer.
n) The on-site commissioning tests shall be conducted under the supervision of the engineer.

**4.2.3.2 (a)** The final acceptance tests shall begin after all on-site commissioning tests have been successfully completed and all defects detected during those tests have been rectified / corrected, which is accepted by the Engineer. The tests shall include full operation tests on the works as a whole and selected technical tests on some or all of the equipment.

(b) On completion of the site acceptance tests, the contractor shall forward the test results certified by him to the Engineer. When the Engineer has received the results and deems that the plant has successfully passed the tests, he will write to the contractor to that effect. During the site acceptance tests the Engineer shall inform the contractor of minor faults detected and which of these minor faults shall be corrected before the beginning of the tests on completion.

#### 4.2.4 TRIAL OPERATION

The trial operation shall occur with full responsibility of the contractor. The trial operation shall take place after finishing the tests on completion. For starting the trial operation, it is required, that all tests on completion are finished positive for the entire installation and shall occur within 21 days.

The trial operation shall show the evidence of a fully functional operation of the tunnel and that security is given during operation. Therefore, the trial operation shall occur without significant malfunctions. The contractor shall test different operation cases during the trial operation (e.g. loss of different equipment etc.).

The contractor shall make organizational measurements during the trial operation, so that malfunctions can be rectified as soon as possible (within max. 2 days).

The results of the different tests during trial operation shall be shown in a protocol. This protocol shall be signed by the contractor and the Engineer.

#### 4.2.5 Energization: -

The Contractor shall prepare operation safety rules and procedures for the review of the Engineer before Energization.

The Contractor shall carry out all necessary checks to ensure safe Energization.

All power equipment shall be subject to inspection by inspectors from the Electrical Inspectorate of Engineer before Energization. The Contractor shall ensure all Engineer requirements are met. Contractor shall be responsible for reliable operation of all Electrical equipment.

### 4.3 COMMISSIONING

#### 4.3.1 General

The Commissioning description, based on the following frame, will have to be defined by the contractor and submitted to the Engineer.

Once the contractor will have completed the above tests, and the various pieces of equipment installation, the assignment should include:

i. Putting into service tests

ii. After energising

The Engineer will be empowered to ask for any additional testing they may deem necessary. The contractor will have to supply the testing installations and measuring apparatuses required to this effect in accordance with the stipulations, provisional acceptance will then take place, followed by final acceptance at the end of the guarantee time.

**4.3.1.1 Putting into Service Tests**

It should be performed at this stage the tests verifying that the different equipment is acting correctly when energised.

**4.3.1.2 Integrated Testing and Commissioning**

The general testing having shown proper operation, an overall integrated test of the installations, should be performed, after the first 15 days of operation, during which the various actuation and operation situation (putting into service, normal actuation, failure tripping) will be simulated.

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# CHAPTER – 5 MAINTENANCE AND TRAINING

## 5.1 INTRODUCTION

This Chapter describes the maintenance philosophy and training of maintenance staff for Electrical system considering RDSO/ Railway board standards and Railway practices.

The Contractor shall provide comprehensive training and documentation to the Engineer staff in accordance with the requirement of this chapter and the chapter of General Specifications.

This training shall enable all the installations, to be operated and maintained in the most efficient and safe manner, to achieve the maximum reliability and economy required by such System.

**Note: - All type of Routine, Preventative and Schedule Maintenance work will be carried out at regular intervals, based on latest SMI's/ Instructions/Guidelines issued by RDSO/Railway Board and equipment manufacturers' recommendations.**

### 5.1.1 Maintenance Management

The management of the maintenance process entails defining various levels of responsibility and enabling them to implement the strategic orientations defined by the directing authority:

i. By defining their respective missions,
ii. By setting objectives for each person,
iii. By translating these objectives into action plans,
iv. By implementing the means required to carry out action plans,
v. By diagnosing the causes of any deviation from the set objectives,
vi. By taking corrective measures concerning the action plans or the objectives.

This management process requires a global approach and helps to improve the performance of the maintenance work of different components with quality, on time and at low cost. It must be implemented at three levels:

i. At the level of human resources and management in the context of the scheduling of work, the allocation of human resources and the training of personnel.
ii. At the skills level to ensure quality, safety and suitable working conditions.
iii. At an economic and financial level to ensure responsible management of production, spare parts, purchasing and miscellaneous costs.

The quality of this management depends on the capability of those entrusted with operation and maintenance responsibilities:

i. To exploit the results of management within their field of responsibility.
ii. To react in the event of any deviation from the action plans defined with a view to achieving the set objectives.

Within the context of this approach, the management control function ensures timely advice to be given to those with operational and maintenance responsibility:

i. By placing at their disposal, the tools and information required for piloting and diagnosis.

ii. By participating in carrying out this diagnosis.

iii. By participating in the task of defining the objectives to be achieved.

In conclusion, the process of maintenance management must incorporate two major components:

i. the management of human resources and the study of the most suitable means of achieving the set objectives.
ii. This is one of the first guidelines of maintenance organisation in the various relevant centres.

### 5.1.2 Determining Requirements in Terms of Facilities and Tools

The achievement of the objectives assigned to the maintenance division about quality, safety and regularity for the lowest possible overall cost requires the implementation of a number of resources which must be perfectly tailored to the requirements.

The facilities and tools are part and parcel of the resources placed at the disposal of the maintenance division to achieve the set objectives.

Owing to the cost of these facilities, the number of maintenance centres to be equipped and the necessity of keeping the maintenance actions consistent and uniform, the main choices of facilities and tools are integral part of the System maintenance policy and program.

When determining these requirements, in-depth knowledge in the dedicated maintenance plan is needed while taking due account of the experience acquired in similar fixed installation which has been in service for several years.

## 5.2 SUPERVISION AND PLANNING OF MAINTENANCE

### 5.2.1 General

The following outlines the Engineer maintenance strategy, various levels of maintenance, the Maintenance Management System and the arrangement for maintenance.

The Contractor shall make use of all relevant information to provide supervision of maintenance.

### 5.2.2 Engineer's Maintenance Strategy

According to the maintenance strategy, all equipment and infrastructure supplied for the 'Project' must be such as to ensure for minimum or no maintenance. Maintenance activities required must be capable of being performed with little or no impact on the train service. In addition, the maintenance work systems shall ensure safety of personnel and equipment.

The Contractor shall ensure that to supervise maintenance during the DNP (Defects Notification Period) personnel are always available with the relevant skills and level of competence.

The Contractor, upon noticing any defects, deficiency in quality and quantity of spares and materials shall without delay, arranges for alternative source of supply and submit his proposal to the Engineer for review.

### 5.2.3 Planned Maintenance

Routine preventative maintenance will be carried out at regular intervals based on condition, reliability, usage, and service history, SMI 's issued by Railway Board/ RDSO and equipment manufacturers' recommendations. The Operating and Maintenance Manual shall describe the different levels of planned maintenance.

### 5.2.4 Supervisory Staff

The Contractor shall provide supervisory Maintenance staffs who are expert in all the different levels of fault finding, maintenance and repair of the various relevant systems supplied under the Contract:

i. Electrical system
ii. Switch gear/power supply arrangement
iii. Other works

### 5.2.5 Maintenance and Maintenance activity

**Maintenance Management System (MMS) and Maintenance Arrangement:**

The contractor will develop maintenance management system and get it approved from Engineer for schedule maintenance of Electrical system.

All type of maintenance activity of all Works will be conducted by the contractor staff under his supervision, till the **expiry of a period of 01 (One) year from taking over**. All type of Routine, preventative and schedule maintenance work will be carried out at regular intervals based on SMI's/ Instructions issued by RDSO/Railway Board and equipment manufacturers' recommendations. Under this, all the labour laws would be applicable and contractor has to submit all the records (EPF/ESI and other certificates) to Engineer.

### 5.2.6 Competency of Personnel and Deployment of Maintenance staff

During the One-year Maintenance the Contractor shall support the Engineer with sufficient trained and competent personnel Such persons shall have their generic competence established and must demonstrate their specific competence and knowledge in the particular systems, environment and procedures. The competency certificates of such maintenance staff shall be issued by Engineer.

**The detail of deploying staff is as under:**

| S. No | Personnel | Qualification | Total work experience (in year) | Required No of staff | Remark |
|---|---|---|---|---|---|
| 1 | Maintenance In-charge | Graduate Degree in Electrical Engineering | Min. 08 Years of working experience of any Electrical/E&M/Ventilation. Project. | 01 | Over all in charge of all type of Electrical work |
| 2 | Maintenance Engineer (Electrical and E&M) | Diploma in Electrical Engineering | Min. 05 Years of working experience of any E&M/Electrical General services project. | 01 | Required as Site Engineer for all type of Electrical General services work |

| S. No | Personnel | Qualification | Total work experience (in year) | Required No of staff | Remark |
|---|---|---|---|---|---|
| 3 | Maintenance Engineer (Electrical and E&M) | Diploma in Electrical Engineering | Min. 05 Years of working experience of E&M Project or E&M maintenance activity. | 03 | Required for Manning of 11 kV Substations/Control Room for round the clock (one person in each shift) |
| 4 | Skilled Staff for Manning Purpose | ITI in Electrical Trade | Min. 04 Years of working experience on any E&M /General power supply arrangement project | 03 | Required for Manning of 11 kV Substations/ control Room for round the clock(one person in each shift) |
| 5 | Skilled Staff for Maintenance activity | ITI in Electrical Trade | Min. 04 Years of working experience on any E&M /General power supply arrangement project | 04 | Required to perform day to day maintenance activity |

The Contractor shall provide evidence of specific competence and knowledge, which shall include:

i. Assessment and certified training in particular software applications and operations.

ii. Receiving or in receipt of sufficient and current exposure to the area of work that the holder is licensed for.

In the event of a failure, the Contractor shall undertake the management and investigation necessary to identify and rectify the cause.

If the Engineer, during the DNP requires further investigations at other Sites throughout the system, the Engineer will formally request the Contractor to undertake such investigations.

### 5.2.7 Maintenance requirements

**I. Testing and Re-commissioning of System and Equipment**

In the event of a failure requiring modifications to the System, the Contractor shall undertake any testing and re-commissioning required.
Any such modification shall be submitted for Engineer review.

**II. Temporary Alterations to Restore Service**

The Contractor shall undertake any temporary modifications necessary to maintain service.
Any such modification shall be submitted for Engineer review.

**III. Discrepancies between Installation and Design Records**

Should the Contractor discover inconsistencies between the maintenance drawings and documentation and the installed equipment, the Contractor shall correct all such errors within two weeks.

**IV. Communications**

The Contractor shall ensure that adequate communication facilities are provided to its staff during the DNP and maintenance period as per approval of Engineer.

**V. Location of Staff**

The Contractor shall be responsible for locating staff such that the Contractor meets its contractual obligations and as per approval of Engineer.

**VI. Maintenance Regimes**

The Contractor shall provide documented maintenance regimes to be followed by the Engineer upon substantial completion of various components of the work until the end of the DNP.

The Contractor shall produce a maintenance regime for the equipment that shall comprise two constituent parts, corrective and routine/preventative maintenance.

Routine/preventative maintenance shall be non-intrusive to the day-to-day operation of the train service and be capable of being pre-planned in advance of the work.

Corrective maintenance shall be available 24 hours per day, able to respond to all foreseeable circumstances**.**

The maintenance regime shall cover all parts and equipment of the system designed, installed and commissioned by the Contractor.

The Contractor shall take into account the requirements of the operations and maintenance when determining and proposing its maintenance regime.

**VII. Scope and Hours of Coverage**

The regime and structure of corrective maintenance shall be robust in design.

**The Contractor shall provide full 24 hour On-Call coverage and shall be such that initial response and rectification of failure are in accordance with the following**:

i. Assistance to first level and corrective maintenance within 30 minutes, upon request of first line maintainer.

ii. All elements of preventative maintenance shall be carried out and completed during non-traffic hours without interrupting train services.

**VIII. Routine and Corrective Maintenance Procedures**

Routine and corrective maintenance procedures shall be supplied for all equipment. The format shall be as follows:

i. Uniform format and layout irrespective of equipment supplier.

ii. Colour coding for each activity.

iii. Cross referenced to the Operation and Maintenance Manuals.

iv. Document control information.

**IX. Maintenance Manuals**

The Contractor particulars of operating parameters, tools for dismantling and testing, methods of assembly and disassembly, tolerances, repair techniques and all other information necessary to set up a repair and servicing programme as per satisfaction of Engineer.

The Contractor shall provide documentation for all hardware and software for computer systems and other associated electronic equipment to meet the following requirements.

Such documents shall include but not be limited to:

i. manufacturers' documentation supplied as standard with the equipment;
ii. hardware configuration with details of expansion capabilities and options;
iii. programme loading instructions, including runtime environment configuration;
iv. programme listing including comprehensive 'comment statements' in hard copy and soft format for source code, compilers and development tools necessary to modify and recompile software;
v. flow charts, data flow diagrams and state diagrams as appropriate;
vi. description of software modules including purpose, linkage with other modules, error routines and any special considerations;
vii. memory maps for both internal and peripheral memory showing description of all programmes, data files, overlay areas, memory available for expansion and the like;
viii. loading and operating instructions for diagnostic programmes and specifically developed debugging tools; and
ix. Programming manuals relevant to operating systems, languages, development tools, etc.

The manual shall also include inspection/overhaul procedure and periodicity of various inspection/overhaul schedules in detail including the tools, special tools/plants, and facilities required.

## 5.3 TRAINING:

During the contract period, the contractor shall provide training manuals, as well as onsite training and training courses to ensure that the Engineer staff associated with this project may acquire full knowledge and appreciation / understanding of all aspects of the design, day to day operation, breakdown and routine maintenance and fault diagnosis of the power supply, the surveillance and control equipment as well as the belonging hard- and software.

The contractor shall train the Engineer personnel about all equipment in theoretical and practical way. Also, the maintenance staff shall be trained. The Engineer will nominate members of his staff, who are attending the training courses.

The contractor shall nominate qualified instructors. It shall be essential that prior approval of the Engineer is obtained for the instructor and the instructor's qualifications in each case.

The contractor shall provide all relevant and necessary facilities which are needed for complete and effective staff training (such as video, TV, slide- and film-projectors and others) and venue. The contractor shall provide all facilities including accommodation, transport and catering of all trainees. Within three months after the signing of the contract, the contractor shall submit a detailed syllabus for the training courses for approval by the Engineer.

### 5.3.1 General Requirements

The Contractor keeping the above aspect in view shall provide comprehensive training to the Engineer's staff in accordance with the requirements contained in this Particular specification and general specification. The training courses and/or sessions shall include system performance requirements and all major equipment and works designed, by the Contractor.

The specific objectives of each course, training facilities to be used, the qualification and experience of the training instructors and the assessment criteria shall be developed by the Contractor and submitted to the Engineer for review at least three months before any course is conducted.

The Contractor shall provide full-time on-Site management and co-ordination of the entire training programme to ensure the continuity of classes, and proper distribution of training materials, and be responsible for interfacing with the instructors.

The training courses shall be delivered to all relevant Engineer's staff, including instructors, operation and maintenance Engineering staff.

### 5.3.2 Mock-Up for Training

The Contractor shall install mock-up equipment for system and any such facility(s) considered necessary for the training of Engineer's staff in the training school.

The training mock-up shall include but not limited to the following: -

i. Clear Cut Section drawings / photographs of various power supply equipment's such as Circuit Breakers, HT/LT panel, Power supply arraignment, Current Transformers and Potential Transformers.

ii. Cut Section drawings / photographs of HT/LT cables.

iii. Cut Section drawings / photographs of Gas Insulated Switchgear and other types of panels.

iv. Clear photographs of transformers, their windings, bushings etc.

v. Samples of various item used in substations.

vi. Clear drawings and photographs of Control panel, protection schemes, earthing and complete power supply arrangement system.

The Contractor shall submit full details of the training span and other mock up equipment, photographs etc. including proposed training activities and objectives.

### 5.3.3 Training of Engineer's Training Instructors (ETI)

The objective of the training is to enable the Engineer's Training Instructors to be competent to deliver future training courses for other employees of the Engineer.

The Contractor shall provide training to the Engineer's Training Instructors on the various Systems. Aspects covered shall include, but not be limited to, the following:

i. Configuration of the entire System, including interface with the DHBVNL supply system at the feeding points;

ii. Feature and functional principles of the entire System;

iii. System design aspects including but not limited to design standards, design criteria and parameters, short-circuit and other calculations, insulation and protection co-ordination;

iv. Details of major equipment and material including but not limited to voltage and current transformers, Electrical fittings, assemblies and protection relays, and cables of different types and their joints used in the system;

v. System operation and maintenance management and procedures;

vi. Earthing arrangement, covering safety aspects of touch and step potential, safety to personnel, passengers and outsiders;

### 5.3.4 Operations Staff Training

The objective of the training is to enable the Engineer's operations staff to be familiar with the Systems, with focus on the operational aspects under normal and emergency conditions.

The training shall also enable the trainee to acquire full capability for identification, trouble shooting and rectification of faults in the specified duration. After classroom training which includes mock ups of equipment, the staff shall be trained in actual operation.

#### 5.3.4.1 Maintenance Staff Training

The objective of the training is to enable the Engineer's maintenance staff and Engineering staff to be familiar with the Systems focus on the maintenance aspects of the System including but not limited to the following: -

i. Full understanding of all the equipment, sub-systems and system, their function, maintenance and overall requirements.
ii. Procedures to be followed for unscheduled maintenance and repair.
iii. Identification of failed components and sub-systems in electronic equipment by use of special test kit as necessary.
iv. Modification in the software to extend or modify the control, monitoring and protection functions.

#### 5.3.4.2 Training Requirements

Man weeks of contractor's Training Instructors for training Engineer's maintenance personnel in India.

| S. No | Training | Man-Weeks |
|---|---|---|
| 1 | HT/LT panels, Transformer, Circuit Breakers, DG set , Switchgear and cables | 2 |
| 2 | Other General services Equipments/Electrical wiring | 2 |
| 3 | Electrical safety & Earthing system | 1 |

### 5.4 Defects Notification Period (DNP)

The Contractor shall be responsible for all the Defects and deficiencies, till the expiry of a **period of 01 (One) year**. The Contractor shall repair or rectify all Defects and deficiencies observed by the Authority Engineer during the Defects Notification Period within time period as may be determined by the Engineer in accordance with Good Industry Practice.

#### 5.4.1 Warranty Certificates from OEM:

i. All Original Warranty Certificates of OEMs of all Electrical system or equipment including contract spare, Commissioning spare, DNP spares and Special tools & Test and Measuring equipment shall be valid for three years or as specified in RDSO Specification of the equipment whichever is later and registered in the name of Engineer. These warranty certificates received from the OEMs should be passed on to Engineer before final Taking over.

ii. Validity of period of Warranty Certificates shall start from date of Commissioning.

iii. Original invoice shall also be submitted with the OEM warranty certificates in a booklet form before Commissioning.

iv. Warranty period and defect liability support shall start from the date of Commissioning.

### 5.5 Inventory/ Spare material

#### 5.5.1 General

The Contractor shall supply spare parts, special tools and test equipment in accordance with the requirements and as decided by Engineer.

#### 5.5.2 Contract Spares

The Contractor shall supply quantity of spare parts with minimum quantity as given below in Table. The price of below quantity of spare should be quoted in the item provided in Sub - Cost Center E2 –Inventory/spares items. The evaluation of the tender shall be done considering this price of spares. Upon approval of the Engineer the procurement of spares should be done by contractor.

| Sr. No | Item | Unit | Quantity |
|---|---|---|---|
| 1 | Copper cable of all sizes | Meter | 5% of the total cable laid subject to a minimum of 500 mtrs of each type. |
| 2 | All other Copper wires | Meter | 5% of the total wire used / laid subject to a minimum of 100 meter of each type. |
| 3 | Maintenance free batteries | Nos. | 10% of each type installed. Subject to minimum of one. |
| 4 | UPS | Nos | 2 Nos |
| 5 | Battery Charger | Nos | 1 No |
| 6 | MCB, surge protection device, fuses | Nos | 15% of each type installed. |

| | | | |
|---|---|---|---|
| | & other switch gears of HT/LT panel | | Subject to minimum of one. |
| 7 | All other interconnecting cables/ connectors not included above | Nos | 10% of each type installed. Subject to minimum of 2 Nos |
| 8 | All type of LED fittings and other Electrical equipment | Nos | 10% of each type installed. Subject to minimum of 10 Nos |

**Note: - Spare shall be procured only after the approval from the Engineer. The quantity of spares given are indicative and final quantities shall be approved by the Engineer. The equipment/kits supplied should be as per latest specifications/models and should be compatible with the existing system being installed in this contract. Approval for the specifications should be taken from engineer before placement of the order.**

### 5.5.3 Long Lead Times

The Contractor shall identify the lead times for all spare parts. Parts with long lead times shall be identified in the spares list.

### 5.5.4 Routine Change

In the event that any item of the supply requires to be routinely changed or calibrated regardless of whether it appears in the spares list or not, it shall be identified to the Engineer together with the routine change interval.

### 5.5.5 Shelf Life

In the event that any of the spares identified have a particular life or storage requirement, this shall be made known to the Engineer with the submission of the spares list, including the necessary action for disposal or storage.

### 5.5.6 Special Tools, Testing and Diagnostic Equipment and Measuring Instruments

The Contractor shall supply adequate quantity of special tools, testing and diagnostic equipment and measuring instruments in accordance in order to carry out all the functions necessary for operation and maintenance of the entire system and also considering the requirements as described in the Operation and Maintenance Manuals. The special tools, testing and diagnostic equipment and measuring instruments shall also include apart from the other necessary items.

The contractor should ensure that the special tools and test equipment provided are compatible with equipment supplied under this Contract.

### 5.5.7 Coding and Tagging of Spare Parts and Special Tools and Test Equipment

i. All Spares/Spare Parts and Special Tools and Test Equipment to be delivered to the Engineer shall each carry a tag suitably marked, bar-coded (as directed by the Engineer) and numbered.
ii. The numbers on the tags shall correspond with those on the coding system developed by the Contractor for all Electrical components, parts and equipment.

# CHAPTER – 6 TECHNICAL SPECIFICATION

## 6.1(11/0.433) kV SUBSTATION :-

Indicative conceptual layout plan of civil structure/building of Sub-stations attached in Section VII-8: Tender Drawings and Documents. The contractor has to construct Sub-Station building accordingly.

**The electrical sub-station consists of following electrical equipments but not limit to:-**

**6.1.1 11 kV GIC HT Panel Board** :-This specification covers design, manufacture, assembly, testing before supply, inspection, packing and delivery of metal clad partitioned, SF6 gas insulated switchgear confirming to IEC- 62271-200.The GIS type switchgears shall be complete with all the accessories and auxiliary equipment's required for their satisfactory operation such as switchboard panels for line bays, bus coupler/bus section bays etc. shall be fitted with vacuum circuit breakers, three position disconnect and earthing switches, voltage transformers, current transformers, metering instruments, protection relays, cable terminal ends/plugs for incoming & outgoing cable feeders etc.

### 6.1.1.1 OBJECTIVE & TOLERANCES:-

It is intended to have:

a. Enhanced safety, availability, maintainability and reliability
b. Maintenance free switchgear
c. Reduction in space requirement with low environmental footprint
d. Integrated remote control and monitoring-SCADA compatible.

**Tolerances**: -
Tolerances on all the dimensions shall be in accordance with provisions made in the relevant IS/IEC standards and in these specifications. Otherwise the same will be governed by good engineering practice in conformity with required quality of the product.

### 6.1.1.2 SERVICE CONDITIONS:

**A. System particulars:**

a) Nominal system voltage ... 11 kV
b) Corresponding highest system voltage ... 12 kV
c) Frequency ... 50 Hz ± 3%
d) Number of phases ... 3

e) Neutral earthing grounded ... Solidly

f) Short Current Rating ... 25 kA

**B. Auxiliary supplies available through UPS are as follows**

a) A. C. Supply ---- 433/240 volts with ± 10% variation
b) Frequency ---- 50 Hz with ± 3% variation

### 6.1.1.3 SWITCH GEAR PANEL: -

a) The Gas insulated Metal clad switchgear shall be complete with all the accessories for efficient and trouble-free operation. The equipment offered shall be safe, reliable, high availability, easily maintainable and compact to install. The workmanship shall be of high order. The circuit breaker, switches and protective device etc. shall be latest design so as to ensure rapid and efficient interruption of fault current low arc energy, small arching time and freedom from fire hazards.

b) The GIS shall be designed, manufactured and tested in accordance with the best international engineering practices under strict quality control to meet the requirement stipulated in the technical specification. Adequate safety margin with respect to thermal, mechanical, dielectric stress, dynamic short circuit fault and insulation coordination is to be maintained during design, selection of raw material, manufacturing process etc. so that the GIS provides long life with least maintenance. The complete switchgear shall be designed to manage the risks associated with it such that there shall not be any safety hazard to the employees in normal service and during inspection and maintenance.

c) The workmanship shall be of the highest quality and shall conform to the latest modern practices for the manufacture of high technology machinery and electrical switchgear.

d) The switchgear panel shall be fully arc proof, free standing, floor mounted, fully compartmentalized, metal enclosed construction complying requirements of IEC 62271- 200. Each circuit shall have a separate vertical panel with required compartments for circuit breaker, cable termination, main bus-bars, three-position switch and auxiliary control devices.

e) The SF6 gas insulated metal enclosed switchgear shall be totally safe against inadvertent touch (by human/animal) of any of its constituent live parts.

f) The design should be such that all parts subjected to wear and tear are easily accessible for maintenance purposes. The Service Class Continuity of Switchgears shall be LSC-2 (as per IEC 62271-200), LSC 2B-PM (as per IEC 62271-200) will be preferable.

g) All louvers (if provided), shall have very fine brass or GI mesh screen. Tight fitting gourmet /gaskets are to be provided at all openings in relay compartment. Relays shall be fully flush mounted on the switchgear panels at a suitable height from operator point of view.

h) Switchgear shall have an Internal Arc Classification of IAC-A-FL / A-FLR 25 KA,1 sec. (as per EI guidelines) The switchgear construction shall be such that the operating personnel are not endangered by breaker operation and internal explosions, and the front of the panels shall be specially designed to withstand these. Gas Pressure relief device/Explosion Vent/Pressure relief duct shall be provided for each SF6 gas compartment, so that in case of a fault in a compartment, the gases produced are safely vented out, thereby minimizing the possibility of it's spreading to other compartments and panels. The pressure relief device/Explosion Vent/Pressure relief duct shall not however, reduce the degree of protection of panels under normal working conditions.

i) The switchgear shall be cooled by natural air flow.

j) Suitable interlock & Indications shall be provided to prevent opening of any HT compartment doors, in case the incoming HT supply is ON.

k) Suitable base frames made out of steel channels shall be supplied along with necessary anchor bolts and other hardware, for mounting of the switchgear panels. These shall be dispatched in advance so that they may be installed and levelled when the flooring is being done, welding of base frame to the insert plates shall be in Contractor' scope. The Contractor may offer panels with built in base frame ready for dispatch and suitable for installation on indoor cable trenches.

l) The switch board shall have the facility for extension on both sides. The facility of extension of additional breakers (to existing set up) for future expansion shall be provided.

m) The manufacturer shall give guarantee for maximum leakage rate of SF6 gas will be lower than 0.1 % per year, sealed FOR LIFE pressure system and guarantee no gas handling at a site during extension, removal and installation at site. In case of Gas leakage, the GIS should have the capability to withstand di-electric strength at 1bar pressure. Separate gas monitoring sensors should be available for all the gas filled chambers.

n) The minimum operating SF6 gas pressure shall be 1.2 bar. Alarm shall be generated if the SF6 gas pressure drops to 85% of the minimum operating pressure and if it further drops below 80% the Circuit breaker shall trip & go into lockout mode.

o) Thermostatically controlled space heater with common MCB shall be provided for various compartments.

p) The SF6 gas insulated metal enclosed switchgear shall be constructed from corrosion resistant stainless-steel sheet of min 2 mm thickness, filled with SF6 accommodating the primary switching devices (Bus bar, VCB and Three position disconnect or cum earthing switch) and all live parts. This panel complying ingress protection min IP 65.

q) The interconnection of individual panels shall not require any gas work neither for installation at site nor for extension of the panel board. It shall be possible to extend the panel board on either side.

r) All the mechanical parts shall be surface treated to prevent corrosion.

s) In case of non-gas enclosing parts of the offered panels are with painted design, the panels must be suitably treated, and powder coated with 60-70-micron thickness, to achieve indoor worthiness and corrosion protection and should pass salt spray test as per ISO 9227-2017.

t) It shall be with pressure relief device with controlled direction of flow of the hot gasses generated in rare event of internal arc. The panel board with minimum gas pressure shall withstand the rated highest system voltage. Temperature compensated gas density monitor shall be provided on the front side to monitor SF6 gas and for interlock purpose. The design of the panel should be such that no permanent or harmful distortion occurs either when being lifted by eyebolts or when moved into position by rollers.

u) Paint shade of Indoor Switchgear shall be 694 /RAL 7032 as per IS:5(Dove Grey).

v) SF6 gas pressure and density should maintained as per relevant IS and IEC, if gas pressure or density goes below specified limits, breaker should go in lockout mode.

### 6.1.1.4 TECHNICAL DATASHEET FOR 11KV GAS INSULATED SWITCHGEAR

| Sl. No | Description | Technical Parameters |
|---|---|---|
| 1 | Switchboard | - |
| 2 | Manufacturer's Name | By Contractor |
| 3 | Type | ------ |
| 4 | Standards Followed | IS/ IEC 62271-100/200 |
| 5 | Main Bus bar | |
| | a) Current Rating | 800A |
| | b) Material | CU |
| | c) Grade | Electrolytic Cu |
| | d) Whether Joints are Silver Plated | N.A |
| | e) Thickness of Coating | N.A |
| 6 | Earth Bus bar | |
| | a) Current Rating | 25kA |
| | b) Material | CU |
| | c) Grade | Electrolytic Cu |
| | d) Whether Joints are Silver Plated | N.A |
| | e) Thickness of Coating | N.A |
| 7 | Continuous current Rating for Ambient Condition of site when installed in IP 65 Switch board | |
| | a) Main Bus bar at Ambient Specified | 800A |
| | b) Tappings at Ambient Specified | 800A |
| 8 | Temperature rise of Bus bars while | |
| | a) Carrying rated Current and Installed in IP65 enclosure at an Ambient Temp specified. | As per IS/IEC-62271 |
| | b) Under Short Circuit Condition | N.A |
| 9 | Degree of Protection of Enclosure | SF6 gas chamber- Stainless Steel IP65<br>Drive-IP2X<br>Low Voltage-IP3X |
| 10 | Minimum Clearance in Air | |
| | a) Between Phases | Since all parts in SF6, clearance is not applicable. |

| Sl. No | Description | Technical Parameters |
|---|---|---|
| | b) Between Phase to Earth | Since all parts in SF6, clearance is not applicable. |
| 11 | Clearance required at the Back & Front of Panel | AFL: 1700 mm @ front and minimum 1200mm from back (in case of AFLR) |
| 12 | Overall Dimension of the Switch Board (mm) | |
| | a) Length | In line with Switch Board Configuration |
| | b) Width | 450m/ 600mm |
| | c) Depth | 1400mm |
| | d) Height | 2400/2800mm |
| 12 | a) Access Height (mm) | |
| | i) Maximum | 1850 mm height of lock of LV box door ( as per site fesibility) |
| | ii) Minimum | 830 mm height of cable box handle |
| | b) Weight of Panel Board (kg) | |
| | i) Maximum: | By Contractor |
| | ii) Minimum: | By Contractor |
| 13 | Insulation Level including all the Components | |
| | a) Power frequency withstand Voltage for 1 min | 28 kV |
| | b) 1.2/50 µ sec Impulse Withstand Level | 75 kV |
| 14 | Circuit Breakers | |
| (i) | Manufacturer's Name | |
| (ii) | Type | |
| (iii) | Manufacturer's Type reference | |
| (iv) | Closing Mechanism | spring |
| (v) | Normal Current rating in Air & corresponding | 800A |
| (vi) | Ambient Temperature | 40°C |
| (vii) | Derating factor for Ambient condition at Site | N. A. |
| (viii) | Service Voltage & Frequency | 11 kV, 50 Hz |
| (ix) | Maximum Voltage at which CB can Operate continuously | 12 kV |
| (x) | Rated Making Capacity | 63kAp |
| (xi) | Rated Breaking Capacity | 25kA |

| Sl. No | Description | Technical Parameters |
|---|---|---|
| (xii) | a) Symmetrical | 25kA |
| (xiii) | b) Asymmetrical | 27kA |
| (xiv) | Short Circuit Withstand Capacity | |
| | a) 3 Sec | 25kA |
| (xv) | Total Make time | Within 60ms |
| (xvi) | Total Break time | Within 60ms |
| (xvii) | No. of Breaks per pole | 1 No. |
| (xviii) | Total Length of Break per pole | |
| (xix) | No. of Auxiliary Contacts (NO/NC) for Engineer use | 8 |
| (xx) | Type of Arc Control Device | Vacuum |
| (xxi) | Arc Duration time | |
| | a) 100 % Load Current | Within 10ms |
| | b) 10 % Load Current | Within 10ms |
| (xxii) | Spring Charging Motor | |
| | a) Type | Universal Motor |
| | b) Voltage | 240 V AC |
| | c) Rating in kW | 0.223 |
| | d) Protection relay provided | Not Applicable |
| | e) Protective MCB s provided | Yes |
| (xxiii) | Power required for : | |
| | a) Closing | |
| | i) Momentary | 250W |
| | b) Holding | N.A |
| | c) Tripping | 250W |
| | d) Time taken for Charging Motor to Charge Spring completely | 8 seconds |
| (xxiv) | Number of consecutive operation the breaker can withstand and the recommended interval between these operations: | O-0.3Sec-CO-3Min-CO |
| (xxv) | Number of short circuit current interruption after which the breaker requires attention & maintenance | by Contractor |
| (xxvi) | Number of normal operations after which the breaker requires attention & Maintenance | 10000 |
| (xxvii) | Rated capacitor breaking current of breaker/ contactor of each rating | N.A. |

| Sl. No | Description | Technical Parameters |
|---|---|---|
| (xxviii) | Confirm that trip and closing coils will be suitable for 110 V DC and the spring charging motor will be suitable for 240 V AC | Yes |
| (xix) | Maximum number of XLPE cables & sizes that can be terminated safely in the cable chamber without extension panel | |
| | a) Single core (Size & No. of Runs) | As Applicable |
| | b) Three core (Size & No. of Runs) | As Applicable |
| (xx) | Maximum no of cables that can be terminated in the cable extension box (Please state the dimensions of such cable extension Box) | N.A |
| (xxi) | Minimum available distance from the bottom of the panel to the terminals in cable box/chamber for terminating cables | 500mm. |
| (xxii) | Weight of circuit breaker and truck | fixed mounted GIS |
| 15 | Instrument Transformers | |
| (i) | Makes | |
| | a) CTs | By Contractor |
| | b) PTs | By Contractor |
| (ii) | Standards followed | IS/IEC |
| (iii) | Confirm that CTs and PTs will be epoxy resin cast insulated | CT foil, VT metal-cast resin |
| (iv) | 3 second short time current rating of CTs, kA. | 25kA |
| (vi) | Dynamic current rating of CTs, kA : | 63kAp |
| (vii) | Confirm that accuracy classes shall be as specified and ratios and capacities shall be as required | Yes/No |
| (viii) | Confirm that all protective, metering, control and annunciation devices, transducers as specified shall be provided | Yes/No |
| (ix) | Enclose technical particulars, data sheets, catalogues of all types of relays and other plant being offered by you | Yes/No |
| 17 | SF6 Gas Pressure | 0.6 bar (0.06 MPA) |
| 18 | Gas Leakage Rate | < 0,1% per year |
| 19 | Gas handling Requirement at Site | No Gas handling allowed at site |
| 20 | Cable Terminations | |
| | Make | By Contractor |
| | Type | Inner cone / Outer Cone |

### 6.1.1.5 Busbar and Insulators: -

a) 11KV bus bar can be housed in SF6 gas chamber. 11 kV bus bars shall be made ofelectrolytic copper and shall be rated for 800 Amps continuous current. Cross sectional area shall not be less than 500 sq.mm. and bus bar size calculation /supporting type test report shall be submitted for approval. Current density of copper shall not exceed more than 1.6Amps/sq. mm. Bus bar cross-section shall be uniform throughout the length of switchgear panel. The bus bar edges/ends shall be rounded off/chamfered so that there will not be any sharp edges/projections. Busbar shall be supported on the insulators such that the conductor expansion and contraction are allowed without straining the insulators and should withstand electrical and mechanical stresses due to specified short circuit currents. (IS)

b) All piping for SF6 gas shall be made of copper & their fittings shall be made of nonmagnetic stainless steel.

c) Busbar insulators shall be of arc and track resistant, high strength, non-hygroscopic, non-combustible type and shall be suitable to withstand stresses due to over-voltages, and short circuit current. In case of organic insulator partial discharge shall be limited to 50 Pico

d) coulomb at rated Voltage X 1.1/√3 as per IS 3156.

e) All busbars shall have suitable phase identification. Bus switching scheme shall be as per Engineer.

f) The temperature of the bus bars and all other equipment, when carrying the rated current continuously shall be limited 65deg C for tin plated joints and 75 deg C for silver plated joint above ambient temperature 40deg C as per the relevant Standards.

g) Clearances between phases and between phase and earth shall be as per OEM type tested design complying to relevant IEC standards.

### 6.1.1.6 Circuit Breaker: -

a) Vacuum circuit breaker shall be used for 11KV GIS (Gas Insulated Switchgear) 11 KV Vacuum circuit breaker shall comprise of three single pole interrupting units or 3-pole interrupting unit, operated through a common shaft by a sturdy operating mechanism. Circuit breaker shall be re-strike free, stored energy operated and trip free type. Motor wound closing spring charging shall be preferred. Anti-pumping features shall be provided for each breaker. An arrangement of two breakers in parallel to meet a specified current rating shall not be acceptable. (No parallel interrupter).

b) Circuit breaker shall be provided with two trip coils.

c) Suitable indicators shall be provided on the front of panel to indicate OPEN / CLOSED conditions of the circuit breaker, and CHARGED / DISCHARGED conditions of the closing spring, SF6 gas density monitor for all gas compartment.

d) The rated control supply voltage shall be as mentioned elsewhere under Technical parameters. The closing coil shall operate satisfactorily at all values of control supply voltage between 85-110% of the rated voltage. The trip coil shall operate satisfactorily under all operating conditions of the circuit breaker up to its rated short circuit breaking current at all values of control supply voltage between 70-110% of the rated voltage. The trip coil shall be so designed that it does not get energized when its healthiness is monitored by indicating lamps and trip coil supervision relay.

e) The spring charging shall take place automatically preferably after a closing operation. Breaker operation shall be independent of the spring charging motor which shall only charge the closing spring. Opening spring shall get charged automatically during closing operation. As long as power supply is available to the charging motor, a continuous sequence of closing and opening operations (CO) shall be possible. Spring charging motors shall be capable of starting and charging the closing spring twice in quick succession without exceeding acceptable winding temperature when the supply voltage is anywhere between 85-110% of rated voltage. The initial temperature shall be as prevalent in the switchgear panel during full load operation with 40 deg. C ambient air temperature. The motor shall be provided with overload protection.

f) Motor windings shall be provided with class E insulation or better. The insulation shall be given tropical and fungicidal treatment for successful operation of the motor in a hot, humid and tropical climate.

g) For 11kv incomer: Tripping time: 60-70 ms (Including Relay Time) Closing Time < 80 ms.

h) For 11kv feeder: Tripping time:45-50 ms (Including Relay Time) Closing Time: 40-60 ms

i) Manual Spring Charging shall be provided. All the basic mechanical ON/OFF Circuit breaker, Disconnect or & earth switch operation, manual spring charge of Circuit Breaker must be possible without opening the door to ensure the operator safety.

j) Breaker operations (Mechanical Endurance) as per relevant IS/IEC Amended up to date. The circuit-breaker has to control at least 10,000 Make-Break cycles without maintenance. The mechanical life and operating cycles of the vacuum interrupter shall confirm relevant IS/IEC amended up to date.

k) Tripping coil, closing coil and motor mechanism shall be easily accessible for maintenance purpose.

l) The circuit breaker shall be provided with motor operated spring charged closing. Spring charging motor shall be suitable for 240V, 50 Hz, single phase AC. Suitable rating starter shall be provided for Motor protection.

m) Tripping of the circuit breakers shall be through "Shunt trip" coils rated for suitable auxiliary supply. It shall be possible to trip the breaker manually in case of necessity.

**6.1.1.7 Disconnect or and Earthing switch**

a) Each Switchgear panel shall be provided with three (3) position disconnecting-cum earthing switch of required rating.

b) It shall be possible to control these switches from front of the panel & remotely from SCADA.

c) Necessary indication shall be provided on the front of the panel for Close/Open status of the three position switches.

d) The safe, positive and fool proof interlocks shall be provided for personnel safety and equipment safety.

e) Key interlocks shall be provided for local manual operations.

f) Mechanical interlocks shall be provided for following conditions Three position disconnect or cum earth switch cannot be operated when circuit breaker is closed.

g) The operating handle /lever cannot be removed until the switching operation has been completed.

h) Earthing shall be additionally secured against" de-earthing" by providing a padlock.

i) The cable compartment cover can only be opened if the panel is earthed.

j) In addition to above, relevant all electrical interlocks shall also be provided.

k) Disconnecting switches shall be motor operated as SCADA is implemented. Isolators or isolators combined with earthing switches (3 position switches) shall be motor operated. In cases of emergency, manual operation must be possible.

l) The earthing position for all 3 phases must be visible via a mechanical position indicator (MIMIC) directly connected to the drive shaft on panel front Fascia. The mechanical operation of isolator / 3 position disconnects or should be with door close only to insure operator safety.

**6.1.1.8 Control and Interlocks: -**

a) The circuit breaker shall normally be controlled remotely from SCADA system through closing and trip coils. However, it shall also be designed to control locally from Indoor Switchgear panel. Suitable mimic on Panel shall be provided.

b) Facilities shall be provided for mechanical tripping of the breaker in an emergency. Facility shall also be provided for manual charging of the stored energy mechanism for a complete duty cycle.

c) Necessary mechanical & Electrical interlocks shall be provided between CB, Isolator & Earth switches for safe operation.

d) Each CB, Isolator & earth switch shall have 8 NO + 8 NC Auxiliary spares of good quality (corrosion free and easy for making connection) for future use. It should be located at accessible position in panel.

e) All the binary inputs/outputs shall be wired to the terminals & kept ready for future SCADA connectivity.

**6.1.1.9 Earthing and Earthing Devices**

a) The grounding system for GIS shall be designed and provided as per IEEE-80-2000 and CIGRE- 44 to protect operating staff against any hazardous touch voltages and electro-magnetic interferences.

b) The earth busbar made of electrolytic high-grade copper with cross sectional area of minimum 240 sq. mm shall be provided at the bottom in all the panels and interconnected with adjacent panels in the panel board through a connecting link to form a common earth busbar for the entire panel board ready to connect to the substation earthing grid. It shall be welded to the framework of each panel and each breaker earthing contact bar. The earth bus shall have sufficient cross section (minimum 240 sq. mm) to carry the momentary short-circuit and short time fault currents to earth without exceeding the allowable temperature rise.

c) Suitable arrangement shall be provided at each end of the earth bus for bolting to station earthing grid. All joint splices to the earth bus shall be made through at least two bolts and taps by proper lug and bolt connection.

d) All non-current carrying metal work of the switchboard shall be effectively bonded to the earth bus. Electrical continuity of the whole switchgear enclosure frame work and the truck shall be maintained even after painting.

e) All metallic cases of relays, instruments and other panel mounted equipment shall be connected to earth by independent stranded copper wires of size not less than 2.5 sq. mm. Insulation color code of earthing wires shall be green. Earthing wires shall be connected to terminals with suitable clamp connectors and soldering shall not be acceptable. Looping of earth connections which would result in loss of earth connection to other devices, when a device is removed is not acceptable. However, looping of earth connections between equipment to provide alternative paths of earth bus is acceptable.

f) PT and CT secondary neutral point earthing shall be at one place only on the terminal block. Such earthing shall be made through links so that earthing of one secondary circuit may be removed without disturbing the earthing of other circuits.

g) The panel shall have Voltage Presence Indicator (VPI) to warn the operator against earthing of live connections.

h) All hinged doors shall be earthed through flexible earthing braid.

Separate earthing for switchgear and C&R panel shall be provided.

### 6.1.1.10 CURRENT TRANSFORMERS:

a) The C.Ts. being prone to failure due to various reasons, the quality and reliability of the CTs are of vital importance. C.T. shall be rated for 25 kA for 3 sec. short time current. Insulation used shall be of very high quality, details of which shall be furnished in the technical offer.

b) The instrument security factor for metering core shall be low enough but not greater than 5 at lower ratio. This shall be demonstrated on metering core in accordance with the procedure specified in relevant IS/IEC.

c) All current transformers for GIS shall be ring type (Tape wound / resin cast). Suitable insulated copper wire of electrolytic grade shall be used for CT secondary winding. Multi ratio in CT shall be achieved by reconnection of secondary winding tapping.

d) Secondary terminal studs shall be provided with at least three nuts, two plain and two spring washers for fixing leads. The stud, nut and washer shall be of brass, duly nickel plated. The minimum outside diameter of the studs shall be 6 mm. The length of at least 15 mm shall be available on the studs for inserting the leads. The space clearance between nuts on adjacent studs when fitted shall be at least 10 mm.

e) The CTs shall be resin/epoxy cast. Contact tips on primary terminals shall be silver plated. Correct polarity shall be invariably marked on each primary and secondary terminal.

**6.1.1.11 POTENTIAL TRANSFORMER**

a) Potential transformers shall be single phase units connected to the line side in the respective incomer. H.V side shall be connected in star formation and L.V. side in star/open delta formation.

b) PT may be provided in a separate compartment. The primary and secondary contacts (moving & fixed type) shall have firm grip while in service. Service position locking mechanism shall be provided and indicated by Contractor in relevant drawing. Rigidity of primary stud point with earth bus in service position shall be confirmed.

c) P.T. shall be epoxy/resign cast. Contact tips of primary/secondary contacts shall be silver plated. Correct polarity shall be distinctly marked on primary and secondary terminal.

d) Secondary terminal studs shall be provided with at least three nuts, two plain and two spring washers for fixing leads. The stud, nut and washer shall be of brass, duly nickel plated. The minimum outside diameter of the studs shall be 6 mm. The length of at least 15 mm shall be available on the studs for inserting the leads. The space clearance between nuts on adjacent studs when fitted shall be at least 10 mm.

e) Each secondary core will be protected by suitable MCB.

f) In case of 2 Power Transformers are in parallel, 2nd core of PTs shall be used for directional protection.

**6.1.1.12 Low voltage Compartment (Instrument Chamber)**

a. The panels shall be with low voltage compartment consisting control switches, indication and metering instruments, protection relays and other secondary equipment's. The dynamic mimic shall be provided on the front fascia and not on the LV chamber.

b. The front side shall have Mimic as per single line diagram with control switches and mechanical and electrical 'Position indicators' circuit breakers, disconnectors and earth switch.

c. Control switches/Pushbuttons shall be provided adjacent to respective equipment position indicators in Mimic for ON-OFF operation of circuit breakers, disconnectors and earth switches.

d. The SCADA compatible Metering instrument shall be provided.

e. Live line Indicators: - Capacitive voltage indicators shall be provided on feeder side in incoming and outgoing feeders to indicate the voltage presence in each phase and to prevent the closing of earth switch in case the part is live. It shall have sufficient output contacts for substation Automation System and interlock purpose.

### 6.1.1.13 Numerical Protection Relays

Numerical relays shall be of modular type and have native IS/IEC 61850 (to latest version/amendment of the series of this standard) communication support for RTU/SCADA integration. Relay shall have graphical LCD dot matrix display with single line diagram mimic with control, indication, programmable function key and LED' relay shall have minimum protections as per SLD however any addition protection if required, is to be considered by the contractor or OEM (price to be included in the offer). Protection relay PCB hardware should be with conformal coating to protect the relay from hazardous environment.

Relay hardware, control cables and separate arc sensors shall be included. Any arc flash fault in the cable compartment is selectively cleared by the feeder protection relay.

***NOTE: Erection, Testing & Commissioning of the GIS panel must be done through the OEM of GIS panel only & OEM will issue the certificate of successful commissioning of GIS panel in all respect.***

### 6.1.1.14 11kV SWITCH BOARDS

The switchgear and busbar shall meet the "sealed pressure system" criterion in accordance with the IS/ IEC 62271. The manufacturer certificate shall confirm that maximum leakage rate is lower than 0.1 % / year. It shall provide full insulation, for switchgear insensitive to the environment (temporary flooding, high humidity, etc.), IP65 degrees of protection in accordance with recommendation IS/ IEC 60529.

a) The switchgear shall be maintenance-free and the switchboard shall be low-maintenance.

b) The switchboards drive suitable for IP protection.

c) The cable compartment shall integrate:

d) Adjustable cable fixing devices

e) Earth connecting point

f) Metal partition between cable compartments and tank pressure relief area.

g) The cable compartment shall be arc resistant and suitable for the following cable

h) connecting systems:

i) Partial insulated cable connectors

j) Fully screened cable connectors

k) Metal enclosed cable connectors according DIN EN 50181, IS-10314, IS/IEC-62155 and IEC-60137 standards to latest versions.

The color shall be as per Engineer requirement / as approved for the enclosure and mimic panel. The switchgear and switchboards shall be designed so that the position of the different devices is visible to the operator on the front of the switchboard and operations are visible as well. In accordance with the standards in effect, the switchboards shall be designed to prevent access to all live parts during operation without the use of tools.

### 6.1.1.14.1 EARTHING OF METALLIC PARTS

There shall be continuity between the metallic parts of the switchboard and cables so that there is no electric field pattern in the surrounding air, thereby ensuring the safety of people. The substation frames shall be connected to the main earth busbar without dismantling any bus bars.

### 6.1.1.14.2 EARTHING OF THE MAIN CIRCUIT

The cables shall be earthed by an earthing switch with short-circuit making capacity, in compliance with IS/IEC 62271-102 standard. The earthing switch can only be operated when the switch is open. The earthing switch shall be fitted with its own operating mechanism and manual closing shall be driven by a fast-acting mechanism, independent of operator action. Mechanical interlocking systems shall prevent access to the operating shaft to avoid all operator errors such as closing the earthing switch when the switch is closed.

### 6.1.1.14.3 FEEDER WITH SWITCH-DISCONNECTOR

They shall be maintenance-free. The position of the power contacts and earthing contacts shall be clearly visible on the front of the switchboard. The position indicator shall provide positive contact indication in accordance with IEC 62271-102 standard.

The switches shall be of the "increased operating frequency" in accordance with IEC 62271-102 standard. They shall have 3 positions, "open-disconnected", "closed" and "earthed", and will be constructed in such a way that interlocking prevents unauthorized operations. The switch disconnector and earthing switch shall be equipped with two separate operating entry points. Manual opening and closing will be driven by a fast-acting mechanism, independent of operator action. Each switch can be fitted with an electrical operating mechanism in a specially reserved location, by addition of a motorization unit and without de-energizing the switchboard. The switch and earthing switch operating mechanism shall have a mechanical endurance of at least 1000 operations, in line with IS/IEC 6227-102.

### 6.1.1.14.4 TRANSFORMER PROTECTION WITH VACUUM CIRCUIT BREAKER

The circuit breakers shall be of the maintenance-free, vacuum type. The position of the power and earthing contacts shall be clearly visible on the front of the switchboard. The position indicator shall provide positive contact indication in accordance with IS/IEC 62271-102 standards and prove reliability of indication in accordance with IS /IEC 62271-102 & 6.105 standard. An operating mechanism can be used to manually close the circuit breaker and charge the mechanism in a single movement. An independent mechanism shall be fitted for the 3-position earthing switch and disconnector and include a local system for manual tripping by an integrated push button. There will be no automatic reclosing. The circuit breaker shall be associated with an integrated protection unit that will operate without any auxiliary power supply and shall include:

a) Three toroidal transformers incorporated in the transformer tee-off bushings,
b) An electronic relay (Self Powered),
c) A low energy release,
d) A system protection testing (with or without CB tripping)

**6.1.1.14.5 MV METERING**

MV Metering shall be carried out by a factory assembled type tested cubicle.

The metering cubicle shall withstand internal arc. Connection with adjacent cells will be direct through bus bar but MV cables shall be possible.

VT's and CT's to comply with type DIN 42600 standards, IS-2705, IS-16227 and the following configuration shall be available:

a) 2 VT's phase-phase,
b) 2 VT's phase-earth,
c) 3 VT's phase-earth 2 or 3 CT's.

**6.1.2 11 kV RING MAIN UNIT (RMU): -**

RMU type, metal-enclosed indoor switchgears, shall be compact switchboard and comply to following requirements. The RMU shall be capable of being installed in either concrete indoor substations or in compact metal substations and kiosks with an IP67 rating.

**6.1.2.1 FUNCTION REQUIREMENTS**

The following functions shall be available:

a) Feeder with switch-disconnector
b) Transformer protection with vacuum circuit breaker

**6.1.2.2 Enclosure:**

The RMU enclosure shall be made up of CRCA of 3 mm thickness with appropriate rust prevention treatment suitable for humid and corrosive atmospheres / alternatively of stainless steel SS316L of at least 1.6 mm thickness. The rating of enclosure shall be suitable for operation on three phase, three wire, 11 KV, 50 cycles, A.C. System with short time current rating in the range of 20kA – 25 kA for 3 seconds with Panels. The enclosure shall provide full insulation, making the Switchgear insensitive to the environment like temporary flooding, high humidity etc. The active parts of the Switchgear shall be maintenance-free and the unit shall be minimum -maintenance. The Switchgear and Switchboards shall be designed such that the position of the different devices is visible to the operator on the front of the Switchboard and operations are visible. The RMU metal parts shall be made of high thickness high tensile steel grit/short blasted, thermally sprayed with Zinc alloy (not for galvanized steel), phosphate and subsequently painted with Polyurethane based powder paint, the overall (including outer and inner paint layer), the thickness of paint layer shall be not less than 150 microns.

#### 6.1.2.3 Configuration requirements

Extensible range:
3 function unit: Switch-disconnector (LBS)- Switch-disconnector (LBS)- Transformer protection with vacuum circuit breaker. The RMU shall meet the criteria for compact, metal-enclosed indoor switchgear in accordance with IS/ IEC 62271-200:
Switchgear classification: PM class
Loss of service continuity class: LSC2
It shall include, within the same metal enclosure, the number of MV functional units required for connection, power supply and protection of transformers.

#### 6.1.2.4 RMU BUSHINGS AND CABLE TERMINATIONS Bushing

It is preferable to have all bushings accessible from the front of the RMU. Bushings along the sides or the rear of the RMU are not acceptable. For each cable compartment, the bushing shall be at the same height in order to facilitate a possible reversal of the cables
The bushing should be conveniently located for working with cables specified and allow for the termination of these cables:

a) 630 A M16 bolted connectors for switch-disconnectors and vacuum circuit breakers functions
b) 200 A plug-in connector for transformer protection feeder with fuse combination. The profiles of the cable connection bushings shall be in compliance with IEC-60137, IS- 10314, IS/IEC-62155 standards of latest versions. A cable clamp arrangement must be provided for all network cables terminated on the RMU.

#### 6.1.2.5 PADLOCKING FACILITIES

Circuit breakers, fuse-switches combination, switches and earthing switches can be locked in the open or closed position by at least 1 padlock.

#### 6.1.2.6 VOLTAGE INDICATORS AND PHASE COMPARATORS

Each function shall be equipped with a voltage indicator box on the front of the device to indicate presence of voltage in the cables. The capacitive dividers will supply low voltage power to the lamps. Three inlets can be used to check the synchronization of phases. This device shall be in compliance with IEC 62271-206, IEC 61243-5(to latest versions).

#### 6.1.2.7 FAULT PASSAGE INDICATORS (FPI)

The FPI shall facilitate quick detection of faulty section of line. The fault indication may be on the basis of monitoring fault current flow through the device. The FPI should be self-powered and should have internal lithium battery for external indication and setting of FPI in the absence of current. The FPIs shall include:
Fault detection - Phase to phase and Phase to earth faults.
One potential-free output contacts for hardwiring to RTUs. On this basis, the SCADA will be able to monitor phase / earth fault condition. Local fault indications – LED/ LCD display on FPI front panel along with LED indication on front panel of RMU enclosure.
The FPI should indicate load current on display to understand loading of RMU.
Multiple reset option –

a) End of time delay
b) Remote reset (Via potential free input contact of FPI)
c) Manual reset (Reset button on front panel of FPI)
d) Automatic reset on current restoration.

The characteristics of the FPIs shall include:

i. ▪ Phase fault thresholds configurable from at least 100 to 800 A
ii. ▪ Earth fault thresholds configurable from at least 20 to 200 A
iii. ▪ Multiple number of steps for adjusting phase and earth fault thresholds.
iv. ▪ Fault current duration range configurable.

RMU should have VCB, FRTU and FPI supplied and integrated by the same OEM to ensure seamless integration.

### 6.1.2.8 OPERATING LEVER

An anti-reflex mechanism on the operating lever shall prevent any attempts to reopen immediately after closing of the switch or earthing switch.
All manual operations will be carried out on the front of the switchboard.

### 6.1.2.9 FRONT PLATE

The front plate shall have suitable IP degree of protection. The front shall include a clear mimic diagram which indicates the different functions.
The position indicators shall give a true reflection of the position of the main contacts. They shall be clearly visible to the operator. The lever operating direction shall be clearly indicated in the mimic diagram.
The manufacturer's plate shall include the switchboard's main electrical characteristics.

### 6.1.2.10 REMOTE CONTROL OF THE RMUS

A limited number of applications for remote operation of the RMU are required.
Remote operation of the RMUs line switches must be possible using motors fitted to the operating mechanism. It shall be possible to fit the motors either directly in manufacturing plant or on site when required. Installation on site shall be possible with the RMU fully energized and manufacturer should provide detailed instructions for installation to the control mechanism.

Auxiliary contacts for remote indication of switch status are also required. The fitting of the motors to the mechanism must not in any way impede or interfere with the manual operation of the switches. An auxiliary contact to prevent motorized operation of the mechanism while the operating handle is inserted into the operating point must also be provided. The device shall be fully designed for use in a hot, humid atmosphere and shall be low maintenance. All metallic parts shall have rust protection. Two lifting rings shall be installed on the top of the switchboards for handling.

### 6.1.2.11 TECHNICAL DATASHEET FOR RING MAIN UNIT (RMU)

| | |
|---|---|
| Network | Three phases - Three wires |
| Rated Voltage | 12 kV |
| Service Voltage | 11 kV |
| System Frequency | 50 Hz |

| | |
|---|---|
| Lightning Impulse withstand Voltage<br>• Phase to phase, phase to earth<br>• Across the isolating distance | <br>75kV<br>85 kV |
| Power Frequency withstand voltage | 28 kV rms - 1 min |
| Rated Normal Current<br>a) Line switch<br>b) Transformer feeder<br>c) Branch circuit breaker feeder | <br>630 A<br>630 A<br>630 A |
| Rated Short time current withstand (3 sec) | 20 - 25 kA |
| Internal Arc IAC – AFL (SF6 tank and cable box) | 20kA for 1sec |
| Rated Short circuit making capacity of line switches and earthing switches | 62.5 kA peak at Rated Voltage |
| Number of operations at rated short circuit current online switches, earthing switches and CB | 5 closing operations |
| Rated load interrupting current<br>Line switch | <br>630 A rms |
| Rated cable charging interrupting current<br>Line switch | <br>30 A |
| Number of mechanical operations<br>a) Line switches and earthing switches<br>b) Switch-fuse combination<br>c) Circuit breaker | <br>1000 O/C<br>1000 O/C<br>2000 O/C |
| Number of electrical operations at full load breaking current | 100 O/C |
| Number of operations at rated short circuit current on circuit breaker | Manufacturer's design |

### 6.1.3 ACCESSORIES FOR 11 KV SYSTEM: -

#### 6.1.3.1 DISTRIBUTED I/O

Distributed I/Os are required for using the advantages of a double-sided feeding at the 11 kV System. The distributed I/Os will be provided by the contractor of Electrical /SCADA. All data points of the 11 kV-System run to the distributed I/Os.

#### 6.1.3.2 FIRE EXTINGUISHER

CO2 fire extinguishers shall be provided in substation, equipment room . This includes necessary fixing arrangement, accessories etc.

### 6.1.4 ACCESSORIES FOR EACH 11KV SUB –STATION: -

Each 11 kV sub- station shall be equipped with:

a) Single Line Diagram of 11 kV-System of tunnel with glass-covering
b) Sheet / Board including the instruction for first aid by electrical accidents
c) - Sheet / Board including the instructions for fire-fighting measures in electrical plants
d) Prescription of operation of High Voltage Systems
e) Suspension Device for accessories
f) Warning Sign "Attention High Voltage"
g) Voltage Detector
h) Earthing Accessories and other safety equipment as per standard.

### 6.1.5 OPERATION MODES: -

All switching equipment, which shall be equipped with a remote control switch, shall need a changeover switch. Therewith a switching between local- or remote-control is possible.

6.1.5.1 **LOCAL CONTROL:** If the changeover switch is positioned at "local control", all up streamed switching equipment has to switch off the remote controlling. The whole switchgear interlocking shall also work at local control.

6.1.5.2 **REMOTE CONTROL:** At this position of the changeover switch the user shall be able to choose between different switch possibilities out of a predefined matrix. Generally, it shall be possible to decide which of the two feedings shall be switched. A remote controlling of the high voltage power supply shall only be possible, if:

a) No changeover switch is positioned at local control
b) No earthing switch is switched
c) No fault is stored.

### 6.1.6 APFC PANEL WITH ALL ACCESSORIES: -

SITC of APFC Panel of 250 kVAR heavy duty capacitor bank with MCCB as incomer or as per site requirement. Automatic Power Factor Correction panel shall be totally enclosed, metal clad, sheet steel fabricated, fixed feeder type, dust and vermin-proof, free standing, floor mounting type. The enclosure shall be pre-treated as per 11 tanks process and finished with powder coating of shade RAL 7032. The panel shall be built to ensure

a) Proper thermal design, by providing louvers and fans in appropriate location,
b) Accurate selection of switchgear, capacitors-reactors and others in the panel.
c) Safety during operation, inspection and maintenance.

#### 6.1.6.1 Minimum features required are: -

i. Advanced microcontroller based APFC relay
ii. Four quadrant sensing
iii. Reliable switching sequence
iv. Hunt free operation
v. Reliability in operation
vi. Program based rotation of duty cycle pre set
vii. Programming ensures stability

viii. Faster response time
ix. Accurate compensation
x. Contactor duty cycle optimization in case of equal step sizes
xi. Various system parameter display
xii. Fully automatic / manual setup and operation
xiii. Minimal joining in all the connections to ensure better reliability and lower losses.
xiv. Use of special connecting cables suitable for high temperature withstands.
xv. Flush mounted meter to indicate line voltage and current.

**6.1.6.2 PROTECTION: The following protection schemes must be provided for APFC panels:**

a) Over voltage: The APFC equipment must be switched off in the event of over voltage with suitable over voltage relay.
b) Under voltage: This condition is not harmful. But protection must be provided to protect system from under voltage.
c) Over Current: All the switchgears are selected on a higher maximum current carrying capacity. Hence, suitable over current relays with alarm can be used for over current protection.
d) Short circuit protection: At the incomer level short circuit protection shall be provided by devices such as MCCB, ACB. At the step protection level, MCCB/ MCB shall be used Thermal Overload: The APFC controller must be tripped in cases where internal ambient temperature exceeds the limits. Reactors are also provided with thermal switches, to trip in the case of temperature increase.
e) Earthing: Two earthing points shall be provided in the APFC panel for connection with the earth bus. This will ensure the overall safety of operating personnel and equipment protection in case of earth faults.
f) Earth Leakage Relay: It must be connected at power incoming side of the panel. Earth leakage relay must be provided to safeguard the operator by tripping the incomer.
g) Timers: Capacitors require a minimum discharge time of approximately 60 seconds after they are switched off before they can be switched on again. This shall be set in the APFC controller. Capacitors must be provided with discharge resistors.
h) Over Temperature trip mechanism: Temperatures sensors (two thermostats) to be connected for operation of the fans/ industrial air conditioners above 35°C and to disconnect main incomer of APFC if the temperature exceeds 55°C inside the panel.

### 6.1.7 11/0.433 KV TRANSFORMERS: -

The transformers shall be installed in that way, that no vibrations will be transmitted to the building / construction. The connecting of the 11 kV-cables at the transformers only shall occur with right-angle connectors. Those right-angle connectors shall be calculated into the price of the 11 kV-cable.

### 6.1.7.1 DRY TYPE 11 / 0.433 KV TRANSFORMER (2000 kVA for Portal sub-station)

Dry transformers shall be built with an air-natural – air-natural cooling (ANAN).
The 11/0.433 kV transformers shall be copper wounded equipped with off-load tap changer on primary side, with positions at +5 %, +2.5 %, ± 0 %, -2.5 % and -5 %. Generally, the tap changers shall operate under OFF-circuit conditions (through the cover) and shall be able to be fixed in any position by an adjusting screw. Winding terminations shall be realized as strip or foil windings. Additional to the turn insulation, the windings shall be embedded with a mixture of epoxy resin.

The mixture of epoxy resin shall be hardly inflammable and self-extinguishing. Transformers shall be at least fire class F1 according to BS EN IEC 60076-11:2018, IS-11171.The neutral point (on the besides copper low-voltage side) shall be designed in a total insulated form, like the phase conductor. The iron core shall be designed with step-lap joints. The yoke shall be mounted with yoke chipboards. The use of bolts is not allowed. The yoke-chipboards of both sides of the yoke
shall be linked with pull rods. On the stiffening frame near the ground a base shall be provided for the approach of winches and lifting jacks. Also, eyebolts with a diameter of at least 60 mm shall be provided on the top. The transformer shall be equipped with massive plain wheels, rotatable for lengthwise and crosswise driving. The ground clearance shall be at least 50 mm. The core assembly of Dry type transformers enclosure shall be electrically connected to the transformer tank for effective core earthing. Also copper flexible foe earth continuity purpose shall connect different parts of transformers.

### 6.1.7.2 PROTECTION AND MONITORING EQUIPMENT

For the windings, a temperature monitoring by using separated PTC thermistor detectors for warnings and alarms shall be provided.

### 6.1.7.3 TECHNICAL DATASHEET FOR DRY TYPE 2000 kVA (11/0.433 KV) TRANSFORMER

| | |
|---|---|
| Rated power: | 2000 kVA |
| Voltage (primary side): | 11 kV |
| Voltage (secondary side): | 0.433 kV |
| Nominal frequency: | 50 Hz |
| Thermic power loss: | 5.5 kW (max.) |
| No Load Loss | 1.3 kW (max) |
| Cooling: | ANAN |
| Tapping range: | + 5%, +2.5 %, ± 0 %, -2.5 %, -5 % |
| Impedance voltage: | 5 % |
| Vector Group: | Dyn 11 |

| | |
|---|---|
| Primary connection: | Totally insulated plug-in connector |
| Secondary connection: | Connection safe insulating cover to touch with connecting lug. |

**Note: - The contractor shall ensure that equipments provided in sub-stations should be compatible to SCADA, so that they can be operated remotely.**

## 6.2 11kV HT/LT COPPER CABLE: -

### 6.2.1 TECHNICAL SPECIFICARTION (HT CABLE): -

Three core 11 kV grade, 90˚C rating heavy duty power cable with stranded compacted circular copper conductor with non-metallic semi-conducting screening, shielded with extruded semi-conducting compound, cross linked polyethylene insulated, shielded with extruded semi-conducting compound and copper tape, shielded cores laid up with fillers, inner sheath of extruded PVC, Galvanized steel wire/strips Armoured and FRLS-H PVC ST-2 overall sheath.

### 6.2.2 STANDARD: -

The 11 kV cables shall, in general, meet the requirements of the latest edition of the IS 7098 (Part-2) 1985. The cables and components in general shall meet the requirement Standards with latest amendments or equivalent International Standards.

| | |
|---|---|
| IS:7098 (Part-2) (R2016) 2011: | Specification for cross linked polyethylene insulated PVC sheathed cables |
| IS:8130 (R2015) 2013: | Specifications for conductors for insulated Electric cables |
| IS:3975 (R2004) 1999: | Specification for mild steel wires, strips and tapes for armouring of cables |
| IS:10810 (Part 1 to 55) (R2016)1984: | Speciation for test on cables |
| IS:5831 (R2016) 1984: | Specification for PVC insulation and sheath of electric cables |
| IS:10418 (R2016) 1982 | Specifications for drums of electric cables |
| IS:10462 (Part-1) (R2016) 1983: | Fictitious calculations method for determination of dimensions of protective covering of cables |
| IEC:60754-1 / IEC:60754-2 2011 | Determination of the amount of Halogen acid Gas, Determination of degree of acidity of gases |
| IEC:60332 / IEC:60331 2004 | Flammability test for electric cables |
| BS 7835 2007 | Armoured cables with thermosetting insulation for rated voltages from 3.8/6.6 kV to 19/33 kV having low emission of smoke and corrosive gases when affected by fire. |

### 6.2.3 TECHNICAL DATASHEET - FOR HT CABLE

| S.NO. | PARTICULARS | 3Cx120 | 3Cx95 | 3Cx50 |
|---|---|---|---|---|
| 1 | Make | as per list of approved makes | | |
| 2 | Voltage Grade in kV (System highest voltage) | 6/10(12) or as per Standard | 6/10 (12) | 6/10 (12) |
| 3 | Type | XLPE Cable | | |
| 4 | Reference Standards | IEC 60502-2, IEC 60228: 2004, BS 7655, IS 5831, IEC 60332, | | |
| 5 | Conductor | | | |
| (i) | Material as per IEC 60228 | Annealed Plain Copper | | |
| (ii) | Nominal Cross Section Area (sq.mm) | 120 | 95 | 50 |
| (iii) | Class of Conductor | Class-2 | | |
| (iv) | Shape of Conductor | Stranded Compacted Circular | | |
| (v) | Min. no. of strands | As per IEC 60228 | | |
| (vi) | Max. DC conductor resistance 20 °C (Ohm/Km) | As per IEC 60228 | | |
| (vii) | AC resistance at 90 °C (Ohm/Km) | As per IEC 60228 | | |
| 6 | Insulation | | | |
| (i) | Material as per 60502-2 | XLPE | XLPE | XLPE |
| (ii) | Nominal thickness of insulation(mm) | 3.4 | 3.4 | 3.4 |
| 7 | Insulation Screening | | | |
| (i) | Material | Extruded Semiconducting compound (bonded type) followed by a layer of copper tape | | |
| (ii) | Min. thickness of extruded layer (mm) | 0.3 | 0.3 | 0<br>. |
| (iii) | Approx. thickness of copper tape | 0.035 | 0.035 | 0.035 |
| (iv) | Layer over laid-up | 2 layers of Glass Mica Tape applied over conductor | | |
| 8 | Core Identification | By colored strip Red, Yellow and Blue | | |
| 9 | Laying Up | Cores laid up suitably | | |
| 10 | Inner Sheath | | | |
| (i) | Material as per IEC 60502 - 2 | Extruded LSZH Compound Type ST-8 | | |
| (ii) | Min. Thickness (mm) | As per IEC 60502-2 | | |
| 11 | Armouring | | | |
| (i) | Material | Single layer of galvanized steel round wire | | |
| (ii) | Nominal Dia of armour wire (mm) | As per IEC 60502 | | |
| 12 | Outer Sheath | | | |
| (i) | Material as per IEC 60502 - 2 | LSZH Compound Type ST-8 | | |
| (ii) | Min. Thickness (mm) | As per IEC 60502-2 | | |
| (iii) | Sheath Color | Black | | |
| (iv) | Approx overall dia of Cable (mm) | As per IEC 60502-2 | | |
| 13 | Marking on cable | Make, Electric cable, Voltage Grade, Size of Cable, ----<br>meter, NR logo | | |

### 6.2.4 TECHNICAL SPECIFICATION (LT CABLE): -

| S.NO. | PARTICULARS | 4Cx300 | 4Cx185 | 4Cx120 | 4Cx95 | 4Cx70 | 4Cx35 | 4Cx25 | 4Cx16 | 4Cx10 | 4Cx6 | 4Cx4 | 3Cx4 | 3Cx2.5 | 3Cx1.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Make | As per list of approved makes | | | | | | | | | | | | | |
| 2 | Voltage Grade (kV) | 1.1 | | | | | | | | | | | | | |
| 3 | Type | Fire Survival Cable | | | | | | | | | | | | | |
| 4 | Reference Standards | BS 7846, IS 8130, BS 7655, IS 5831, IEC 60332 | | | | | | | | | | | | | |
| 5 | Conductor | | | | | | | | | | | | | | |
| (i) | Material | Annealed Plain Copper Conductor as per IS 8130 | | | | | | | | | | | | | |
| (ii) | Nominal Cross Section Area (sq.mm) | 300 | 185 | 120 | 95 | 70 | 35 | 25 | 16 | 10 | 6 | 4 | 4 | 2.5 | 1.5 |
| (iii) | Class of Conductor | Class-2 | | | | | | | | | | | | | |
| (iv) | Shape of Conductor | Stranded sector shaped | | | | | | | Stranded compacted circular | | Stranded circular | | | | |
| (v) | 2 layers of Glass Mica Tape applied over conductor | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Ye s | Yes |
| (vi) | Min. no. of strands | As per IS 8130 | | | | | | | | | | | | | |
| (vii) | Max. DC conductor resistance 20 °C (Ohm/Km) | As per IS 8130 | | | | | | | | | | | | | |
| (viii) | AC resistance at 90 °C (Ohm/Km) | As per IS 8130 | | | | | | | | | | | | | |
| 6 | Insulation | | | | | | | | | | | | | | |
| (i) | Material | XLPE | | | | | | | | | | | | | |
| (ii) | Nominal thickness of insulation(mm) | 1.8 | 1.5 | 1.2 | 1.1 | 1.1 | 0.9 | 0.9 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 |
| 7 | Core Identification | Red, Yellow, Blue and Black | | | | | | | | | | | Red, Yellow and Blue | | |

| | | |
|---|---|---|
| 8 | Laying Up | Cores laid up suitably by Plain Glass Fibre tape |

| S.NO. | PARTICULARS | 4Cx300 | 4Cx185 | 4Cx120 | 4Cx95 | 4Cx70 | 4Cx35 | 4Cx25 | 4Cx16 | 4Cx10 | 4Cx6 | 4Cx4 | 3Cx4 | 3Cx2.5 | 3Cx1.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Inner Sheath | | | | | | | | | | | | | | |
| (i) | Material as per BS 7846 : 2000 | Extruded LSZH compound | | | | | | | | | | | | | |
| (ii) | Min. Thickness (mm) | as per BS 7846 : 2000 | | | | | | | | | | | | | |
| 10 | Armouring | | | | | | | | | | | | | | |
| (i) | Material as per BS 7846 : 2000 | Single Layer of Galvanized steel Round Wire | | | | | | | | | | | | | |
| (ii) | Nominal Dia of armour wire (mm) | as per BS 7846 : 2000 | | | | | | | | | | | | | |
| 11 | Outer Sheath | | | | | | | | | | | | | | |
| (i) | Material as per BS 7655 | LSZH Compound Type LTS-1 | | | | | | | | | | | | | |
| (ii) | Min. Thickness (mm) | as per BS 7655 | | | | | | | | | | | | | |
| (iii) | Sheath Color | Black | | | | | | | | | | | | | |
| (iv) | Approx overall dia of Cable (mm) | By Contractor | | | | | | | | | | | | | |
| 12 | Marking on cable | Make, Electric cable, Voltage Grade, Size of Cable, meter, NR logo | | | | | | | | | | | | | |

### 6.2.5 CONTROL CABLES

The control & instrumentation cables shall be multicore, colour coded, annealed stranded high conductivity copper, single conductor, insulated with PVC insulation, PVC sheathed, conforming to IS 1554 (Part I & II) / IS 7098 Part 1, relevant IEC. The outer sheath is of specially formulated PVC compound which will give the following properties: -

Oxygen - Index Min. 29,
Smoke density - Min. 40% light transmittance,
Acid gas - Max. 20% by weight,
Flame propagation - Shall meet IEC 60332-1, IEEE 383.
Cables for use in the tunnel shall be low-smoke, non-halogenated type and FRLS type.
The cable flame temperature shall conform to category B 750 ± 40 °C for 3 has stipulated in BS 6387:1994.

### 6.2.6 MODBUS CABLE

Communications cable suitable for Modbus RS-485 providing a master / slave communication between intelligent automation devices, controllers and FLTA wireless interfaces.

**6.2.6.1** These shall have following minimum features:

a) Outer sheath Low smoke halogen Free
b) Insulation material polypropylene
c) 22 (7) multi - paired AWG Tinned copper conductor
d) Individual Aluminium foil screen 100% coverage
e) Individual tape polyester each pair Overall tape polyester
f) Cores twisted into pairs, pairs laid up
g) Polyethylene insulation
h) Drain wire 24 (7) AWG Tinned copper conductor
i) Working voltage 300 V
j) Velocity of propagation 66%
k) Temperature range - 20 deg C to +80 Deg C Nominal conductor resistance < 53 Ohm per kilometre
l) Insulation resistance > 200 M Ohm.M
m) Characteristic Impedance 50 Ohms
n) Capacitance Core to Core 98 pF/m
o) Capacitance core to screen 180 Pf/m
p) Nominal velocity of propagation 66%

#### 6.2.6.2 Relevant standards to be complied:

a) Low smoke generation: EN 61034 - 2
b) Halogen Gas Emission: EN 60754 - 1&2
c) Flame retardant: EN 60332 - 1 - 2
d) RoHS2 compliant: Yes
e) CE complaint: LVD(2014/35/EU), CPR (305/2011)
f) CPR classification: ECA (EN50575: 2014+A1 :2016)

## DATASHEET FOR MULTICORE CABLES

| S.NO. | PARTICULARS | 19Cx1.5 | 12Cx1.5 | 7Cx1.5 | 2Cx1.5 |
|---|---|---|---|---|---|
| 1 | Make | as per approved makes | | | |
| 2 | Voltage Grade (kV) | 1.1 | | | |
| 3 | Type | Fire Survival Cable | | | |
| 4 | Reference Standards | BS 7846, IS 8130, IS 10462, BS 7655, IEC 60331, IEC 60332, BS 6387, BS EN 61034, IEC-60754 | | | |
| 5 | Conductor | | | | |
| (i) | Material | Stranded Annealed Tinned Copper Conductor as per IS 8130 | | | |
| (ii) | Nominal Cross Section Area (sq.mm) | 1.5 | 1.5 | 1.5 | 1.5 |
| (iii) | Class of Conductor | Class-2 | | | |
| (iv) | Shape of Conductor | Stranded circular | | | |
| (v) | 2 layers of Glass Mica Tape applied over conductor | Yes | Yes | Yes | Yes |
| (vi) | Min. no. of strands | As per IS 8130 | | | |
| (vii) | Max. DC conductor resistance 20 °C (Ohm/Km) | As per IS 8130 | | | |
| (viii) | AC resistance at 90 °C (Ohm/Km) | As per IS 8130 | | | |
| 6 | Insulation | | | | |

| S.NO. | PARTICULARS | 19Cx1.5 | 12Cx1.5 | 7Cx1.5 | 2Cx1.5 |
|---|---|---|---|---|---|
| (i) | Material | XLPE | | | |
| (ii) | Nominal thickness of insulation(mm) | 0.6 | 0.6 | 0.6 | 0.6 |
| 7 | Core Identification | For 2 cores: Red & Black, For 3 cores: Red, Yellow, Blue. For 7 cores & above: White color cores with number printing on cores. | | | |
| 8 | Screening/ Shielding | The laid up Cores shall be screened with Aluminium Mylar/ Polyster tape (min. thickness 0.028 mm) with 100% coverage & min. 20% overlap. ATC Drain Wire of 0.5 Sq.mm (7/0.3 mm), shall be provided under Al- Mylar tape in continuous touch with Aluminium side of the tape. | | | |
| 9 | Inner Sheath | | | | |
| (i) | Material as per BS 7846 : 2000 | Extruded LSZH compound | | | |
| (ii) | Min. Thickness (mm) | as per BS 7846 : 2000 | | | |
| 10 | Armouring | | | | |
| (i) | Material as per BS 7846 : 2000 | Single Layer of Galvanized steel Round Wire | | | |
| (ii) | Nominal Dia of armour wire (mm) | as per BS 7846 : 2000 | | | |
| 11 | Outer Sheath | | | | |
| (i) | Material as per BS 7655 | LSZH Compound Type LTS-1 | | | |
| (ii) | Min. Thickness (mm) | as per BS 7655 | | | |

### 6.2.7 CABLE CONDUITS

Cable conduits shall consist of stainless steel, material no. 1.4401 and shall be free of halogen. They shall be laid in accordance with the relevant standards. Those cables which run from the cable pit outlets along the tunnel wall to the safety equipment will run in conduits (control and power cabling).
These conduits shall be fixed with help of brackets and C-section rails on the wall. The material of these brackets, section rails and their fasting bolts shall be made of stainless steel, material no. 1.4401.

### 6.2.8 INSTALLATION ON WALL /INSIDE THE CONDUITS AS PER SITE REQUIREMENT

3 nos. 3 core, 11 KV copper cables shall be laid all along the route forming two 3 phase circuits and one cable as standby. Each circuit is capable to carry full design load of the tunnels as per load summary sheet.

11 KV cables in the tunnel are proposed to be laid on the wall / tray/inside the conduit as there is a space constraint in cable trench as per requirements for respective tunnels.

The 11 kV cable laying configuration on the wall / inside the conduit of the tunnel & and actual fixing arrangement (with cover) will applicable to suit site condition as per recommendations and approved by the Engineer.

### 6.2.9 CABLE JOINTS & TERMINATIONS

All joints and terminations shall be of the heat-shrink type, manufactured and tested to meet the requirements of IS-13573-2/3, IEC-60502-2/4 & IEEE48 standards to latest versions. Material used for construction of a joint/termination shall perfectly match with the di-electric, chemical and physical characteristics of the associated cable. The material and design concepts shall incorporate a high degree of operating compatibility between the cable end joints. The Straight through joint kit or termination kit shall be complete with all accessories, jointing material, insulating stress control and sealing material, lugs, nuts, bolts etc. as well as an instruction booklet explaining the method of using the kit. In case of heat shrinkable type kit, the joint shall include a heat shrinkable dual wall tubing which shall be insulating from inside and semi conductive from outside. Detailed sectional views of the assemblies shall be submitted along with the offer.

The cable termination kit shall be suitable for terminating the cable on indoor or outdoor installation as per requirement. The type of cable will be armoured PVC / XLPE insulated H.T/L.T. Cable. The straight through joints should be absolutely impervious to the entry of water. The manufacturer shall use the proven technologies and design to ensure a construction which will prevent entry of water or any other liquid inside the straight through joint and cable

#### 6.2.9.1 Heat Shrinkable Straight Through Joints for MV Cables

The heat shrinkable straight through joints shall have following function abilities:

a) For encapsulation, environmental sealing set of heat shrink outer insulating tubes with hot melt adhesive coating is required to be provided.
b) To reduce stress over conductor, heat shrinkable stress control tube to be provided. The stress control tube has to be in electrical contact with the outer insulation screen of the cable. Impedance of the tube shall be constant up to an operating temperature and shall be within the range 1x108 ohm-cm to 8x108 ohm-cm and with Relative permittivity shall be minimum 15. Voids filling and stress relief over crimped connector and cut point of the insulation screen to be provided with void filling and moisture sealing high permittivity yellow mastic and lubricant.
c) For joining of main conductor cores suitable size of ferrules/mechanical connectors with range taking feature should be provided. The cross-sectional area (CSA) of the ferrule/mechanical connector shall not be less than CSA of the conductor of the cable.
d) Earth Continuity between armor to be provided by tinned copper braid of adequate cross section. This is required for proper earthing of the joint. Also, to support armor wire supporting is to be provided. The material of support ring to be steel (G.I.) for 3 core Cable
e) For cleaning of cores, removing burrs on ferrules & rough insulation sufficient quantity of cleaning solvent & aluminium oxide cloth is required to be provided.

**6.2.9.2 Heat Shrinkable Termination for MV Cables**

a) The cable termination (Indoor & Outdoor) shall be of Class-I type which consist of following points:
   i. Stress control layer
   ii. Resistance against UV light environmental protection
   iii. Moisture seal-for environmental sealing against ingress of moisture & aggressive gases.
b) To protect the cable breakout mono-plats tape/non-adhesive PVC tape is required to be applied.
c) For proper sealing of Lugs at end of the termination suitable size & length of Heat Shrinkable tube is to be provided.
d) Suitable size of heat stress control tubes is to be provided to reduce stress at cut back of scree. Void filling yellow mastic is to be provided at semi-conducting screen. Heat shrinkable anti tracking tubes are to be provided to cover bare XLPE insulation and to provide UV resistance & environmental sealing.
e) For cleaning of cores, removing burrs on ferrules & rough insulation, sufficient quantity of cleaning solvent & aluminium oxide cloth is required to be provided. Adhesive tapes to be provided in sufficient length for marking on cables.

**6.2.10 The Scope of this work also includes**: -

a) Supply, Laying, testing & commissioning of PE DWC/HDPE pipe 160/75 mm type 750N pipes as per RDSO Spec. No. RDSP/SPN/204/2011 with latest amendment & as per IS 16205 Part-24 for cables including along with all accessories like bends, couplers, etc. as required.

b) Excavation and refill of 0.50 mtr. Width, 1.20 mtr. Deep trench and Hard trench in all kinds of soil/ Hard surface for laying of HDPE/DWC pipe for underground cable crossing. Contractor will clear all metallic part & stones etc. after cable/pipe laying contractor will clear all site, refilling by available soil and ramming the same for made good in same level.

## 6.3 EMERGENCY POWER SUPPLY ARRANGEMENT (DG SETS of 900/910 kVA **Capacity)**

Adequate no of 11 KV DG sets shall be installed in each substation. DG sets must be automatically start direct coupled engine- alternator assembly mounted on rigid fabricated steel base frame with resilient anti-vibration mountings complete with but not limited to engine, alternator, exhaust piping (as per CPCB norms) with silencer to provide at least 25 dBA insertion loss, electric starting equipment including batteries and battery chargers, acoustic enclosure, auxiliary system, AVR, AMF panel with protection and metering equipment, etc. connected to the 11 KV panel through cables.

a) The DG sets shall be kept outside the tunnel at portals substations to prevent unsafe conditions inside the tunnels due to fuel handling and exhaust fumes. The DG set terminal voltage has been chosen as 11 KV since the system bus at portal substation is at 11 KV.

b) Diesel engine shall be turbo-charged, multi-cylinder, electronic fuel injection cold starting with speed variation within 2% between 10% and 100% load, with positively pressurized lubricating oil with engine driven lube oil pump, low lube oil pressure sensors and potential free contacts for conveying the signal to SCADA system, sensor and alarm for high jacket- cooling water temperature with suitable potential free contacts for conveying the signal to SCADA system, speed control mechanism with automatic fuel oil supply cut-off system for stopping the engine. Also, the engine shall be adequately protected against operating under overload conditions either by fixed overload limit stop on the fuel pump rack control rod or an alternate reliable mechanism to prevent the DG set being subject to a load exceeding the site rating plus 10% complete with potential free contacts for conveying the signal to the SCADA system.

c) The DG set shall be silent type in each substation in the covered but naturally ventilated area with adequate exhaust piping planning (as per latest CPCB norms) and comply generally to IS:13364-Part 2:1992(R2018).

d) The 11 KV DG set shall be complete with cooling system, fuel system, lubricating system, air intake system, exhaust system as per latest CPCB norms, governing and speed control system, standby system, engine protection safety system with microprocessor based power control command generator set monitoring, metering, protection and control system to meet demands of engine driven generator sets.

e) The alternator shall be brushless, rotating field design alternator voltage 11 kV, power factor 0.8, with voltage regulation ± 0.5% for all loads between no load to full load conditions of insulation with sound proof enclosure, weather proof enclosure Prime Power Rating (PRP) conforming to ISO 8528 part - I as per environment noise level norms 75 Db (decibels) as at one meter.

f) The alternator shall be self-excited, self-regulator, self-ventilated in brushless design processed with suitable AVR and shall conform to BS:269, BS:5000, IS/IEC 60034-1 2004 and shall give rated output at NTP conditions.

g) One number free standing 990 liters Day Fuel tank shall be provided with each DG set fabricated from MS sheet with inlet, outlet connections, air vent tap, drain plug and level indicator (gauge) M.S. fuel piping from tank to engine with valves, unions, reducers, flexible hose connection and floor mounting pedestals, twin fuel filters and fuel injectors. The location of the tank shall depend on standard manufactures design.

h) Foundation should be designed considering safe bearing capacity of soil. Anti-Vibration Mountings (AVMs) should be provided to reduce vibration transmission to the surrounding structure.

i) One number free standing 990 litres or suitable size Fuel tank shall be provided with each DG set fabricated from MS sheet with inlet, outlet connections, air vent tap, drain plug and level indicator (gauge) M.S. fuel piping from tank to engine with valves, unions, reducers, flexible hose connection and floor mounting pedestals, twin fuel filters and fuel injectors. The location of the tank shall depend on standard manufactures design.

j) Foundation should be designed considering safe bearing capacity of soil. Anti-Vibration Mountings (AVMs) should be provided to reduce vibration transmission to the surrounding structure.

### 6.3.1 TECHNICAL DATASHEET FOR 910 KVA DG SET

| **GENERATOR SET SPECIFICATION** | |
|---|---|
| Duty | Prime |
| Power Rating kVA | 900/910 KVA |
| No. of Phases | 3 |
| Output Voltage and Frequency (kV and Hz) | 11 kV, 50 Hz |
| Power Factor | 0.8 (lagging) |
| Current (A) | 48 |
| RPM | 1500 |
| **ENGINE SPECIFICATION** | |
| Make | As per approved make |
| Model | as applicable / EQU approved |
| Certified Power (hp) | 1069 |
| Required Power for Rated kVA (hp) | 1069 |
| Cooling | Liquid cooled<br>(Distilled Water +DCA2) |
| Aspiration | Turbocharged After-cooled |
| No. of cylinders | 12, Vee arrangement |
| Bore (mm) x Stroke (mm) | 159 x 159 |
| Compression ratio | 16.7:1 |

| | |
|---|---|
| Displacement (litre) | 38 |
| Fuel | High Speed Diesel |
| Fuel consumption @75% load with radiator and fan* (litre/hr) | 151.22 |
| Fuel consumption @100% load with radiator and fan* (litre/hr) | 192.55 |
| Performance class of generator set | ISO 8528-5 G2 |
| Starting system | suitable DC battery supply |
| Lube oil sump capacity, High-Low level (litre) | 140 - 114 |
| Total lubrication system capacity (litre) | 155 |
| Lube oil consumption @ full load** (litre/hr) | 0.28 |

### 6.3.2 TECHNICAL DATASHEET FOR ACOUSTIC ENCLOSURE FOR DIESEL GENERATORS

| | | |
|---|---|---|
| 1 | DG Set Capacities | 900/910 KVA |
| 2 | Structure | MS Press bend 2 mm |
| 3 | Panels | Steel Fabricated double wall insulated panel |
| | Thickness of panels | 100 mm thick |
| | Outer Sheet | 2 mm thick CRCA sheet steel |
| | Inner Sheet | 1.25 mm thick CRCA perforated sheet steel |
| | Frame & Strainer | 2 mm thick CRCA sheet steel |
| 4 | Insulation | Mineral Wool as per IS 8183 – 1993 |
| | Thickness | 100 mm thick (50 mm x 2 slabs) |
| | Density | 64 Kg / m3 |
| | Anti-Droning | HDPE sheet |
| | Thickness | 6 mm thick |
| 5 | Air Circulation System | Axial flow fans of suitable capacity required for DG set offered |
| 6 | Finishing | Powder coating of color shade approved by consultant/ owner |
| 7 | Noise level | 75 DBA at a distance of 1 meter |
| 8 | Location | Outdoor |

| | | |
|---|---|---|
| 9 | Painting of Exhaust Piping | High Temperature aluminium paint shall be used (600- 700 deg C) for painting of uncladed exhaust pipe and top of the chimney |
| 10 | Base Frame for canopy | Powder coated as per approved color. |

### 6.3.3 AUTO MAINS FAILURE (AMF) PANEL/ AUTO SYNCHRONIZING PANEL: -

The AMF panel shall be capable of starting DG set automatically in the event of unhealthy conditions of main power supply including power (MAINS) failure, single phasing or voltage going below 85% of bus bar of main panel and shall switch over essential load from main power supply to DG set. The DG set will start automatically within 10 seconds of main supply failure. The synchronising logic shall be achieved through MICRO PROCESSOR based circuitry to monitor engine control, with an online MIMIC giving status. The generator set shall be capable of starting and taking up the load with-in-time stipulated in data sheet. The DG set will have protection / annunciation system conforming to latest standards like BS/ IEC or IS with soft control and torch resets shall be designed comprising complete protection/ annunciation requirement (overload, high temperature, alarms, earth fault, low battery voltage, fault indication alarm, fuel low level, metering indication etc.) The DG sets AMF panel shall be provided with interface for remote monitoring by SCADA. The sequence of operation of synchronization of DG sets and Utility power, and NGR panels' operation with Transformers and DG sets neutral are as per standard.

### 6.3.4 TECHNICAL DATASHEET FOR NGR & NIS PANEL WITH VACCUM CONTACTOR

| NEUTRAL GROUNDING RESISTOR PANEL | | |
|---|---|---|
| 1.0 | SYSTEM DESIGN DATA | |
| 1.1 | Design Ambient | 50˚C |
| 1.2 | Reference Standards | IEEE-C57.32:2015 |
| 1.3 | Rated Voltage | 11 kV |
| 1.4 | Location of NGR | Outside |
| 1.5 | Resistance per resistor element | As per requirement |
| 1.6 | Material for resistor element | |
| i) | For high value of current | AISI-304, ASTM-A240 |
| ii) | For low value of current | AISI-406 |
| 1.7 | No. of parallel path | Two |
| 1.8 | Max. allowable temperature rise (over ambient) of resistor element | 300˚C - 350˚C |
| 2.0 | ENCLOSURE | |
| 2.1 | Material and thickness | Sheet steel of 2.0 mm |
| 2.2 | Degree of protection (as per IS2147 /IEC-60529) | |
| i) | Enclosure | IP-55 with canopy |
| ii) | Terminal Box | IP-55 |
| 3.0 | SUPPORT INSULATORS | |
| 3.1 | Material | Porcelain |

| | | |
|---|---|---|
| 3.2 | Rated Voltage for 11 kV NGR | 12 kV |
| 3.3 | One-minute power frequency dry withstand voltage | 75kVp/28kV r.m.s. |
| 3.4 | Creep-age Distance | 25 mm / kV |
| 4.0 | PAINT / FINISH | |
| | | Powder Coated or epoxy painted as per specification. Synthetic enamel shade 632 as per IS-5 |
| 5.0 | MOUNTING STRUCTURE | |
| 5.1 | Material | Hot dip galvanized standard steel section |
| 5.2 | Thickness / deposit of galvanization | 75 Microns / 610 g/m2 |
| 6.0 | TERMINAL CONNECTION | |
| 6.1 | Type | Bushing |
| 6.2 | Material | Porcelain |
| 6.3 | Rated Voltage | 11 kV |
| 6.4 | One minute power frequency dry withstand voltage | 75kVp/28kV r.m.s. |
| 6.5 | Creepage Distance | 25 mm / kV |
| 6.6 | Connection neutral between NGR & Transformer | Tinned Copper Flat |

### 6.3.5 AUTOMATION SYSTEM

The EPC contractor shall ensure that following operations of DG will be controlled or monitored through SCADA.

a) Stop/Manual/Auto switch along with potential free contacts for monitoring the manual operation status (wherever applicable), to be provided for that equipment whose start/stop is controlled by SCADA Automation System.

b) Potential frees 'NO' contacts for monitoring 'RUN' status of equipment wherever required.

c) The installation of current transformer & transducer along with wiring between current transformer & transducer up to the terminal block shall be provided by the Electrical Contractor. All transducers shall be supplied by SCADA contractor.

d) Provide all necessary relays, contactors, current & potential transformers required by SCADA system. CT's for SCADA system shall be of 15 VA rating and of metering class. Also, adequate space in the panels shall be provided for mounting of electrical transducers as required.

e) The low voltage SCADA cables shall be brought up to AMF panels by SCADA contractor and all terminations into AMF panels shall be made by Generating set contractor after satisfying himself of the wiring system. It is to be clearly understood that the final responsibility for the sufficiency, adequacy and conformity to the contract requirements, lies solely with the Generator Contractor. The following (but not limited to) shall be monitored through SCADA:

i. Radiator temperature at each generating set.
ii. Start / Stop each Transfer pumps.
iii. Status monitoring for oil transfer pumps
iv. Duplicate monitoring of each indication as given in annunciation window of AMF panel
v. Battery voltage status.
vi. Voltage, current, power factor, frequency and power consumption monitoring at each generating set.

Auto / Manual / Stop changeover switch shall be provided by the generator supplier for each mechanical equipment related to generating sets with potential free contacts. For the temperature monitoring, all nipple / sockets in the pipe shall also be in scope of Generator supplier.

## 6.4 TUNNEL LIGHTING: -

### 6.4.1 GENERAL

This covers the complete Tunnel Lighting System for the tunnel, consisting of tunnel lighting and emergency lighting including control, all required equipment, materials, and accessories. The detail drawing of **power supply arrangement** (Indicative) is attached in section VII-II: Tender Drawings and Documents.

This includes SITC of following Panel/ DB's: -

a) Lighting SDB (Day time lighting) Threshold-1 and Threshold-2 1100x200x1200 mm, IP 54 stainless steel (AISI 316)
b) Lighting DB with 1 no. incomer (63A, FP, MCCB) from Main LT Panel, Copper Bus bar (433V, TPN, 63A) and 10 nos. outgoing feeders (6-16A, FP, MCB) including 2 nos., 3nos. or 4nos. spare feeders, IP54 stainless steel. (AISI 316)

c) Lighting DB with 1 no. incomer (63A, FP, MCCB) from Main LT Panel, Copper Bus bar (433V, TPN, 63A) and 14 nos. outgoing feeders (6-16A, FP, MCB) including 2 nos. spare feeders, IP54 stainless steel (AISI 316)

d) Lighting DB with 1 no. incomer (63A, FP, MCCB) from Main LT Panel, Copper Bus bar (433V, TPN, 63A) and 18 nos. outgoing feeders (6-16A, FP, MCB) including 2 nos. spare feeders, IP54 stainless steel. (AISI 316)

e) Lighting SDB, 700x200x1200 mm, IP 54 stainless steel (AISI 316)

f) Main UPS Panel with 1 no. incomer (80A, TPN, MCCB) from UPS, Copper Busbar (433V, TPN, 80A) and 6 nos. outgoing feeders 16A - 63A, TP MCB) including 2 nos. spare feeders, IP 55 stainless steel (AISI 316)

g) UPS SDB, 700x300x1200 mm, 12 Outgoing panel, IP 54 stainless steel (AISI 316)

h) Main UPS Panel with 1 no. incomer (160A, TPN, MCCB) from UPS, Copper Busbar (433V, TPN, 160A) and 18 nos. outgoing feeders 16A - 63A, TP, MCB) including 4 nos. spare feeders, IP 55 stainless steel (AISI 316)

i) UPS Lighting DB with 1 no. incomer (63A, FP, MCCB) from Main LT Panel, Copper Bus bar (433V, TPN, 63A) and 6 nos. outgoing feeders (6-16A, FP, MCB) including 2 nos. spare feeders, IP54 stainless steel (AISI 316)

j) Maintenance SDB with 1 no. incomer (32A, FP, MCCB) from Maintenance power socket DB, Copper Busbar (433V, FP, 50A) and 6 nos. (16A, DP, MCB) outgoing feeders including spare feeders, IP 54 stainless steel (AISI 316).

k) Maintenance DB with 1 no. incomer (63A, FP, MCCB) from Main LT Panel, Copper Busbar (433V, TPN, 63A) and 4 nos. outgoing feeders (32A, FP, MCB) including 1 no. spare feeders, IP 54 stainless steel (AISI 316)

### 6.4.2 VALUES AND DEFINITIONS

Regular lighting inside the tunnel for service, maintenance works and for rescue reasons shall be provided. The lighting system consists of LED lamps. The lighting is partitioned in individual sections. Each section contains normal supply and UPS power supply. All normal and UPS supplied sections shall be connected.

#### 6.4.2.1 Level-1, Round the Clock / emergency illumination (10 lux minimum or as per latest guideline issued by RDSO/Railway Board)

20 watt LED luminaries shall be fixed at every 24 meters (or as per lux level calculation to maintained minimum lux level inside the tunnel) distance on each of the side walls of the tunnel at a height of 2.5 meter from the walkway level. These luminaries are connected with UPS power supply and after every two normally power supplied luminaire, there is a UPS supplied luminaire. As per NFPA-130, these luminaries shall give minimum illumination of 10 lux (or as per latest guideline issued by RDSO/Railway Board) throughout the tunnel round the clock.

#### 6.4.2.2 Level-2, Reading and Maintenance illumination (27 lux minimum or as per latest guideline issued by RDSO/Railway Board)

2 nos. 20 watt LED luminaries shall be fixed at equal distance of 8 meters between two round the clock luminaries on each of the side walls of the tunnel at a height of 2.5 meter from the walkway level. Normally these luminaries shall be off and shall be switched on only when maintenance and inspection work is carried out. These luminaries will be on separate circuit, supplied by normal power supply. These luminaries along with round the clock luminaries shall give a minimum of 27 lux illumination.

### 6.4.3 Day / Night Time Lighting

The day time lighting has been designed in two zones (Threshold zone: 1 & Threshold zone: 2) at lux level of 350 lx Avg. and 180 lx Avg. respectively for both entrance and exit portal of each tunnel. Day and night time luminaries are connected through two different circuits. The Night time luminaries at spacing of 24 meter (10 lux) are connected through UPS circuit which will remain on round the clock while Day time luminaries are controlled through photometer sensor / timer. These photo sensors sense the outdoor lighting intensity and weather conditions for switching ON / OFF/ control of luminaries through SCADA system.

### 6.4.4 Day time Lighting Design

Tunnel Portal Entrance

i. Threshold Zone 1 (TH 1): Zone Length – 100 Meters, Lux Level – 350 lx Avg.
ii. Threshold Zone 2 (TH 2): Zone Length – 100 Meters, Lux Level – 180 lx Avg.

Tunnel Portal Exit

iii. Threshold Zone 1 (TH 1): Zone Length – 100 Meters, Lux Level – 350 lx Avg.
iv. Threshold Zone 2 (TH 2): Zone Length – 100 Meters, Lux Level – 180 lx Avg.

### 6.4.5 Emergency Tunnel Lighting

The emergency lighting allows illumination while the main power supply has broken down. Therefore, each third lamp of the Tunnel Lighting System shall be supplied from UPS power which is also known as round the clock lighting. Emergency lighting allows safe walking on the walkway path throughout the tunnel in case of evacuation. During abnormal conditions (e.g. fire alarm) the lights must remain switch ON.

### 6.4.6 Cross Passages / Adits Lighting/pathway Lighting

The cross passages/ Main tunnel/pathway luminaries shall fulfil following conditions:
Degree of protection: IP 66 (as in the main tunnel tube) – IP 66
Impact Resistance: IK 10
Protection class: II
Luminaire: 1 X 20 watt LED
Installation of Luminaries: The LED Luminaires in the cross passages shall be fixed below the cable trays. A distance of 8 m spacing on the both side of the wall.
The lighting in the Accesses will be switched ON, if:

i. A fire is detected, automatically
ii. The doors of the air locks will be opened, automatically
iii. By the tunnel operator, manually
iv. By the tunnel's maintenance personal, manually with switch on-site.

### 6.4.7 LIGHTING CONTROL

Tunnel lighting shall be controlled from the control units at SCADA control room. Additionally, it shall be controlled by switches at the substation niches/ EM niches as applicable.

### 6.4.8 POWER SUPPLIES – SPECIFICATIONS

Detailed specifications of luminaries shall be as per Northern Railways (NR) CEE Spec No: CEE/NR/121-Elect/PS/2019(REV-04) Dated-04.11.2019 or latest for LED light specification.

**OPERATIONAL INFORMATION**
Supply voltage - 240 V a.c.
Supply frequency - 50 Hz
Output - SCADA
Maximum output current - 235mA per Line
Ambient temperature - 0-50˚ C
Relative humidity - 0-90% non- condensing

Mounting - Surface

**TESTS:** The LED, LED driver and luminaries shall be tested with the applicable IS/IEC reference standards.

### 6.4.9 TECHNICAL SPECIFICATIONS - GENERAL 433 / 240 V – 50 Hz POWER SUPPLY

The general power supply of the 433 / 240 Volt-level to the different equipment occurs from the main power supply (portal substation / niche substation) to the Electrical Niches/ as applicable and then further to the ultimate equipments.
In the tunnel the distribution of the energy occurs from the portal substation/niches substation to the electrical Niches and then further to the ultimate equipments. All power and control units shall be installed into distribution panels, all different voltages (e.g. Main power, UPS power, safety extra-low voltages, different control units and so on) shall be placed in separated or comprehensive different distribution panels. Grounding and protection cables shall be coloured yellow-green as per standards compliance. The inlet of the cables into the distribution panel generally shall be made from bottom with a degree of protection of IP 54 in Electrical Niches and Service Buildings / control room. The Niches also shall have cable inlets on top. This is necessary to lay the cables from the Niche to the cable tray along the tunnel wall. Switches, push buttons, pilot lamps and measuring instruments shall be installed into the distribution panels' front doors. All electrical equipment, inside a distribution panels / boards shall be labelled. Also, the distribution panels themselves shall be labelled with a combination of letters and numbers, which shall be engraved into an aluminium-plate. Equipment inside the tunnel, measuring instruments, etc. shall be labelled with stainless steel-boards. Each distribution panel shall be provided with a pocket for the drawings, this pocket shall be fixed on the inside of the distribution panel's door (fixed with screws or rivets, the use of glue is not allowed). All distribution panels shall be grounded. Distribution panels shall have lightning arrestors/ surge protection device to protect all facilities from voltages higher than 433 V. All distribution panels, situated in the main tunnel, as well as in the cross passage shall be equipped with anti-condensation heating. Circuit breakers and fuses shall be discriminating to each other facilities (discriminating ratio) in direction of the power / current flow. The contractor is obligated to offer a system which shall be installed without any structural alteration.

### 6.4.10 Central Connection Element:

All control and data cables shall be connected with the central connection element, this shall be a distribution panels equipped with terminals for jumpering the cables and relay units for order multiplexing. All data shall be available at the central connection element, this element shall be at the central data exchange location of the tunnel site (inside niches substation / control room) and the SCADA system shall be connected to this.

### 6.4.11 MAIN LT PANEL & DISTRIBUTION PANELS

All wiring and cabling inside the panels shall be laid in PVC-ducts. All metal parts which are not under voltage shall be pre-treated with an anti-corrosion coating. All incoming and outgoing cables with a cross section equal to or less than 25 mm² shall be based on terminal boards and shall have strain relief devices. For cable centres at distribution panels with degree of protection of IP54 cable glands shall be used.

All cables with larger cross sections shall be directly connected to the particular electrical equipment inside the distribution panels. If the cross section of the cables is although too high for connecting with the electrical equipment, nevertheless terminals for reducing the cross section shall be used. Terminal strips shall be provided with a numbering-system. The strips shall be labelled. All incoming and outgoing cables also shall be labelled (number of cables, starting position and destination).

The internal wiring, cabling and bus bars in the panels and small accessories to follow the function and regulations, like coverings, top-hat rails, C-profiles, PVC-ducts, screwed conduit entries, etc. shall be calculated in the position of the distribution panels. Light-current parts installed in panels shall be suitable for a mounting on top-hat rails or Profiles and respectively in 19 inch racks / as applicable.

Each distributor which will carry electrical equipment, which is provided for mounting at 19" frames, shall have 19" swing frames or 19" fixed frames / as applicable. The height of those frames depend on the height of electrical equipment which shall be installed on it, and the height of distributor. Depending on the thermos technical requirement, the distribution panels shall be equipped with ventilation openings with grids. The degree of protection shall be observed for standards compliance.

The contractor shall provide enough mounting rails for all devices and equipment which shall be installed inside the distribution panels. All equipment shall be accessible.

For cable entries at distribution panels with a degree of protection of IP 54 cable glands shall be used. The Electrical Panels shall be a minimum of Form 4b Type 5 separation in accordance with BS EN 61439-2/IEC 61439-2 for Main LT Panel and Form 3b separation as per IEC 60439 for Distribution panels.

Each distribution panels shall be equipped with 1 lock (incl. key). The lock shall be fixed at 3-points at each door of distribution panels (on the top, on the bottom and in the middle of the doors). The 3 fixed points shall be connected with one rod/ latest version as applicable for distribution panels of reputed manufactures of approved make. The maximum height of panel shall be 2400 mm. with maximum height of operating handle be 1800 mm. from bottom. The termination height shall be 300 mm (minimum).

### 6.4.12 JUNCTION BOX:

Cable junction boxes shall be used for normal and emergency equipment's (lighting, power, control circuit) conforming to IP66 with intrinsic fire resistance & insulation integrity (E90) complete with cable glands suitable for the connected cable.

Application area

- Day time lighting, night-time lighting, accentuating light, inside main tunnel.
- cross passage lighting inside the tunnel.
- Functional integrity E90 junction boxes for fire alarm system.

• Emergency communication or telecom box inside the tunnel.
• Functional integrity E90 junction boxes for operating the emergency exhaust and smoke extractor.
For Lighting, the junction box is required for reducing the cable's cross section, if they are higher than 4 mm2, and for dividing the main supplier cable into the individual single feeders for the lamps. They shall be made for through-wiring in a 3-phase system with maximum wiring diameter of 4mm2, feeder cable to luminaries is a single feeder cable 3x2.5mm2. The lighting cables shall be FRLS with min. functional integrity E30.the junction box shall also be with E90 resistance integrity. The junction boxes shall be equipped with compressed synthetic cable glands suitable for the connected cables.

### 6.4.12.1 JUNCTION BOX SPECIFICATION FOR EMERGENCY EQUIPMENT'S

The junction boxes shall be made of sheet steel material with IK 10 impact resistance having no toxic or corrosive resistance. The junction box shall comply and test certificates for intrinsic fire resistance accordance with DIN 4102 part 12 together with function retaining cables. The junction box shall comply to IEC 60670-22 for requirement, as per connecting boxes & enclosures. The JB shall be complete with screw anchors for external wall fixing and connecting terminals made of high grade ceramic and resistant to high temperature. The sheet steel junction box shall be power coated & suitable earthed.
Supply of **IP 66** cable boxes for emergency equipment (lighting, power and control circuits). The junction's boxes shall be made of Sheet **Steel Powder Coated material** and shall be Orange in colour **RAL 2003** having no toxic or corrosive emissions. The junction box shall comply and shall be tested for **intrinsic fire resistance accordance DIN 4102 part 12 (German standard)** together with function-retaining cables of 1.5 sq. mm to 16 sq. mm as specified. The junction box shall comply to **IEC 60670-22** for particular requirements for connecting
boxes and enclosures. **The insulation integrity E90 of the boxes shall be BS EN 50200**. The junction boxes shall have included screw anchors for external wall fixing and connecting terminals shall be made of high grade ceramic and shall be resistant to high temperatures E90 and cable entries shall be with metric system.

The terminals will be 5 pole and shall be suitable for 1.5 sq. mm upto 16 sq. mm cable sizes, multi-level knockouts shall be provided for cable glands in different sizes. The material of construction used shall be free of halogen and junction box shall be insulated and shock-proof. In case of sheet steel, power coated, the box shall be suitably earthed. The junction boxes shall be used only with type tested cables for the functional integrity class E90 (Tested with cables of approved make). The entire solution shall be tested in accordance with DIN 4102 part 12 for functional integrity and EN50200 for insulation integrity and the vendor shall submit the test report/certificate for the product from Exova laboratories or equivalent institute for fire safety.

### 6.4.12.1.1 TECHNICAL DATASHEET FOR EMERGENCY JUNCTION BOXES

| | |
|---|---|
| Materials | Sheet Steel |
| Degree of Protection | IP66 |
| Degree of protection against mechanical load | IK 10 |
| Fire Protection in the event of internal faults | Minimum requirements:<br>-Intrinsic Fire resistance accordance with DIN 4102 part 12 together with function retaining cables.<br>- 650°C for boxes & cable glands<br>- 860°C for conducting components |
| Burning behavior | - Junction Box shall comply to IEC 60670-22<br>- Insulation integrity E90 of the boxes shall be BS EN 50200<br>- Intrinsic fire resistance / fire rated & insulation integrity (E90) |
| Toxic behavior | Halogen free, Silicon free, conform to RoHS directive 2002/95/EC |

| | |
|---|---|
| Chemical resistant | Acid, Lye, Petrol, Mineral Oil & partially resistant from Benzene |
| Rated Insulated Voltage | AC/DC 690V |
| Connecting Terminals | High grade ceramic resistant to high temperatures |
| Terminals | 5 pole |
| Cable entries | Shall have option for cable plate |
| Protection Class | Class II, totally insulated |
| Type test certificate | Comply to IEC 60670-22 as per connecting boxes & enclosures |
| Mounting Type | Wall / floor mounting. |

### 6.4.12.2 JUNCTION BOX SPECIFICATION FOR NORMAL EQUIPMENT :-

The Junction Box shall be insulated and made out of Polycarbonate with glass fibre reinforced. The Polycarbonate Junction Box shall be environment friendly, recyclable, UV resistant, halogen & silicon free, anti-acid & anti corrosive. The Junction Box shall be rated for Degree of Ingress Protection IP66 in accordance with IEC 60529. The gasket material shall be Polyurethane and the gasket shall be internally embedded. The JBs shall be complying the standards IEC 60670 – 1, IEC 60670 – 22 &
IS-13252. The manufacturer of Junction Box / Enclosure shall submit a copy of IEC Certificate.
For better safety the Polycarbonate encl. shall be fire retardant & self-extinguishing in accordance with IEC 60 695-2-1, DIN VDE 0304 Part 3. It should be tested at Glow Wire test for 960 deg. Cent. The impact strength of polycarbonate enclosures / boards i.e. the Degree of Protection against Mechanical load shall be in accordance with EN 62208: 2012
for IK 09. **Cable junction boxes with intrinsic fire resistance / fire rated & insulation integrity (E90).**

#### 6.4.12.2.1 TECHNICAL DATASHEET FOR NORMAL JUNCTION BOXES

| | |
|---|---|
| Materials | Thermoplastic Polycarbonate (PC-GFS) |
| Gasket | Internally embedded made of Polyurethane |
| Degree of Protection | IP66 |
| Fire Protection in the event of internal faults | Minimum requirements: - Glow wire test in accordance with IEC 60 695- 2-11- UL Subject 94, IS-11000<br><br>- 650°C for boxes & cable glands<br>- 860°C for conducting components |
| Burning behaviour | - Glow wire test in accordance with IEC 60 695- 2-UL Subject 94 at 960°C, flame retardant &self-extinguishing. |
| Degree of protection against mechanical load | IK 09 (10 Joule) |
| Toxic behaviour | Halogen free, Silicon free, conform to RoHS directive 2002/95/EC |
| Temperature resistant | -40°C to +120°C |
| Chemical resistant | Acid, Lye, Petrol, Mineral Oil & partially resistant from Benzene |
| Rated Insulated Voltage | AC/DC 690V |
| Cable entries | Shall have option for cable plate |
| Protection Class | Class II, totally insulated |

| | |
|---|---|
| Type test certificate | Should hold type test certificate with switchgear assemblies (TTA), according to IEC 60 439-1 (IS 8623) |
| Mounting Type | Wall / floor mounting. |

### 6.4.13 NETWORK PANELS

These Panels carry the components for network. The Network panels, installed inside the tunnel, are made of stainless steel of 316L grade. The dimensions of Network panels are as per standard or as per site conditions requirement for those situated in the Control Centre. The Network Panels will have a single door, to have only front accessibility for the Network equipment's installed. The Network Panels also have front panels made of glass, to see the electrical equipment inside. These will comply to IS standards.

6.4.13.1 **CIRCUIT BREAKER:** Circuit breakers shall have a rated breaking capacity of at least 36 kA / 50 kA at 433 VAC and a current limiting class 3. Some shall be executed inclusive switched neutral conductor (+N).

**Residual-Current-Operated Circuit-Breaker:** They shall be alternating current sensitive;
surge-proved up to 36kA / 50 Ka.
**Residual-Current-Operated Circuit-Breaker with Integral Overcurrent Protection:** They shall be alternating current sensitive; surge-proved up to 36kA/ 50kA; 2 or 4-pole switched and at least 1 or 3-pole protected (2 pole or 4 pole).

### 6.4.13.2 AIR CIRCUIT BREAKER

a. ACB should be mechanically robust of compact moulded case design, air break horizontal and withdrawable type, conforming to IS / IEC / BS EN 60947-2. 24-240 V A.C shunt-trip coil shall be operable, within operational voltage range of 70% to 110% of rated voltage as per Clause 7.2.1.3 of IEC 60947-1.

b) Maximum number of circuit breaker auxiliary switches, spare auxiliary switches to be equally divided between normally open and normally closed. Additionally, 4 spare pairs of N.O. and N.C. volt free contacts shall be provided.

c) Indicating lamps for on, off, ready to close, tripped on fault with all necessary push buttons, panel wiring, bus wiring, terminals, fuses, etc.

d) Power and control cable terminals with undrilled gland plates for outgoing power cables and multi-core cables.

e) An interlock to prevent withdrawal when the breaker is closed.

f) The automatic control shall be defeated when the selector switch is put at local or OFF position as per requirement.

g) Remote indication and alarm facilities shall be provided for Circuit-breaker open, Circuit-breaker closed, Circuit Breaker is ready to close (UV release energized, Shunt release de-energized, spring charged, Breaker is not "ON", Breaker is not mechanically interlocked with other breaker and ACB is not racked in completely in service position) and Circuit-breaker tripped on fault.

h) Automatic changeover and interlocking with the help of an external controller.
i) Operation of emergency push button.

### 6.4.13.3 MOULDED CASE CIRCUIT BREAKERS (MCCB)

Moulded case circuit breakers shall be in accordance with IS: 2516 (Pt-I&II)/1977, IEC 60947, IEC 60664, IEC 61557-12 with degree of protection IP 20 and shall be of microprocessor based release having a quick break, quick make trips free mechanism and according to the relevant standards, which were mentioned herein. The electronic trip shall be adjustable.

The operating switch dolly shall provide a clear indication of "ON", "OFF" and "TRIPPED" positions and shall have provision for locking in the "OFF" position. They shall be equipped with time delay tripping on low overloads and high speed tripping on short circuits. Contacts shall be tipped and shall have a quick break and quick make wiping action. The case shall be moulded in non-hygroscopic material of arc resisting characteristics and shall incorporated- ionising type arc chutes.

MCCBs shall comprise a device, designed to trip the circuit-breaker in the event of high value short-circuit currents. This device shall be independent of the thermal-magnetic or electronic trip unit. The breaking will be carried out in less than 10ms for short-circuit currents above 25 In. MCCBs with ratings up to 250 A shall be equipped with fully interchangeable trip units in order to ensure the protection against overcharge and short-circuit. The trip units shall be either of:

a. thermal-magnetic
b. electronic

MCCBs with ratings over 250 A shall be equipped with electronic trip units. Electronic and thermal-magnetic trip units shall be adjustable and it shall be possible to fit lead seals to prevent unauthorised access to the settings

Thermo-magnetic trip units shall offer:

a. Adjustable Thermal protection from 0.7 to 1.0 times the current rating.
b. Fixed Magnetic protection for current ratings up to 200A.
c. Adjustable (from 5 to10 times the current rating) for current ratings greater than 200A.
d. Adjustable (from 9 (or less) to 14 times) the current rating for magnetic only motor protection.

Electronic trip units shall offer:

a. Electronic trip units shall be fitted with thermal memory
b. It shall be possible to adjust basic protections with a knob without any power supply or when the main is off.
c. It shall consist 2 LED for load indication, one lighted above 90% of Ir, and one lighted above 105% of Ir.
d. A test connector shall be installed for checks on electronic and tripping mechanism operation using an external device.
e. MCCBs shall be equipped with a self-test of the connection between the electronic trip unit, the current transformers and the actuator. The self-test will be of positive logic and visible through the flashing of a green LED in case the self-test occurred correctly and the extinction of the LED in case the self-test failed.

Each moulded case circuit breaker shall be equipped with auxiliary contacts to monitor its control state. An accumulated fault alarm (one per system, e.g. lighting, ventilation, etc.) shall be handed over to the SCADA system via local distributed unit and further to the PLC.

#### 6.4.13.4 MINIATURE CIRCUIT BREAKERS (MCB)

Miniature circuit breakers shall be in accordance with a degree of protection IP 20 and shall be of magnetic and thermal trip type and according to the relevant standards of IEC 60898, IEC 60947, which were mentioned herein. For arc quenching, the breakers shall be equipped with magnetic blow out contacts.

Each miniature circuit breaker shall be equipped with an auxiliary contact to monitor its control state. An accumulated fault alarm (one per system, for example lighting, ventilation, etc.) shall be handed over to the SCADA system via local distributed unit and further to the PLC.

### 6.4.14 COMMUNICATION WITH CONTROL CENTRE

Following signals and control states shall be transmitted to the Control Centre by use of the Tele control system (SCADA). Therefore, all these signals and control states shall be based in / at the central connection element. Signals and control states to be transmitted are:

a. Tripping of any isolating circuit breaker, moulded circuit breaker or miniature automatic circuit breaker, combined to one signal per network for niches substation / E & M Niches / E & M NICHEs (one signal for each distribution point and one for each network) for following but not limited to:
b. Breakdown of the main power supply
c. Power supply from the UPS
d. Failure of the UPS
e. Actual active power (kW) at the niche's substation / E & M NICHEs/ control room
f. Transformers secondary voltage
g. Cumulative fuse tripping
h. as per data points (I / O points approved by Engineer).

**Note: -The tunnel is situated in an area highly endangered by lightning and unstable power supply is expected. Therefore, all the electrical equipment installed shall have Over voltage protection, Under Voltage Protection and surge voltage protection as per standard and requirement.**

## 6.5 PLUG SOCKETS & MAINTENANCE SOCKETS CABINET

The cabin of the plug sockets its size shall be about 200 x 178 mm (width x height) or as per drg. The depth is about 150 mm or as per standard. The used material shall be stainless steel, material no. 1.4401, high quality stainless steel equivalent to SS-316L, degree of protection min IP 65. The Power Socket shall be made of High quality Thermoplastic Polycarbonate (rust free, shock proof, corrosion free, fire retardant) with IP-67 protection, contact terminals made of high quality copper alloy (brass) & all steel components (screws, springs, etc.) shall be zinc plated or nickel plated. The socket outlets shall be compatible to the rescue and maintenance equipment. Power sockets also shall be provided for emergency and maintenance. These plug sockets shall consist of power sockets and standard electrical sockets. The power socket shall be supplied by standard power**.** In the Access-Tunnel, the plug socket and maintenance cabinets are different to those cabinets in the main tunnel tube. The ones in the Accesses shall not be equipped with plug sockets. These cabinets only shall provide space for spare / reserve.

### 6.5.1 CABIN FOR PLUG SOCKETS, MOUNTED ON TUNNEL WALL

Housing: 260 mm x 210 mm x 168 mm (w x h x d) (max)

Material: Polycarbonate / Stainless steel Protection Class: min IP 65

The Maintenance Power Sockets should hold type test certificates as per IEC 60309, EN60529, DIN 4102-12. The Socket assembly should consist of proper Insulation bolt, Stainless steel screws / bolts and fasteners, MCB, Hinged Flap (optional), along with wiring accessories, Earth strips, Sleeves, etc. of standard specifications.

Single Phase Maintenance power socket should consist of 16 A DP 10 kA MCB with allowable cable sizing of 3Cx4 Sq.mm cable. Three Phase Maintenance Power Socket should consist of 16A FP 10 kA MCB with allowable cable sizing of 4Cx4 Sq.mm cable.

Allowable number of single phase sockets shall be 4 nos. and three phase sockets shall be 2 nos. per circuit or as per standard.

## 6.6 UNINTERRUPTIBLE POWER SUPPLY SYSTEM (EMERGENCY POWER SUPPLY SYSTEM): -

This covers the emergency power supply of all required equipment, materials, accessories, and all labour for the complete emergency power installation. All data required by the Control Centre shall be based at the central connection element.

### 6.6.1 UNINTERRUPTIBLE POWER SUPPLY

The UPS units (Uninterruptible power supply) will be installed with two hours (120 minutes) autonomy period as required to guarantee that following plants/ equipments can be supplied power in case of main power failure:

a. Tunnel emergency lighting
b. Emergency call system
c. Signs, escape route lighting and orientation signage, other sign guidance
d. Public address & sound system (if Available)
e. Integrated tunnel control system (SCADA)
f. Other emergency requirement
g. Fire detection and fire alarm system

The UPS system will be complete with inverter battery bank, rectifier charging unit, inverter units, protective devices, filter circuits, system static transfer switches/by pass switches, auxiliary equipments etc. All the characteristics of UPS (like THD, overload, etc.) shall be as per IEC/EN 62040.

The UPS has to be fed from the main power supply (433 V, 50 Hz) and shall supply the connected equipment via rectifier, battery and inverter.

In the event of a main power supply failure the equipment has to be fed from the battery and inverter system without any interruption.

The UPS shall be equipped inclusive bypass switch and an interface for Tele control System/ SCADA.

### 6.6.2 TECHNICAL SPECIFICATION (UPS COMPONENTS) BATTERY BANK

#### 6.6.2.1 BATTERIES:

Sealed Maintenance-free (SMF) Lead-Acid Power Battery Voltage as required by the UPS-system. The battery capacity at all locations shall ensure supplying the full load for at least 120 minutes with elevated temperatures up to 40 Deg C. Batteries shall be of rugged design in order to provide a heavy-duty operation of at least 5 years with low internal resistance and minimal maintenance with minimal ventilation. Operational temperature range: + -5° to + 40° C with humidity up to 95% non-condensing

#### 6.6.2.2 INTERCONNECTION BUS BARS:

The bus bars shall be made of copper according to the relevant standards, which were mentioned herein. Suitable size to provide a minimum voltage drop PVC clad to provide protection against accidental contact.

#### 6.6.2.3 BATTERY STANDS / RACKS:

The batteries at the niches S/S & control room shall be mounted on steel racks to provide a compact arrangement, with easy installation and access for servicing.
The racks shall be made of steel with electro statically deposited powder coating.
The coating shall be resistant against acid, saline and highly resistant against scratching and / or impact. All other required materials shall be highly resistant against environmental conditions as
experienced in battery rooms .an electric ventilation and climate shall ventilate the battery room in niches substation/ control room as applicable. The complete air shall be changed a minimum of six times per hour.
The ventilation has to be realized with all required facilities like ducts, louvers, installation of the fan with a switch beside the door. All wall ducts shall be closed and covered after the ventilation is installed. The ventilation to comply with international / IS standards as per site requirements.

### 6.6.2.4 RECTIFIER / CHARGER UNIT

This unit has to be equipped with output current limiting, whereby the maximum output current shall be limited to 125 % of the nominal output current rating. The UPS unit shall have ammeter and voltmeters to indicate both charging and mains current / voltage and amps meter to indicate rate of charge and discharge of batteries. This current limit shall be adjustable from 100 % up to 125 %.

The output filter shall minimize the ripple of the current in the batteries. Under normal conditions the ripple of the current in the battery shall comply to 3 % RMS.

The filter shall be adequate to ensure that the DC output of each rectifier / charger shall meet the input requirements of the inverter.

The UPS shall have the capability of operating the inverter directly from the rectifier with the batteries being disconnected.

Quick charging equipment shall be capable of charging fully discharged batteries within six hours.

Input: 433 VAC, 3-phase, 4 wire, 50 Hz +/- 2 %

INVERTER UNIT

Input: Output from the rectifier / charger unit (batteries).

Output: 433/ 240 V sinusoidal AC.

Maximum of total harmonic distortion: +/- 1 % at power factor 1 from No-load operation to full load. 50 Hz +/- 1 % at power factor 1 from no-load to full load.

Maximum dynamic Voltage deviation: +/- 5 % during power failure +/- 10 % during major load change Recovery to a maximum deviation of +/- 3 % within 50 ms and to+/- 1 % within 100 ms.

Total harmonic Distortion: 2.5 % maximum

The rectifier shall be able to operate 10 minutes at 125 % overload at unity power factor after the working temperature has been stabilized at the nominal workload. Under normal conditions, the surrounding temperature will not exceed + 25 °C. A self-protecting current limiting circuit shall limit the inverter output to 125 % of the rated load or respectively in case of a short circuit. UPS system should consist of integrated Surge protection circuit.

Constant synchronisation of the oscillator shall define the converter frequency and its stability during stand-alone operation. During normal operation, the inverter shall be synchronised by the main supply. In case of mains failure or frequency-deviation larger than +2 % / -1 %, the inverter shall automatically switch-over to its interior oscillator.

Upon return of main supply, resynchronisation shall be started automatically. Resynchronisation at full load and / or full voltage shall be achieved within 30 seconds.

The deviation from 50 Hz shall never exceed +/- 1 Hz. The power semiconductors of the inverter shall be fused with fast blowing fuses to prevent cascading failures.

Each fuse shall be controlled by fuse monitoring circuit leading to an indicator light on the UPS's control panel as well as to a common fault indication.

### 6.6.2.5 PROTECTIVE DEVICES AND FILTER CIRCUITS

A DC (direct current) smoothing equipment shall enable the system to achieve a total harmonic distortion, which isn't larger than 2.5 % RMS of the output. Protective devices shall avoid any damage or failure on the UPS caused by excessive overload, short circuits, surges, high voltages caused by lightning activity and/or other conditions.

### 6.6.2.6 DC CIRCUIT BREAKER

The UPS shall contain a DC circuit breaker. If open, the battery shall be completely disconnected from the rectifier / charger and the inverter.

### 6.6.2.7 SYSTEM BYPASS SWITCH

The UPS system shall be by-passed automatically in case of overload.
The static switch detection and transfer time shall not exceed 5 ms.

### 6.6.2.8 STATIC TRANSFER SWITCH

The static transfer switch shall be equipped with a manual selector switch to allow manually controlled switching between the UPS and the bypass source for maintenance and service purposes. The static transfer switch shall be rated higher (power, respectively current) than the inverter current limiting rate and shall have a short circuit current and time rating equivalent to the fault level of the bypass source at the static transfer switch. Control interlocks shall be provided in order to prevent the inverter from being manually switched back to the essential bus (main power) without synchronisation.

### 6.6.2.9 ISOLATING TRANSFORMER

In-built Isolation transformers should be provided for galvanic isolation and are used to protect against electric shock, to suppress electrical noise in sensitive devices, or to transfer power between two circuits which must not be connected.

### 6.6.2.10 AUXILIARY EQUIPMENT

a. Emergency flash light with battery charger installed in the battery room.
b. All facilities required for handling of acids and gasses.
c. Warning notices concerning the handling of the whole UPS system in English and Hindi language.
d. Working instructions for UPS Warning notices and working instructions shall be in two separate and properly indicated pockets on the inside of the UPS switchboard as well inside the battery room. Cable dimensioning shall be in accordance to the relevant

standards and shall have a diameter that the voltage drop is not more than 4 % to the nominal voltage from the transformer to the furthest supplied electrical facility. Also, the cables shall have such a diameter that, if there is a short circuit at the furthest point to the circuit breaker, the circuit breaker cuts off without the cable exceeding its rated temperature.

### 6.6.2.11 MAINTENANCE

The emergency power supply shall be designed for continuous reliable operation such that the "Mean-Time-Between-Failures" (MTBF) for individual modules of the UPS through the rectifier / charger unit, inverter unit and static switch etc., shall be more than 80 000 hours. To ensure a minimum down-time, the "Mean-Time-To-Repair "(MTTR) of the emergency power supply shall not exceed 24 hours for the UPS.
The MTTR shall be the time, excluding travel time, required to diagnose the fault and restore the emergency power supply to normal working condition by means of modular replacement at the tunnel site. The travel time must not exceed 12 hours to keep down time to bare minimum.

### 6.6.2.12 TECHNICAL DATASHEET FOR UPS (10 kVA & 20 kVA)

| | SPECIFICATIONS | REQUIREMENT |
|---|---|---|
| 1 | **TECHNOLOGY & CAPABILITY** | |
| | UPS should have its own DSP controller and contains a full rated rectifier, full rated inverter and battery charging circuit | |
| | UPS should be with inbuilt Isolators for Input, Output, static & maintenance bypass. | |
| | There should be isolating transformer at UPS output. | |
| | Integrated Surge Arrestor must be included in UPS system. | |

| | | |
|---|---|---|
| 2 | **INPUT** | |
| | Input facility -Phases / Wires | 3-Phase / 4-Wire & Ground (R, Y, B -Phases & Neutral + Ground) |
| | Input Voltage | 433 V AC |
| | Nominal Input Frequency | 50 Hz |
| | Input Frequency | 50 Hz ±10% |
| | Input Power Factor | 0.9 on rated load |
| | Generator Compatibility | Compatibility to genset supply required |
| 3 | **OUTPUT** | |
| | Nominal Output Voltage | 380 / 400 / 433V AC (Selectable) |
| | Output Voltage Regulation | +/- 1% |
| | Nominal Output Frequency | 50 Hz |

| | | |
|---|---|---|
| | Output Frequency Regulation | +/- 0.05 Hz (Free Running / Self Clocked Mode)<br>+ / - 5 % (Synchronized to Mains Mode, Selectable) |
| | Output Frequency Slew Rate | 1 Hz / s |
| | Output Wave Form | Pure sine wave |
| | Output Voltage Distortion | <=2.5% (For 100% Linear)<br><= 5 % (For 100% Non-Linear) |
| | Crest Factor | 3: 1 On Full Load |
| | Unbalanced load on phases | 100% unbalanced load should be allowed |
| | Voltage symmetry with 100% Unbalanced Load | +/- 2 % |
| | Displacement angle for 100% balanced Load | 120 deg +/- 2 deg |
| | Transient Response / Recovery | |
| | Dynamic Regulation for 0% to 90% step load | +/- 5 % |
| 4 | EFFICIENCY (at nominal voltage & Resistive load upto KW rating of UPS | |
| | Overall Efficiency (AC to AC) – Online | >85 % @ 100 % load |
| 5 | Alarms | |
| | Audible Alarms | Mains Failure / Battery Low Alarm / UPS Overload / Fault / Shutdown / Charger Fails Alarm / Battery High / Battery Temperature<br>Cut off Alarm |
| 6 | Battery Backup / Battery Bank & Charger | |
| | Backup Required | hours (120 min) |
| | Battery Bank V Ah (Vendor to include battery sizing calculations with tender) | |
| | Batteries Type | Inbuilt Sealed Maintenance Free (SMF)<br>Lead-Acid batteries- 12V Cells |
| | Minimum Charger Rating (Including internal / external) | 10% of Battery Ah rating offered |
| hanger type / Charging Method & Charging Voltages | | Constant Voltage Constant Current Solid state SMPS charger designed for at least 10% of Battery Ah offered Float Voltage: |

| | |
|---|---|
| | 2.25 VPC Boost Voltage: 2.32 VPC |
| Battery recharge time (After complete discharge) to 90% capacity | 8 to 10 hours to 90% capacity |
| Quick Charge System | 6 Hours after complete discharge of system (optional) |
| Battery Housing (Vendor to provide the GA drawings of the offered Battery open Rack) | |
| Battery End Cell Voltage | 1.7 V / Cell |
| Interfaces | |
| Serial Communication Port | RS232: Should be provided as standard |
| REPO (Remote Emergency Power Off) | Provided in-built in the UPS |
| Interface to SCADA System | Modbus Card for connecting to UPS to SCADA through RS485 & monitoring thru SCADA |
| Restart / Testing Capability | |
| Automatic Restart | UPS should start up automatically on mains resumption after battery low shutdown |
| Battery Self-Test | Manual / Scheduled battery test to ensure healthiness of batteries. However, in event of weak batteries, test should be aborted and fault reported to the user thru replace battery warning |
| Physical | |
| Operating Temperature | 0 to 40 deg C |
| Storage Temperature | -25 to 55 deg C |
| Operating Humidity | 0 to 95% RH (Non-condensing) |
| Ambient Relative Humidity | 20% to 80% |
| Operating Altitude | < 1000 m above sea level |
| Protection Class | IP – 20 |
| Type of Cooling | Forced Air |
| Noise Level | < 65 dbA at I meter distance |

| | |
|---|---|
| Form Factor | Free Standing Floor Mounted UPS |
| Dimension (w x d x h) in mm | To be furnished by the vendor |
| Weight - in kg | To be furnished by the vendor |
| Packaging Material | Recyclable (No CFC) |
| Connections - Rectifier Input / Output / Bypass Input / Battery | Hardwired |
| Conformity and Standards | |
| General and safety requirements for UPS used in operator access areas | EN50091-1-1/IEC62040-1-1/AS 62040-1- 1/IS-16242 (Part-1):2014 |
| Electromagnetic compatibility (EMC) requirements for UPS | EN50091-2/IEC62040-2/AS 62040-2 (C3) /IS-16242 (Part-1):2014 |
| Method of specifying the performance and test requirements of UPS | EN50091-3/IEC62040-3/AS 62040-3 (VFI SS 111) /IS-16242 (Part-1):2014 |

## 6.6.2.13 TECHNICAL DATASHEET FOR UPS (80 kVA)

| | SPECIFICATIONS | REQUIREMENT |
|---|---|---|
| 1 | **TECHNOLOGY & CAPABILITY** | |
| | UPS should have its own DSP controller and contains a full rated rectifier, full rated inverter and battery charging circuit | |
| | UPS should be with inbuilt Isolators for Input, Output, static & maintenance bypass. | |
| | There should be isolating transformer at UPS output. | |
| | Integrated Surge Arrestor must be included in UPS system. | |
| 2 | **INPUT** | |
| | Input facility -Phases / Wires | 3-Phase / 4-Wire & Ground (R, Y, B - Phases & Neutral + Ground) |
| | Input Voltage | 433 V AC |
| | Nominal Input Frequency | 50 Hz |
| | Input Frequency | 50 Hz ±10% |
| | Input Power Factor | 0.9 on rated load |
| | Generator Compatibility | Compatibility to genset supply required |
| 3 | **OUTPUT** | |
| | Nominal Output Voltage | 380 / 400 / 433V AC **(Selectable)** |
| | Output Voltage Regulation | +/- 1% |
| | Nominal Output Frequency | 50 Hz |

| | | |
|---|---|---|
| | Output Frequency Regulation | +/- 0.05 Hz (Free Running / Self Clocked Mode)<br>+ / - 5 % (Synchronized to Mains Mode, Selectable) |
| | Output Frequency Slew Rate | 1 Hz / s |
| | Output Wave Form | Pure sine wave |
| | Output Voltage Distortion | <=2.5% (For 100% Linear)<br><= 5 % (For 100% Non-Linear) |
| | Crest Factor | 3: 1 On Full Load |

| | | |
|---|---|---|
| | Unbalanced load on phases | 100% unbalanced load should be allowed |
| | Voltage symmetry with 100% Unbalanced Load | +/- 2 % |
| | Displacement angle for 100% balanced Load | 120 deg +/- 2 deg |
| 4 | **Transient Response / Recovery** | |
| | Dynamic Regulation for 0% to 90% step load | +/- 5 % |
| 5 | **EFFICIENCY (at nominal voltage & Resistive load up to KW rating of UPS** | |
| | Overall Efficiency (AC to AC) – Online | >85 % @ 100 % load |
| 6 | **Alarms** | |
| | Audible Alarms | Mains Failure / Battery Low Alarm / UPS Overload / Fault / Shutdown / Charger Fails Alarm / Battery High / Battery Temperature Cut off Alarm |
| 7 | **Battery Backup / Battery Bank & Charger** | |
| | Backup Required | hours (120**min**) |
| | Battery Bank V Ah (Vendorto include battery sizing calculations with tender) | |
| | Batteries Type | Inbuilt Sealed Maintenance Free (SMF) Lead-Acid batteries- 12V Cells |
| | Minimum Charger Rating(Including internal / external) | 10% of Battery Ah rating offered |
| | Charger type / Charging Method & Charging Voltages | **Constant Voltage Constant Current** Solid state **SMPS** charger designed for at least 10% of Battery Ah offered Float Voltage: 2.25 VPC Boost Voltage: 2.32 VPC |
| | Battery recharge time (Aftercomplete discharge) to 90% capacity | 8 to 10 hours to 90% capacity |
| | Quick Charge System | 6 Hours after complete discharge of system (optional) |

| | | |
|---|---|---|
| | Battery Housing (Vendor to provide the GA drawings of the offered Battery open Rack) | |
| | Battery End Cell Voltage | 1.7 V / Cell |
| 8 | **Interfaces** | |
| | Serial Communication Port | RS232: Should be provided as standard |
| | REPO (Remote EmergencyPower Off) | Provided in-built in the UPS |
| | Interface to SCADA System | Modbus Card for connecting to UPS compatible to SCADA |

| | | |
|---|---|---|
| 9 | **Restart / Testing Capability** | |
| | Automatic Restart | UPS should start up automatically on mains resumption after battery low shutdown |
| | Battery Self-Test | Manual / Scheduled battery test to ensure healthiness of batteries. However, in event of weak batteries, test should be aborted and fault reported to the user thru replace battery warning |
| 10 | **Physical** | |
| | Operating Temperature | 0 to 40 deg C |
| | Storage Temperature | -25 to 55 deg C |
| | Operating Humidity | 0 to **95**% RH (Non-condensing) |
| | Ambient Relative Humidity | 20% to 80% |
| | Operating Altitude | < 1000 m above sea level |
| | Protection Class | IP – 20 |
| | Type of Cooling | Forced Air |
| | Noise Level | < 65 dbA at I meter distance |
| | Form Factor | Free Standing Floor Mounted UPS |
| | Dimension (w x d x h) in mm | To be furnished by the vendor |
| | Weight - in kg | To be furnished by the vendor |
| | Packaging Material | Recyclable (No CFC) |
| | Connections - Rectifier Input / Output / Bypass Input / Battery | Hardwired |
| 11 | **Conformity and Standards** | |
| | General and safety requirements for UPS used in operator access areas | EN50091-1-1/IEC62040-1-1/AS 62040-1-1/IS-16242 (Part-1):2014 |
| | Electromagnetic compatibility (EMC) requirements for UPS | EN50091-2/IEC62040-2/AS 62040-2 (C3) /IS-16242 (Part-1):2014 |
| | Method of specifying the performance and test requirements of UPS | EN50091-3/IEC62040-3/AS 62040-3 (VFI SS 111) /IS-16242 (Part-1):2014 |

## 6.7 Escape Route Orientation sign and Fire Extinguisher glow signage

These signs indicate the escapees the direction of escape route into the cross passage or out of the tunnel. Those signs shall be mounted at both sides of the main tunnel. The signs shall fulfil following conditions: -
Degree of protection: min. IP 65
Protection class: II
Static symbol: LED≥ 200 cd/m2
Dynamic symbol: LED with minimum 5 arrows for each direction

The escape route indication is giving escape route orientation with signs which are installed throughout the entire tunnel and shall increase the level of visibility of the escape route during fire.

Therefore, the escape route orientation signs shall be mounted in a distance of 50 meters or as per standard on both tunnel walls (next to the railway track and walkway path) throughout the tunnel at a height (lower edge) of 1 m above the path respectively the rail track.

The escape route indication shall consist of two parts; the upper part is a static sign which is illuminated by LED-lamps and shows an escaping person. The lower part of the sign shows flashing LED-arrows which shall display the direction (north or south) of the escape route by flashing.

Dimensions of the static symbol (h x w), approx.: 400 x 400 x 80 mm (h x w x d)
Dimensions of the LED symbol (h x w), approx.: 150 x 400 x 80 mm (h x w x d)
The dimensions are approx. values only; they can vary depending on the manufacturer.
The luminance of the static part of the symbol shall be ≥ 200cd/m2.

The controlling of the escape route orientation signs shall be realized by a main control unit. This control unit shall be placed in the control room.

In emergency case the distributed I/O Unit in the control Room shall transmit the data to the Escape Route Orientation Sign Control Unit (EROSCU), which shall switch on the signs with the correct direction. Every escape route orientation sign shall be adjusted separately with determined patterns. For example, when the pattern "one" will be activated, all signs will be switched on and the LED symbols shall display the direction "right". The pattern "two" indicates the direction "left". The escape route orientation signs also shall have the function of indicating both directions simultaneous. The contractor shall design the program of the sign in accordance with Engineer. (when/ which directions are shown).
The data connection from the EROSCU to the signs shall be realized by OFC (optical fibre cabling).

### 6.7.1 ESCAPE ROUTE SIGNS

The illuminated signs (escape route orientation-, emergency- and escape route sign) shall be illuminated with LEDs.

a) Degree of protection: IP 65
b) Luminance: ≥200 cd/m2
c) Housing material: Stainless steel (material No. 1.4401 = "AISI 316"), thickness 2 mm, with powder coating. The swing-out bezel shall be fixed with hinges made of stainless steel
d) Support: Stainless steel (material No. 1.4401)

### 6.7.2 EMERGENCY SIGN

This sign indicates the people the situation of an emergency telephone. Those signs shall be mounted above the E & M NICHEs and panels.
The signs shall fulfil following conditions:

a) Degree of protection: min. IP65
b) Protection class: II
c) Static symbol: LED ≥ 200 cd/m2
d) Dimensions: approx. 470 mm x 470 mm
e) Front sheeting: on both side(s) 3 mm Acryl glass with emergency telephone
f) Symbol, dimensions and colours according to Indian standards.

### 6.7.3 Visibility Sensors

Visibility is monitored in Infrared units with necessary reflector which monitor the density of smoke between the IRU and the reflector.it indicates the % level/status of visibility to present values on SCADA station. Alarm will sound in the control room along with indication when visibility falls below the present prescribed limit.

#### 6.7.3.1 Technical Data of Visibility Sensors

**a) Features Parameters**

i. Measuring units' ppm for CO & NO, m-1 or m for visibility
ii. Path Length - 3m (6m folded beam)
iii. Calibration - Automatic zero calibration - manual span check by check cell
iv. Measurement - Visibility (Opacity)
v. Measurement Technique – Optical Transmissivity
vi. Measurement range - 0.015 m-1
vii. Accuracy - ± 0.0002 m-1
viii. Resolution -- ± 0.0001 m-1
ix. Response Time - 10 sec to 2 min.

x. Analogue outputs - 3 x 4-20mA current outputs as standard, isolated, 500Ω maximum load.
xi. Relay Outputs - 3 x volt-free SPCO contacts, 50V/1A maximum load, configurable as alarm contacts
xii. Communications Port - RS485 interface
xiii. Power supply - to be derived from available UPS supply

xiv. Construction - Corrosion resistant epoxy coated aluminium housing sealed to IP65

**b) Calibration Accessories:**

Flow Through Check Cell - CO/NO span check using bottled audit gases
Check Cell - Visibility span check optical cell

c) **Temperature Sensors:** -Tunnel temperature monitoring equipment are used for monitoring the tunnel ambient temperature with sensors placed at suitable locations inside the tunnel. When the tunnel ambient temperature rises beyond a pre-set limit (>40$^{o}$C), an audio-visual alarm shall be activated in the control room as per site requirement.

## 6.8 SITC OF STAINLESS STEEL CABLE TRAY (LADDER AND PERFORATED TYPE) : -

The cable tray in the tunnels will mainly be used to carry the power cabling of the tunnel's safety equipment. If necessary, also the control cabling of safety equipment shall be laid in the cable tray. Following size of cable tray will be in the scope of work but not limited to: -

**6.8.1 SITC of Stainless Steel Cable Tray for HT and LT cables, Ladder type of size 150 x 50 x 2 mm thick**, wall mounted on suitable supporting arrangement, throughout the tunnel and both side of wall tunnel made of material no. 1.4404, continuously connected including reducers, tees, coupling plate and nut bolts, washers, etc. made of stainless steel material no. 1.4401 conforming to specifications complete as per requirement.

**6.8.2 SITC of Stainless Steel Cable Tray for Lighting cables, Perforated type of size 150 x 50 x 2 mm thick,** wall mounted on both sides on suitable supporting arrangement, throughout the tunnel, made of material no. 1.4404, continuously connected including reducers, tees, coupling plate and nut bolts, washers, etc. made of stainless steel material no. 1.4401 conforming to specifications complete as required, as per the specification.

The cable tray shall be mounted on the tunnel wall, next to the walkway path side. In front of the EM-Niches, the cable tray shall be mounted on the ceiling (height of down-hanging between 150-200 mm). The height of lower edge shall be as per standard. For fixing the cable tray on the tunnel wall, substructures shall be needed. The substructure shall have a L-profile and shall be made of one piece.

The cable trays shall consist of U-section sheets made of stainless steel, material no. 1.4401, with a width as per Engineer approval. The fixing arrangement (including support arm/ angle) shall be "hot dip galvanized heavy duty steel".

**Note:** -

1. **The Contractor should refer cable tray size for reference only. Detailed size and fixing arrangement shall be furnished by EPC contractor after award of work for approval by Engineer.**

2. **The contractor will have to ensure that the HT and LT cable is placed on separate trays.**

Depending on the used cable tray, expansion joints shall be required. These expansions joints shall be included in the price of cable tray. The fastening bolts for mounting the substructure on the tunnel wall also shall be made of stainless steel, material no. 1.4401. Each Cable tray section should be properly connected to the adjacent trays to maintain the earth continuity of the cable tray. The cable tray's substructure normally shall be mounted in a span of about 1.0 m / as per drawing. Due to the fact that in the areas of Electrical Niches and of the Access-Tunnel, the cross section of tunnel is different to the other sections, so there the cable tray cannot be mounted in a height of 3.5 m lower edge. The cables shall be laid along the tunnel wall up to upper edges of Electrical- Niches. For leading the cables along the tunnel wall there, cable ladders shall be used.

The substructures of the cable trays above the Electrical-Niches and cross passage have to be different to the remaining tunnel. That means, the substructures shall not be mounted at the tunnel walls, but hanging down from ceiling, above the walkway path side.

The material also shall be stainless steel. The length of the suspension is determined as per standard.

The EPC contractor has to guarantee, that the cable tray shall be laid in one level.

## 6.9 ELECTRIFICATION OF SUB-STATION AND OTHER SERVICE BUILDING/ROOMS WITH ALLIED FACILITIES

a) Wiring for light/ceiling fan/exhaust fan/call bell etc. points including circuit wiring, sub-main wiring with Fire Retardant (FR), PVC insulated, multistranded, copper conductor (3x1.5sqmm,3x2.5sqmm,3x4sqmm and 3x6 sqmm single core cable) on surface/in recessed PVC conduits, distribution boards, sub distribution boards, earthing and suitable number of modular switch & socket and single phase/ Three phase DB complete in all respect as per requirement specification and standard Railway practices.

b) SITC of LED tube light fittings, LED flood light fittings, ceiling fan, Exhaust fan with lower shutter and other Electrical equipment as per requirement and standard Railway practices.

c) SITC of 150 Ltrs water cooler – 01 Nos and 1.5 Ton heavy duty, 5-star inverter type split air conditioner with required suitable size nuts, bolts, fasteners, cu pipe & petty hard ware in all respect. Top up the required refrigerant & maintain the pressure (If required) as per company recommendation or latest Eco-friendly refrigerant for Control room or any other service building as per decision of Engineer.

## 6.10 EXTENSION/AUGMENTATION OF ELECTRICAL POWER SUPPLY (3 PHASE, 11 KV) FOR BOTH SUBSTATIONS OF HORC TUNNEL AND ALL ASSOCIATED WORKS:-

The EPC contractor has to take (3 Phase,11 kV) connection from **Dakshin Haryana Bijli Vitran Nigam (DHBVN)** at both side of tunnel.

Total Sanctioned load/connected load of each substation will be decided by the EPC contractor after load calculation of each tunnel. This includes all HT/ LT work, metering arrangement, Cabling work, liaising work with state electricity authority and other related works to complete this work.

## 6.11 DESIGN, SUPPLY, INSTALLATION, TESTING AND COMMISSIONING OF EARTHING SYSTEM BY USING OF: -

a) The earthing shall be done with 3 meters long 50 mm dia. 'B' class G.I. Pipe earth electrode with l2 mm dia. holes around the pipe at distance of 30 cm, downside tapered. Earth electrode to be put vertically 3-meter-deep with alternate layer of salt & charcoal approx. 50 kg charcoal and l0 kg salt. 8 SWG hot dip G.I. or 7/4 mm dia. galvanized steel stranded earth wire shall be connected from earth electrode top with l2 mm dia. G.l. nut bolt to main board / equipment with masonry / RCC earth enclosure of size 300x300x300 mm (ln side to inside) with I25 mm wall thickness & suitable size MS/RCC pull out cover. The G.l. wire shall run in l2 mm 'B'class G. I. Pipe along with wall / pole up to height of 1.5 meter. The depth of 8 SWG hot dip G. I. or 7/4 mm dia galvanized steel stranded earth wire including connections from earth pipe to main board / equipment /H pole etc in ground shall be 30 cms.

b) Supply, Erection and commissioning of maintenance free earthing (chemical to enhance earth bonding improving compound) using 80 mm Dia. Copper earth electrode of tube/ rod of 3 Mtr. Length including inspection chamber, CI funnel with 20 gauge G.I wire mesh, RCC chamber 300X300 mm with concrete base, MS/ heavy plate manhole cover with frame.

c) Supply, Installation, testing & Commissioning of Copper Bonded Steel Earth Rod of 3-meter length, 17.2 mm dia with Exothermically welded busbar along with 50 kg Earth Enhancement Compound in each pit. With pit covers made up of Poly plastic with SITC of 10 mm Copper Clad Steel Round Conductor laid at 600mm below the ground, as per specification and code of practice.

d) SITC of Earthing Grid of 11/0.433kV portal substation: -

An earthing grid with a combination of 17.2mm dia. horizontal conductor & 17.2 mm dia. 3 meter length vertical rod conductors along with 50 kg Earth Enhancement Compound and exothermic welding joints shall be laid in a grid foundation layout of 15x6 meter at a depth of 0.5 meter below the ground for 25kA of fault current at each portal. The both portal of 11/0.433kV shall be interconnected with each other using 150 sq. mm Copper Clad Steel Stranded Conductor. This conductor shall be laid throughout the tunnel. The calculations shall be done as per IEEE 80:2013. The earth resistance for the portal/external **station grid shall be less than 1 ohm**. The interconnection of 11/0.433 kV grid shall be done using 150 sq. mm copper bonded steel conductor along with ISG.

**Note: - Earth resistance value of each type of earth should be with in limit and as per standard issued by RDSO/Railway Board**.

### 6.11.1 EARTHING DESIGN FOR ELECTRICAL NICHE STATION

Two isolated maintenance free earth pits with 17.2mm dia, copper bonded rod of 3-meter length along with 50 kg Earth Enhancement Compound shall be installed for Transformer Neutral in order to avoid floating Neutral. For Transformer Body two separate earthing pits shall be installed with same specification and both these pits shall be interconnected with the main earthing conductor (150 sq.mm) coming from the portal stations.

For PLC Panels, an Isolation Spark Gap shall be connected before connecting it through the main earthing busbar.

## 6.12 SUPPLY & INSTALLATION OF EARTHING AND POTENTIAL EQUALIZATION SYSTEM FOR INSIDE TUNNEL WITH CROSSINGS

### 6.12.1 Earthing Design for Main Conductor and Equipment Installed In The Tunnel: -

A conductor of 150 sq. mm shall be laid through the overall length of the tunnel on both the sides. At every crossing, the conductor on the opposite sides shall be interconnected with each other for equi-potential bonding. Also, an equi-potential bus-bar shall be installed at every crossing, which will again connect through these conductors. All the electrical equipments shall be connected to these bus-bars for the earthing and equipotential bonding.

For the tunnel body earth, the EPC contractor needs to leave a point at every crossing for connecting the reinforcement of the tunnel with the earthing conductor for proper equipotential bonding and for cathodic protection.

All equipment, which is placed outside of the tunnel also shall be included to the potential equalization.

All metal constructions, although they are not current-carrying, for example cable trays, E & M niches, distributors, doors and others shall be included to the potential equalization.

The fire main also shall be connected with the earthing system at every 100 m or as per standard. The insulation of these potential equalization connections in the tunnels in the niches shall be free of halogen or as per design requirement. The connections of earthing and bonding shall be stud- or clamp-type. These requirements shall apply irrespective of the operating voltage and purpose of the equipment. All necessary suppression chokes / filters shall be included and shall be capable of withstanding fault conditions. All cable shields shall be bonded together and connected to the ground rod. Particular attention shall be paid on the correct bonding and grounding of single core cable shields.

The design of the system shall include protection against lightning, all effects of stray current and else due to faults in adjacent circuits, which may cause damage or incorrect performance of the equipment.

### 6.12.2 Potential Equalization Bus Bar/ Main Earthing Terminal (MET):

In Niches potential equalization bus bars shall be erected. The materials of the bus bars are:
Main Tunnel Tube (E & M NICHE, etc.): Tinned Copper
Cross passages: Tinned Copper
Buildings (Control Centre): Tinned Copper
The bus bars shall be insulated (this shall be calculated into the price of the PE bus bars).

### 6.12.3 Electrochemical Reaction:

A connection of two different metals, affects by electrolytes (e.g. tunnel wash water), causes a chemical reaction. To avoid these reactions, precautions have to take place. If required, the connections to the potential equalization bus bars shall be made with a two-metal conductor, for avoiding electrochemical reaction. Before the contractor connects the potential equalization to the earthing, he shall measure the resistance of the earthing. Metallic pipes, conduits and cable tray sections for cable installation shall be bonded to ensure electrical continuity and connected to earthing conductors at regular interval. Apart from intermediate connections, beginning points shall also be connected to earthing system.

### 6.12.4 Tinned Copper MET:

Copper earth terminal 500mm long and 50mm wide and 6mm thickness with 8 no. of factory drilled holes mounted inside the enclosure boxes, for terminating incoming / outgoing earth conductors mounted with nylon insulated supports with brass threaded inserts, entire assembly supported on galvanized steel channel suitable for mounting on tunnel wall / Electrical niche wall. Suitable disconnecting link(s) shall be provided to facilitate earthing measurement. A transparent enclosure shall be given for more protection.

### 6.12.5 Isolation Spark Gap:

An isolation spark gap shall be used with every transformer neutral at portal stations and with every PLC & SCADA Connection when connecting them with a common Earthing Grid. Also, when interconnecting 11/0.433kV station, an ISG shall be installed. Inside the tunnel also, at every crossing the ISG shall be considered with PLC panels, Transformer Neutrals and with other sensitive equipment.

**Note: -**

a) All materials used in the work shall be procured from RDSO approved sources or ISI marked only and of the best quality and of the class suited for the purpose specified.

b) Design codal life of all type of material/equipments should be as per RDSO codal life standard.
c) The contractor shall be solely responsible for the correctness of the position, levels and dimensions of the works according to approved drawings, notwithstanding that he may have been assisted by the Engineer or his men in setting out the same.
d) Notwithstanding anything given anywhere else all work execution shall be as per latest design and drawing of RDSO and latest guideline issue by Railway Board.
e) The contractor should follow all the clearances as per latest CEA regulation.
f) Meet the all protective provisions relating to electrical safety.

**XXXXX**