MUNICIPAL CORPORATION OF GREATER MUMBAI

Mithi River Water Quality Improvement Project
Package IV: Diversion of Dry Weather Flow from Bapat Nalla and Safed Pul Nalla to Dharavi WwTF through Tunnel

Design and Build Contract

VOLUME 2

EMPLOYER'S REQUIREMENTS

Employer:
Municipal Corporation of Greater Mumbai
Municipal Head Office Building,
Mahapalika Marg, Fort, Mumbai - 400001
India

MUNICIPAL CORPORATION OF GREATER MUMBAI

Mithi River Water Quality Improvement Project

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LAYOUT OF THE DOCUMENTS

This volume is one of several that comprise the documents.

These are:

NIT	Notice of Invitation of Tenders
ITT	Instruction to Tenderers
Volume 1	Conditions of Contract
Volume 2	**Employer's Requirements**
Volume 2A	General Technical Specification
Volume 2B	Void
Volume 2C	Drawings
Volume 2D	General Mechanical Specifications
Volume 2E	General Electrical Specifications
Volume 3	Schedule of Payments
Volume 4	Contract Forms
Volume 5	Background Information

MUNICIPAL CORPORATION OF GREATER MUMBAI

Mithi River Water Quality Improvement Project

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VOLUME 2 – EMPLOYER'S REQUIREMENTS

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1 DEFINITIONS

Drawings – The Employer's design, as provided in Volume IIC of the Employer's Requirements

Drop Shaft – Structures that permit a significant change in invert level within the network, and which form part of the Permanent Works

HDPE – High Density Polyethylene

ID - Internal Diameter

IPS – Influent Pumping Station

Microtunnelling – The installation of precast pipes using pipe jacking following behind a TBM

MCGM – Municipal Corporation of Greater Mumbai

PCC – Plain Cement Concrete

RCC – Reinforced Cement Concrete

TBM – Tunnel Boring Machine

THD – Town Hall Datum

Tunnel Shaft – Structures at junctions between each tunnel section, and which form part of the Permanent Works

Tunnelling - The installation of formed segmental lining pipelines by using a TBM

WwTF – Wastewater Treatment Facility

2 INTRODUCTION

2.1 Introduction

This volume describes the Employer's Specific Requirements for the Mithi River Water Quality Improvement (Package IV: Dry Weather Flow Interception and Tunnel, Transfer to Dharavi Sewage Treatment Plant) Contract. The Contract includes the Design-Build of the Works.

The general technical specifications are included in Volumes IIA, IIB, IID and IIE and describe the general requirements of the general technical, modelling, mechanical and electrical works. Contract Drawings are included in Volume IIC and Site Data is included in Volume V. By reference in this clause, Volumes IIA, IIB, IIC, IID, IIE and V form part of the Employer's Requirements.

If there is a conflict between the specific requirements of this Volume II and the General Technical Specifications in Volumes IIA, IIB, IID and IIE, the Contract Drawings in Volume IIC, and the Site Data in Volume V, then the specific requirements of this Volume II shall take precedence in accordance with Clause 1.5 of the Conditions of Contract.

The terms of the Contract are based upon the FIDIC Conditions of Contract for Design and Build Projects (The Yellow Book).

2.2 Background to the Contract

The sewage collection system, wastewater treatment and effluent disposal systems in Mumbai are based on seven independent operational zones comprising sewers, tunnels, pumping stations, rising mains, wastewater treatment facilities and treated effluent outfalls.

Mithi River

The Mithi River in sewerage zone 3 runs 17.8 kilometres through densely populated residential and industrial areas. Except during the monsoon, the river is a non-perennial water body and carries only sewage and industrial effluent during the rest of the year. This is due to wastewater nallas which outfall into the Mithi River over its length. There is an overall Mithi River Water Quality Improvement project to curb the pollution load entering the river.

Bapat and Safed Pul Nallas

These two large nallas contribute a significant percentage of the overall wastewater pollution load into the Mithi River adjacent to the CSI airport throughout the year.

Dharavi WwTF

This new STP in the tidal zone of the Mahim Creek is due to be constructed in the next few years.

Bandra STP

This existing STP at the lowermost point of the Mithi River is due to be upgraded by 2020.

WSP Site STP

This new 8MLD capacity STP in the upper reaches of the Mithi River is due to be constructed by 2021.

Mithi River Water Quality Improvement Project

Through the Employer's (MCGM's) Delivery Strategy which sets out four Contract Packages, the overall aim of the Project is to curb the pollution load of the Mithi River. This will be undertaken by intercepting the DWF outfalls currently entering the Mithi River and conveying the DWF to either existing or new STPs for treatment.

Due to insufficient sewer capacity upstream of the sewage treatment sites at Dharavi and Bandra, coupled with limited available land for future expansion at these STPs, a strategic decision has been taken to transfer a proportion of DWF from the Mithi River catchment in zone 3 to Dharavi WwTF for treatment.

To prioritise the overall improvements within the Mithi River Water Quality Improvement project, the work has been divided into the following four packages:

- Package 1 – DWF interception and transfer for treatment at a new STP at the WSP Site, Powai;
- Package 2 – DWF interception and transfer of nallas in the Mithi River (non-tidal zone);
- Package 3 – DWF interception and transfer of nallas in the Mithi River (tidal zone); and
- Package IV – DWF interception and tunnel transfer to the New Dharavi WwTF. Note that a new IPS as well as treatment of the transferred DWF at Dharavi WwTF is **not** included in this Package.

This contract is for Package IV only.

Package IV (Dry Weather Flow Interception and Tunnel Transfer to the Dharavki WwTF)

All DWF currently entering the Mithi River via Bapat and Safed Pul nallas adjacent to the CSI airport will be intercepted and transferred via tunnel to Dharavi WwTF.

Objectives of the Contract for Package IV

The main objectives of this DB Contract for Contract Package IV are:

Sr. No.	Objective
1.	Interception of DWF ingress to the Mithi River (from Bapat and Safed Pul nallas) (to include a blend of DWF / storm flow during the wet season, based on the same interception flow setting during the wet season as the dry season).
2.	Hydraulic transfer of intercepted DWF from Bapat and Safed Pul nallas via vortex drop shafts to a new transfer tunnel.
3.	DWF transfer by segmental tunnel from Bapat nalla via Safed Pul nalla to Dharavi WwTF.
4.	Undertake all work in a safe manner, minimising health and safety risk to all involved or affected by the project.
5.	Comply with all relevant environmental regulations and legislation throughout the construction and operation of the Contract.
6.	Hand back the Works to the Employer in a well maintained, operating condition at the end of the Contract.

2.3 Responsibility for Design

Design responsibility for the Works is split as follows:

Party	Design Responsibility
Employer	Indicative details of DWF interception / vortex drop shafts, and tunnel profile between Bapat nalla, Safed Pul nalla to Dharavi WwTF.
Contractor	Outline / detailed design and construction of all necessary works.

Indicative Description of Package IV Works

DWF Interception

DWF from Bapat and Safed Pul nallas shall be intercepted prior to it entering the Mithi River. Two major interception chambers shall be constructed adjacent to each nalla to divert the DWF through debris deflectors and screens into vortex drop shafts. Refer to indicative drawings in Volume IIC.

Vortex Drop Shafts

A vortex drop shaft shall be provided at both Bapat and Safed Pul nallas to effectively convey the DWF from the level of the nalla down to the level of the transfer tunnel to Dharavi WwTF. Refer to indicative drawings in Volume IIC.

Transfer Tunnel

A transfer tunnel shall be driven between Bapat nalla (Shaft A), Safed Pul nalla (Shaft B) and Dharavi WwTF (Shaft C). The number and location of intermediate access shafts shall be determined by the Contractor to suit their method of working / buildability considerations and overall H&S aspects. Refer to indicative drawings in Volume 2C.

Transfer Tunnel Connection to New IPS at Dharavi WwTF

The shaft at the Dharavi WwTF shall be used as the wet well for the IPS at Dharavi.

2.4 Description of the Works

Contract specific information for the Works is as follows:

No	Item	Details
1	Scope of Work	<u>General</u> The Works required under the Contract include the design, specification, procurement, supply of material, labour, equipment, permits and consumables to construct, commission and test a fully functioning, fit-for-purpose DWF interception / screening facility, hydraulic drop shaft and tunnel transfer system to convey DWF from Bapat and Safed Pul nallas to a location within the Dharavi WwTF. The Permanent Works include but are not limited to, two DWF interception / screening structures, two vortex drop shafts, a common transfer tunnel with associated structures and access shafts. The Works include temporary works, site offices, and all other requirements necessary for the construction of the Permanent Works in accordance with the Employer's Requirements. All utilities shall be identified and protected (including communications, electrical HV and LV cables / chambers, water mains, storm water drainage channels and pipelines) within each Site as required. The Contractor shall include for the provision of all temporary power during the construction period and Tests on Completion, including all commissioning. The Contractor shall ensure minimum disturbance to the operation of the Employer's existing facilities by permitting the operation of all existing sewers for the duration of the construction period. The Contractor shall ensure the restoration of all work Sites. <u>Bapat and Safed Pul Nalla Interception Sites</u>

No	Item	Details
		The Works include but are not limited to the construction of DWF interception / screening structures and vortex drop shafts at Bapat and Safed Pul nallas. These shall intercept all DWF during the dry season, and a proportion of DWF during the wet season (when the DWF may be diluted by storm flow). The interception / screening chamber shall be designed and constructed to ensure there are no spills to the river during the dry season diurnal cycle. The design shall incorporate the outputs from CFD and physical modelling of the two interception / screening structures and vortex drop shafts. Refer to indicative drawings in Volume IIC for the above scope of work, which has been developed on an indicative basis. <u>Between Bapat / Safed Pul nalla and Dharavi WwTF</u> The Contractor shall undertake geotechnical / structural / civil / mechanical / electrical and any other design as required to enable the construction of a minimum 2.6 m ID tunnel from Bapat nalla via Safed Pul nalla to a location within the Dharavi WwTF (of total length approximately 6.5 km). The Works include determination of trenchless technology and methodologies to be utilised for the construction of the tunnel including but not limited to structural design of jacking pipes and / or tunnel segments. The structural design shall include detailing of reinforcement for the Permanent Works. Construction of all Permanent Works (and any temporary shafts provided by the Contractor) shall be in accordance with the indicative general arrangement drawings in Volume IIC. The Contractor shall determine the number and location of permanent Tunnel Shafts. The Contractor shall construct all feeder sewers between the Drop Shafts and Tunnel Shafts by open-cut method, micro-tunnelling, or conventional tunnelling. The Contractor shall provide internal structural HDPE liners for the Tunnel and Drop Shafts. The Contractor shall not form the primary lining of the tunnels by cast in-situ method. Refer to indicative drawings in Volume IIC for the above scope of work, which has been developed on an indicative basis. <u>Dharavi Shaft</u> The shaft at the Dharavi WwTF shall be used as the wet well for the future IPS there. <u>Demolition</u> The Contractor shall obtain written agreement from the Employer should there be a requirement to demolish any existing structures within the Works Site. The Contractor shall be responsible for determining the location / land and

No	Item	Details
		proper disposal route for all debris and waste materials arising as a consequence of demolition including any sludge, and for paying all tipping fees and other associated costs. The Contractor shall dispose of any hazardous materials off-site in accordance with existing laws and regulations. All permissions and consents from respective authorities including MCGM shall be obtained by the Contractor <u>Existing Site</u> Dharavi WwTF site is owned by the Employer, and contains areas to which access by the Contractor is excluded. Therefore, the Contractor shall plan and carry out the tunnel connection Works in such a manner so as not to cause any disruption to the Employer, his Agents / Contractors, or his ability to utilise, operate, maintain, or undertake activities at the STP. The Contractor shall liaise with the Employer to agree the construction methodology, time for construction, and access arrangements. Immediately after completion of the work, the sites shall be left in a tidy state, and cleared of construction debris. Refer to indicative drawings in Volume IIC for the above scope of work, which has been developed on an indicative basis.
2	Engineering Services	The Works shall include but not be limited to the design, specification, procurement, supply, construction, commissioning and testing of a fully functioning DWF interception / screening facilities, vortex drop shafts and a tunnel transfer system which are fit-for-purpose.
3	Flows	The Contractor shall be responsible for conveyance of all DWF from the interception / screening structures at Bapat and Safed Pul nallas via the vortex drop shafts and the tunnel to a location within the Dharavi WwTF.
4	Provision of Service Infrastructure	The Contractor shall be responsible for temporary relocation measures should these be required for any affected slum hutment inhabitants. The Contractor shall be responsible for all service connections to the DWF interception / screening facilities, vortex drop shafts and tunnel required for construction of the Works. The Contractor shall be responsible for the payment of all such services for the entire Contract Period.

The word segmental tunneling in this Contract shall be interpreted as the installation of ring shaped precast steel reinforced segments immediately after the drilling process under the protection of shield. The drilling is to be carried out using Tunnel boring machine (TBM). The word microtunnelling shall be interpreted as the installation of precast pipes using pipe jacking following behind a TBM.

The Contractor shall not form the primary lining of the tunnels by any cast in-situ method.

Where specified in the Drawings and Schedules, sections of the pipeline shall be laid by microtunnelling or tunnelling using TBMs and as approved by the Engineer.

The works proposed within shaft sites and the proposed tunnel corridor are in close proximity and sometimes below private properties The Contractor shall undertake all necessary investigations/ surveys to determine the precise location of services.

The Contractor's attention is drawn to the residential and commercial properties in the vicinity of proposed shafts. The Contractor shall minimise disturbance to all existing structures and shall be responsible for any damage to structures.

2.5 Deleted

2.6 Other Contracts

Dharavi WwTF

MCGM is planning to develop a new WwTF at Dharavi.

The potential interface is likely to be use of the shared access road to the Dharavi site owned by the Employer.

Refer to the site constraints drawing in Volume IIC for details.

The Site

The following tables identify information about existing site areas including:

- Bapat and Safed Pul nalla interception sites;
- Between Bapat / Safed Pul nalla and Dharavi WwTF; and
- Dharavi WwTF Site.

Sr. No.	Item	Details
1	Site Area / Constraints	General As indicated in Condition of Contract Clause 4.10, the Contractor shall be deemed to have inspected the work sites and surrounding areas before submitting his tender and made himself aware of the physical and environmental conditions governing the work. All areas where Works are to be carried out shall be deemed to form part of the Site, including areas where surplus material is disposed of and areas where materials are abstracted. Bapat and Safed Pul Nalla Interception Sites The Contractor's attention is drawn to the residential / commercial properties, highways and other infrastructure in the vicinity of proposed shafts. The Contractor shall minimise disturbance to all existing structures and shall be responsible for any damage to structures. Between Bapat / Safed Pul nalla and Dharavi WwTF The indicative route of the tunnel predominantly consists of slum settlement areas or busy trafficked streets. In addition to the tunnel, the Site includes two vortex drop shafts in addition to any access shafts which the Contractor may determine are necessary for construction or maintenance. The Contractor's attention is drawn to the fact that the work

Sr. No.	Item	Details
		sites may be located on or adjacent to busy trafficked public roads, passages, private rights of way or access passages, where access must be maintained. When carrying out any works within the Employer's sites, the Contractor shall permit the continuous operation of existing facilities by the Employer. The Contractor shall not have uninterrupted access to the tunnel shaft work sites and all works shall be carried out in accordance with the Traffic Management Requirements. The tunnel will be required to pass under numerous roads, highway structures, private and public buildings, services, railways and the suchlike. Details of existing structures / deep foundations are very limited, therefore the Contractor shall exercise extreme caution in determining an appropriate horizontal and vertical alignment for the tunnel. Refer to indicative plan / long section with overlaid Google Earth image in Volume IIC. <u>Dharavi WwTF</u> The shaft at the Dharavi WwTF shall be used as the wet well for the new IPS at Dharavi.
2	Flow Measurement	<u>Bapat and Safed Pul Nalla Interception Sites</u> Refer to Volume 5 for the average DWF / instantaneous peak flow rates from an hourly flow measurement survey held over a 7-day dry weather period in Jan / Feb 2017 for Bapat and Safed Pul nallas. There is no flow measurement data for the monsoon period. <u>Between Bapat / Safed Pul nalla and Dharavi WwTF</u> N/A.
3	Water Quality Analysis	<u>Bapat and Safed Pul Nalla Interception Sites</u> Some DWF water quality analysis has been undertaken for Bapat and Safed Pul nallas at their ingress locations into the Mithi River. The minimum parameters sampled and analysed include: Biological Oxygen Demand (BOD); Chemical Oxygen Demand (COD); Total Suspended Solids (TSS); PO_4-P; pH; and Faecal coliforms.

Sr. No.	Item	Details
		Where additional analysis is considered critical to the transfer regime or treatment process, the following additional parameters have been sampled and analysed: NH_4-N; Total Nitrogen; Alkalinity (as $CaCO_3$); Oil and Grease; Total Phosphorous; Dissolved Oxygen; and Chlorides. Refer to Volume 5 for details. <u>Between Bapat / Safed Pul nalla and Dharavi STP</u> N/A.
4	Topographical Survey	<u>Bapat and Safed Pul Nalla Interception Sites</u> Refer to topographical survey data which is included on the relevant drawings in Volume 2C. <u>Between Bapat / Safed Pul nalla and Dharavi WwTF</u> No data is provided.
5	Geotechnical Information	<u>Bapat and Safed Pul Nalla Interception Sites</u> Refer to site investigation data adjacent to the Mithi River (from the historic contract to install the river training wall) in Volume VA. <u>Between Bapat / Safed Pul nalla and Dharavi WwTF</u> No data is provided.
6	Existing Services and Infrastructure	Where relevant details of existing services and infrastructure have been received from the Employer, these are shown on the drawings. The Contractor shall not rely on this information and shall ensure that any critical measurements, locations, or the suchlike are verified on site. Refer to Volume IIC for drawings. <u>Bapat and Safed Pul Nalla Interception Sites</u> The Works proposed within the vortex drop shaft sites are likely to be in close proximity to public and private properties (and below ground services which may be indicated in the Drawings), therefore the Contractor shall exercise diligence and caution in undertaking the Works.

Sr. No.	Item	Details
		No data is provided. <u>Between Bapat / Safed Pul nalla and Dharavi WwTF</u> The Works proposed within the proposed tunnel corridor are likely to be in close proximity to public and private properties (and below ground services which may be indicated in the Drawings), therefore the Contractor shall exercise diligence and caution in undertaking the Works.
7	Other Contracts	The Employer intends to progress other contracts / work packages which may be executed at the same time as this Contract and which may impinge upon the execution of the Works. The Contractor shall ensure that its activities do not have a detrimental impact on these other contracts / work packages. Mithi River Contract Package 2 (DWF interception and transfer of nallas in the Mithi River (non-tidal zone)). Dharavi WwTF Development.

3 PARTICULAR REQUIREMENTS

3.1 Tunnel Alignment

The position, location and size of the permanent shafts, described in Section 3.12, are fixed and shall be as per the Drawings.

The Contractor shall construct the tunnels between the permanent shafts along the general alignment shown on the Drawings. The Contractor shall determine the exact alignment of the tunnels based on his proposed method of construction and all other factors. For example, the Contractor may choose straight tunnel drives with temporary intermediate shafts or curved tunnels with fewer or no temporary shafts.

The Contractor may if he wishes would install further temporary access shafts, for example to replace with straight sections a tunnel section or sections indicated as being curved. The cost of any such additional temporary access shafts and/or changes in tunnel alignment from that shown on the Drawings shall be deemed to be included in the contract rates.

Tunnelling is the only method of construction permitted for the main tunnel, although microtunnelling may be required for connection works.

If the Contractor proposes to re-align the route of the sewer outside the areas specified above or through private properties, it shall be the Contractor's responsibility to obtain agreement from landowners and pay any costs/compensation associated with same.

Similarly the Contractor shall be solely responsible for any risks and cost in case of any changes in the alignment considered necessary after commencement of the works.

3.2 Design of Permanent Shafts

All permanent shafts shall be constructed at the locations identified, and are to meet the hydraulic requirements by maintaining the minimum internal geometry shown on the Drawings.

In order to maximise the flexibility available to the Contractor in proposing methods of construction, the Employer's Requirements define the required internal geometry of the permanent shafts but are based on no specific method of construction.

Accordingly, the structural thickness of the external walls and bases of all structures as shown are designed to resist the full factored earth and hydrostatic loads, and purposely ignores restraint from any elements of the Temporary Works which may be left in place.

The detailing of all reinforcement for the permanent shafts is included within the scope of the Contract, and the Contractor shall submit full structural design calculations of all Temporary and Permanent Works, i.e. both those designed by the Employer and Contractor, for acceptance by the Engineer.

To enable the Contractor to adopt the most economical construction techniques alternative structural designs are permitted. Where the Contractor wishes to deviate from the Employer's Permanent Works design, on award of the Contract, the Contractor shall carry out the structural design of the Permanent Works in accordance with the Employer's Requirements.

If any work strategy or plan adopted by the Contractor involves construction of additional permanent structures, the responsibility of design and construction of the same shall be the responsibility of the Contractor. Under such circumstances the Contractor shall obtain prior acceptance of the Engineer for the same and no extra cost shall be payable on such account.

Should the Contractor construct temporary shafts where the change in direction between incoming and outgoing sewer tunnels exceeds 45 degrees, the Contractor shall construct an additional permanent shaft at the same location.

3.3 Design of Temporary Shafts

It is envisaged that the Contractor shall utilise the locations of the permanent shafts as construction shafts for the construction of the tunnels (i.e. drive or reception shafts). The Contractor may if he wishes install further temporary shafts to suit his construction methodology.

In accordance with Volume I Conditions of Contract the Contractor's proposal forms part of the Contract. This proposal includes the Contractor's proposed construction methodology and alignment including number, size and location of temporary shafts. The Contractor shall submit his structural design of these temporary shafts and method statements for their construction to the Engineer for acceptance.

The Traffic Management Plan shall take account of all relevant Temporary Works proposed by the Contractor.

In order to ensure safety during construction, temporary shafts (Temporary Works) are to be spaced in accordance with the British Tunnelling Society and Pipejacking Association document, 'Tunnelling and Pipejacking: Guidance for Designers'.

The Contractor's design shall ensure that the dimensions of Temporary Works are the absolute minimum required and the method of construction shall be such that the shafts are constructed without causing unacceptable obstruction to the existing traffic flow in the vicinity of the construction.

It may be required to provide shafts in multiple stages of depths to allow for tunnels at different invert levels and the designs and methods of construction shall allow for the same.

3.4 Tangential Vortex Drop Structure Modelling

A tangential vortex drop structure is required for Drop Shaft at Bapat Nalla and at Safed Pul Nalla as detailed in drawing DE178004C036, DE178004C037, DE178004C038 and DE178004C039. The Contractor shall undertake CFD modelling prior to physical modelling of the proposed drop shafts at Bapat Nalla as specified separately in Volume IIB.

The physical modelling shall be completed prior to commencement of construction of Drop Shafts. Following completion of the Contractor's Final Report on the physical modelling, any recommended changes to the design shall be incorporated into the Drawings by the Employer.

3.5 Structural Design of the Permanent Works

Reinforced concrete for tunnel segmental linings and jacking pipes shall comply with Sections 14 and 15 of this Employer's Requirements. The tunnelled sewer system is designed to normally operate with partial flow conditions, i.e. no internal pressure in the tunnel. In the rare event of a power failure in the downstream pumping station the tunnel system will surcharge up to ground level, i.e., to a maximum of approximately 20 m above tunnel invert. When designing the tunnel this should be considered together with the external pressure acting upon the tunnel.

In addition to and taking precedence over the requirements given in the General Specification (Volume IIA), due to the severity of exposure of the site (sea water, high chlorides, high sulphates) the following concrete specification shall be used for all other Permanent Works:

Minimum Grade of Concrete:	M-50
Cementitious Materials:	Portland Slag Cement (GGBS shall be maximum of 30% of the cement content or Flyash and Silica fume shall be maximum of 20% and 6% of the cement content respectively)
Minimum Cementitious Content (kg/m^3):	400
Maximum Cementitious Content (kg/m^3):	500
Maximum Water Cement Ratio:	0.40
Minimum nominal cover to reinforcement (mm):	50
Maximum Shrinkage Rate:	0.04%
Penetration Limit:	8 mm (measured in accordance with BS EN 12390 Part 8)
Water Absorption Limit:	1.6% (to BS 1881 Part 122)

The total water soluble chloride content of the concrete arising from all the mix constituents shall not exceed 0.4% expressed as a percentage of ion by weight of cementitious content.

The total acid soluble sulphate content of the concrete arising from all the mix constituents expressed as SO_3 shall not exceed 4.0% SO_3 by weight of cementitious content.

The alkali content of the concrete expressed as sodium oxide (Na_2O) equivalent shall not exceed 3.5kg/m^3, when calculated in accordance with BS 8500.

Super Plasticiser shall be provided where necessary to ensure necessary workability and wet curing is required.

All the grade of RCC concrete specified for this work should be replaced by M50 grade conforming to relevant IS code unless otherwise specified

The following present the minimum grades of concrete which may be used for particular non-structural application:

M–20: - Pavements

M–15: - Plinth protection work

M–10: - Mud mat below foundations, plinth beams, drains, trenches, pits etc.

Reinforcing bars shall be of minimum grade Fe 500-D corrosion resistant steel conforming to IS 1786.

All the reinforcement for this work shall be of Fusion Bonded Epoxy coated type conforming to IS 13620:1993

The design of RCC structures shall be carried out by ultimate limit state or working stress method as per the provisions of IS 456. Concrete exposure shall be considered as severe for the purposes of the depth of cover to reinforcement.

Permanent shafts shall be designed as liquid retaining structures with either un-cracked sections in accordance with the recommendation of IS 3370 or using limit state design for reinforced concrete in accordance with IS 3370 with a design crack width of 0.1mm. The design must take into account cracking due to shrinkage, and the amount, size and spacing of reinforcement must be adequate for strength and serviceability for shrinkage effects.

The shafts shall be designed for full water pressure inside (up to ground level / top of shaft) and no earth pressure or ground water pressure outside as well as full earth pressure and ground water pressure outside and no water pressure inside. Where shafts are to be constructed on the Employer's sites the final ground level (FGL) that the shafts are to be designed for is stated on the Drawings.

RCC walls shall include reinforcement on both faces for sections of 200mm or more, even if not required from a structural design consideration.

3.6 HDPE liners

High Density Polyethylene (HDPE) liners are required on the internal structural faces of all Tunnel Shafts and Drop Shafts.

The thickness of the HDPE liner shall be 3.0mm or more. Light-coloured lining materials are to be chosen to allow for easier internal and visual inspections.

The HDPE liner shall be installed in situ and the HDPE liners shall be secured by integral anchors in order to maintain the adhesion between the HDPE and the concrete. The height of each anchor shall be minimum 13mm to minimise the risk of pull out of the liner.

The liner anchors and locking system shall resist the full hydrostatic head of water pressure acting upon the exterior of the shafts.

These liners are required to achieve the required resistance to degradation and durability over the design life and are expected to have a design life equal to that of the tunnels and shafts. The liners shall not impact upon the structural integrity of the Permanent Works and shall not hinder the physical performance of the sewerage system.

The HDPE liner shall be chemically inert and able to resist chemical attack.

Joints and welding strips shall have the same corrosion resistance as the liners.

The HDPE liner shall comply with the physical properties given in the below table:

	Standard	**Test Method**
Density	0.94 g/cm^3	ASTM D1505
Elongation at yield	15 %	ASTM D638 Speed D (50 mm/min)
Elongation at break	800 %	
Tensile strength at yield	18 N/mm^2	
Tensile strength at break	24 N/mm^2	
Stud pull-out strength	>670 kN/m^2	
Water absorption	0.085 percent maximum	ASTM D570
Water soluble matter	Zero	
Porosity	No pin holes	Spark Tester 8 kV/mm
Coefficient of Liner Thermal Expansion	0.00012 / degree C	ASTM D696
Plasticiser	Nil	Nil

The manufacturer of the HDPE liner shall be ISO 9001 certified.

The seaming of the installed liners shall be performed by extrusion welding. All HDPE welded joints shall be carried out by a competent welder, certified in such welds, and authorised by the manufacturer.

3.7 Deleted

3.8 Stub Pipes

To permit future connections to the Tunnel Shafts and Drop Shafts the Contractor shall construct stub pipes at Tunnel Shaft at Dharavi WwTF, Drop Shafts at Bapat and Safed pul nalla and as described in Section 3.12. They shall be constructed with precast RCC pipes by open trench excavation and the precast RCC pipes shall be NP3 grade.

The precast RCC pipes shall comply with IS 458 and be in accordance with the General Specification (Volume IIA).

3.9 Vent Pipes

Every covered Tunnel Shaft and Drop Shaft shall be provided with a vent pipe.

Vent pipes at the Employer's sites shall be provided as U-bend cast iron pipes in accordance with the General Specification.

Vent pipes in public areas are to be manufactured from mild steel (MS), a minimum of 8mm thick, with a 12mm thick internal cement mortar lining and shall be installed adjacent to public footpaths. MS vent pipes shall be in accordance with IS 11906.

3.10 Cover Slabs

The precast RCC cover slab on each Tunnel Shaft and Drop Shaft shall be manufactured of precast RCC sections designed and installed in such a manner as to facilitate subsequent removal for tunnel access and maintenance purposes. The RCC cover slabs shall be installed at the level given on the Drawings, and where indicated on the Drawings they shall be backfilled over and up to the existing ground level.

The sections shall include suitable lifting points (cast in hooks, rings or threaded connectors). Joints between sections, and between the sections and the shaft walls, shall include joint detailing to minimise water and dirt ingress into the shaft.

The maximum weight of a single component shall be no more than 10 tonnes.

At least one of the sections shall include an opening to the dimensions given on the Drawings provided with a removable precast RCC access cover installed on a concrete upstand such that the top of the cover is flush with the finished surface level and as shown on the Drawings.

3.11 Access Covers

Where shown on the Drawings removable precast RCC access covers shall be installed flush with the existing ground level or at the level specified on the Drawings.

The Contractor shall be responsible for the structural design of the covers. Recessed lifting points (cast in hooks, rings or threaded connectors) shall be provided, which shall be flush with the top surface of the covers.

Joints between the covers and their frames shall include joint detailing to minimise water and dirt ingress into the shaft, and shall be secure against vandalism.

The Contractor shall supply the Employer with five (5) sets of lifting keys upon completion of the Works.

Manhole covers required for any sewer diversion works shall be in accordance with the General Specification.

3.12 Site Area Requirements

3.12.1 General

The Site of the Works is shown on the Drawings and is described in the following sub-sections.

Specific work site areas on the Employer's sites have been arranged for the Contractor to carry out the Works. The approximate working areas within the Employer's sites, as shown on the Drawings are designated in order to permit him to operate and maintain the existing facilities throughout the Contract Period. Should the Contractor require access to any additional areas of the Employer's sites he shall agree this in advance with the Employer.

The approximate working areas in public areas, if shown on the Drawings, are indicative only. At every work site the Contractor is to determine his own working area requirements and obtain approval for the same with the Traffic Police, as detailed in Section 6.7.1.

The Contractor shall not have sole possession of any other areas unless he arranges for same at his own cost. The shaft site areas will only be made available to the Contractor in a sequential manner so as to minimise traffic disturbance. For any delay on this count the Employer shall not be responsible. Appendix B of the Employer's Requirements lists any traffic management requirements identified prior to preparation of the Contract which shall be incorporated in the Traffic Management Plan.

Each work site area must be fully protected to prevent third party access or accidents. The site area boundaries and fencing shall be constructed in accordance with Section 6 of the Employer's Requirements. Where compound walls at the Employer's sites are to be demolished the Contractor shall provide a temporary barrier that is equal in height and strength equivalent to the permanent compound wall. Upon completion of the Works the Contractor shall restore the existing compound walls to the same standard.

The Works at the Site shall include the full restoration of the Employer's existing sites and public areas to the same condition as was found prior to the Works. Prior to commencing construction at each site the Contractor shall have a joint inspection with the Engineer to agree on the existing condition of the site and photographs shall be taken to record the condition.

The tunnel is aligned below several building structures between S02 and S03. The tunnel depth is sufficiently below the foundation of these structures however the contractor should investigate the foundation depth of each structures along the length of the tunnel and inform the same to the Engineer.

3.12.2 Work Site

Work Site Bapat Nalla

The works at Work site at Bapat Nalla include tunnel drop shaft S01, interception chamber, screens and connection of 1800mm sewer to the drop shaft. The location of drop shaft is at the junction of the road and screens are to be placed at the open space on the side of Bapat nalla.

Location of Work site is shown in drawing DE178004C441. The site is an access road for airport facility which the contractor should take into account and make alternate arrangement for access.

The contractor shall note that the site for screens is at the end of a ramp adjacent to the road and there is difference in level. To construct the permanent works at this site the contractor will be required to demolish part of existing wall so he shall plan his temporary works accordingly. The retaining wall and road should be restored.

The Contractor shall ensure that security of the Employer's site is not affected by the Works. Prior to demolition of any existing compound wall the Contractor shall install a temporary barrier in its place.

WorkSite Safedpul Nalla

The works at Work site at Bapat Nalla include tunnel drop shaft S03, interception chamber, screens and connection of 1800mm sewer to the drop shaft. The location of the drop shaft is on the road along the side of safedpul nalla.

Location of work site is shown in drawing DE178004C431. The site is an access to Tanaji nagar slum residents. The contractor shall take a note to provide and alternate access road to the residents.

The connections from nearby outfalls will be connected to this drop shaft so the contractor shall take a note to leave a stub pipe for these connections.

Worksite Dharavi WwTF

The work at work site at Dharavi WwTF include tunnel shaft which shall be used as the wet well for the new IPS at the location.

3.12.3 Site Reinstatement

Upon completion of the Permanent Works the Contractor shall backfill all excavations and trenches in accordance with the Employer's Requirements and the General Specification (Volume IIA) and shall remove his Temporary Works. All backfilling of excavations and trenches shall be subject to the acceptance of the Employer's Representative.

In public areas the Site shall be restored in accordance with this Employer's Requirements document and the MCGM Guidelines for Trenching Activity.

At the Employer's sites the Contractor shall backfill around the Permanent Works up to the original ground level at each location, and as given on the Drawings, and shall be subject to the agreement of the Employer's Representative. Site grading and surface reinstatement at the Employer's sites shall be included in the Contract.

At the Employer's sites any compound walls and drainage channels that are demolished or damaged by the Contractor shall be restored prior to completion of the Works.

3.13 Additional Requirements

(a) The Contractor shall divert the existing utilities encountered during Construction as per Section 6.15 6.16 and 6.17. However if additional underground utilities are discovered during construction work the Contractor the same shall also be diverted as per Employer's requirement.

(b) The contractor should note that the work is required to be carried out in phases as permitted by the Traffic Police Dept. The contractor will have to obtain permission from Traffic Police Dept. well in advance for closing down the road or part thereof for the execution of the work. The work will have to be carried out in stages depending upon the permission granted by the

Traffic Police for closure of the road or part thereof. The contractors should therefore take this into account while quoting.

(c) The contractor shall obtain specific permission or approval through the engineer wherever required. Only recommendatory letters will be issued by M.C.G.M. The Contractor shall be responsible for obtaining permissions from traffic police, PWD, M.M.R.D.A., Railway authorities or any other concerned authority outside M.C.G.M., with due regard to the method of work and detailed designs involved. The contractor shall be responsible for submission of the detailed designs, drawings and clarification on time to the concerned authorities.

(d) The contractors shall make his own arrangement for water connection etc at his own cost. Extra water required for construction purposes will have to be brought by the contractors at his own cost.

(e) All material required for the work can be stacked near the site of work in such manner so as not to cause any inconvenience to the pedestrian and vehicular traffic. If no space is available on site then contractor shall make his own arrangement for stacking of material etc.

(f) The contractors shall make necessary arrangement for adequate lighting during night time.

(g) The sewer line laid by open excavation shall be tested for various tests as per the codes in presence of representative of Employer representative during the progress of the work.

(h) The RMC/Asphalt works required to be done under the captioned contract shall be got executed with RMC/Asphalt plant registered with MCGM. In case of non availability, alternate RMC/Asphalt plant can be used with the approval of Engineer.

(i) All the Frame & covers required for the works to be carried out under the captioned contract shall be procured from the specified manufacturers registered with M.C.G.M.

(j) All trenches and shafts taken in connection with the work should be sufficiently barricaded as per MCGM circular MGC/F/6342 DATED.05.05.2018. or as directed by Engineer) as specified. It will be entirely responsibility of contractor to provide and install secure barricades on work site fully at his cost. Due to non-installation of barricades/or due to inadequate installation of barricades on sites, if any accident occurs on site leading to injury or loss of life, then the contractor will be liable for consequent action as per law.

(k) It will be the responsibility of the contractors to arrange for a joint inspection in every quarter of the year after completion of the work till the expiry of defect liability period and also 4 weeks before expiry of the defect liability period. Further, if the contractor fails to do so, the observations made by the staff during site inspection will be considered for the purpose of noting the defects.

(l) Any amount of Dewatering required for crossing nallah / culvert / S. W. drains, crossing of sewer lines, seepage of ground water from adjoining area and to the intermediate manhole pit and leakage through utilities etc. and also for making connection of the proposed sewer lines to the existing sewer line in surcharge conditions / to get connected to pumping station should be considered in the cost.

(m) The contractors will have to make connections to the existing manhole including plugging, diverting or pumping the existing flow or accumulated water, making holes of any size in the masonry, breaking the existing cement concrete haunches, making sand plaster, constructing new channels and haunches with M 20 Cement concrete finished smooth with 20 mm thick cement mortar 1:1, deplugging and desilting the manhole on upstream side and downstream including passing disc in the length complete as directed.

(n) Contractor shall pay any deposits that are required to be paid to Government Agency/Authorities etc, for obtaining any permission from them.

(o) Where the excavation is required to be done across the road or along the part of a road where there is high volume of traffic, the Engineer may direct the contractor, to execute the work in more than one shift, so as to complete the work, in least required time, so as to reduce the inconvenience caused to the free flow of traffic. Arrangement will have to be made by the contractor to provide additional lights, sign boards etc. as required by the Engineer and traffic police. No extra payment will be made for this arrangement. The program of the work to be done in additional shifts shall be submitted to the Engineer and got approved before starting the work, so that the work can be completed in a time bound manner.

(p) It is incumbent on the Contractors to remove all "Pardis" put up by them during the progress of sewer work so as to obviate the necessity of such removal after the sewer is put into commission. If any such "Pardi" is found after the Sewer is put into commission the cost of breaking and removing the same will be recovered from the Contractors.

(q) Contractor should note that the sewer connections are to be made to the existing manholes which may be in surcharge condition and no extra claim of any sort will be entertained for plugging, desilting, diverting the flow or pumping out water from the existing sewer line as well as from the trench, to any extent, and contractors should consider all this in his quote.

(r) The backfilling of the trench shall be completed upto 30th April so that reinstatement of trenches including asphalting work can be completed prior to 10th May.

(s) Employer reserves the rights to reduce the scope of the work during the execution of the work for any reason. For the reduction in the scope of the work no claims whatsoever of nature by the contractor will be entertained.

3.14 Screening

The Contractor shall provide mechanically operated, front-raked screening equipment suitable for open channel type flow.

The Contractor shall provide a sufficient number of appropriately sized units operating in parallel to meet the Flows and Loads specified in Appendix B1 of the Employer's Requirements.

The Contractor shall provide a means of isolating each screen with motorised penstocks in upstream and Stop log in downstream capable of manual operation.

Screens shall have clear openings not less than 75mm for interceptors. Design velocity through the apertures shall not exceed 1.5 m/s at PFF.

Screens shall be equipped with an automatic cleaning system to prevent blockage. The Contractor shall ensure that the screen cleaning system can be operated intermittently and be controlled by both an adjustable timed cycle and a pre-set differential head across the screen using ultrasonic level sensors. The screens shall be equipped with multiple rakes such that the maximum time between raking any point on the screen is 20 seconds in fair season and 10 seconds during monsoon.

The Contractor shall select the screens and screening handling equipment from suppliers with a proven track record for this application.

The capacity of the screenings treatment plant shall be adequate to treat the peak screenings loads, which may occur following a storm. The Contractor shall demonstrate that this has been taken into account in the design of the screenings handling system.

The Contractor shall be responsible for the transport and disposal of screenings to a legal, licenced landfill site.

The Contractor shall remove screenings from the Site in sealed bags / containers designed to ensure no release of odours or liquid to the environment along the route to the disposal location.

The Contractor shall make provision for storage of empty screenings containers / bags on the DWFIF Site. These containers shall be thoroughly clean and odour free.

3.15 Hydraulic Design

3.15.1 General

The principal hydraulic design requirements applicable to the Works are that:

- All aspects of the hydraulic design shall be based on sound principles and good common engineering practice typical for municipal engineered works;
- The Dry Weather Flow Interception Facility and all parts thereof shall be capable of passing the required wastewater flows;
- The hydraulic design shall comply, where applicable with relevant international standards.

3.15.2 Channels

The Manning Formula or similar shall be used for the design of open channels and shall, except where expressly permitted otherwise, be designed for sub-critical flow, with a Froude number no higher than 0.5.

Channels collecting flows from weirs along one or both sides of the channel shall be designed and analysed taking account of both friction losses and losses due to mixing of the incoming flow. The modified 'Camp' formulae may be used for headloss calculation for 'staged flows' in effluent launders with weirs.

3.15.3 Control and other Hydraulic Structures

As far as practicable, sharp crested weirs with free discharge shall be used and shall be designed with standard profiles for which flow characteristics are readily available, so that their hydraulic performance can be predicted reliably from reputable hydraulic texts.

Sharp-crested weirs shall include adequate provision for maintaining atmospheric pressures beneath the nappe.

Flumes shall be designed with the appropriate approach distance and the discharge shall be designed to be free flowing (not drowned) with the appropriate maximum submergence. Flumes shall be designed to work under all hydraulic flow conditions from minimum to maximum.

3.15.4 Penstocks

Penstocks in channels shall be designed so that, when fully open, there is no encroachment on the cross-sectional area of the maximum flow depth.

3.15.5 Hydraulic Gradient

The hydraulic gradient shall be calculated according to the following criteria:

a) The roughness coefficient 'C' or 'K' shall be as per common engineering practice (pipes and channels), the pipe manufacturer's guidelines, taking into account whether the use is for wastewater or surface water;
b) A freeboard of at least 25 mm shall be provided to upstream weir crests under maximum flow conditions when one stream is isolated, and at least 100 mm shall be provided under full flow with all streams operational;
c) The ADWF hydraulic gradient shall be calculated assuming one stream of process plant is offline, and weir levels set accordingly; and

d) Self-cleansing velocities shall be achieved in all pipes and channels as appropriate at least two times per day.

4 HEALTH AND SAFETY REQUIREMENTS

4.1 General

The Contractor shall appoint an accident prevention officer in accordance with Clause 6.7 of the Conditions of Contract.

The Contractor shall comply at all times during the Contract with all relevant Indian health and safety legislation, and all amendments thereto and also IS 18001:2007 Occupational Health and Safety (OH&S) Management System.

This standard prescribes requirements for an OH&S management system, to enable an organization to formulate a policy and objectives, taking into account legislative requirements and information about significant hazards and risks, which the organization can control and over which it can be expected to have an influence, to protect its employees and others, whose health and safety may be affected by the activities of the organization.

The Contractor shall immediately notify the Engineer or, in his absence, the Employer, if any accident occurs whether on or off the Site in connection with the Works which results in any injury to any person whether directly concerned with the Site or a third party. Such notification may initially be verbal and shall be followed by a written report within 24 hours of the accident.

4.2 Safe Systems of Work

The Contractor shall be responsible for all safety systems on site. Throughout the Contract Period the Contractor shall:

i) At all times maintain a safe system of working and shall comply with all enactments, regulations and working rules relating to safety, security, health and welfare of all persons who may be affected by his work

ii) Ensure that only persons who are properly trained for their duties are employed, that the correct tools and procedures are used and that adequate personal protective equipment is provided to all persons who may be affected by the work

iii) Carry out toolbox talks for all Contractor's Personnel at least once per week

iv) Erect suitable warning signs, barriers, etc. as necessary for the activity which is being carried out – the Contractor shall maintain such signs, barriers, etc for the duration of such activities

v) Submit to the Employer or Employer's Representative, no later than 28 days before work commences on the Site, his Health and Safety Plan containing comprehensive proposals relating to the management of health, safety and welfare of all his personnel on the Site and all persons who may be affected by his work.

The Contractor shall be responsible for the safety of all his personnel and other persons directly or indirectly employed for the Works and shall take all measures at his own expense necessary to ensure their safety. In particular such measures to be taken by the Contractor shall include the following:

i) Provision of proper safety and emergency plans and regulations; fire, gas and electric shock precautions, stretchers and first aid box together with rescue facilities generally for each place of working;

ii) Provision of appropriate and effective safety work gear, including certified safety helmets and certified work boots for all personnel including the Engineer and each of his staff and any authorized visitors to the Site (see further data in Appendix D);

iii) Safe control of the water table, including provision of ample standby generating and pumping plant to maintain dry conditions;

iv) Provision and maintenance of suitable lighting to provide adequate illumination of works with appropriate spares and standby equipment;

v) Provision and maintenance of safe, sound mechanical equipment, each item of plant having an up-to-date testing certificate;

vi) Provision and maintenance of safe, sound ropes, slings, pulleys and other lifting tackle, each appliance having an up-to-date testing certificate, where appropriate;

vii) Provision of notices on weather-proof boards measuring 1.25m x 1.5m in size, written in bold letters in English, Marathi and Hindi to be erected on existing footpaths and at points of access likely to be used by the public, which shall warn the public of the existence of the Works. These notices shall be in addition to any statutory requirements demanded of the Contractor.

viii) Suitable scaffolds shall be provided for workmen for all activities that cannot be safely executed from the ground, or from solid construction except such short period work as can be done safely from ladders. When a ladder is used, an extra person shall be engaged for holding the ladder and if the ladder is used for carrying materials as well, suitable footholds and handholds shall be provided on the ladder and the ladder shall be given an inclination not steeper than ¼ to 1 (¼ horizontal and 1 vertical);

ix) Scaffolding or staging more than 3.25m above the ground or floor, swung or suspended from an overhead support, or erected with stationary support, shall have a guard rail properly attached, bolted, braced and otherwise secured at least 1 metre above the floor or platform of such scaffolding or staging and extending along the entire length of the outside and ends thereof with only such openings as may be necessary for the delivery of materials. Such scaffolding or staging shall be so fastened as to prevent it from swaying from the building or structure;

x) Working platforms, gangways and stairways shall be so constructed that they do not sag unduly or unequally, and if the height of a platform or stairway is more than 3.25 metres above ground level or floor level, it shall be closely boarded, have adequate width and be suitably fenced; and be provided with toe boards to stop tools and materials falling off onto those below,

xi) Every opening in the floor of a building or in a working platform shall be provided with suitable means to prevent fall of persons or materials by providing suitable fencing or railing with a minimum height of 1 metre;

xii) Safe means of access shall be provided to all working platforms and other working areas. Every ladder shall be securely fixed. No portable single ladder shall be over 3 metres in length.

xiii) The Contractor shall take adequate precautions to prevent danger from electrical equipment. No material on the Site shall be so stacked or placed as to cause danger or inconvenience to any person or the public.

xiv) Excavation and trenching: All trenches 1.5 metres or more in depth shall be considered confined spaces and shall at all times be supplied with at least one ladder every 30 metres, or fraction thereof. Ladders shall be extended from bottom of trench to at least 1 metre above surface of the ground. Sides of a trench which is 1.5 metres or more in depth shall be stepped back to give suitable slope, or securely held by timber bracing, to avoid the danger of sides collapsing. Excavated material shall not be placed within 1.5 metres of the edge of a trench, or half of the depth of the trench, whichever is more. Cutting shall be done from top to bottom. Under no circumstances shall undermining or undercutting be done.

xv) Demolition: Before any demolition work is commenced and also during the process of the work:

a) All roads and open areas adjacent to the work Site shall either be closed or suitably protected.

b) No electric cable or apparatus which is liable to be a source of danger other than a cable or apparatus being used by an operator shall remain electrically charged.

c) The Contractor shall take all practical steps to prevent danger to persons employed from risk of fire or explosion, and the Contractor shall ensure that no part of a building shall be so overloaded with debris or materials as to render it unsafe.

i) All necessary personal safety equipment shall be provided by the Contractor for use by persons employed on the Site and maintained in a condition suitable for immediate use, and the Contractor shall take adequate steps to ensure proper use of equipment by those concerned:

a. Workers employed on mixing asphaltic material, cement and lime mortars / concrete shall be provided with protective footwear, gloves and goggles.

b. Those engaged in handling any material which is injurious to eyes shall be provided with protective goggles.

c. Those engaged in welding works shall be provided with welder's protective eye-shields.

d. Stone breakers shall be provided with protective goggles and protective clothing and seated at sufficiently safe intervals.

e. Those working with loud machinery or near loud activities shall be provided with appropriate ear protection such as ear muffs.

f. When workers are employed in sewers and manholes, which are in use, the Contractor shall ensure that manhole covers are opened and manholes are ventilated by mechanical means for at least one hour before workers are allowed entry. Manholes so opened shall be cordoned off with suitable railing and provided with warning signals or boards to prevent accident to public. H2S and Methane detectors shall be used for verifying the gas levels prior to allowing the personnel inside the manholes. The personnel should enter the manhole with breathing apparatus only

i. When work is done near any place where there is a risk of drowning, all necessary equipment shall be provided by the Contractor and kept ready for use and all necessary steps taken for prompt rescue of any person in danger and adequate provision made for prompt first aid treatment of all injuries likely to be sustained during the course of the work;

ii) Use of hoisting machines and tackle including their attachments, anchorage, and supports shall conform to the following:

a. These shall be of good mechanical construction, sound material and adequate strength and free from patent defects and the Contractor shall keep same in good repair and in good working order.

b. Every rope used in hoisting or lowering materials or as a means of suspension shall be of durable quality and adequate strength, and free from patent defects.

c. Every crane driver or hoisting appliance operator shall be properly qualified and no person under the age of 21 years shall be in charge of any hoisting machine including any scaffold winch or give signals to operator.

d. In the case of every hoisting machine and of every chain ring hook, shackle, swivel and pulley block used in hoisting or lowering or as a means of suspension, safe working load shall be ascertained by the Contractor by adequate means. Every hoisting machine and all gear referred to above shall be plainly marked with safe working load by the Contractor. In case of a hoisting machine having a variable safe working load, each safe working load and the conditions under which it is applicable shall be clearly indicated by the Contractor. No part of any machine or of any gear referred to above in this paragraph shall be loaded beyond safe working load except for the purpose of testing.

e. The Contractor shall notify safe working load of each machine to the Engineer whenever he brings it to Site.

   i. Motors, gearing, transmission, electric wiring and other dangerous parts of hoisting appliances shall be provided with efficient safeguards. Hoisting appliances shall be provided with such means as will reduce to the minimum risk of accidental descent of load. Adequate precautions shall be taken to reduce to the minimum risk of any part of a suspended load becoming accidentally displaced. When workers are employed on electrical installations which are already energized, insulating mats, wearing apparel such as gloves, sleeves and boots, as may be necessary, shall be provided. Workers shall not wear any rings, watches and carry keys or other material which are good conductors of electricity;

   ii. All scaffolds, ladders and other safety devices shall be maintained in a safe condition and no scaffold, ladder or equipment shall be altered or removed while it is in use. Adequate washing facilities shall be provided at or near places of work;

   iii. These safety provisions shall be brought to the notice of all concerned by display on a notice board at a prominent place at the work spot. Persons responsible for ensuring compliance with the safety provisions shall be named therein by the Contractor;

   iv. To ensure effective enforcement of the rules and regulations relating to safety precautions, arrangements made by the Contractor shall be open to inspection by the Engineer and any safety inspection officer.

   v. All movement of vehicles to and from the sites shall comply with the Traffic Management Plan described in Section 6.7 and in the Traffic Management Requirements in Appendix B.

Notwithstanding the above provisions, the Contractor is not exempted from the requirements of any other Laws in force.

The Contractor shall submit to the Engineer for review detailed proposals under (i) above in conjunction with detailed construction and installation method statements for each element of work to be undertaken. When accepted by the Engineer, and before the work is started, the Contractor shall distribute copies in English or in other language as appropriate to all his employees and to the Engineer.

The Contractor shall ensure that all his employees are fully conversant with the plans and regulations and the Contractor shall enforce the rule that any employee committing a serious breach of such plans and regulations shall be instantly dismissed and shall not be re-employed.

4.3 Paint

Paint or other products containing lead shall not be used.

4.4 First Aid and Life-saving apparatus

The Contractor shall provide on the Site such life-saving apparatus as may be appropriate and shall provide, equip and maintain at the Site of Works first aid boxes as directed and shall be subject to approval by the Engineer for the use of his own as well as Engineer's Personnel on Site.

In addition, the Contractor shall instruct an adequate number of persons permanently employed at the Site in the use of the apparatus and equipment, and the Contractor shall make known the persons so designated to all employees by the posting of their names and designations in a prominent position on Site.

The Contractor shall advise the Engineer of measures to be taken in the event of a serious accident.

The Contractor shall post a list of emergency telephone numbers (including ambulance) at several locations on site.

4.5 Electrical Safety

While any electrical equipment is being installed or tested, the Contractor shall ensure that all necessary precautions are taken to safeguard personnel working on Site. If necessary, this shall include fencing off areas that are considered to pose a risk, and erecting warning notices.

The Contractor shall ensure that the installation of electrical equipment is carried out by suitably trained competent personnel and that the work is carried out in a safe manner. No electrical cables shall be laid across rebar. No joints or repairs shall be made to cables except by suitably trained competent personnel using appropriate protective equipment. All power sockets used on the Site shall be protected by a residual current service.

The Contractor shall be responsible for the operation on the Site of a permit to work system during the period of electrical equipment installation and testing. This system shall regulate the installation, the energising and the use of electrical Plant installed and the method of work adopted.

4.6 Asbestos

The Contractor shall not use any product that contains crocidolite (blue asbestos). Prior to use of any asbestos materials, whether in permanent works or temporary works, the Contractor shall submit to the Engineer for review evidence that his insurance policies permit the use of asbestos. The Contractor shall notify the Engineer of the presence of asbestos on site throughout the entire Contract Period, including the Operation Service Period. When handling any asbestos materials he shall comply with all appropriate national and internationally accepted regulations and codes of practice relating to the handling and disposal of asbestos.

4.7 Supply of Potable Water and Sanitation Facilities

The Contractor shall, having regard to local conditions, provide on the Site an adequate supply of fresh and chlorinated potable water suitable for drinking and other water for the use of the Contractor's staff on a daily basis. The Contractor shall also provide sanitation facilities for his staff employed on the site for the duration of the Contract.

4.8 Measures against Insect and Pest Nuisance

The Contractor shall at all times take the necessary precautions to protect the Contractor's staff employed on the Site from insect and pest nuisance, and to reduce their danger to health. The Contractor shall comply with all the regulations of the local health authorities, including use of appropriate insecticide.

4.9 Measures against Sunburn and Heat Exhaustion

The Contractor shall at all times take the necessary precautions to protect the Contractor's staff employed on the Site from sunburn and heat exhaustion including provision of adequate breaks.

4.10 Alcoholic Liquor or Banned Substances

The Contractor shall not allow alcoholic liquor or banned substances on site. The Contractor shall not import, sell, give barter or otherwise dispose of any alcoholic liquor or drugs, or permit or allow importation, sale, gift barter or disposal thereto by Contractor's staff.

4.11 Arms and Ammunition

The Contractor shall not allow arms and ammunition of any kind on the site. The Contractor shall not give, barter, or otherwise dispose of, to any person, any arms or ammunition of any kind, or allow Contractor's staff to do so.

4.12 Festivals and Religious Customs

The Contractor shall respect the Country's recognized festivals and religious or other customs. As a minimum, the statutory/mandatory holidays as declared by the Central and State governments shall be adhered to by the Contractor

4.13 Employment Records of Workers

The Contractor shall keep complete and accurate records of the employment of labour at the Site. The records shall include the names, ages, genders, hours worked and wages paid to all workers. The Contractor shall summarise these records on a monthly basis and submit to the Engineer, and the Contractor shall make these records available for inspection during normal working hours. The Contractor shall include these records in the details to be submitted by the Contractor under Sub-Clause 6.10 of the Conditions of Contract.

4.14 Repatriation of Labour

The Contractor shall be responsible for the return of persons (recruited and employed for the purpose of or in connection with the Contract) to the place from where they were recruited or to their domicile and shall maintain such persons in a suitable manner until they shall have left the Site or, in the case of persons who are not nationals of and have been recruited from outside India, shall have left India.

4.15 Epidemics

In the event of any outbreak of illness of an epidemics nature, the Contractor shall comply with and carry out such regulations, orders and requirements as may be made by the Government, or the local medical or sanitary authorities, for the purpose of dealing with and overcoming the same. In the event of any outbreak of illness of an epidemics nature, the Contractor shall comply with and carry out such regulations, orders and requirements as may be made by the

Government, or the local medical or sanitary authorities, for the purpose of dealing with and overcoming the same

4.16 Burial or Cremation of the Dead

The Contractor shall make all necessary arrangements for the transport, to any place as required for burial or cremation, of any of his expatriate employees or members of their families who may die in India. The Contractor shall also be responsible to the extent required by the local regulations, for making any arrangements with regard to burial or cremation or any of his locally employed personnel who may die while engaged upon the Works.

4.17 MCGM Health Department Guidelines

The Contractor shall keep a check on the health of all labour / employees as per MCGM Health Department Guidelines, including the appointment of a MBBS doctor to carry out regular checks at the site.

4.18 Tunnel Safety

4.18.1 General

The Contractor shall submit descriptions of the installations he proposes to use for supply of water, ventilated air, compressed air, lighting, power supply, etc., and for the disposal of drainage and waste water, contaminated air, etc., for the acceptance of the Engineer in advance of starting underground works.

The tunnelling work shall be carried out in accordance with the following:

a) Government of India Rules and Regulations

b) BS 6164: 2011 Code of Practice for Safety in Tunnelling.

c) CIRIA Report 80: A review of instruments for gas and dust monitoring underground

d) Requirements for Site Electrical Installations

e) The Contractor's Health and Safety Plan

4.18.2 Telephone Communications to tunnels

The Contractor shall provide and maintain in good working order an internal site telephone system with instructions prominently displayed as near to every tunnel working face as is practicable, and linked to the appropriate Working Sites on the surface. The telephone network should be provided for Engineer's office including telephone connection to the work's place and tunnel shafts.

4.18.3 Electric Cables

All lighting and power cables installed underground shall be adequately insulated with joints made in an agreed manner. All installation and maintenance work shall be done by qualified personnel to a high standard. Cables shall be securely fixed above floor level with the exception of cables needed for occasional work.

Separate circuit breaker systems shall be provided for the supply of power for equipment and for lighting, respectively, and they shall be kept well separated from signalling and telephone cables.

All electric installations shall be adequately earthed in accordance with normal practice and local requirements and be accepted by the Engineer. Installations shall furthermore be protected by earth-fault breakers, all in accordance with current practice and safety standards and accepted by Engineer.

4.18.4 Ventilation System

During the construction of the works, but not during operation, the Contractor shall provide an underground ventilation system which shall be capable of serving all areas where work is going on. After installation, the ventilation ducts shall be checked at regular intervals and any damage, which might decrease their efficiency, shall immediately be repaired. Spare ducts and spare ventilators shall be available on Site for this purpose.

The ventilation system shall be designed such that the temperature at the working face does not exceed 32ºC.

The ventilation system shall be removed on completion of the Works.

Petrol engines shall not be permitted underground.

Diesel plant used underground shall be fitted with suitable emission control equipment to maintain the tunnel environment in accordance with the requirements of the Factories Regulations. The engines shall be regularly checked and kept well-adjusted so that all harmful substances in the exhaust gases and smoke are kept to the minimum.

An electronic gas detector approved by the Engineer shall be maintained at each tunnel face or shaft bottom at all times, and wherever a person is working within the tunnel. The Contractor shall perform continual measurements of gas pollution underground along the length of the tunnel in order to detect at an early stage the presence of carbon monoxide, nitrogen dioxide, methane and other harmful or explosive gases. In doing so, the Contractor shall ensure that pollution percentages including that resulting from dust are kept within acceptable limits according to internationally recognised standards. The results of measurements shall be recorded and submitted to the Engineer.

The Contractor shall ventilate the underground works so that at all times, the concentration of contaminants in the atmosphere is kept below levels that can cause damage to health. The oxygen content of the air shall not be less than 20% and the absolute limits of concentration of nitrous fumes, carbon monoxide and carbon dioxide shall be 5 ppm, 10 ppm and 5000 ppm respectively by volume.

Clean fresh air shall be supplied by forced ventilation at the rate of not less than 5.7m^3/minute per worker, 2.5m^3/minute per diesel hp, or 13m^3/minute/m^2 face area in the tunnel, whichever is the greatest. The ventilation system shall be so arranged that air may be blown into or drawn from the face. The ducting shall be properly maintained and kept free from leaks and other defects.

At least once in every shift, the Contractor shall test the quality of air to ensure that it remains within the requirements of the Factories Regulations. If the presence of other gases not specified or other contamination is suspected, suitable methods of detection shall be implemented.

Precautions shall be taken to minimise dust production. Where sprayed concreting or mechanical excavation operations are being carried out such additional measures shall be taken by the Contractor as are required to allow safe and proper execution and inspection of the work. The measures shall include, inter alia, the use of respirators, breathing apparatus or auxiliary fans.

4.18.5 Lighting

All underground areas where work is going on shall be illuminated with electric lights of adequate strength and number to allow work, inspection, mapping and surveying to be carried out in a proper and safe manner. The Contractor shall provide lighting at the working face or at any operation where more than five operatives are working, with a minimum illumination of 100 Lux. Elsewhere in the tunnel including walkway the minimum illumination shall be 50 Lux at walkway level.

Battery operated emergency lights shall be provided at appropriate intervals

4.18.6 Walkway

The Contractor shall provide a dedicated prefabricated walkway with a non-slip surface in each tunnel where human access is required throughout its construction

4.18.7 Access Ladders

The Contractor shall provide and maintain throughout the Contract adequately protected and secured access ladders and landings in shafts, together with guard rails and toe boards.

4.18.8 Fire Precautions and Evacuations in Tunnels

The Contractor shall submit a comprehensive plan concerning Fire Precautions and Evacuations in Tunnels, both during boring and the equipment installation phase, to the Engineer for acceptance. The following shall be addressed:

a. Burning and welding.

b. Materials to be used.

c. Any other activities, which may pose a fire risk.

d. Fire fighting equipment.

e. Fire fighting procedures (including fire drill).

4.19 Confined Spaces

4.19.1 Control of Access to Underground Works

The Contractor shall operate and maintain throughout the contract a control-of-entry system for the underground works which will provide a record of who is underground at any time, for use in emergencies. Nobody shall be allowed underground without recording their presence using the established system.

4.19.2 Control of Access to Existing Underground Structures

Where existing Underground Structures have to be entered the Safety Officer must be informed in advance and the following precautions must be taken:

a) Air quality / gas testing must be carried out before entry

b) There shall be an agreed system in place for rescue of injured or incapacitated persons underground

c) All persons entering existing underground structures shall have received training in the hazards of confined spaces.

5 ENVIRONMENTAL REQUIREMENTS

5.1 Environmental Management Plan

The environmental requirements given in the Employer's Requirements are in line with those issued by the National Environmental Engineering Research Institute (NEERI) for similar projects.

The Contractor shall prepare an Environmental Management Plan in order to comply with the environmental requirements stated in the Employer's Requirements. The Contractor is cautioned that this document is not an exhaustive list and the Contractor is required to identify all other licences or approvals required.

The Contractor shall designate tasks to personnel to take overall responsibility for all or parts of the Environmental Management Plan. These personnel shall manage environmental control facilities on a day-to-day basis and liaise with the Engineer's environmental monitoring team.

The Engineer shall have the right to order the work to be stopped in the event of an infringement of the requirements of the Environmental Management Plan until the situation is rectified to the satisfaction of the Engineer. In this event the Contractor shall not be entitled to claim for delays or expenses incurred.

5.2 Protection of Environment

The Contractor shall ensure that at all times during construction of the Works all reasonable precautions are taken to the satisfaction of the Engineer to prevent pollution of the Site and of the environment. In particular, the Contractor shall prevent pollution arising from the disposal or spilling of pumped water, sewage, diesel, fuel oil, liquid mud or from the disturbance of natural dust, aggregate dust or cement dust.

The Contractor shall take all reasonable steps to avoid damage or nuisance to persons or to property of the public or others resulting from pollution, noise or other causes arising as a consequence of his methods of construction, operation and for demolishing existing structures.

The Contractor and his Subcontractors shall abide at all times by all existing enactments on environmental protection and rules made there under, regulations, notifications and bye-Laws of the state or central government, and any other Law, bye-Law, regulations that may be passed or notification that may be issued in this respect in future by the state or central government.

Principal environmental regulations include but are not limited to:

Year	Environmental Regulations
1974	The Water (Prevention & Control of Pollution Act) Amendments, 1988
1975	The Water (Prevention & Control of Pollution) Rules
1977	The Water (Prevention & Control of Pollution) Cess Act, Amendment 1992
1978	The Water (Prevention & Control of Pollution) Cess Rules
1981	The Air (Prevention & Control of Pollution) Act, Amendments, 1987
1982/1983	The Air (Prevention & Control of Pollution) Rules
1986	The Environment (Protection) Act, Amendments (1989,1990,1993,1996,1997,1998,1999,2000,2001) The Environment (Protection) fourth Amendment Rules 2008
1986	The Environmental (Protection) Rules
1992	E (P) Act Notification – "Environment Statement"

Year	Environmental Regulations
1994	E (P) Act Notification – "Environmental Clearance" EIA Notification 2009
1997	Amendments in the Environment Clearance, EIA Notification – "Public Hearing" made mandatory
1989	The Hazardous Wastes (Management and Handling) Rules, Amendments, 2000 and 2003
1989	Manufacture, Storage and Import of Hazardous Chemical Rules, Amendments, 1989, 2000
1991	The Public Liability Insurance Act, 1991
1995	The National Environment Tribunal Act
1997	Prohibition on the Handling of Azodyes
1997	The National Environment Appellate Authority Act
1998	The Bio-Medical Waste (Management &Handling), Rules
1999	Notification for making 100% Utilization of Fly-ash made mandatory, Amendments 2003
2000	Municipal Solid Waste (Management &Handling) Rules
2000	Ozone Depleting Substance (Regulation &Control) Rules
1999	Regulation on recycling of Waste Oil and Non-ferrous scrape
2000	The Noise Pollution Regulations and Control Rules
2001	Batteries (Management &Handling) Rules
2012	Environmental Guidelines for Public Building Projects in Maharashtra State

5.3 Green Building Materials

The Contractor shall make use of locally available materials to reduce emissions due to transportation. At least 10% of civil construction materials by value, such as concrete, steel, tiles, glass, etc., shall be sourced within a radius of 400km from the Site.

Internal paint coatings, finishes, polishes and adhesives and sealants, shall have low or zero Volatile Organic Compounds (VOC).

The Contractor shall source civil construction materials with recycled content, which shall constitute at least 10% of the total civil construction materials, by value.

5.4 Spoil Removal

The Contractor shall include in his Environmental Management Plan a Site Waste Management Plan (SWMP), which sets out in detail how spoil and all waste is to be categorised, disposed of and monitored, the programme for disposal and how legislation is to be complied with. This plan will address all waste matters at the site and have specific documented mechanisms for adopting a 'reduce, reuse, recycle' approach to waste minimisation for dealing with all wastes. The SWMP shall be submitted to the Employer or Employer's Representative for review and acceptance.

The Contractor shall set up a system to control and monitor the transport of spoil from the Site to the tip site. The system shall be agreed with the Employer's Representative and will provide evidence that each load has been deposited at an agreed tip site.

The Contractor shall retain auditable records of waste removed from site. Waste Transfer Notices should be collated and submitted to the Employer's Representative. Transfer and Consignment notes shall be kept in the site file.

The Contractor shall comply with all legislation and regulations relating to spoil disposal.

5.5 Discharge of Water into Existing Watercourse

The Contractor shall make provision for the discharge or disposal from the Works of all water and waste products howsoever arising and the method of disposal shall be to the satisfaction of the Employer's Representative and of any Authority or person having an interest in any system (drainage or sewers), land or watercourse in which waste may be so discharged. Before discharging any surplus water, the Contractor shall obtain the necessary written approvals.

The Contractor shall be permitted to discharge rain water and clean groundwater to adjacent nallahs and storm water drains (SWDs). However, no pollutants, soils, bentonite, or mud of any sort shall be permitted to be discharged to nallahs or SWDs.

The Contractor shall make his own arrangements for trapping of the silt, separating lubricants, bentonite, drilling mud, or other pollutants before disposal.

The water discharged from any source in connection with the construction shall comply with the requirement of the discharge norms stipulated under the Environment Protection Rules (under Environment Protection Act 1985) and the regulations laid down by the Maharashtra Pollution Control Board (MPCB). The parameters to be monitored include pH values, temperature and suspended solids.

5.6 Tree Felling

It is a requirement of the Contract that the Contractor obtains consent from the Tree Authority for removal of any trees and shall follow the instructions of the consent. The Contractor shall assume that the consent will require that the Contractor plant 2 trees on the Site for every 1 removed, in addition to re-plantation of the removed tree.

The Contractor shall allow an appropriate amount of time in his programme for liaising with the authority, including organising a Site visit with the authority, and obtaining the necessary consent. The Contractor shall avoid as far as possible the cutting of trees.

No tree shall be felled without the permission of the Employer's Representative and clearance of the site shall be kept to the minimum necessary for the Works and temporary works.

Trees shall be protected from damage during the course of the work and earth level within one metre of each such tree shall not be changed. Where necessary, such trees shall be protected with temporary fencing.

5.7 Mangroves

The mangroves beneath which the tunnel alignment is passing are reserved forests and the Contractor shall take every precaution to protect them.

Mangrove cutting is not permitted without prior permission from the Ministry of Environment & Forests. At downstream side of proposed tunnel If additional land (having mangrove trees / non mangrove trees/ no trees) is required beyond existing footprint of Dharavi WwTF contractor have to obtained prior permission from the Ministry of Environment & Forests.

Any harm done to the mangroves as a consequence of the work of the Contractor shall be entirely at the risk and cost of the Contractor.

5.8 Noise and Vibration

The Contractor shall carry out his operations in such a manner as to minimise noise and vibration nuisance.

The Contractor shall comply with the requirements of The Noise Pollution (Regulation and Control) Rules 2000 and all latest amendments.

The Contractor shall ensure that all his equipment used in the Contract shall be designed to be reasonably quiet in operation and shall check the measures taken by the manufacturers to minimise noise during operation of the equipment. The Contractor shall ensure that all his equipment and associated platforms and connections are properly maintained to be in efficient working order and reasonably quiet in operation for the full duration of the Works. The Contractor shall fit effective silencers to machine exhausts and adopt such other means as may be necessary to reduce noise to acceptable levels.

Machines in intermittent use shall be shut down when not in use, or throttled back to a minimum. The Contractor shall remove from the Site any items of Contractor's equipment which is, in the opinion of the Engineer ineffectively silenced.

All compressors, pumps and mechanical static plant shall be low noise models fitted with properly designed acoustic covers, or screens, to reduce noise to acceptable levels. These covers shall be kept closed whenever the machines are in use. All ancillary pneumatic percussion tools shall be fitted with mufflers or silencers of the type recommended by the manufacturer.

The Contractor shall organise his operations with regard to the positioning of plant and the location of haul routes, etc. to minimise construction noise to adjacent properties.

He shall further employ the best practical means to minimise noise produced by his activities.

The Contractor shall ensure that the sound levels arising from his activities during construction do not exceed the following values when measured at the Site boundary:

Area Code	Category of Area/Zone	Limits in dB(A) Leq*	
		Day time	Night time
(A)	Industrial Area	75	70
(B)	Commercial Area	65	55
(C)	Residential Area	55	45
(D)	Silence Zone	50	40

Source: Rule 3(1) and 4(1) of the Noise Pollution (Control and Regulation) Rules, 2000

* When the existing ambient noise levels are higher than the limits shown in the table, the Contractor shall ensure that sound levels arising from his activities do not exceed the lesser of 5 dB(A) above ambient noise levels or 75dB(A).

a) Day time shall mean from 6:00 am to 10:00 pm

b) Night time mean from 10:00 pm to 6:00 am

c) Silence Zone is defined as an area comprising not less than 100 meters around hospitals, educational institutions and courts. The silence zones are zones which are declared as such by the competent authority.

Categories of the areas around the main shafts are as shown below. Categories at intermediate points along the alignment, including at possible intermediate shaft sites have not been determined and will need to be investigated by the contractor to suit his work plan.

			Limits in dB(A)	
Shaft	Nearby buildings	Zone	Day	Night
S01	Bapat Nalla Shaft	Mixed	75	45
S02	Safed Pul Shaft	Residential	55	45
S03	Mangroves	Industrial	75	70

If so ordered by the Engineer, the Contractor shall take measurements of background noise and noise attributable to his operations. Measurements and analyses shall be carried out in accordance with ISO 1996, Acoustics – Description and Measurement of Environmental Noise.

In addition, noise emitted between 8:00 pm and 8:00 am shall be free from tonal or impulse qualities and pile driving or drilling shall not be permitted during these hours.

The Contractor shall carry out the Works in such a manner as to limit vibration at adjacent properties and at the works, due to his construction activities, to an acceptable level.

If required by the Engineer the Contractor shall carry out vibration monitoring at adjacent properties.

Vibration caused by construction plant to be limited to the recommended values:

Allowable vibration (in terms of peak particle velocity) at the closest part of any sensitive property to the source of vibration, at a frequency of		
	At Property	**At Source**
Less than 10 Hz	10 to 50 Hz	50 to 100 Hz (and above)
3 mm/s	3 to 8 mm/s	8 to 10 mm/s

5.9 Dust Disturbance

Dust generation at the site shall be suppressed by suitable methods, such as periodic water spray, to the satisfaction of the Engineer. Trucks carrying excavated muck shall be adequately covered to prevent any spillage of muck on the roads while transporting the same to the locations of disposal.

The Contractor shall comply with the requirements of The Air (Prevention and Control of Pollution) Act 1981 and all associated Rules and Notifications.

The Contractor shall take adequate measures to control the emission of dust from the Site. Such measures shall include sprinkling of surfaces, revegetation and delayed stripping of vegetative cover where practical.

The Contractor shall cover or water stockpiles and storage areas to prevent dust pollution. The Contractor shall also cover trucks transporting construction materials to minimise spills and shall not overload vehicles.

The Contractor shall not cause any dust nuisance to third parties or to the Engineer's offices or Employer's facilities.

The Contractor shall tune and service regularly all construction and transportation equipment in order to prevent air pollution.

6 GENERAL CONSTRUCTION WORKS

6.1 Accommodation for Contractor's Personnel

The Contractor shall be responsible for providing accommodation for all his staff and workmen. No workmen camp or temporary huts shall be allowed to be erected on any public land without proper permission. In case of any workmen camp set up at any location for the workmen of the Contractor or his subcontractor or labour contractor, the Contractor shall be solely responsible for permissions as well as safety of the workmen thereat.

The Employer is not in a position to make available any land for the Contractor's camp for labour or staff, or for any casting yard, or any other off site activity in connection with the Contract.

The Contractor shall be responsible for arranging for such space for his use in the vicinity of the work sites at his own cost. For this purpose, the Employer shall only issue a recommendation letter on specific request from the Contractor to facilitate obtaining necessary permission from private parties.

6.2 Electricity

The Contractor shall be responsible for procurement of power required for execution of the Works. It is anticipated that this will be either through the local Electricity Company (Reliance Energy or Tata Power) or installation of adequate size of DG power generating units along with indoor/outdoor substation together with supply of necessary outdoor/indoor equipment and accessories such as but not limited to DG sets, transformers, switchgears, cables, control/protection/metering/earthing etc.; and, operation, maintenance and subsequent removal of temporary supplies of electricity, which the Contractor may require in connection with construction of the Works at each of the Sites and for adequate illumination on the Sites and approach roads. If power is supplied through DG sets, it must comply with the noise and air pollution norms.

Where electricity is supplied through the local Electricity Company the Contractor shall pay all connection charges and prevailing commercial rates for electricity consumed. Contactor to identify the source of power supply at various locations, however, necessary support/correspondence will be provided by M.C.G.M.

6.3 Accommodation for the Engineer

The Contractor shall provide and maintain offices, fixtures and equipment services as specified in Appendix D for the Design-Build Period and for a further 6 months for the exclusive use of the Engineer and his staff.

All items provided shall be to the satisfaction of the Engineer and shall become the property of the Contractor at the end of the Design-Build Period unless specified otherwise.

The Engineer's main office shall be established on the same Site as the Contractor's Representative's main office. The accommodation shall be separate from, and located adjacent to the Contractor's accommodation and shall be clearly marked "Engineer". The accommodation shall be in a single storey, single, weatherproof building which shall be of good quality and of substantial build.

The accommodation area shall be covered by hardstanding surface with macadam, and properly drained and fenced off. A parking area shall be indicated within this area with space for 5 cars. The parking area shall be clearly signposted.

Rooms within the office shall be divided by full height partitions, suitably insulated. Walls and ceilings shall be lined in approved colours and the external walls shall be in an approved colour.

Floors shall be close boarded and carpeted with industrial quality carpets, with the exception of the messing areas where the floors shall be linoleum covered.

All doors shall be secure and lockable and 2 nr. sets of keys provided. A doormat and boot scraper shall be provided at each external door together with boot cleaning facilities.

There shall be adequate natural and artificial lighting and ventilation and windows shall be fitted with blinds. Air conditioning units shall be integrally fitted and adequate power points provided in each room.

Emergency exits and emergency lighting shall be provided. Suitable fire extinguishers shall be provided.

An adequate and reliable electricity supply shall be provided to each office and a potable water supply and sanitation facilities provided to the kitchen messing area and toilets.

Rooms shall be clean and freshly decorated at the start of the Contract and the Contractor shall clean the floors, kitchen, basins and toilets daily and windows weekly.

The Contractor shall be responsible for providing and removing the electrical, water, telephone and sanitation services. He shall be responsible for the cost of all bills and user charges relating to their use or consumption, with the exception of the unit costs of telephone calls made by the Engineer and his staff, which shall be refunded to the Contractor from the Provisional Sum in the Schedule of Payments in Volume III.

6.4 Assistance for the Engineer's Staff

The Contractor shall provide all necessary assistance to the Engineer and his staff in carrying out their duties of checking the setting-out, inspecting and measuring the Works. The Contractor shall provide surveyors, chainmen, staffmen, office attendants and labourers as may be needed from time to time by the Engineer.

6.5 Publicity Notice Board

During execution of the work the Contractor shall erect notice boards/ display boards in any material and size as directed by the Engineer and remove the same upon completion of the work. Such display boards shall not interfere with any functional requirements of local authorities like road signs and signals. The Contractor shall obtain permissions from local authorities for erecting such notice boards for which recommendation letters shall be issued by the Engineer.

6.6 Continuous Working / Working Outside Normal Hours

Normal working hours are identified in the Contract Data. However, the Contractor may decide to work longer hours. However, all necessary agreements and approvals must be arranged by the Contractor at his own cost. It should be noted that noise restrictions may limit working hours. For example, between 10.00 p.m. to 6.00 a.m. the Contractor may not be permitted to carry out certain activities which would create noise to the level of causing nuisance to the inhabitants.

6.7 Working in Public Roads

6.7.1 Traffic Management Requirements

The ultimate traffic authority is the traffic police. Traffic management and re-routing arrangements will require the approval of the traffic police and any instruction given by them shall be complied with.

Before commencing the Works the Contractor shall co-ordinate with the traffic police for necessary arrangement required for diversion, if required, and the Contractor shall prepare a detailed Traffic Management Plan in accordance with these requirements.

The Contractor should be aware that the traffic police may cancel any approval in the case of a violation of any of the provisions of the traffic management requirements.

Where works are to be undertaken in one road it will be an essential requirement of the Traffic Management Plan that other works under the Contract will not impact on the traffic flow in a significant way.

The Contractor's Programme, Method Statements and Traffic Management Plan shall be submitted to the Engineer and traffic police for review and the Contractor shall allow for such review times in his programme. It shall be the responsibility of the Contractor to obtain any additional permissions/consents from the traffic police and other authorities in advance of the commencement of the works.

The Plan shall include:

- Traffic Flows
- Road Closures & Relief Routes
- Emergency Use
- Deliveries to Business Premises
- Pedestrian Access
- Safety
- 24 hour access to Hospitals, Hotels, Hostels and Presbyteries
- Warning Signs
- Diversion Signs – Public Announcements
- Servicing of Excavations

The essence of the Contract shall be the completion of construction activities including temporary restoration in one public road prior to the commencement of excavation in another.

The tunnelling works must be arranged into appropriate sections and where necessary special traffic diversions arranged in accordance with the traffic management requirements.

The Contractor must arrange to contain the works within the narrowest possible area. Excavated material must be removed as the work proceeds as no additional areas are available for storage.

The Contractor shall carry out the work in such a manner as to cause minimum interference with the public use of roads, footpaths and other thoroughfares.

All workmen working on roads are required to wear approved reflective vests at all times.

The Contractor should appoint sufficient nos. of traffic warden / men in two shifts at the place of work in consultation with the traffic police.

The Contractor's attention is drawn to the draft Traffic Management Plan format regarding traffic control, access, signage, etc. contained in Appendix B, which shall be used as a template for the Contractor's draft Traffic Management Plan to be submitted, plus any additional requirements to be requested by the traffic police in order to obtain approval from the traffic police.

The Contractor shall include in his rates for compliance with all the conditions stipulated above and as given in Appendix B.

6.7.2 Road Opening

The Contractor is required to submit a detailed road opening schedule to the Engineer for approval. In case of works requiring breaking of concrete roads for shafts the Contractors shall provide for reinstatement of concrete road as per Municipal specifications and guidelines for this purpose and the cost of same shall be deemed to be included in the rate of tunnelling. The Contractor shall also provide for additional time for getting the necessary permission from traffic and roads department in this regards.

Sufficient lighting, road signs, barricades and traffic diversion signs must be established along the sites of the works in accordance with the Traffic Police requirements and to the entire satisfaction of the Engineer.

The Contractor shall also comply with the requirements of the MCGM "Guidelines for Trenching Activity", and any other conditions imposed by Traffic Police, Roads Department, MCGM or any other Authority.

Rubble, debris earth etc. should not be piled / stored on the carriage way / footpath and the same should be removed immediately and reinstatement work should be carried out on priority.

Upon the completion of the pipeline or manholes, the Contractor shall backfill and make good all disturbances to the road, side table, road kerb and drains to the satisfaction of the Authorities and the Engineer.

If required the pits shall be covered with decking plates with appropriate support so that all traffic shall be allowed to run over the decking. No extra payment shall be admissible for such arrangements and the Contractor's rates shall be deemed to cover such requirement. If directed by the authorities or the Engineer, the Contractor shall construct temporary diversion roads at his own cost to allow the traffic to flow through during the construction at no extra cost to the Employer.

6.7.3 Reinstatement of Road and affected Surfaces

The Contractor shall carry out the reinstatement of road foundation and road surfaces and attached street appurtenances/furniture in accordance with the specifications and requirements of the Roads Department, MCGM or MMRDA. Any work not conforming in standard or meet the requirements of the Engineer or the concerned authorities must be immediately removed and replaced at the Contractor's risk and cost.

This shall include machine-paving as and when directed by the Engineer. Where road markings are affected, the Contractor shall reinstate with thermoplastic instead of paintings to the satisfaction of Roads Department, MCGM. The Contractor shall include in his rates for compliance with all the conditions stipulated above.

The Contractor will be required to maintain in a clean, safe and tidy state the temporary reinstatement of trench and other damage surfaces in roads as specified previously until such time as the permanent reinstatement is carried out.

Permanent reinstatement must only be carried out on receipt of an instruction from the Engineer and the reinstatement will then be commenced within 3 days and completed as soon as possible. The Engineer may instruct the Contractor to reinstate the road intersections as the work proceeds.

Should the Contractor fail to carry out all the required reinstatement works within 7 days of his being instructed to do so, the Engineer may arrange for the execution of the work at the expense of the Contractor without issuing any further notice.

On completion of the reinstatement the Contractor will be required to maintain all the road surfaces etc., affected for the full period of the Contract Period. All faults, settlement etc.,

developing within this period must be made good immediately upon receipt of an instruction from the Engineer.

The Contractor's attention is also drawn to the fact that he will be liable for all claims for injury or damage arising from any defect in the reinstated road surface during the Defects Notification Period.

The Contractor shall allow for carrying out this reinstatement work in one or more stages; the maintenance of the reinstatement to the satisfaction of the Engineer; the provision of temporary surfacing, maintenance and subsequent breaking out and removal in the event of this being required for the reinstatement of carriageways; reinstating whatever widths shall have been taken out and any additional width the Engineer considers require reinstating due to the Contractor's operations or to subsidence or traffic; any expense incurred in carrying out the work in short lengths or in stages.

The Contractor shall also allow for the complete reinstatement of all surfaces damaged in side-tables, and all Private or Government's or Employer's Lands to approval of the Engineer and generally to a condition at least equal to the original ground surface before the Works commenced.

In the event of the Contractor failing to carry out maintenance work and this work being done by others, on the orders of the Engineer as set out in the Employer's Requirements, then the cost so incurred shall be borne by the Contractor and deducted from money due or to become due to the Contractor.

The Contractor shall also allow for matching paving in all reinstatement of road surfaces

6.7.4 Fencing of the Site

Temporary steel sheet fencing of a minimum height of 2.0m shall be erected at every site location as agreed with the Engineer and the Traffic Police to separate the Site from third parties at the Contractor's own expense, and the same shall maintained throughout the Contract Period.

6.8 Geotechnical Investigations

The contractor shall carryout whatever geotechnical investigations he deems necessary to facilitate completion of the works along the tunnel alignment finalised by the Contractor. Based on the Geotechnical investigation report contractor shall make his own assessment. The Contractor shall use approved methodology of tunneling and adopt adequate safety measures as may be necessary for successful tunneling from this strata. The Contractor's attention is drawn to the importance of establishing the subsurface ground conditions and their range of variability along the tunneling route before embarking on the Works.

The Contractor is deemed to have obtained, studied and evaluated all the geological and geotechnical data for the sites including any data if available with the Employer for the sites and made his own judgement and conclusion on the types of soils and rock to be excavated along the tunnel route. The Contractor may supplement this information possessed by him with appropriate geotechnical investigation prior to selection of appropriate tunnelling/ machinery and selecting the technique for construction of shafts.

The Contractor shall review all data thoroughly and make his own deductions as to the nature of the materials to be excavated; the difficulties of making and maintaining the required excavations and of doing other work affected by the geology of the Site and shall accept full responsibility thereof.

The subsurface investigation shall include study of all existing geological and geotechnical information for the area including the information pertaining to the project and the location

maps of all the services in the area from the utility companies/authorities for initial planning. Data on abandoned and existing obstruction, foundation, piles and the structures in the vicinity of the alignment shall be also collected. Field survey using utility services locator and trial trenches may also be carried out to verify the location of the services and obstructions.

The Contractor may map out the subsurface soils/rock profile along the pipeline alignment and locating underground utilities and buried objects by geophysical testing. The Contractor is deemed to be aware of latest ground probing/mapping technology currently available on the market and to have made provision for its use in the project as part of his subsurface investigation works.

MCGM shall not entertain claims of whatsoever nature arising out of this at any stage of the work.

6.8.1 (Not Used)

6.8.2 (Not Used)

6.8.3 Borelogs and Ground Probing

Sufficient numbers of boreholes shall be taken by the Contractor, if deemed necessary, in areas where the soil strata is complex. The Contractors shall also carry out simple probing or Geophysical Sounding techniques at closer interval to reaffirm the types of soils to be encountered along the tunnel route. The Contractor shall submit the Geotechnical profile along the route of the tunnel and buried services data for particular work package as per the schedule for submittals.

The Contractor shall collect soil/rock samples at the level of the proposed pipeline in the presence of the Engineer and get the same tested for Unconfined Compressive Strength (UCS) in the Municipal laboratory or at any laboratory approved by the Engineer. Samples taken in the absence of the Engineer and tested in a laboratory not approved by the Engineer shall not be valid for determination of any parameters.

6.8.4 Ground Water Investigation

Ground water condition is one of the critical data required when selecting the tunnelling system. Ground water affects the safety of the excavation face, start and exits of the tunnelling/drilling equipment from the shafts. Uncontrolled extraction of water from the surrounding ground during excavation can affect the adjacent structures. Piezometric pressure, water leakage, ground water level and etc. shall be carefully checked before and during tunnelling/ drilling works.

6.9 Effects of Weather

Only certain types of work shall be permitted to be executed during the monsoon period. The monsoon period shall be deemed to be from 10 June to 30 September of the calendar year. No new shaft excavation works shall be started after 15 May, shaft anti-flooding protection works shall be completed by 31 May, and all surplus materials shall be removed from the Site on or before 10 June. During the monsoon period the Contractor shall be permitted to carry out tunnelling works using established shafts that are adequately protected from rains and secured to ensure safety of workmen and third parties. The Contractor shall plan his works accordingly.

The Contractor shall ensure that no damage occurs to the Works during construction by arranging adequate protection for the work against the effects of any natural cause such as drought, sunshine, wind or rainfall (including erosion and flooding). No work shall be performed when in the opinion of the Engineer such work is liable to be injuriously affected by the weather.

The Contractor shall have no claim against the Employer on account of loss alleged to have been sustained directly or indirectly by reason of the Engineer declining to permit such work to start or continue, or ordering any work damaged by the weather to be made good or removed and re-executed.

If permitted by the Engineer to work during the monsoon season, the Contractor shall be solely responsible for preventing entry of any excavated material, slurry, debris, drilling mud, etc., into storm water drains.

If any dewatering system is discharging into the storm water drains, the Contractor shall plan for overflowing of the storm water drains as a result of discharging water and rainwater runoff.

6.10 Works to be kept clear of Water

The Contractor shall keep the Works well drained until the Engineer certifies that the whole of the Works is substantially complete and shall ensure that so far as is practicable all work is carried out in the dry. Excavated areas shall be kept well drained and free from standing water.

The Contractor shall construct, operate and maintain all temporary works including pumping arrangements that may be necessary to exclude water from the Works while they are in progress and until they are handed over to the Employer. Such temporary works shall not be removed without the agreement of the Engineer.

Notwithstanding any approval or acceptance by the Engineer of the Contractor's arrangement for the exclusion of water, the Contractor shall be responsible for sufficiency thereof and for keeping the Works safe at all times, particularly during any floods and for making good at his own expense any damage to the Works, including any that may be attributable to floods. Any loss of production or additional costs of any kind that may result from floods shall be at the Contractor's own risk and cost.

6.11 Site to be kept Tidy

The Contractor shall keep the Site and all working areas in a tidy and workmanlike condition and free from debris, muck, rubbish and waste materials. Any Temporary Works, construction equipment, materials or other things which are not at that time required for use by the Contractor may, with the consent of the Engineer, be removed from the Site at Contractor's risk and cost or kept in the available stacking area in orderly manner.

Stacking of pipes or liners outside the defined site areas for shafts shall not be permitted. The Contractor shall plan the logistics of pipes and liners with due consideration for the availability of stacking space.

6.12 Setting Out

The Works have been set out using Universal Transverse Mercator (UTM) projected coordinate system - WGS 84, using the Mumbai Town Hall Datum (THD).

The existing topographical data provided in the Drawings includes data provided by a third party. The Contractor shall be solely responsible for confirming that all of the given topographical data is true prior to commencing construction works. The Contractor shall survey and confirm the position of all relevant existing features and proposed works prior to setting out the works.

The Contractor shall be deemed to have thoroughly examined the sites, the location of the buried services, utilities availability of space for footprint, access to sites, etc. and adjusted the tunnel alignment and shaft locations as deemed necessary and obtained agreement of the final alignment and location of shafts from the Engineer before construction and final setting out of the proposed Works.

He shall set out and mark on the ground the proposed tunnel / pipeline routes and the locations of the shafts and the area they occupy for the Engineer's inspection and acceptance.

The Contractor shall be solely responsible for the accuracy of the setting out and any expenses or delays arising from errors made in the setting out shall be borne by the Contractor. Any consequential work or abortive work carried out by the Contractor to rectify the errors shall be entirely borne by the Contractor.

6.13 Limitation on Footprint

The working space at the sites is restricted and hence the Contractor shall carefully plan his site layout in advance to set-up the equipment and accessories.

The Contractor shall be deemed to have visited the sites and carefully planned and located any temporary shafts at convenient points along the roads so as to minimise the road area to be occupied by his works. The Contractor shall be deemed to have allowed for such site constraints and measures required, including working in the night and construction of decking over the shafts, provision of access roads for construction plant and machinery, to allow the traffic to flow.

6.14 Location and Diversion of Buried Services

Prior to commencing his Temporary Works the Contractor shall locate all the buried services and he will be held solely responsible for any consequential expenses and delays if he ignores this specific requirement or fails to locate any services along the route.

The Contractor shall as far as possible not interfere with the operation of any existing or proposed service. He shall carefully plan the tunnel route and the locations of his Temporary Works and shall identify the services that require diversion well ahead so as to give ample time to obtain approvals for getting the permissions from the authorities, and undertaking the diversion or shifting works.

It is the responsibility of the Contractor to co-ordinate and arrange meetings with Utility Companies or the Government or Municipal Departments and obtain necessary permissions to get any utilities diverted. The Engineer may be present in such meetings and where applicable, the Engineer would assist the Contractors in getting the approval as expeditiously as possible from the authorities.

The Contractor will be held solely responsible for making his own investigations of any buried services in the vicinity of the Works and to protect them from damage due to his work. The protection shall be maintained until in the opinion of the Engineer the general progress of the work renders further protection unnecessary. All damage occasioned by the Contractor to these works and services shall be repaired at once at the Contractor's risk and cost, as directed by and to the satisfaction of the Engineer.

The Contractors shall investigate and determine the actual location of the buried or over the ground services and physical obstructions, if any, along the tunnel route and at the locations of his Temporary Works, and submit service location drawings to the Engineer and the authorities responsible for electricity, telecom, water supply, sewerage, gas, etc and obtain their approval or permission to excavate in their vicinity.

The Contractor shall engage at his own cost a competent service detecting technician or agency who shall have state-of-the-art detecting equipment to locate and verify all the buried services such as pipeline, water, telecom, electricity, gas and all other services, and abandoned services and structures well ahead of commencing the works.

The detector shall be able to receive narrow signal responses from buried services in order to pinpoint the position and direction of the services. It shall also be able to pick up the position and direction of different services in congested area and detect the buried services regardless of almost any environmental interference.

Combination of Ground Penetrating Radar (GPR) and Electromagnetic Location (EML) testing is considered effective for locating the underground utilities and buried objects. The lines tested using GPR and anomalies located using EML shall be topographically surveyed using a total station / theodolite at the same time as the geophysical testing is carried out.

The Contractor shall be deemed to have allowed for any extra costs in his rates for detecting all obstructions and buried services including appropriate measures to protect the services and temporarily or permanently divert the same in consultation with the concerned agency with its prior approval regardless of whether they are indicated on the Drawings or not.

When carrying out diversion works the Contractor shall comply with the requirements of the MCGM "Guidelines for Trenching Activity".

The Contractor shall produce as-built drawings of all permanent service diversions and submit these to the Engineer.

6.14.1 Diversion of Gas Lines

The Contractor shall coordinate his surveys to locate existing gas lines with Mahanagar Gas Limited (MGL) before commencement of his Temporary Works.

Excavation and tunnelling works shall be carried out in compliance with the following guidelines:

a) Prior to commencing the works MGL shall be contacted and the Contractor shall provide details of the location, date when the work is scheduled, etc. These details will be passed onto the Officer in-charge of the district office who will provide guidance as to the location of MGL pipelines, the safety precautions to be taken, etc.

b) Trial pits shall be taken at proper intervals along the complete span of excavation.

c) The Works shall only commence in the presence of responsible person from MGL.

d) During excavation, if warning tapes/tiles or gas mains are exposed then MGL shall be contacted immediately and thereafter the Contractor shall start further excavation manually and carefully.

e) Horizontal directional drilling shall be at a minimum depth of 4m

6.15 Diversion of Existing Sewers

6.15.1 General

The Contractor shall note that where diverting existing sewers he shall take all precautionary measures to ensure no interruption to the flow in the existing sewer.

The diversion of the Employer's existing sewers shall be carried out in compliance with the following requirements.

6.15.2 Temporary Diversions

Where temporary diversions of existing sewers are required the diversion shall be to the nearest unaffected downstream manhole, and prior to making the diversion the Contractor shall first obtain the approval of the Engineer in consultation with main sewer western suburb division.

Where it is necessary to divert sewer flows into storm water drains / nallahs this shall only be permitted after the approval of the Engineer and in consultation with main sewer Eastern suburb division, wards and Storm Water Drainage Department.

All temporary diversions shall be removed after completion of the Works but prior to removing any temporary diversion the Contractor shall obtain the approval of the Engineer.

6.15.3 Connecting to Existing Manholes

The Contractor shall note that in connecting sewers to existing manholes, every care shall be taken to ensure that the connections are watertight and the existing sewers and manholes are not damaged. Special precautionary measures shall be taken to ensure the stability of the existing manholes and sewers connected to them.

In connecting the sewer to the existing manhole, a circular hole large enough to accommodate the sewer shall be made in the wall and the cut end of the pipe neatly rendered to form a smooth bore.

No debris shall be allowed to fall or be discharged into the existing sewers. Any debris which falls into the existing sewer and any obstructions thereby caused shall be removed at the Contractor's expense.

The Contractor shall not seal off the existing sewer until the new line has been completely inspected and certified fit for use by the Engineer. For such cases, the Contractor shall plug up the ends of the newly constructed pipes until diversion of flow can be implemented. The breaking up of the existing sewer, blocking of flow, etc, shall be done during night hours.

The Contractor shall also note that intermediate manholes may have to be constructed over completed sewers. These shall be provided at every change in direction and at 30m intervals.

The Contractor shall ensure that no drainlines affected by the Works are sealed off without prior and proper diversion of the affected drainlines to the satisfaction of the Engineer.

6.16 Diversion of Water Mains

In addition to the requirements given in Section 6.14 the Contractor shall coordinate his surveys to locate existing water mains with MCGM's Assistant Engineer for Water Works (AEWW) of the respective ward where the Works are located in order to identify the alignment, diameter and approximate depth of water mains before commencement of his Temporary Works.

The diversion and protection of existing water mains shall be carried out in compliance with the following requirements:

a) All Works shall be executed in close co-ordination with the AEWW of the respective ward.

b) Adequate precaution shall be taken to safe guard the existing water mains, during execution of work. The same shall be properly supported and protected against, if exposed during execution of work.

c) All service connections damaged during execution of the Works and any leaking old connections shall have to be renewed with Galvanised Iron C class pipes by the Contractor.

d) Any visible leakage observed on water main and service connections during the progress of work shall be immediately brought to the notice of AEWW of the respective ward.

6.17 Co-operation with other Contractors

The Contractor may be given joint possession in some sections of his sites with other contractors for the purpose of carrying out his contractual obligation and shall in no way interfere with,

impede or otherwise prevent these other contractors from carrying out their contractual obligations.

Where there are other contractors employed by the Employer or any other agency like MMRDA working in the same area, the Contractor must programme/plan his works to be contained within his working space to avoid any interference to and by the other contractors, and shall schedule the work in co-ordination with them. No claim on account of this clause will be entertained by the Employer and his prices are to include for such contingency.

6.18 Provision of Temporary Access

The Contractor shall be responsible for arranging temporary access to any part of the Site, and shall liaise with those public and private parties who may be affected including the Traffic Police

6.19 Laying Pipelines in well-established Residential Areas

The Contractor shall comply with the requirements of the MCGM "Guidelines for Trenching Activity".

The Contractor shall note that many sections of the pipeline will be laid in close proximity to existing premises. He shall take all necessary precautions, including the provision of steel sheet piling cut-off walls where necessary, to prevent any damage to the existing premises and shall be responsible for the damage and complete repairs of the same.

The Contractor shall be responsible for obtaining permissions from the owners of private premises if needed by him for his work. He shall be responsible for restricting his workmen to the site of the work while working in private premises.

The Contractor shall ensure that any entrance gates or access roads to any property are not unduly obstructed in any manner. In case it is required to close any such access, the Contractor must ensure acceptable alternative temporary access and shall restore the original one at his risk and cost within reasonable time on completion of the Works.

6.20 Minimisation of Obstruction to the Flow of Water

The Contractors shall ensure that the methods adopted by them including the temporary shafts cause minimum obstruction to the flow through existing nallahs/creeks. In case of any situation requiring need for diversion of flow through a nallah and/or construction within the nallahs/creeks, the same shall be entirely at the risk and cost of the Contractor.

6.21 Explosives and Blasting

Explosives and blasting shall not be permitted on the Contract.

6.22 Fees for Disposal of Excavated Material

The Contractor shall be responsible for disposal of excavated materials in accordance with Maharashtra Minor Mineral Extraction Act. The Contractor shall pay necessary royalties and submit documentary evidences of such payments to the Engineer for his information and records. If and when royalties become payable to the Government Authority on excavated material as per statutory requirements, the payment shall be made by the Contractor. The Contractor shall submit documentary evidences of such payments to the Engineer for his information and records.

The Contractor shall comply with any statutes, regulations, conditions laid down by any authority in connection with disposal of the materials.

6.23 Fees for Purchase of Excavated Material

If the Contractor requires any of the materials for execution of the Works under the Contract, he shall apply to the Engineer in writing and the materials may be sold to him after taking joint measurements. Measurement shall be taken either by forming depots or by any other method accepted by the Engineer, there being no deductions for voids. The cost of material to be sold to the Contractor is indicated below and is inclusive of royalty. However, the cost is exclusive of supervision charges which will be charged extra at 10%.

i) Stone rubble of good quality - Rs. 265 per Cu. M.
ii) Stone rubble of inferior quality - Rs. 230 per Cu. M.
iii) Excavated earth, murrum, quarry spalls (up to size of 150 mm) - Rs. 150 per Cu. M.

If surplus material from any other work is available from the Employer, it will also be released to the Contractor for work under the Contract at the same rates as above on the same terms and conditions at the Engineer's discretion. For this purposes, the Contractor shall have to sort out the material in separate stacks and transport the same to the site of work at his cost.

The Contractor shall pay all costs and compensation associated with tonnage, permits, royalties, rent or other payments if any, including any payments due under the Mineral Act, associated with the importation to site of materials such as stone, sand, gravel, clay or any other materials obtained from off-site excavations.

The Contractor shall pay necessary royalties and submit documentary evidences of such payments to the Engineer for his information and records. If and when royalties become payable to the Government Authority on excavated material as per statutory requirements, the payment shall be made by the Contractor. The Contractor shall submit documentary evidences of such payments to the Engineer for his information and records.

6.24 Codes and standards

As a minimum, the Contractor shall ensure that the Works are designed, manufactured, constructed, tested and operated in accordance with all relevant codes and standards of practice of India.

In addition, the Works must be in accordance with codes of practice and standards specified in this Contract including those in the General Specification (Volume IIA).

For items which have not been specified in either Indian codes/standards or in this Contract the Contractor shall ensure the following standards are met:

a) European codes of practice, such as those Euronorms which are codes of practice; and

b) International Electrotechnical Commission (IEC) and International Organisation for Standardization (ISO) codes of practice.

If the Contractor determines that there are conflicting requirements the more stringent shall apply. However, the Engineer reserves the right to make the final decision on the matter.

Each item of equipment and materials shall comply with those standards of the country of manufacture which are relevant to the item concerned. The Contractor shall also ensure that each item of equipment and materials comply in all respects with the standards cited in the General Specification.

Where, because the proposed manufacturer is domiciled in one country and a national standard of another country is cited in the General Specification, and the Contractor proposes an alternative standard, the Contractor shall submit to the Engineer for review details of the proposed standards with which the item of equipment and materials will comply, and the

differences to the standard specified in the Contract, together with a resume of the scope and content of each such standard.

Where the requirements of the standards cited in the General Specification are more stringent in any respect than the requirements of the standards of the country of manufacture and, in the opinion of the Contractor, the proposed manufacturer cannot reasonably meet these more stringent requirements, the Contractor shall submit to the Engineer for review a list of all the deviations from the standards cited in the Contract.

If requested to do so by the Engineer, the Contractor shall submit to the Engineer at least one copy of each code of practice, standard, and reference work which is referred to in the General Specification or elsewhere in the Contract or proposed by the Contractor. All such documents shall be in the language stated in the Contract Data in accordance with Clause 1.4 of the Conditions of Contract.

The Engineer reserves the right to reject or approve any materials manufactured to a different standard which he considers to be unacceptable.

References in these documents to standards shall be deemed to their equivalent current standard in the event that they have been withdrawn or new more applicable standards are in force.

Only proven technologies shall be incorporated in the Works. The Contractor may only incorporate new technology in the works subject to his being able to demonstrate each of the following to the Employer:

- the new technology is permitted by the Laws of India
- the new technology has a proven track record (of similar size and application)
- the application of the new technology will not be detrimental to the life of and the safe, environmentally sound, reliable, cost efficient and correct operation of the Works
- the incorporation of new technology in part of the Works will not result in any undesirable incompatibility or monopoly
- the application of the new technology will yield benefits to the design life of the Works, for example by reducing operating & maintenance costs.

6.25 Design Life

The materials incorporated in the works and the workmanship shall be of required quality to sustain the specified life span.

Unless stated otherwise in this Employer's Requirements, the Contractor shall design the Works such that the design life shall be:

- 100 years minimum for microtunnels / tunnels / shafts and all internal structures
- 50 years minimum for civil engineering and building works (including underground services and pipes)
- 50 years minimum for external pipework
- 25 years minimum for roads

6.26 Construction Materials

All construction materials including cement, reinforcing steel, structural steel, mild steel plates, sand, aggregates and sulphate resistant cement (if situation demands) shall be procured by the Contractor from reputed suppliers and shall be subject to acceptance tests. Any material found

unacceptable shall be promptly removed from work site under acknowledgement from the Engineer. If it is found that the Contractor has used such unacceptable material for any works, temporary or permanent, the Engineer shall be entitled to order demolition of such works at the Contractor's risk and cost.

6.27 Testing of Materials

All materials shall be tested in reputed testing or quality assurance agencies/ institutions as approved by the Engineer.

Some of the acceptable testing institutions are:

- Indian Institute of Technology (IIT), Mumbai
- Veermata Jeejabai Technical Institute (VJTI)
- SGS
- Govt. approved Lab/ MCGM approved lab.

6.28 Progress Photographs and Video Films

The Contractor shall take digital photographs, including 10 photographs of the Site based activities at every Work Site, and 10 other photographs as required by the Engineer every month. The photographs shall:

- be dated and labelled
- be mounted in albums
- be accompanied by digital files on CD

The Contractor shall arrange to have the progress photographs taken by a person acceptable to the Engineer during the course of the Contract. The Contractor shall submit the entire set of photographs as 150mmx100mm colour proofs from which the Engineer will select progress photographs. The Contractor shall supply up to 20 suitably annotated prints not less than 250mmx200mm from the selected proofs, each month, as required. These photographs shall also be dated and labelled and presented in separate albums.

All digital files, hard copies, etc., shall become the property of the Employer and the Contractor shall not make use of them for his own purposes unless specifically permitted by the Employer.

The Contractor shall also arrange for recording of video footage of the progress of work covering important events during the Works, starting from commencement and including periodic achievement of significant milestones up to Handover and when ordered by the Engineer. Video footage shall be for about 2 hours duration per month. The Contractor shall provide six copies of the video footage on DVDs after proper editing and incorporating suitable audio and/or narration. All original and copies of the video footage shall become the property of the Employer and the Contractor shall not make any use of them for his own purpose unless specifically permitted by the Employer.

6.29 Daily Review Meeting

The monitoring instrumentation shall be read on a regular basis - as per the monitoring plan - and the results 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, face logs, tunnel boring machine (TBM) reports and any recent non-conformance reports relating to the tunnel construction. It will also include all recent data on surface utilities and structures ahead of the tunnel.

The review meeting will include appropriate discussion of all known features ahead of the advancing tunnel, including geotechnical conditions as well as surface structures or utilities that could be affected by tunnel construction.

The meeting will maintain up-to-date information on all conditions and relevant surface features extending 500m ahead of the advancing tunnel. This information together with the Risk Assessment for damage to surface structures will be maintained throughout the tunnel construction period.

This DRM shall be held daily during the excavation of the tunnels unless otherwise agreed by the Contractor and the Engineer.

At the meeting the Contractor shall present the current results of monitoring of the tunnels, together with trends in these results and comparison with the deformations predicted by the calculations.

The outcome of the meeting shall be a report, the Required Excavation and Support Sheet (RESS), agreed by the Contractor and the Engineer, which states that tunnelling may continue as proposed, or gives the requirements for modifications to the tunnelling (e.g. shorter advances, smaller headings, higher face pressure and annulus grouting around the TBM).

If no agreed report is available by a specified time each day then the tunnel shall be made safe and tunnelling be stopped.

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.

6.30 Key Performance Indicators

A key performance indicator (KPI) system shall be developed for monitoring movements so that actions can be taken in a timely manner, thereby ensuring that damage to existing buildings and subsurface infrastructure is within calculated predictions.

The KPIs to be used to guide construction shall relate to specific monitoring activities:

a) In-tunnel or in-shaft convergence monitoring (segmental lined tunnels and sprayed concrete lined shaft sinking)

b) Spoil reconciliation (TBM tunnelling)

c) Ground movement monitoring

d) Monitoring of adjacent and overlying structures.

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 summarised below:

a) 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.

b) 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.

c) The Contractor shall assess the extent to which the deformations comply with the Sprayed Concrete Lining (SCL) serviceability and extreme limit conditions.

d) Together with the Engineer, the Contractor shall decide whether changes in the SCL excavation sequences or TBM face pressure 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.

e) 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 emphasised that the response must be rapid.

f) The performance of the tunnel is kept under continuous review until the monitoring data indicate that KPI trends show a stable condition.

At least three trigger values shall be established: a green, amber and red limit. The green limit marks the boundary of normal behaviour. 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.

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 trigger has really been breached then contingency measures will be instigated, in accordance with a predefined Action Plan and as directed in the DRM. The contingency measures are designed to correct any anomalous behaviour.

6.31 Required Excavation and Support Sheet

Based on the design and the evaluation of the results of monitoring, a Required Excavation and Support Sheet (RESS) will be issued as the outcome of the Daily Review Meeting (DRM). In the absence of any agreed changes, the RESS will reflect exactly what is shown on the relevant design drawings.

The RESS shall be prepared and endorsed by the Contractor's Site Manager responsible for the tunnelling works, the designer and the Engineer on site. Unless all the three signatures are obtained, the proposals indicated on the RESS shall not be implemented.

The RESS for tunnels shall address, but not necessary be limited to, the following matters:

a) The tunnel section (chainages) to which the RESS is applicable

b) Method of operation of the TBM including:
    a. Advance Rate
    b. Face pressure
    c. Soil conditioning
    d. Annulus grouting

c) Monitoring results, both in-tunnel and surface monitoring

d) Monitoring to be installed in the tunnel section in question or on the surface

e) Measures to be taken during stoppage of works

f) Other instructions relevant to the tunnel section in question

g) Reference to relevant design drawings

h) Face pressure

i) Soil conditioning

The RESS for shaft sinking shall address, but not necessary be limited to, the following matters:

a) The shaft section (depths) to which the RESS is applicable

b) The support to be installed

c) The excavation sequence

d) The method of working related to ground support including staging of application of sprayed-concrete layers and lapping of reinforcement

e) Monitoring results, both in-shaft and surface monitoring

f) Monitoring to be installed in the shaft section in question or on the surface

g) Measures to be taken during stoppage of works

h) Other instructions relevant to the shaft section in question

i) Reference to relevant design drawings

A copy of the RESS will be given to the foreman in charge of the work in the tunnel and shall be kept at the working face.

A RESS is required to cover all of the tunnel excavation. No excavation of a tunnel or shaft shall proceed without a current RESS.

If for any reason the agreed 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.

6.32 Progress Meetings

Monthly progress meetings shall be held at the Site. These shall be held at the Engineer's office until the Site facilities are available. These shall be chaired by the Engineer and attended by the Contractor and any Subcontractor or supplier deemed necessary by the Engineer. The dates for the meetings shall be determined by the Engineer. Minutes shall be recorded by the Engineer and endorsed by the Contractor. They shall be issued to all attendees.

6.33 Clearing of Site on Completion

On completion of the Works, the Contractor shall clear away and remove from the Sites all construction equipment, surplus materials, rubbish, temporary works of every kind including any sheds, site offices etc. and leave the whole of the Site and the Works clean and in a workmanlike condition to the satisfaction of the Engineer.

6.34 Dry Weather Flow Interception Structures

All dry weather flow interception structures (channels, chambers etc.) and foundations shall be constructed using cast-in-place reinforced concrete.

All interior faces of walls, exposed roofs of structures of above and below grade and exterior surfaces above finished grade shall have a smooth form finish in accordance with ACI 301 Surface Finish 3.0 (SF-3):

1. Patch voids larger than 10mm wide or 10mm deep;
2. Remove projections larger than 3mm;
3. Patch tie holes; and
4. Provide surface tolerance Class A in accordance with ACI 117.

All exterior walls below finished grade and other surfaces shall have an unworked finish free from substantial voids, honeycombing or other large blemishes, unless otherwise specified.

The external visible surfaces shall be painted.

All dry weather flow interception structures (channels, chambers, etc.) shall be water tight without leaks.

Cement and chemical materials to be utilized in the concrete make-up shall be suitable for final use with wastewater and its potential aggressive conditions.

All dry weather flow interception structure wall and slab thicknesses shall be designed to suit the load conditions, geographical conditions, geotechnical conditions and in any case not be less than 300 mm in thickness.

Where a dry weather flow interceptor is an integral part of an adjoining dry structure, the interior of the dry structure must be protected by waterproofing the interior surface area of the process tank wall/slab adjacent to that dry structure to a distance of 2 m beyond the limits of the adjoining dry area. Waterproofing shall be for Service Condition D.

6.34.1 Dry Weather Flow Interception Facility Roads and Hardstanding Areas

Geometric design of roads, junctions, turning circles etc. shall be in accordance with national guidelines. They shall be designed to provide an adequate number of lay-bys, turning areas, parking spaces etc. to enable screening removal vehicle and other vehicles to discharge or pick up without causing obstructions to others. Hardstanding areas for skips shall be of concrete construction. Junction radii shall be a minimum of 10m.

Carriageway widths shall be adequate to accommodate all vehicles required to operate and maintain the Works and shall provide adequate manoeuvrability in accordance with accepted guidelines. Generally, this shall be a minimumof5 m width. All internal roads shall have adequate turning circles at bends and junctions to allow easy vehicular movement of the type and size of vehicles and loads anticipated to use the site.

Road drainage shall be provided. The roads shall be laid to falls and have adequate capacity to be free draining. Roads shall be sealed and paved to prevent soil loss.

Off road parking shall be provided for operational staff cars, maintenance vehicles etc. as determined by the Contractor but with a minimum space for atleast2vehicles at the dry weather flow interception facility.

Footpaths of minimum 1.5 m width shall be provided around all buildings and to all areas where equipment is provided.

7 CONTRACTOR'S DOCUMENTS

7.1 General

7.1.1 General

In accordance with Clause 5.2 of the Conditions of Contract, the Contractor shall prepare Contractor's Documents and submit to the Engineer for approval. The Contractor shall not commence any related work without the approval of the submissions by the Engineer.

Approval or acceptance by the Engineer of any proposal for executing the Works, including drawings, specifications or resources employed under the Contract shall not relieve the Contractor of his responsibility for any errors thereon and shall not be regarded as an assumption of risk or liability by the Engineer or Employer. The Contractor shall have no claim under the Contract on account of the failure or partial failure or inefficiency of any plan, method of work or equipment approved or accepted by the Engineer. Such approval or acceptance shall be considered to mean only that the Engineer had no objection to these proposals.

Notwithstanding any approval or acceptance by the Engineer, the Contractor shall remain fully responsible for completing the Works correct in every detail.

7.1.2 Format of Contractor's Documents

The Contractor shall submit three paper copies and one copy in electronic format (unless otherwise stated) of each drawing or document required to be submitted. The Contractor shall mark incomplete areas of drawings 'hold'. Any revisions to drawings or documents shall be clearly highlighted by the Contractor. The Contractor shall note drawing amendments in the title box and mark amendments with a triangle containing the revision number. Amendments to documents shall either be redlined/struck out or marked in the margin.

Drawings shall all have a similar title block which shall include the name of the designer, the Contractor and the Employer, the name of the Contract, a unique description of the content and a unique reference number complying with a formalised numbering system. The title block shall be such that the whole title block is visible including space for amendment information when folded to A4 size.

Documents shall be in Microsoft Office format or equivalent approved by the Engineer. Programmes shall be in the latest version of Primavera and/or MS Project. Drawings shall be in AutoCAD or compatible equivalent.

Typical details of the documents required for the technical submittals are included in Appendix A.

7.1.3 Programme

The Programme to be submitted within the times specified in Section 9, in accordance with Clause 8.3 of the Conditions of Contract, and shall conform to the Traffic Management Plan which shall be in accordance with the Traffic Management Requirements contained in Appendix B.

The Programme shall also contain the following additional information:

a) Number of work faces to be started simultaneously

b) Number of shafts simultaneously being excavated

c) Number of Tunnel Boring Machines to be deployed simultaneously

d) Traffic and Road diversion periods

e) Utilities diversion

f) Shaft excavation

g) Tunnelling schedule

h) Ancillary works components

i) Testing

j) Backfilling

k) Reinstatement/ Restoration

7.1.4 Contractor's Organisation

The Contractor shall provide and keep updated a single document including the following information:

1. The Contractor's proposed organisation chart
2. Details of where the Contractor's design and procurement activities will be based
3. Details of all proposed Subcontracts, the proposed scope of each Subcontract, the names of the proposed Subcontractors (together with the country in which each Subcontractor is based) and the qualifications of proposed Subcontractors to carry out the subcontracted work
4. Details of how the Contractor proposes to monitor and, if necessary, expedite the manufacture and delivery of the Contractor's equipment and materials which will be manufactured by Subcontractors.
5. Details of the way in which the Contractor proposes to manage the packing, storage in the country of manufacture, shipping, overland transportation and storage of the Contractor's equipment and materials on and/or off the Site. Details of forwarding agents, storage Subcontractors, etc shall be provided. Those items of equipment and manufactured materials which will not be packed in containers shall be identified.

7.1.5 Quality Assurance Plan & Quality Control

The Contractor shall submit a Quality Assurance Plan for acceptance of the Engineer and implement the same for the entire project including tunnelling, micro-tunnelling, pipe jacking, manufacture of jacking pipes, segments, and other activities. The Quality Assurance Programme shall be maintained in accordance with the provision of the manual. No works shall commence until the Quality Assurance Plan has been accepted by the Engineer.

The Contractor's Quality Assurance System shall incorporate but not be limited to the following:

i) The Quality Assurance and Quality Control procedures covering all materials, design, manufacture, supply and installation carried out by the Contractor and any of his sub-contractors.

ii) Such tests necessary to demonstrate that materials comply with the requirements of these Employer's Requirements and the requirements of the relevant Standards and Codes.

iii) Contemporary records to be maintained pertaining to progress of the work.

7.1.6 Health and Safety Plan

The Contractor shall submit to the Engineer, no later than 28 days before work commences on the Site, his Health and Safety Plan in accordance with Section 4 of the Employer's Requirements

7.1.7 Environmental Management Plan

The Contractor shall submit to the Engineer, no later than 28 days before work commences on the Site, his Environmental Management Plan that demonstrates the Works compliance with Section 5 of the Employer's Requirements.

7.1.8 Geotechnical Profile and Geotechnical Reports

The Contractor shall prepare a comprehensive geotechnical profile along the pipeline route with detailed descriptions of the types of soil or rock to be expected during boring/ tunnelling. This shall be based upon the Site Data and any additional geotechnical data the Contractor has obtained. He shall clearly identify the types of soil or rock that is likely to be encountered during boring or tunnelling along the entire pipeline alignment. This shall be submitted to the Engineer prior to commencing construction of the Temporary Works.

7.1.9 Schedule for obtaining approval from Authorities

The Contractor shall submit a schedule for obtaining approvals/ permissions from all necessary authorities. The Contractor shall be responsible for obtaining permissions from traffic police, MMRDA, and other authorities with due regard to the method of work and detailed designs involved. The Contractor shall allow reasonable time in the schedule for such approvals and shall be responsible for submission of the detailed designs and clarification or any other document sought by the authorities on time to the concerned

7.1.10 Traffic Management Plan

The Contractor shall submit his draft Traffic Management Plan in accordance with the Traffic Management Requirements described in Section 6.7 and as agreed with the Traffic Police.

7.1.11 Monthly Progress Reports

The Contractor shall prepare and submit monthly progress reports at least one week in advance of the monthly site meetings described in Section 6.32. In addition to the requirements identified in Clause 4.21 of the Conditions of Contract, each monthly report shall include a summary.

The Monthly Progress Report shall be in a format agreed with the Engineer.

7.2 Design

7.2.1 Survey of Existing Utilities

Prior to completion of the Contractor's Temporary Works designs and his Permanent Works designs the Contractor shall submit to the Engineer his survey of existing sewers as detailed in Section **Error! Reference source not found.**.

7.2.2 Temporary and Permanent Works

The Contractor shall submit complete design details for all Temporary and Permanent Works including calculations and drawings for the acceptance of the Engineer. The Contractor shall be wholly responsible for the designs, drawings and calculations to be submitted as Contractor's Documents for acceptance by the Engineer. No work shall proceed unless these documents are accepted by the Engineer.

7.2.3 Site Layouts

Contractor's attention is drawn to work sites in extremely busy roads and space availability as well as presence of buried services in vicinity of the proposed alignment.

For all temporary and permanent shaft locations, the Contractor shall submit site layout plans showing the site boundaries, arrangement of various ancillary equipment required for works, spoil removal equipment and slurry tanks, lubricant systems/ mud recycling system, generators, control cabin, tracking facilities, crane, storage of pipes etc for each drive.

7.2.4 Physical Modelling of Drop Shafts at Bapat Nalla and Safed Pul Nalla

Deleted

7.2.5 Temporary Shaft Design

The Contractor shall submit the design and construction details of all Temporary Shafts and their proposed locations along the tunnel alignment to the Engineer for acceptance.

The submission shall also include details on shoring system, entry and exit arrangement, thrust wall layout and design details, general layout of guide rail and jacking table arrangement etc.

Temporary Shaft drawings are to include but not limited to:

1. Launch/jacking and reception shaft configurations.
2. Design and construction of launch/jacking and reception shaft.
3. Details for excavation and backfilling procedures, ground support systems, and ground stabilisation if required.
4. Special requirements for jacking and receiving shaft penetrations, thrust blocks, backstops or other reactions required for Microtunnelling, casing pipe jacking or any other jacking.
5. Full calculations supporting maximum jacking capacity that jacking shafts will withstand
6. Dewatering and ground water control plans for all temporary and permanent shafts.

When the Contractor opts for additional shaft locations to facilitate the Works, he shall provide complete details of the final structures to be erected at these points to allow for a smooth change in direction for the completed tunnels, and to provide details of the restoration works at each location.

7.2.6 Permanent Shaft Design

The Contractor shall submit to the Engineer for acceptance his reinforcement designs and bar bending schedules for the each of the shaft designs provided by the Employer. His design shall be in accordance with the Employer's Requirements. When requested by the Engineer, the Contractor shall submit full design calculations.

In accordance with Section 3.2 should the Contractor revise the structural design provided by the Employer in order to adopt the most economical construction technique he shall submit the revised shaft general arrangement drawings and full structural design to the Engineer for acceptance.

7.2.7 Jacking Pipe Design, Manufacturing and Procurement

The Contractor shall submit full details of the jacking pipe design and their applicability for the intended use and anticipated stresses including the jacking force. The design of jacking pipes shall take into account the jacking strategy proposed to be adopted by the Contractor.

Calculations shall clearly state:

1. Maximum calculated jacking resistance for installing complete casing.
2. Maximum allowable face pressure or slurry pressure that can be exerted at tunnel face without fluid loss to surface, other structures or features or heave of ground.
3. Relationship between hydraulic jacking pressure and force applied to casing pipe during jacking.

The Contractor shall, with the agreement of the Engineer, engage a reputable pipe manufacturer to design and manufacture the jacking pipes. In which case, the Submission shall include the manufacturer's name, address, contact telephone and facsimile numbers and the manufacturer's quality assurance /control and testing plan for the jacking pipe. The manufacturer's representative's name shall be also included in the Submission. A dimensioned drawing of the jacking pipe with design calculations from the manufacturer shall be also submitted to the Engineer for acceptance.

No change in pipe manufacturer or procurement mode shall be permitted without the Engineer's agreement.

In case the Contractor intends to manufacture the pipes in his own facility set up for this purpose, he shall submit all details of equipment, design and process to the Engineer for acceptance.

When requested a certificate shall be provided to the Engineer to confirm that the jacking pipes comply in all respects with the relevant standards.

7.2.8 Segmental Lining Design, Manufacture and Procurement

The Contractor shall submit full details of the segmental lining design and its applicability for the intended use and anticipated stresses.

The Contractor shall, with the agreement of the Engineer, engage a reputable segmental lining manufacturer to design and manufacture the segments. In which case, the Submission shall include the manufacturer's name, address, contact telephone and facsimile numbers and the manufacturer's quality assurance /control and testing plan for the segments. The manufacturer's representative's name shall be also included in the Submission. A dimensioned drawing of the segmental lining with design calculations from the manufacturer shall be also submitted to the Engineer for acceptance.

In case the Contractor intends to manufacture the segmental lining in his own facility set up for this purpose, he shall submit all details of equipment, design and process to the Engineer for acceptance.

When requested a certificate shall be provided to the Engineer to confirm that the segmental lining complies in all respects with the relevant standards.

7.2.9 HDPE Liner Procurement and Installation

The Submission shall include particulars of the HDPE liners including the name of the establishment supplying the lining system, installation and testing methods, supplier supervision and product warranty.

A sample of the liner, weld strips and joints shall be submitted to the Engineer for approval prior to procuring the product.

7.2.10 Polyurea Coating Procurement and Installation

The Submission shall include particulars of the Polyurea coating including the name of the establishment supplying the coating system, installation and testing methods, supplier supervision and product warranty.

Prior to procuring the product the Contractor shall demonstrate to the Engineer that the Polyurea subcontractor (supplier & applicator) must have completed a minimum of two (2) projects for wastewater application for sewer tunnels of greater than 2,000 mm ID and a minimum area of 15,000m^2.

A sample of the coating shall be submitted to the Engineer for approval prior to procuring the product.

7.3 Construction

7.3.1 Contractor's Method of Construction

The Submission shall contain a detailed explanation of various steps involved in the construction process. It shall include detailed alignment plan he intends to employ and the drive segments whether curved or straight ones. It shall include details of the equipment, specific manufacturer's instructions and guidelines pertaining to the project, a methodology statement outlining the operation of the equipment and, details of materials including pipe materials, rubber ring, compressible packers and jointing of pipes.

The Submission shall also include construction details of all temporary structures such as jacking and receiving shafts or intermediate/ temporary/rescue shafts, thrust bed, thrust walls, and entry and exit arrangements.

The details of other equipment such as intermediate jacking stations, spoil removal system including slurry and feed pumps, control systems, slurry tanks, separation system and associated machinery, jacking frames, spacers, thrust ring etc. shall also be included in the Submission.

7.3.2 Piling Works

Submit two copies of these records to the Engineer not later than noon of the next working day after the pile was installed. Any unexpected boring conditions shall be noted in the record.

- Contract
- Pile reference number (location)
- Pile type
- Nominal cross-sectional dimensions or diameter
- Nominal diameter of under-ream (if any)
- Length of preformed pile
- Standing groundwater level
- Date and time of boring
- Date of concreting
- Ground level at commencement of installation of pile
- Working level
- Depth from working level to pile toe
- Toe level
- Depth from working level to pile head level

- Length of temporary and permanent casing (If any)
- Soil samples taken and insitu tests carried out
- Length and details of reinforcement
- Concrete mix
- Volume of concrete supplied to pile where this can be measured in practice
- All information regarding obstructions/delays and other Interruptions to the sequence of work

The Contractor shall submit to the Engineer as-built details of the piling works including soil conditions encountered during boring on completion of all piling for a section of work.

7.3.3 Submission on Tunnelling System

7.3.3.1 General

The Contractor shall furnish complete details of the tunnelling system covering the make, model, manufacturer's technical literature for the equipment and all other data on ancillary equipment and justification in support of the equipment proposed. The Submission shall include information to ensure that the tunnelling equipment proposed for the project meet with the general requirements specified in these Employer's Requirements and also the anticipated geological conditions as assessed by the Contractors.

The Submission shall also include a certification from the manufacturer of the equipment about adequacy in the anticipated geotechnical conditions as also design calculations showing maximum anticipated jacking force and torque needed for tunnelling/ boring and ensuring tunnel driving and pipejacking to the required grade and alignment within permissible tolerance limits.

7.3.3.2 Procedures

The Contractor shall supply full details of procedures and resources that will be employed to carry out work including method and sequence of:

a) Establishment of drive lines and elevation at base of shaft.

b) Casing pipe handling and connections.

c) Maintaining line and grade, and reestablishment of line and grade as required.

d) Spoil separation and disposal.

e) Spoil and slurry containment during tunnelling work.

f) Installation of tunnel lining, including placement of grout between the lining and the walls of the excavation, and procedures to prevent floatation during grouting.

The Contractor shall submit to the Engineer for agreement a detailed method statement for instrumentation and monitoring, including instrumentation layout, trigger levels, design and allowable values and the procedures for evaluating the monitored data. The data to be captured shall be obtained from the computerized control unit and shall be supported with manually kept observations and readings as per agreed formats.

7.3.4 Submission on Monitoring of Ground Settlement and Upheaval

Monitoring of ground settlement and upheaval shall be carried out in accordance with the general requirements in Section 13.4, microtunnelling requirements in Section **Error! Reference source not found.** and

segmental lined tunnel requirements in Section 15.4.11.

Prior to commencing the Works, the Contractor shall submit for review a photographic survey of all existing structures within the zone of influence and a schedule of defects, along with the Contractor's surveying and monitoring plan with the location of settlement monitoring points, reference benchmarks, survey schedules and procedures, and reporting formats.

Throughout the excavation and tunnelling works the Contractor shall submit a copy of all recorded results of the monitoring of settlement or upheaval caused by excavation and tunnelling works to the Engineer on a daily basis or as agreed; however, movement greater than predicted shall be reported to the Engineer immediately.

The Contractor shall keep records of all inspections of existing structures and a copy shall be submitted to the Engineer.

7.3.5 Submission on Remedial Measures to be adopted by the Contractor

The Contractor shall take each and every precaution to ensure that the tunnelling or drilling equipment will successfully excavate along the chosen pipeline alignment before he commences the operation. In the event of inability to complete the drive, due to break down or any other reasons, the Contractor shall be fully responsible to recover the equipment safely from the ground and restore the incomplete work to the original condition at his risk and cost by a method agreed with the Engineer and the concerned authorities within the time stipulated by the Engineer or the concerned authority.

The Contractor shall in his Submission clearly state the measures that he would implement to retrieve the shield without causing interruptions to traffic and public life and without causing any damage to the property belonging to the MCGM/ MMRDA or any other third party etc. The cost for such retrieval measures or any consequential expenditure or delays arising from thereof shall be entirely borne by the Contractor. Any failure of remedial measures shall be entirely at the risk and cost of the Contractor.

Any abandoned hole or tunnel must be backfilled to the top of the hard strata with concrete or gravel with grouting to provide a solid infill, or other method agreed with the Engineer completely at the Contractor's cost so as to prevent subsequent settlement.

7.4 Handover

7.4.1 Tests on Completion

The Tests on Completion shall not commence until relevant Contractor's Documents have been submitted and consent to commence tests has not been refused by the Engineer. Relevant Contractor's Documents shall include inter-alia:

1. Site installation, inspection and test certificates
2. Tests on Completion of method statement and programme
3. Test schedules and performance data schedules

7.4.2 As-built Documentation

The Contractor shall prepare and submit as-built documents including drawings and records during the construction works and shall submit them to the Engineer following completion of each part of the Works, or as otherwise agreed with the Engineer.

As-built documents shall constitute a permanent record of the Works as completed or executed.

As-built documents shall consist of final versions of those Contractor's Documents as are necessary to fully record the design and construction of the Works, incorporating any additional information that will assist the operator of the facility. They shall include inter alia:

1. The final version of the design calculations
2. Key construction records and tests
3. Final versions of all drawings prepared
4. Quality control records for Materials
5. Asset sheets
6. Borehole records and soil test reports
7. Survey records
8. As-built records of service diversion
9. Any information requested to be provided in the form of as-built records elsewhere in the Employer's Requirements.

Final approved as-built drawings shall consist of one copy on CD in AutoCAD and .pdf formats, three A1 and three A3 printed and durable copies.

8 LICENCES AND CONSENTS

8.1 General

The Contractor shall be responsible for obtaining all consents, permits, licences and approvals required to construct the permanent works and temporary works necessary for the completion of the Works. The Contractor shall also allow sufficient time for the necessary procedures in his programme. Any delays associated with obtaining any licences, permits, and consents shall be the responsibility of the Contractor.

The Contractor shall comply with the MCGM Guidelines for Trenching Activity and the sample list of procedures for general construction works as given in Appendix C. The Contractor is cautioned that Appendix C is not an exhaustive list. The Contractor shall be required to identify all other licences or approvals required.

The Contractor shall submit to the Employer in advance a list of licences, permits and consents required for the Contract and the Employer shall determine which of these shall be in the name of the Employer. However, the Contractor shall bear all costs associated with the licences, permits and consents.

9 KEY PROGRAMME REQUIREMENTS

The Contractor is required to complete each of the following activities, items of work or stages in the performance of the Contract in full in accordance with the Contract by the date or within the period specified for each such activity or item or stage in the table below. Week numbers refer to weeks after the Commencement Date unless otherwise stated. Other submissions as specified in the Contract shall be required in addition to the key submissions identified below.

No	Activity/Item of Work/Stage	Date or period by which item is to be completed
1.	Submission of programme in accordance with Clause 8.3 of Conditions of Contract	As per Clause 8.3 of the Conditions of Contract
2.	Submission of project execution plan	Within 28 days of receipt of Notice of Commencement Date
3.	Submission of Environmental Management Plan	No later than 28 days before commencement of Works on Site
4.	Submission of Health and Safety Plan	No later than 28 days before commencement of Works on Site
5.	Submission of Quality Plan	By end of week 4
6.	General method statement	No later than 28 days before commencement of Works on Site
7.	Modelling Design Report	Deleted
8.	Final Modelling Report	Deleted
9.	Submission of all licenses, consents, clearances, NoCs, etc. required for commencement of Construction Work	By end of week 20
10.	Submission of construction stage documents (excluding method statement)	No later than three weeks prior to commencement of that element of work
11.	Submission of construction and installation method statements	No later than three weeks prior to commencement of that element of work
12.	Submission of plant delivery documents	No later than two weeks prior to commencement of that element of work
13.	Submission of Tests on Completion method statement and programme	No later than 6 weeks prior to commencement of the Tests on Completion
14.	As-built documents submission	No later than 2 weeks prior to commencement of the Tests on Completion
15.	Commencement of Tests on Completion	No later than 2 months before the date for completion
16.	Final approved as-built documents	No later than the date set out in the Taking Over Certificate in accordance

No	Activity/Item of Work/Stage	Date or period by which item is to be completed
		with Conditions of Contract Sub-Clause 10.1, or 28 days after completion of the Tests on Completion whichever is the earlier
17.	Time for Completion	As stated in the Particular Conditions Part A - Contract Data

10 TESTS ON COMPLETION/TESTS AFTER COMPLETION

10.1 General

On substantial completion of the Works, the Contractor shall issue a notice to the Engineer for Tests on Completion.

10.2 CCTV Inspection

The Contractor is required to carry out CCTV inspection of the completed work using dedicated CCTV sewer inspection cameras upon completion of the Works.

All completed pipelines, shafts and tunnels shall be inspected using a CCTV or person-entry sewer inspection camera system and the footage captured on DVDs for a permanent record to be submitted to the Engineer.

The equipment to be used shall be specialised for sewer inspections. The following general requirements shall be adhered to during pipeline inspections:

- The tunnels and chambers shall be sufficiently cleaned and made free of residual water for a clear view of the pipe surface;
- The pipelines shall be inspected by means of CCTV imagery using a CCTV camera with pan, tilt and zoom facilities providing colour footage in MPEG 2 format, 400 lines, and a variable 5 to 8mbs bit rate;
- Still images of the chambers showing the internal details shall be taken and maintained as permanent records along with the as-built drawings.

10.3 Leakage and Infiltration

It is the responsibility of the Contractor to ensure that the Permanent Works are substantially watertight with no identifiable flow of water penetrating the lining.

For tunnels, shafts and underground works the works shall be substantially watertight if there are occasional drops of water and the daily leakage does not exceed 0.5 litres per day per square metre of tunnel or shaft surface.

Inspections of water tightness shall only be made in the wet season unless it can be demonstrated that the elevation of the groundwater surface has recovered to its elevation prior to tunnel construction.

In the event that the leakage exceeds the limit, the Contractor shall ascertain the areas where leakage or infiltration occur and seal them using agreed methods and materials.

In addition any leakage which in the opinion of the Engineer is concentrated or significant or affects the use of the works shall be sealed by the Contractor using agreed methods and materials.

11 QUALITY ASSURANCE

11.1 General

Further to the requirements of Section 7.1.5 of the Employer's Requirements and Clause 4.9 of the General Conditions of Contract the Contractor shall:

1. Develop and submit his Quality Control Plan and the procedures for implementation of the Plan. The Quality Control Plan shall identify individuals responsible for the Contractor's Quality Control Program and submit their qualifications to the Engineer for approval.
2. Monitor quality control over Sub-Contractors, manufacturers, products, services, site conditions, and workmanship, to produce Work of specified quality.
3. Before ordering any material, submit a sample and notify the Engineer where such material is to be obtained. The Engineer will, if necessary, inspect and test the material at source and if the material is satisfactory, the Contractor will be permitted to ship to the casting yard.
4. Comply fully with manufacturers' instructions, including each step in sequence.
5. Should manufacturers' instructions conflict with the Contract Documents, request and obtain clarification from the Engineer before proceeding.
6. Comply with specified standards as a minimum quality for the work except when more stringent tolerances, codes, or specified requirements indicate higher standards or more precise workmanship.
7. Employ persons qualified and trained to produce workmanship of specified quality.
8. Secure products in place with positive anchorage devices designed and sized to withstand stresses, vibration, physical distortion or disfigurement.
9. Where work that is to be done away from the construction site is subject to inspection on behalf of the Engineer during its fabrication, manufacture, or testing, or before shipment, give notice to the Engineer of the place and time where such fabrication, manufacture, testing or shipping is to be done. Such notice shall be in writing and delivered to the Engineer in ample time so that the necessary arrangements for inspection and witnessing or shop tests can be made.
10. Where tests or additional tests show the work to be outside contractual requirements, dispose of the defective work and replace with new at his own cost.
11. Where tests or inspections are called prematurely or the testing laboratory is delayed by the Contractor, pay all additional costs incurred.

11.2 References

The Contractor shall conform to standards with date of issue that was current on the date of receiving bids.

Should specified reference standards conflict with Contract Documents, the Contractor shall request and obtain clarification from the Engineer before proceeding.

The contractual relationship of the parties to the Contract shall not be altered from the Contract Documents.

11.3 Laboratory Testing Services

The Contractor shall perform inspections, tests, and other services specified in individual specification sections.

The Contractor shall appoint, employ, and pay for the services of an independent firm to perform testing.

Reports shall be submitted by the independent firm to the Engineer indicating observations and results of tests and indicating a compliance or non-compliance with Contract Documents.

The Contractor shall co-operate with the independent firm; furnish samples of materials, equipment, tools, storage and assistance as requested.

If retesting is required because of non-conformance to specified requirements, this shall be performed by the same independent firm on instructions by the Engineer. Costs for retesting will be paid for by the Contractor.

12 EXCAVATION WORKS FOR SHAFTS AND TUNNELS

12.1 General

The Contractor shall be responsible for the safety and security of excavations at all times during the execution of the Contract.

Mechanised techniques for excavation shall be used wherever practicable to eliminate or reduce health and safety risks.

Use of hand-held tools shall comply with the guidance given in "The Management of Hand- Arm Vibration in Tunnelling, Guide to Good Practice", by the British Tunnelling Society.

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.

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.

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.

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.
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.

Where necessary to ensure the safety and security of the Works, excavation shall be continuous by day and night.

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.

Any voids formed during the excavation process by machine overcut slips, falls of material, overbreak and temporary works shall be filled completely with grout, concrete, sprayed concrete or other accepted durable material.

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.

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.

The volume of excavated material shall be measured and recorded as the Works proceed. The Contractor shall present to the Engineer at regular intervals specified in the Contract a reconciliation of volumetric advance of tunnel against volume of materials excavated and volume of grout placed.

All excavation shall be carried out to a profile as close as possible to the specified excavation line.

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.

The proximity of other tunnels and excavations shall be taken into account when determining the method of excavation.

Where stated on the Drawings or in the Employer's Requirements, the Contractor shall undertake tunnel excavation, support and grouting to control ground loss to below the specified values.

12.1.1 Rock

On exposure of a fresh stratum during shaft excavation, the strata in the face walls shall be mapped geologically in accordance with the requirements of the Contract. The Contractor shall provide access for mapping.

Any unsound areas of rock shall be reported to the Engineer immediately together with a record of the Contractor's action. Excavation shall not continue until the area is properly secured.

Where an in-situ lining is specified, at no point will rock be allowed to intrude within the specified limit as shown on the Drawings.

Any face of exposed ground, where excavation is to be discontinued for whatever reason shall be supported by timber, rock bolts, sprayed concrete or other means agreed with the Engineer.

12.1.2 Soft Ground

In ground which is not self-supporting, measures shall be taken to ensure that no undue loss of or softening of the ground occurs at the face, and that there is no run of material from behind supports or lining.

In any exposed ground, temporary emergency support shall be available at the face at all times.

Ground and ground water conditions encountered shall be logged.

12.1.3 Disposal of Spoil

The Contractor shall remove all excavated material, spoil, surplus materials and rubbish from whatever source from the site.

The Contractor shall be responsible for treatment of spoil to remove contaminants from material which is to be used as backfill. Material that is acceptable for backfill shall be disposed of at a tip site within Mumbai municipal limits, the location to be agreed with the Employer.

The Contractor shall make his own arrangements for the disposal of unacceptable material.

12.2 Ground Treatment for Ground Stabilisation and Groundwater Control

12.2.1 Limits on Ground Settlement and Upheaval

The trenchless technology method adopted by the Contractor shall be such that the surface settlement measured directly above the front face of the shield or boring equipment during the tunnelling/ boring operations does not exceed 15mm. The affected ground and the structures shall be subsequently reinstated to their original condition at Contractor's risk and cost.

However, for the sections of tunnel crossing under roads and railways the Contractor shall be required to incorporate in his tunnelling method measures to arrest the expected settlements so as to safeguard the integrity of the road surfaces and collapse of bed. The Contractor shall ensure that the traffic flow along the roads is not affected by ground settlement or upheaval in any way as a consequence of his work.

12.2.2 Ground Stabilisation

It shall be the responsibility of the Contractor to maintain stable soil conditions at the excavation face to prevent loss of ground above the tunnelling operation and movement of the surrounding earth. The methods of maintaining face stability and preventing ground movement and subsidence shall be by means of fluid slurry or earth pressure applied to the tunnel face. Alternatively, unstable ground ahead of the face may be stabilised by the injection of suitable chemicals. Methods which require dewatering of the ground will not be accepted, nor will methods which may lead to significant ground loss.

Movement or settlement of structures, railways, utilities and pavement shall be monitored by the Contractor during the tunnelling operation and reported to the Engineers and railway or highway authorities. The Contractor shall make provision to install required instrumentation and tools for monitoring of ground movement.

If movement or settlement occurs, the Contractor shall take immediate action to prevent further movement, settlement or damage. The Contractor shall repair at his risk and cost any damage and restore structures and pavements to the satisfaction of the Engineer. The Contractor shall pay expenses if the owner or concerned agency such as MMRDA elects to carry out such repairs by themselves.

12.2.3 Grouting

Grouting for ground stabilisation shall mean injecting grout for the safe progress of the Works, the elimination or mitigation of settlement and the reduction of groundwater inflows into the Works. Cementitious grout with suitable additives will be used, followed where necessary with chemical grouts as the nature of the ground to be treated and the purpose of the grouting dictates.

Grouting shall be carried out only 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 Contractor shall carry out such trials, additional tests and ground investigation as he deems necessary to formulate his proposals.

The Contractor shall take precautions to minimise hydrofracture stress levels within the ground imposed by grouting which might cause damage to structures and/or heave. Where significant stress changes are likely to be imposed, the Contractor shall employ systems to monitor and protect sensitive structures.

The Contractor shall take precautions to avoid injected grout entering sewers, drains, granular drainage blankets or other underground structures.

The performance of any grouting system shall be monitored by the Contractor in accordance with the Contract, and interpretation of the results agreed with the Engineer.

12.2.4 Contractor's Proposals

The Contractor shall agree with the Engineer details of the proposed grouting scheme including:

(a) Where grouting design is the responsibility of the Contractor, specific criteria to measure the adequacy, sufficiency or completeness of the ground treatment

(b) Details of the treatment zone and grout injection patterns with respect to the Works and adjacent structures

(c) Details of plant proposed

(d) 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

(e) An assessment of the environmental impact of the materials and methods proposed

(f) An occupational health risk assessment, including methods of risk reduction on all aspects of the grouting operation, Where the grouting contractor is responsible for the design of the grouting, he shall automatically record grouting pressures and flows and produce ongoing assessments of the grout performance in relation to the objectives of the design.

12.2.5 Drilling

Any drilling to be undertaken for the grouting works shall be carried out in such manner as to minimise ground disturbance and soil loss. Where drilling or treatment techniques employing air or foam/air are proposed, the issues of escape of air into the ground and disturbance of previously grouted ground shall be agreed with the Engineer.

Drill tubes left in the ground after final use shall be flushed out and filled with an accepted cementitious grout. Each tube shall be cut off at least 1m below ground level and the area restored.

12.2.6 Plant

Plant shall be brought to site and maintained in good working order. Batching and mixing plant shall be provided with gauges and equipment which will control accurately the proportions of materials within the required limits and ensure proper mixing and injection of the grout. Gauges shall be checked at the start of each shift. Spares for plant and spare gauges shall be held at site. Current calibration certificates shall be available on site for all electronic measurement equipment.

12.2.7 Disposal of Waste

The Contractor shall dispose of leakage and wash-out water from injection points and risers in a safe way and shall not allow them to contaminate the site or watercourses or property elsewhere. The Contractor shall take preventative measures to avoid leakage and shall take measures to stop up leakages should they occur. He shall submit his proposals to the Engineer for his consent.

The Contractor shall adopt proper safety precautions to avoid health hazards to all persons, dependent on the nature of the grouts in use.

12.2.8 Records

The Contractor shall keep full and detailed records as are appropriate to the type of treatment being carried out, including direction and full depth of injection pipe, quantities of materials used, time, location and volume of grout injected, volume of grout to waste by leakage and other reasons, pressure of injection (measured as close to the injection point as possible), both for initial injections and re-injections. Copies of such records shall be given on a daily basis to the Engineer. Continuous automated monitoring of grout pressures and flows shall be made and presented electronically along with summary records. Records of tests carried out on the treated ground shall also be given to the Engineer.

12.3 Piling

12.3.1 General

All piling works are to be integrated and coordinated with all other site activities and the overall programme for the project to ensure the stability of all parts of the works at all times and at all stages, and allowing for any restrictions, constraints or phased possessions required by those other site activities.

The Contractor shall comply fully with the relevant recommendations of British Standards, relevant Indian standards and the requirements of this section of Employer's Requirements, unless the Contractor has reasons acceptable to the Engineer for departing therefrom. In matters relating to local conditions not specifically covered by the British Standard BS 8004:1986, Indian standards and these Employer's Requirements, the Contractor's proposals shall be in accordance with accepted principles of good foundation engineering practice and shall also be subject to the Engineer's acceptance.

Not less than 2 weeks before any piling work is commenced, the Contractor shall submit to the Engineer full details of his proposed piling plant, and detailed method statements for carrying out the Works. Such details shall include where applicable a full description of the piling frame, hammer, helmet and packing, methods of handling, pitching and supporting the piles before and during driving, the proposed driving procedure to obtain the required penetration, or the proposed set and the method of calculation of the specified working load of the piles and such further information as the Engineer may require.

Details of casings and concreting methods in respect of any driven or bored cast in place concrete piles are to be provided.

The Contractor shall not commence any piling until the plant and methods which he proposes to use have received a 'Notice of No Objection' from the Engineer but such acceptance shall not relieve the Contractor from any of his obligations and responsibilities under the Contract. If for any reason the Contractor wishes to make any change in the plant and methods of working, he shall not make any such change without having first obtained the Engineer's 'Notice of No Objection' thereof.

The Contractor is fully responsible for the detailed design of the piling system. Piles may be either considered as part of the permanent structure or as a temporary structure.

The Contractor's design of piling system shall be for all loads including ground loads, ground water, surcharge, TBM and pipe loads.

The Contractor shall submit piling records to the Engineer in accordance with Section 7.3.2 of the Employer's Requirements.

12.3.2 Tolerances

12.3.2.1 Setting Out

The Contractor shall establish and maintain permanent datum level points, base lines and grid lines to the satisfaction of the Engineer and shall set out with a suitable identifiable pin or marker the position of each pile. The setting out of each pile shall be agreed with the Engineer at least 8 working hours prior to commencing work on a pile and adequate notice for checking shall be given by the Contractor.

Notwithstanding such checking and agreement, the Contractor shall be responsible for the correct and proper setting out of the piles and for the correctness of the positions, levels, dimensions, and alignment of the piles.

12.3.2.2 Position

Piles shall be bored accurately vertical or to the specified rake and the permitted deviation of the pile centre from the centre point shown on the setting out plan shall not exceed 50 mm measured at the working level of the piling rig, or other level agreed by the Engineer. Variation of level of top of piles shall be limited to ±25 mm.

The maximum permitted deviation of the finished pile shall be 1 in 75 from the vertical for vertical piles.

Variation in cross sectional dimensions shall be limited to + 50 mm and - 0 mm.

Variation of levels at the top shall not be beyond ±25 mm.

For secant pile walls tolerances refer to Section 12.3.12 of the Employer's Requirements.

12.3.3 Disturbance and Noise

The Contractor shall carry out the piling work in such a manner and at such times as to minimize noise and disturbance in accordance with Sections 5.7and 5.9 of the Employer's Requirements.

The Contractor shall take precautions adequate to avoid damage to existing utilities and services and adjacent structures.

The Contractor shall ensure that damage does not occur to any part of completed piling works and shall submit to the Engineer for acceptance his proposed sequence and timing for boring piles having regard to the avoidance of damage to adjacent piles.

12.3.4 Programme and Progress Report

The Contractor shall inform the Engineer each day of the programme of piling for the following day and shall give adequate notice of his intention to work outside normal hours and at weekends, where agreed.

The Contractor shall submit to the Engineer on the first day of each week or on such other date as the Engineer may decide, a progress report showing the rate of progress to that date and progress during the previous week and/or period of all main items of piling works, as required by the Engineer.

12.3.5 Obstructions

If during the execution of the Works the Contractor encounters obstructions in the ground, he shall forthwith notify the Engineer accordingly, submit to him details of proposed methods for overcoming the obstruction and proceed according to the Engineer's instructions.

12.3.6 Damage to Completed Piles or Wall Elements

The sequence and timing for installation of piles shall be such that piles already constructed are not damaged.

Excavation close to recently formed piles or wall elements shall take place only after those recently formed piles or wall elements have achieved their characteristic concrete strength.

12.3.7 Supervision and Control of the Piling Works

Contractor's personnel whom the Contractor considers competent to supervise the piling shall be capable of recognising and assessing unexpected ground conditions, or any potential dangers,

such as noxious or dangerous gases, or whether the piling works are adversely affecting existing structures as such situations arise.

12.3.8 Requirements for Reinforced Concrete in Piles

12.3.8.1 General

The method of placing and the workability of the concrete shall be such as to ensure that a continuous monolithic concrete shaft of the full cross section is formed. The method of placing shall be as accepted by the Engineer and shall be carried out after inspection without such interruption as would allow the previously placed batch to have hardened. No contamination of the concrete by spoil, liquid or other foreign matter shall be allowed.

Concrete and reinforcement grade shall be as specified in the Employer's Requirements.

12.3.8.2 Workability of Concrete

The Contractor shall take all precautions to ensure that the mix and placing of the concrete does not result in arching of concrete in a casing. Slump measured at the time of discharge into the pile boring shall be in accordance with requirements as specified in IS: 2911 Part I Section 2-1979.

12.3.8.3 Compaction

Internal vibrators shall not be used to compact concrete unless the Contractor is satisfied that no segregation or arching of the concrete will result and this should be put up for consent of the Engineer.

12.3.8.4 Placing and Cleaning of Reinforcement

The steel reinforcement shall be lowered accurately into position with sufficient spacer blocks to ensure the correct cover is maintained at all times. The steel reinforcement cage shall be adequately stiffened against collapse due to side sway. If required by the Engineer, the reinforcement in the pile shaft or socket shall be flushed with fresh water immediately prior to concreting to remove accumulated salt or other deposits.

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, all to the acceptance of the Engineer.

Welding of cold worked high tensile requirement bars at joints in main longitudinal bars will not be permitted unless given the express permission of the Engineer in which case the requirements of IS: 9417- 1989 shall be fulfilled. Welding of hot rolled high tensile steel bars shall be permitted provided the method used for the same will not adversely affect the properties of bars.

12.3.8.5 Placing Concrete in Dry Shafts

Where concrete is placed in dry borings, measures subject to the consent 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.

12.3.8.6 Placing Concrete under Water or Under Drilling Fluid

Concrete placed under water or drilling fluid shall be by means of a tremie unless otherwise agreed with the Engineer. This should also satisfy requirements as per IS: 2911 Part I Section 2-1979.

The hopper and pipe of the tremie shall be scrupulously clean and watertight throughout. The pipe shall extend to the base of the pile or boring and a sliding plug shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie pipe and the water or drilling fluid. At all times during concreting, the tremie pipe shall penetrate the previously placed concrete and shall not be withdrawn from the concrete until completion of concreting. A sufficient 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.

The internal diameter of the tremie pipe shall not be less than 200 mm for concrete made with 20 mm aggregate, or as otherwise agreed with the Engineer.

12.3.8.7 Trimming of Pile Head

The pile shall be cast to a minimum 600 mm above the cut off level so as to achieve sound concrete upon trimming down to the cut off level.

When cutting off and trimming piles to the specified cut-off level, the Contractor shall take care to avoid shattering or damaging the rest of the pile. Any cracked or defective concrete shall be cut away and the pile repaired in a manner to provide a full and sound section at the cut-off level. Pile heads cut off as necessary shall be removed from the Site by the Contractor.

12.3.8.8 Monitoring of Concrete Level during Pile Casting

For each truckload of concrete discharged, the rise in concrete level shall be counter checked against the expected increase. If the rise in concrete level is found to be higher than it is physically possible with the amount of concrete discharged, the Contractor shall demonstrate that the integrity of the pile is to the satisfaction of the Engineer.

12.3.9 Bored Cast In-situ Piles

12.3.9.1 Boring

The Contractor shall check and agree with the Engineer the casing position for each pile during and immediately after placing the casing. Piles shall be constructed in a sequence submitted in advance to the Engineer.

Diameters of the piles shall not be less than the diameters specified by the Designer and accepted by the Engineer. Where enlarged bases are required, these shall be mechanically formed and concentric with the pile shaft to within a tolerance of ten per cent of the shaft diameter and shall not be smaller than the required dimension. The sloping surface of the frustrum forming the enlargement shall make an angle not less than 55º to the horizontal.

During boring, the Contractor shall where required by the Engineer take soil, rock or groundwater samples and transport them to an approved testing laboratory or carry out soil tests in situ as directed. A complete record of the construction of each pile shall be kept by the Contractor and submitted to the Engineer for inspection as and when required.

12.3.9.2 Temporary Casings

Temporary casings of accepted quality or an accepted alternative method shall be used to maintain the stability of pile excavation which might otherwise collapse.

Where temporary casings or an alternative method for maintaining stability of a boring are used, these shall be to the acceptance of the Engineer.

Temporary casings shall be free from distortion and of uniform cross section throughout each continuous length. During concreting, they shall be free from internal projections, encrusted concrete or other materials to the satisfaction of the Engineer. For minimum standards the length of such casing shall be as per IS: 2911-1979.

12.3.9.3 Stability of Pile Excavation Using Drilling Fluid

Where the use of drilling fluid is agreed for maintaining the stability of a boring, the level of the fluid in the excavation shall be maintained so that the fluid pressure always exceeds the pressures exerted by the soils and external groundwater, and an adequate temporary casing shall be used in conjunction with the method to ensure stability of the strata near ground level until concrete has been placed. Where bentonite drilling fluid is used in boring for maintaining stability, the level of the fluid in the excavation shall be kept at not less than 1.5 m as per IS: 2911-1979 above the level of the external groundwater 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.

In the event of a rapid loss of bentonite suspension from the pile excavation, the excavation shall be backfilled without delay and the Engineer shall be informed immediately. The instructions of the Engineer shall be obtained before excavation at that location is resumed.

12.3.9.4 Spillage and Disposal

All reasonable steps shall be taken to prevent the spillage of bentonite suspension on the site in areas outside the immediate vicinity of boring. Discarded bentonite shall be removed from the site without delay. Disposal of bentonite shall comply with the regulations of the appropriate authority.

12.3.9.5 Pumping from Pile Excavation

Pumping from a pile excavation shall not be permitted unless a casing has been placed into a stable stratum which prevents the flow of water from other strata in significant quantities into the boring, or unless it can be shown that pumping will not have detrimental effect on the surrounding soil or property.

12.3.9.6 Continuity of Construction

A pile constructed in a stable cohesive soil without the use of temporary casing or other form of support shall be bored and concreted without prolonged delay and in any case soon enough to ensure that the soil characteristics are not significantly impaired.

12.3.9.7 Inspection

Each pile boring, where it is feasible to do so and where it is required by the Engineer, shall be inspected prior to the placing of concrete in it. Equipment shall be provided to enable the Contractor and the Engineer to descend into the boring for the purpose of inspection. Adequate lighting shall be provided.

12.3.9.8 Pile's Verticality

Prior to the concreting of a bore shaft, the Contractor shall check and record the verticality of the borehole in the presence of the Engineer. If the shaft is found to be out of specified

tolerance, the Contractor shall take appropriate remedial measures to correct the bore where possible to the acceptance of the Engineer.

12.3.10 Drilling Fluid

12.3.10.1 Supply

Drilling fluid shall comprise bentonite complying with specification IS:2720-1965, IS:2911 Part I Section 2- 1979 Appendix A or DFCP 4 of the Oil Companies Materials Association or otherwise accepted by the Engineer thoroughly mixed with clean fresh water to form a suspension meeting the 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.

12.3.10.2 Mixing

The temperature of the water used in mixing the suspension shall not be lower than 5ºC.

Where saline or chemically contaminated groundwater occurs, special precautions to the satisfaction of the Engineer shall be taken to modify the bentonite suspension so as to make it suitable for pile construction.

12.3.10.3 Tests

The frequency of testing drilling fluid and the method and procedure of sampling shall be proposed by the Contractor and agreed by the Engineer prior to commencement of piling work. Such control tests on the bentonite suspension as are required or agreed by the Engineer shall be carried out during the course of the piling work.

Before concreting a pile, the Contractor shall take measures to remove any heavily contaminated bentonite suspension which could impair the free flow of concrete from the tremie pipe. A sample of the bentonite suspension shall be taken from the base of the boring using an agreed slurry sampling device and the specific gravity of the sample shall not exceed 1.2 as per standard practice and also as per IS:2911. Placing of concrete shall proceed only with due modification as per consent of the Engineer. Consistency of the mud suspension shall be controlled throughout the poring as well as concreting operations in order to keep the hole stabilized as well as to avoid concrete getting mixed with the thicker mud suspension.

Control tests shall be carried out on the bentonite suspension, using suitable apparatus. The density of freshly mixed bentonite suspension shall be measured daily as a check on the quality of the suspension being formed. The measuring device shall be calibrated to read to within 0.005 g/ml. Tests to determine density, viscosity, shear strength and pH value shall be applied to bentonite supplied to the pile boring. For average soil conditions, the results shall generally be within the ranges stated in the table below. The tests shall be carried out until a consistent working pattern has been established, account being taken of the mixing process, any blending of freshly mixed bentonite suspension and previously used bentonite suspension and any process which may be used to remove impurities from previously used bentonite suspension.

When the results show consistent behaviour, the tests for shear strength and pH value may be discontinued, and tests to determine density and viscosity shall be carried out as agreed. In the event of a change in the established working pattern, tests for shear strength and pH value shall be reintroduced for a period, if required.

Tests on Drilling Fluid:

Property to be Measured	Range of Results at 20° C	Test Method
Density	Less than 1.10 g/ml	Mud density balance
Viscosity	30-90 s or less than 20 cP	Marsh cone method Fann viscometer
Shear strength (10 minute gel strength)	1.4 - 10.0 N/m^2 or 4.0 - 40.0 N/m^2	Shearometer Fann viscometer
pH	9.5 - 12.0	pH indicator paper strips or electrical pH meter

* Where the Fann viscometer is specified, the fluid sample should be screened by a number 52 sieve (300 micron) prior to testing.

12.3.11 Concreting and Extraction of Casing

The plant and methods of extraction shall be subject to the acceptance of the Engineer.

12.3.11.1 Workability of Concrete

Temporary casings shall be extracted before the initial setting time of the concrete expires and when the concrete remains sufficiently workable to ensure that it is not lifted.

12.3.11.2 Concrete Level

Concrete shall be placed continuously as the casing is extracted whilst maintaining the required head of concrete. The pile should be formed at least 600 mm above the cut-off level. Guide lines in this regard as mentioned in IS: 2911, shall be followed along with other international standard practices

No concrete shall be placed in the boring once the bottom of the casing has been lifted above the top of the concrete; it shall be placed continuously as the casing is extracted until the desired head of concrete is obtained.

Adequate precautions shall be taken in all cases where excess heads of water or drilling fluid could be caused as the casing is withdrawn because of the displacement of water or fluid by the concrete as it flows into its final position against the walls of the shaft. Where two or more discontinuous lengths of casing (double casing) are used in the construction, the proposed method of working shall be agreed.

12.3.12 Secant Pile Walls

12.3.12.1 General

Secant Piles are interlocking (Male/ Female) bored cast-in-place piles along the line of the wall. In the case of a Hard/ Firm or Hard/ Soft Secant Piled Walls, the female pile has no reinforcement. For Hard / Hard secant piles, reinforcement is provided in the female (as well as the male) piles.

12.3.12.2 Concrete

Refer to Section 3.5 of this document. Concrete for female firm piles shall have early-age strength appropriate to the boring of the male piles.

12.3.12.3 Reinforcement

Pile reinforcement cages shall be fitted with cover spacers. These shall be of the 'sledge runner' type of steel bar in a rigid plastic sleeve welded or rigidly fixed to a collar ring type cage former. The Contractor shall define the location of spacers to ensure cover requirements are achieved.

Cover to reinforcement shall be as given in the General Specification (Volume IIA).

Use of any alternative for reinforcement e.g. Glass Fibre Reinforced Polymer for areas such as openings shall be agreed with the Engineer.

12.3.12.4 Construction Tolerances for Secant Piles (male and female)

At cut-off level the maximum permitted deviation of the pile centre from the centre point shown on the setting out drawings shall be 25mm in any direction except that an additional tolerance of 10mm shall be permitted for each 1.0m that the cut-off level is below the top of the guide wall.

The exposed face of the pile shall be vertical with a tolerance of 1:200 in any direction, except where secant piles are constructed using continuous flight augers where the verticality tolerance may be relaxed to 1:100.

Notwithstanding the other tolerance requirements, the overlap of secant piles at underside of base slab level shall be a minimum of 25mm.

12.3.12.5 Water Retention and Groundwater Cut-off

The secant pile walls shall be free from running or dripping water after the inside face has been exposed. Beads of water (provided these are single spots and do not run) and areas of dampness not exceeding 0.2 m^2 will be accepted without remedial work. Remedial work for any leakages which occur as running or dripping water shall be covered by a method statement submitted by the Contractor.

The specified criteria apply to permanent walls and to walls where a permanent reinforced concrete wall is formed against the piled wall.

Inspections to assess watertightness shall be carried out following completion of the base slab supporting the embedded wall (and any remedial works completed).

The Contractor shall ensure that all secant wall piles have sufficient overlap to form a groundwater cut-off.

12.3.13 Piles as Permanent Works

Where piles are to be incorporated into the Permanent Works the piles shall be in accordance with the General Specification (Volume IIA), with the concrete specification as per Section 3.5 of the Employer's Requirements.

12.4 Cast In-situ Secondary Concrete Lining of Shafts

12.4.1 Formwork

Effective devices shall be used to hold adjacent edges or ends of formwork tightly together and in accurate alignment and in all cases to hold the formwork tightly against the concrete, which has been placed previously.

Wherever it is necessary to position grout or other pipes through the forms, the Contractor shall drill holes through the forms at the required positions. Where the holes are to be provided for

embedded grout pipes to a regular pattern, the holes shall be reinforced by suitable threaded bosses with flush fitting plugs. Where the holes are provided for a single pour they shall subsequently be filled flush to the face of the form before re-use.

The formwork shall be maintained at all times in good condition as to accuracy of shape, strength, rigidity, water tightness and smoothness of surface. The Contractor shall keep all formwork clean and in good repair and shall supply and apply accepted release agents to facilitate stripping.

No part of any metal tie or spacer or pipe remaining permanently embedded in the concrete shall be nearer than 300mm to the finished bearing surfaces of the concrete and the face cavity shall be so formed as to permit satisfactory filling.

The Contractor shall carry out all corrective measures required by the Engineer to rectify work not constructed within these tolerances.

For the walls of circular shafts the lining may be formed in a series of chords provided that the minimum thickness of lining is maintained and provided that the tolerances on the position of the finished surface are not infringed.

12.4.2 Preparations for Placing Concrete

The surfaces of the shaft excavation or of previously placed concrete or waterproofing membranes shall be thoroughly cleaned to remove all loose and foreign materials. Rock and concrete surfaces shall be cleaned by washing with a strong stream of air and water under pressure. Concrete and grout spillage from previous pours shall be broken out and removed. Reinforcement shall be cleaned of loose rust, mill scale and concrete spillage by the use of suitable steel wire brushes or other means to the satisfaction of the Engineer.

Formwork shall be cleaned and freshly coated with a release agent immediately prior to concreting.

Concrete shall not be placed in still or running water and shall not be subjected to the action of running water until after the concrete has hardened. Where water flows from surfaces against which the concrete is to be placed, it shall be excluded from the space to be filled with concrete by caulking, diverted by pipes, pans or other means and pumped from sumps until the concrete has hardened sufficiently to be unaffected by the action of water.

12.4.3 Concrete Placing Equipment

Concrete shall be placed by pumping equipment of suitable types with adequate placing capacity.

Pumping equipment shall have adequate placing capacity and be capable of delivering the concrete in a continuous uninterrupted flow. The equipment shall incorporate gauges for measuring the pressure in the delivery line and a pressure regulating system.

Pumping equipment, storage hoppers, and delivery pipelines shall be lubricated at the start of each concreting operation and shall be thoroughly cleaned at the end of the operation. Lubricating materials that will come in contact with the concrete shall be such that they do not have any deleterious effect on the concrete.

12.4.4 Placing of Concrete

Concrete shall be transported from the mixer to the formwork as rapidly as practicable by methods which will prevent the segregation or loss of any of the ingredients and maintain the workability.

Concrete shall be placed as close as possible to its final position and in continuous near-level layers between construction joints located as agreed. The depth of the layers shall not exceed 500 mm and each layer shall be compacted using mechanical vibrators specified below before succeeding layers are placed.

Where concrete is placed against a waterproofing membrane, particular care shall be taken to avoid penetration of the membrane during the concrete placing operations.

In the event of equipment breakdown or if for any other reason placing is interrupted, the Contractor shall thoroughly consolidate the concrete to a reasonable level or flat slope while the concrete is plastic. The concrete at the surface of such cold joints shall be cleaned with a high-pressure air and water jet before the concrete hardens, to provide an irregular clean surface free from laitance. Prior to restarting concreting, the surface shall be wetted and a thin layer of cement sand mortar shall be vigorously brushed into the surface. Planned cold joints in permanent linings shall not be permitted. The work shall be so carried out that a sound dense lining is produced, admitting water only at the temporary drainage channels, where provided. The build up of water pressure behind uncured linings shall be prevented.

The Contractor shall keep on the site a complete record of the work showing the time, date and location of concrete placed in each part of the Works. His record shall be available for inspection by the Engineer.

12.4.5 Compaction of Concrete

Concrete shall be compacted by mechanical vibrators producing not less than 3600 vibrations per minute. Immersion type vibrators shall generally be used, supplemented, where necessary, by appropriate heavy-duty formwork vibrators.

Where immersion vibrators are used, one vibrator shall be provided for every 6 cubic metres per hour of concrete to be compacted. Immersion vibrators shall, wherever practicable, be operated in a near vertical position, and the vibrating head shall penetrate and re-vibrate concrete in the upper portion of the underlying layer. They shall be withdrawn slowly to avoid the formation of voids and shall be carefully positioned to avoid contact of the vibrating head with the formwork.

Care shall be taken to avoid damage to waterproof membranes and displacement of prefixed pipes, blockouts, bolts and the like.

Formwork vibrators shall be used for compacting concrete where access for an immersion vibrator is not practicable. They shall be operated at intervals of not more than 1.2m behind the advancing slope of the concrete. The location and operation of the vibrators shall be carefully co-ordinated with the withdrawal of the discharge line so as to avoid settlement and flow of the concrete due to improperly positioned and timed vibration.

12.4.6 Curing of Concrete

All in situ shaft concrete shall be cured by either moist curing, or membrane curing.

Curing shall be maintained for a period of 4 days from the time of placing.

12.4.7 Concrete Replacement and Repair

The Contractor shall develop and provide for the acceptance of the Engineer a Concrete Replacement and Repair procedure.

12.4.8 Grouting of In-situ Concrete Lining

At least 14 days after concreting, the lining shall be grouted at the lowest pressure necessary to fill any remaining voids behind the lining.

Grouting and vent pipes may be put into position prior to concreting or may be positioned through holes drilled in the finished lining, taking care to prevent damage to any waterproof membrane.

12.4.9 Construction Joints

Construction joints shall be positioned only where agreed with the Engineer.

Formed construction joints shall be formed using purpose made stop ends. Expanded metal stop ends shall not be used.

Unformed construction joints shall be formed using a grout check or similar so that the exposed edge is a crisp true line.

Kickers shall be constructed integrally with the structure below.

The joint surface shall be either brushed using water to remove laitance and expose the aggregate without disturbing it, treated with retarder and then water-jetted to remove laitance and expose the aggregate without disturbing it; or lightly roughened by light chipping or needle-gunning of set concrete. Hacking of set concrete shall not be permitted.

Construction joints shall be clean and damp, with no standing water, immediately before wet concrete is placed against them.

12.4.10 Defective Work

Concrete which is honeycombed, damaged by faulty curing, or fails to attain the specified or characteristic strength, and concrete work which in any way fails to comply with the Employer's Requirements, will be considered defective.

Defective work shall be removed and replaced. The methods used for such removal and subsequent reconstruction shall be agreed with the Engineer.

12.5 Shotcrete Lining of Shafts

12.5.1 General

"Shotcrete", for the purposes of the Employer's Requirements, is defined as a Portland cement concrete, containing aggregate with a nominal size of up to 10mm, applied from a spray nozzle by means of compressed air.

12.5.2 Qualification of Applicators

The Contractor shall employ nozzlemen who have had previous experience or training in the application of shotcrete, and the work shall be performed under the immediate supervision of a foreman having at least three years' experience. The Contractor shall adopt appropriate procedures to ensure that nozzlemen have a proper understanding of the requirements for the placed concrete, and are competent to achieve these requirements. Each nozzleman shall demonstrate acceptable proficiency in uniformity of application and quality of shotcrete to vertical and overhead test panels to the satisfaction of the Engineer 14 days prior to beginning production work.

12.5.3 Shotcrete Constituents

The maximum aggregate size shall be determined by the laboratory and field trials.

The same source of cement, aggregate, admixtures and water used in agreed test mixes and field trials shall be used for production work. Minor adjustments may be permitted subject to

prior written acceptance from the Engineer. Specified strengths and toughness requirements shall be maintained.

Material sources shall only be accepted if they can guarantee sufficiency of supply

Steel Fibre Reinforcement

Where required, steel fibres in steel fibre reinforced shotcrete shall comply with the following:

a) Fibres shall be collated or uncollated deformed steel fibres conforming to the requirements of ASTM A820-90.

b) Fibres shall be stored in dry sealed containers until ready for use and shall be free from corrosion, oil, grease, chlorides and deleterious materials which may reduce the efficiency of mixing or spraying processes, or which may reduce the bond between the fibres and the sprayed concrete.

c) Fibres shall have an aspect ratio in the range of 30 to 150 for lengths of 12.7 to 63.5mm. Tolerances shall be in accordance with ASTM A820-90.

d) Steel fibre suppliers must be able to satisfy the performance criteria of the specification by means of an appropriate and established energy absorption test.

e) The in-situ quantity of steel fibres shall be 40kg/m minimum. The Contractor shall add sufficient additional fibres to allow for preferential rebound subject to the agreement of the Engineer.

f) The steel fibres shall have hooked ends.

g) The tensile strength of the steel fibres shall not be less than 1100N/mm2.

h) Mixing of the fresh concrete shall be such that all bundles of steel fibres have separated into individual fibres.

12.5.4 Mix Design and Testing

Detailed specifications for shotcrete mixes shall be developed by the Contractor to ensure that the design requirements for the shotcrete lining are achieved. The shotcrete mix shall be developed by laboratory tests and field trials at least two months prior to the actual application. In developing the mix specification the full range of options such as wet or dry mixes, fibre reinforcement, early rate of strength gain, and mix design shall be considered so that the highest degree of certainty in the quality and the timely strength of the finished product can be secured. Alternative shotcrete mix designs should be considered if there is any doubt about continuing availability of materials.

An acceptable accelerating additive shall be included in the mix to provide an initial setting time of 5 minutes maximum, and a final setting time of 20 minutes maximum. Additives shall not be corrosive to steel, and shall not encourage other detrimental effects such as spalling. Accelerators based on calcium chloride will not be permitted. The proportions of the accelerating additive for normal use shall not exceed 6% of the cement content by weight. Only the minimum quantity of additive required to meet the specified high early strength requirements of the Employer's Requirements shall be included in the mix for normal shotcreting operations.

Three test cubes shall be made and tested for each combination of materials in the laboratory tests. The average strength of these three cubes shall be not less than 40 N/mm2 at 28 days. Individual cube strengths shall not deviate from the mean by more than 15%.

After completion and acceptance of laboratory tests, field trials shall be carried out using the selected mixes to confirm the capabilities of equipment, workmanship and materials under field conditions. For each mix selected for trial, at least two vertical trial panels shall be produced of

minimum dimensions 600mm x 600mm, in ambient conditions equivalent as far as possible to those inside the shaft.

Six hours after shooting, a minimum of 12 No. 75mm diameter full-depth cores shall be taken from each panel, prepared and tested using an agreed method of end preparation. In every case the length of specimen as sawn ready for capping shall be at least equal to the diameter. Cores for testing at 72 hours and 28 days shall be stored in water. Each test shall represent the average of three cores from one panel. Individual core results shall not deviate from the mean by more than 15%. One set of three cores for each test panel shall be tested at curing ages of 8 hours, 72 hours and 28 days. The following average strengths shall be achieved:

a) minimum 2.5 N/mm^2 at 8 hours

b) minimum 15 N/mm^2 at 72 hours

c) minimum 30 N/mm^2 at 28 days

Tensile strength shall be at least 15% of these compressive strengths, as measured by an indirect tensile test.

Following satisfactory field trials on test panels, a full-scale field trial shall be carried out by shotcreting an area of approximately 20 m² to demonstrate that a uniform quality can be produced. A minimum of 12 No. cores shall be taken at each of vertical and overhead locations and tested and shall achieve the same minimum strengths as required for the test panels.

The Contractor shall submit to the Engineer full details of field trials and cube tests to demonstrate compliance with the specified requirements.

12.5.5 Proportioning and Mixing

Aggregate and cement shall be proportioned by an acceptable batching plant, based on weight. Aggregate and cement shall be thoroughly mixed in the surface dry state before being deposited in the placing equipment.

Additives shall be accurately proportioned and thoroughly mixed with other ingredients. The accelerating additive shall not be added until immediately prior to depositing the materials in the placing equipment, or, if in a liquid form, may be accurately proportioned into the water supply at the application nozzle. Details of additive quality control shall be included in the Contractor's method statement.

The moisture content of the combined aggregate shall be maintained in the range of 3% to 6% of oven-dry weight of aggregate at the time of mixing with cement.

Mixed material shall be used within one hour of adding cement.

12.5.6 Welded Wire Mesh

Welded wire mesh reinforcement, splices and starter bars shall conform to IS 1566.

All wire mesh shall be securely fixed using pins, nails or tie wires to prevent excessive vibration during subsequent shotcrete application.

Provide minimum overlap of welded wire fabric of 300mm in each direction or use splice bars.

12.5.7 Rock Dowels

Rock Dowels shall be at least 25 mm diameter deformed bars of types and shall meet the relevant IS or BS specification.

Each bar shall be furnished with bearing plate, washer and nut. Nuts shall have hexagonal heads of the heavy-duty type, conforming to the specification.

Where so directed by the Engineer, rock bolts shall protrude a sufficient length outside the rock surface to allow load testing. For such purpose, the protruding ends of rock bolts shall be threaded and provided with anchor plates. Where the rock surface will be covered with reinforced spray concrete, the anchor plates shall be located outside the reinforcement. After testing, protruding ends shall be bent back or cut and covered with spray concrete.

Cement Grouted Rock Dowels are un-tensioned rods inserted into a drilled hole and grouted along the entire length using cement grout. These are used as part of the systematic design but can also be used to stabilise small blocks of rock that are kinematically admissible. Information regarding the materials, length, and installation angle for the systematic design shall be provided by the Contractor. The use of rock dowels to support individual blocks of rock shall be subject to Contractor design.

Rock dowels shall be installed as required. The exact locations of dowels shall be adapted to suit prevailing geological conditions.

Holes constructed for the installation of dowels shall be drilled into the rock to the minimum lengths required. The inclination, length and number of holes shall be adapted to suit specific conditions encountered. Holes shall be drilled with an accuracy of ± 5 degrees.

Drill hole diameter shall be as stated on the drawing. If other dowels are used for local block support the diameter shall be within the range recommended by the rock dowel manufacturer to match the particular rock dowel diameter and any couplers required for extending the dowels. The hole diameter shall provide a minimum grout annulus of 10mm.

Holes shall be drilled using sharp bits to produce straight holes of the required length. On completion of each drill hole and prior to the installation of each dowel, drill holes shall be cleaned to remove debris by flushing with compressed air or with clean water. The amount of any water flushing shall be kept to an absolute minimum and details of its use shall be agreed with the Engineer.

Installation shall be made in accordance with the rock dowel manufacturers' recommendations. The grouting material shall be injected starting from the furthest point of the drilled hole so that the dowel rod is completely encased in grout. The dowels shall be installed centrally within the drilled hole. Where required hole centralisers shall be used at a spacing which prevents sagging of the bar between centralisers. Centralisers shall be provided on tendons to ensure a minimum cover of 10 mm of grout at suitable centres depending on the angle of inclination of the anchor. Centralisers shall not be bulky or compressible and shall minimise debonding at the grout/ tendon interface

Records shall be kept for each dowel installed and copies of all records shall be maintained on site after installation of the dowel or completion of testing, as appropriate. Copies shall be provided to the Engineer within 2 working days of completion. Records to include the following information:

a) Dowel reference number;

b) Engineer's name and person taking record;

c) Date of drilling;

d) Diameter, length and orientation of drill hole;

e) Consistency, colour, structure and type of rock, and penetration rate through the various materials encountered in drilling;

f) Date of dowel installation;

g) Dowel type, including manufacturer's batch number;

h) Dowel length and diameter;

i) For tested dowels, details of maximum load and dowel head displacement

12.5.8 Testing of Rock Dowels

Sets of six cubes of cement grout shall be taken when installation of each series of grouted rock dowels is in progress. Sampling, preparation, curing and testing shall be in accordance with BS EN 196. Half of the cubes shall be tested at 7 days and the remainder at 28 days. The average compressive strength determined from any group of three tests shall exceed the specified characteristic strength by 3 N/mm2 for cement grout tested at 28 days. Individual results shall not differ from the mean by more than 15%.

Five percent of the installed dowels shall be tested at 150% of the working load between 3 and 21 days after installation as directed by the Engineer. Dowels which fail the tests shall be replaced and retested, and all other dowels installed on the same shift shall be tested.

The in-situ test shall be carried out generally in accordance with the suggested method for determining the strength of a rock bolt anchor given in "Rock Characterisation Testing and Monitoring: ISRM Suggested Methods edited by E.T. Brown (Pergamon Press 1981)". The specified test load shall be applied and then released at the end of the tests.

The rock dowels shall be deemed to be acceptable provided the test load is sustained for at least 10 minutes.

Rock dowel trials shall be undertaken using the equipment and materials specified for the systematic support. Tests to failure shall be carried out on six dowels of each length proposed for use in the works. No failure load shall be less than the specified working load.

12.5.9 Application of Shotcrete

A suitable working environment shall be provided to facilitate construction and monitoring, including a high standard of lighting and local exhaust ventilation to the satisfaction of the Engineer.

Sufficient material shall be stockpiled to provide for ready availability, including lattice girders, mesh, and other necessary items.

Indicators shall be incorporated in the lining reinforcement or otherwise affixed to the excavation face at a rate of at least 1 per 2 m2 to provide a simple visual indication that the correct thickness of concrete is applied.

The plant for mixing and delivery systems shall be such as to secure a guaranteed flow of suitable quality and volume at the face whenever required.

For shotcrete produced by the wet method, the base concrete including any admixtures except accelerator shall be transported by a suitable means which ensures complete mixing during transportation such that segregation of the mix components is prevented. Pumping shall ensure a continuous conveyance of base concrete including any admixtures except accelerators which may be added at the nozzle. The equipment shall incorporate a suitable metering device for liquid accelerators.

For shotcrete produced by the dry method, the dry mixture shall be transported by non-agitating containers. Placing equipment shall consist of a spray nozzle providing for ejection of dry materials and water in intimate mixture, separate hoses to deliver dry materials and water to the nozzle, a suitable machine to introduce the dry materials to the delivery hose under air pressure, a feed conveyor, and air and water supply systems as described below.

Placing equipment shall incorporate methods of checking:

a) Water pressure at off take from supply line at face

b) Water volume used

c) Air pressure at machine inlet

d) Rate of feed of dry mix

e) Rate of feed of admixtures

The equipment shall have positive settings on the various control devices so that the quantities can be easily and accurately controlled by the nozzleman or machine operator.

The air and water supply systems shall be capable of supplying the delivery machine and hose at the pressures and volumes recommended by the manufacturer of the machine. No air supply system shall be used that delivers air contaminated by oil.

The feed conveyor shall be of a screw type or as otherwise accepted by the Engineer and so arranged that additive and shotcrete can be fed to the delivery machine at a regular rate. Additive shall be introduced from an accepted dispenser in a regulated flow to the tail of the feed conveyor so that complete mixing with the dry shotcrete material is achieved before discharge into the delivery machine.

The delivery machine shall be capable of introducing materials to the delivery hose at a uniform rate with ejection from the nozzle at velocities that will allow adherence of material to the treated surface with minimum rebound and maximum adherence and density.

The entire system shall be so arranged that the nozzleman may use air and water in any combination to prepare raw surfaces or to clean completed work.

Access platforms and other equipment shall be provided to allow application of shotcrete to all surfaces. A boom mounting or similar device shall be provided for the spray nozzle for use in conditions where manual spraying from the required nozzle distance is unsafe or otherwise unsuitable or undesirable.

Shotcrete lining shall be applied in accordance with the sequence defined in the Contractor's method statement, and using the exact proportions of ingredients demonstrated in the trial panels. The sequence for applying two or more layers of sprayed concrete to various panels to build up lining thickness shall be specified. The control and removal of rebound material shall also be covered in the method statement.

All excavated surfaces shall be cleaned and prepared before application of shotcrete so that satisfactory bonding is achieved and delamination avoided. Surfaces that are to receive shotcrete, whether freshly cut ground or previously shotcreted, shall be cleaned of all loose material, mud and other foreign matter. After cleaning, surfaces shall be kept moist until the shotcrete is applied.

Shotcrete shall be applied with uniform consistency to maximise binding, cohesion and density, to minimise rebound and segregation and to prevent sagging of the applied shotcrete. A dense, uniform concrete layer shall be produced without segregation or discernible weakness of bond between layers, accomplished without use of rebound material.

The application nozzle shall be held at a predetermined distance and position such that the stream of flowing material is applied as nearly as possible at right angles to the surface to be covered. A steady nozzle motion shall be maintained as the shotcrete layer is built up to the required thickness. Shotcrete shall be built up in a continuous sequence to the minimum thickness defined in the method statement. Where a single thickness greater than 50mm is specified, this thickness shall be applied as more than one layer and the method statement amended accordingly, if observations show that separation is occurring between the shotcrete and ground.

Shotcrete shall be left as sprayed until it has set and not worked by float or any other means. If a smooth surface is required, the Contractor shall apply a floated off mortar layer after the shotcrete has set.

Water flows and seepage shall be controlled in such a manner that detrimental effects are completely and permanently eliminated. The Contractor shall drain water by pipes, chases or other appropriate methods acceptable to the Engineer. In abnormally wet conditions, additional accelerator may be included in the mix provided it has been demonstrated by prior trials that this will not unacceptably reduce the strength requirements of the lining.

12.5.10 Curing

Curing is not required in shafts under normal conditions. Should undue shrinkage cracking become evident in any particular circumstances, modifications shall be made to the method of application, cement content, ventilation procedures or other operations. Addition of curing agents to the mix shall also be considered.

In shafts and portal areas, all shotcrete shall be covered as soon as possible after application with polyethylene film or jute fabric covering and shall remain covered for a period of seven days. Where ambient temperatures exceed 35^{o}C, sprayed water curing shall be required.

12.5.11 Testing During Construction

The surface of the shotcrete shall be sounded with a hammer to verify the absence of voids, rebound pockets, aggregate pockets and unbonded areas. All shotcrete, which lacks uniformity or exhibits segregation, low strength, honeycombing or laminations shall be broken out and replaced.

The thickness of placed shotcrete shall be checked by drilling small holes at intervals directed by the Engineer in such a manner that the rock/ shotcrete interface can be recognised. The number and position of holes shall be as directed by the Engineer.

The slump of shotcrete produced by the wet method shall be measured by slump tests in accordance with BS EN 12350-2 after the addition of plasticiser. Samples shall be tested for every 50 m^3 produced. The workability of wet method shotcrete shall be within ± 25mm or ± one third of the target value as determined by trials, whichever is the greater.

The bond between the shotcrete and the rock and between different shotcrete layers shall be tested by taking rock and concrete cores of 100mm diameter, grinding of the surfaces of the concrete cores level, affixing of a tensile plate and testing the tensile strength. Each test shall comprise at least 3 cores taken where directed by the Engineer. The bond strength at failure in the contact between the rock and the shotcrete shall be at least 0.5 MPa in 2 cores out of 3. Failure in the shotcrete shall not occur at a tensile stress of less than 0.5 MPa.

12.6 Cavity Grouting

12.6.1 General

The term cavity grouting shall mean the grouting required to fill the cavities or voids between the excavated profile and the permanent linings of underground works including that due to ground relaxation and any void between permanent and temporary linings.

Primary grouting is the initial cavity grouting which is applied immediately after a unit of lining has been built.

Where primary grouting does not completely fill all cavities, secondary grouting shall be carried out.

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.

For each ring the Contractor shall record at each stage of the grouting process the quantity and type of grout, and the pressure applied at each injection point in a format agreed with the Engineer. The records shall be kept in the Contractor's offices and shall be available for inspection by the Engineer.

Grout shall be used within one hour of mixing.

The annulus between the segmental lining and the ground shall be grouted immediately after leaving the shield tail skin, or as otherwise agreed with the Engineer. Where grouting through the tail skin is being adopted, this shall be concurrent with the TBM advance.

Grout shall be prevented from entering the space between the tail of the shield and the lining, and from flowing into the face around the cutting edge of the shield or otherwise being wasted.

12.6.2 Primary Grouting

Primary grouting shall be undertaken at a pressure sufficient to place the grout properly but not greater than 1 bar above the prevailing hydrostatic pressure at the location of grouting unless the lining and equipment have been designed for higher pressures, and agreed with the Engineer.

Primary grouting shall be timed so as to minimise ground movement.

For linings erected behind a closed-face TBM, primary grout shall be injected via the shield tail skin unless otherwise agreed with the Engineer. In other cases primary grout shall be injected through grout holes provided in the linings.

In segmental linings grouted through grout holes, primary grouting shall proceed in sequence from invert to soffit in such manner that all air and excess water are expelled from the cavity progressively ahead of grouting. Valves shall be connected into the grout holes in order to allow the grout to set under pressure when the grout hose is disconnected. After the grout has set, permanent plugs shall be installed.

Any sealing material or device installed at the leading edge of the ring to prevent grout loss shall be removed upon completion of primary grouting.

For segmental linings grouted through the tail shield, the Contractor shall propose a grouting sequence for acceptance by the Engineer.

The Contractor shall ensure that grouting pressures do not result in ground heave or overstress or distortion of lining or distortion or damage to gaskets or damage to other structures.

Grouting equipment shall be fitted with a pressure gauge. Grout pressure is to be measured at the nozzle with a suitable gauge.

Grouting shall be carried out at pressures to completely fill the cavity with grout.

Where the primary void filling is by pea gravel injection, subsequent grouting shall be carried out in stages to the agreement of the Engineer.

12.6.3 Secondary Grouting

Secondary grouting shall be undertaken in selected rings by means of removing grout plugs from the tunnel lining and drilling a hole to the back of the existing grout.

Secondary grouting is the regrouting of lining and shall be completed as soon as practicable but within 14 days of the primary grouting or when the face has advanced 50 m from the location of primary grouting whichever first occurs. Secondary grouting shall be at a pressure consistent with filling all voids but shall not exceed the design pressures.

Upon completion of grouting, threaded grout plugs shall be fully tightened into the lining.

12.6.4 Deleted

12.6.5 Cement Grout for Cavity Grouting

12.6.5.1 General

General-purpose cement grout shall be mixed in accordance with the proportions given in the table below. The water content shall be kept to the minimum required to ensure a smooth, fluid mix

Mix Proportions for Cement Grout

Class	Proportions by Mass		
	Cement	Sand	PFA
G1	1	-	-
G2	1	3	-
G3	1	10	-
G4	1	-	10
G5	1	-	4
G6	1	-	0.5

Pulverised fuel ash (PFA) shall not be used as a constituent of grouts which contain sulphate-resisting cement.

Grout shall be used within 1 hour of mixing.

12.6.5.2 Special Grouts

Special grouts supplied by proprietary manufacturers may be used subject to agreement with the Engineer.

Details of accelerating and retarding agents for proposed inclusion within the grout mix shall be submitted to the Engineer for agreement. Any such proposal shall be submitted in conjunction with a statement which outlines the Contractor's interpretation of ground behaviour during tunnel construction.

Primary grout for machine-driven tunnels shall be special grout injected through the tail skin of the machine as it advances.

The Contractor shall propose details of the primary grout, including the required setting times and strength gain to support the weight of the tunnel boring machine (TBM) and the backup and prevent ring distortion. As a minimum the initial set of the grout shall be achieved within 45 minutes of injection at 20°C. The minimum strength requirement from the grout as measured from testing 100mm cubes shall be 1.5 N/mm² in 24 hours. The proposals shall be submitted to the Engineer for agreement prior to commencement of the Works.

Preconstruction grout trials shall be undertaken to demonstrate that the required setting times and strength gains will be achieved. Details of the trials and results shall be submitted to the Engineer.

Records of batching and batcher calibration shall be maintained to demonstrate that grout batching is in accordance with the design mix. Alternatively, grout strength tests may be used.

12.6.5.3 Mixing

Grouts containing polymer additives shall only be mixed in a colloidal-type mixer.

Special grouts from proprietary manufacturers shall be mixed and used in accordance with the manufacturers' instructions.

12.6.5.4 Storage and Delivery

Bagged grouts shall be stored under cover in dry surroundings and on a suitable platform, clear of the ground.

Bulk deliveries of grout constituents shall be stored in appropriate silos with suitable dust control and batch weighing equipment.

12.7 Waterproofing System for Shafts

12.7.1 General

The waterproofing system for shafts shall consist of impermeable heat welded sheeting and an underlying geotextile drainage and protective sheeting attached to the Primary Support and behind the in situ concrete Permanent Lining.

12.7.2 Drainage and Protection Layer

The protective geotextile placed against the Primary Support shall have the following mechanical and physical properties tested in accordance with the appropriate DIN standards:

Property Specified	Specified Value	Standard
- Weight	500 g/m2 min	DIN 53854
- Thickness under load of 2 bar	> 1.8mm	DIN 53855
- Perforation Strength	1500 N	DIN 54307E
- Min. Tensile Strength (any direction)	90 N/50mm	DIN 53857
- Min. Tensile Strain (any direction)	70%	DIN 53857

The geotextile shall have a hydraulic transmissivity (HT) of at least 1 x 10-6 m2/s under a hydraulic gradient of 1m of water per metre length of the geotextile with a pressure of 2 bars acting perpendicular to the geotextile, i.e.

$HT = K_h \times d \ (m^2/s)$

Where

K_h = Coefficient of permeability of geotextile m/s

d = Thickness of geotextile under a pressure of 2 bars

The geotextile shall be non-degradable and shall be resistant to water with pH values in the range 2 to 13.

The compressibility of the geotextile shall be such that the reduction in thickness of the material under a load of 2 bars does not exceed 10% of the original thickness.

12.7.3 Waterproofing Membrane

The waterproofing membrane shall consist of heat welded sheets of Soft polyvinyl chloride (PVC) and shall have the specified mechanical and physical properties in both the longitudinal and transverse directions when tested in accordance with the appropriate DIN standards.

Mechanical and Physical Properties of the waterproofing membrane shall be:

Property Specified	Specified Value	Standard
-Thickness	2 mm ± 5%	DIN 53370
-Tensile Strength	> 8 N/mm^2	DIN 53455
-Elongation at Break	> 300%	DIN 53455
-State during and following storage at 80°C: General No blister formation Change in Dimensions < 3% Change in Tensile Strength < +10% Change in Elongation < +10% Cold Bend Behaviour at -20°C No cracking		DIN 16726 DIN 16726
-Behaviour when subjected to hydrostatic pressure at 5 bars	No leakage	DIN 16726
-Puncture Resistance	No perforation for 750mm drop of test tool	DIN 16726
-Cold Bend Behaviour	No cracking	DIN 16726
-Behaviour after Storage in Aqueous Solution: Change in Tensile Strength < +10 % Change in Elongation < +10 % Cold Bend Behaviour at -20°C No cracking		DIN 16726
-Testing Channel Width	20mm	
-Testing Pressure	> 2.5 bar	
-Drop of Testing Pressure after 10 minutes	< 10%	
-Shear Resistance when Bonded with Bitumen	> 100 N/50mm width	DIN 16726

Where reinforced concrete is to be placed against the waterproofing membrane a signalling layer, to give a visual indication of any mechanical damage, shall be provided on the exposed surface of the waterproofing membrane. The signalling layer shall be such that it does not adversely affect the seam welds.

Evidence shall be obtained from the manufacturer that no components of the PVC leach out in the long term such that the durability of the following is deleteriously affected:

a) The waterproofing membrane

b) The geotextile drainage/protective layer, and

c) other plastic materials or PVC materials such as waterstops

12.7.4 Preparation of Surfaces

The surface of the Primary Support, onto which the membrane is to be fixed, shall be well finished without sharp projections, or any edges with radius of less than 200mm. The ratio of width of any depression to its depth shall be greater than 5. Where necessary the support surface shall be prepared by application of a regulating layer. All projecting dowel ends, anchor plates, nuts, arch ribs, joints and the like shall be covered by a regulating layer. All prepared surfaces shall be inspected and accepted by the Engineer.

12.7.5 Fixing of Drainage and Protective Layer

The protective geotextile layer shall be placed tightly against the Primary Support and fixed by means of percussion nails or similar fixing devices, driven through a disc or strip of membrane compatible material approximately 100mm in diameter, and then through the geotextile material. Any projecting nail heads shall be removed. Fixings shall be at the deep points of concavities in the Primary Support surface on a grid of not more than 1000mm x 1000mm. The geotextile shall be installed in accordance with the manufacturer's recommendations with at least 100mm laps.

12.7.6 Fixing of Waterproofing Membrane

The waterproofing membrane shall be installed closely against the geotextile protective layer. The membrane sheets shall be fixed at all the nailing discs or strips by spot welding. Alternative methods of fixing the waterproofing membrane may be used subject to acceptance by the Engineer. Nails, welding tools and any other objects shall not penetrate the membrane except in accordance with agreed fixing details.

Welding of the membrane sheet edges shall be carried out by experienced personnel and with purpose made equipment, to form a flat double weld seam. Each weld shall be at least 6mm wide and the space between the two welds shall not exceed 20mm. Repairs and T-joints may have solid weld up to 30mm wide, and shall be as recommended by the manufacturer. Upright or protruding double seams shall not be used. The connections between the nailing discs and the membrane shall be weaker than the membrane itself.

The installation of the waterproofing membrane shall be carried out only when the atmospheric temperature in the area of installation is higher than 5°C and in accordance with the manufacturer's recommendations.

12.7.7 Testing

Each completed double seam weld shall be tested by the application of air pressure to the space between the two seams. The Contractor shall submit details of his test procedure to the Engineer for acceptance.

The test pressure shall be applied, in the presence of the Engineer, at one end of the seams and measured at the other end to test the integrity of the whole joint. The test pressure shall be not less than 2 bars, and reduction of pressure after 10 minutes shall not exceed 20%. Vacuum testing to 0.2 bars shall be carried out on solid welds with no loss of vacuum.

Testing pressures and results shall be marked on the membrane. Any areas which have been repaired shall be recorded.

12.7.8 Protection of Membrane

The membrane shall be protected carefully until the concrete is placed against it. Any reinforcement in the area where the waterproofing membrane is used shall be provided with plastic caps over cut ends and PVC tubing shall be used as spacers. These spacers shall be of sufficient diameter and short length that they will be filled with concrete. Any burning, drilling or welding of steel within the tunnel shall only be carried out where the membrane has been protected as agreed with the Engineer.

Water percolating outside the membrane shall be led away, so that formation of water-filled blisters is avoided.

Invert membranes in cross passages shall be immediately protected with a layer of concrete at least 100mm thick which shall achieve a compressive strength of 10 N/mm2 before allowing traffic on it.

The membrane shall be installed not more than 100m in front of the Permanent Lining installation and it shall not be left exposed for more than 14 days.

Strips of membrane at least 0.5m wide shall be spot welded to the waterproofing membrane at the formwork stop ends to protect the installed membrane from being damaged.

13 TUNNELLING SYSTEMS

13.1 Tunnel Boring Machines (TBMs) and Shields

13.1.1 General

Though the basic requirements for the TBM are given here, the Contractor is fully responsible for the selection, design and supply of tunnelling machines, shields and ancillary equipment capable of excavating the materials including rocks and mixed ground that may be encountered.

The geotechnical information available from the Employer does not guarantee that these accurately represent the actual ground conditions at site. The Contractor shall be responsible for carrying out any additional geotechnical investigations for determination of soil and rock that may be encountered during execution of the project.

The TBM shall be capable of successfully excavating in the wide ranging ground conditions from tuffacious rock to trachyte/andesite as well as basaltic hard rock strata that may be encountered at the sites. It must take in to account the hydrostatic pressure the pipe gaskets and the entrance and exit seals have to be designed for.

Tunnel shields supplied by the Contractor shall be truly circular, strong enough to avoid distortion during driving, and suitable for building the tunnel linings as stated in the Employer's Requirements.

The Contractor shall take into consideration all geological and other relevant information made available to him. The Contractor shall satisfy himself as to the suitability of the machines or shields which he will provide.

The tunnelling machine selected shall provide adequate settlement control when operating in the anticipated strata and shall be suitable to meet settlement limits where defined in the Employer's Requirements.

The primary standards to be complied with are BS EN 12336 and BS EN 815.

The Contractor shall supply, erect, drive, maintain, dismantle and remove the shields, which shall remain the property of the Contractor upon completion.

Shield design shall make adequate provision for the safety of the workmen and the application of safe methods of tunnelling.

The shields shall be shop manufactured in units of convenient size, suitable for field erection and dismantling under the site conditions of the Contract.

The shields shall be equipped with shove rams of sufficient capacity to move them through all materials encountered, to the lines and grades shown. The rams shall be capable of simultaneous and individual actuation, controllable individual pressure and variable extension.

Rams shall be fitted with proper shoes so placed, secured and articulated that the reaction of the rams will be safely distributed against the tunnel linings.

The shields shall be equipped with a tunnel lining erector system capable of placing each lining segment safely into its final position along the periphery of the ring being erected.

The shields shall have an anti-roll device details of which shall be accepted by the Engineer prior to commencement of works.

During the tunnelling operation, the Contractor shall provide and maintain a CCTV system with 2 cameras placed strategically within each tunnel drive. The CCTV system shall be linked to the Engineer office and the 2 cameras shall move in tandem with the shield and the location shall be agreed by the Engineer.

13.1.2 Machine Characteristics and Design Requirements

All tunnelling machines shall be designed with adequate safety margins for the anticipated duty and manufactured to comply with all relevant safety standards. The design and layout of the TBM control and other workstations shall be carefully considered to provide good ergonomics, visibility and a safe working environment.

Adequate provision shall be made for maintenance, including handling heavy components. Individual replacement of major components such as electric motors, hydraulic pumps and motors, propulsion and face rams shall be possible.

The machine design shall consider the safe replacement of excavation tools during the tunnel drive.

The external diameter of the TBM or shield shall be designed to produce minimum overbreak and the least necessary clearance for the proper construction of the Works. Design shall take into account the horizontal and vertical alignment to be negotiated. Provision shall be made to limit and correct roll of the machine.

The machine shall be designed to allow forward drilling through the cutterhead for the purpose of probing ground conditions and to carry out ground treatment to the face.

Where probing ahead may be required, there shall be a provision for making horizontal and raking exploratory holes. Where machines have pressure bulkheads the probing and grouting points shall have the facility to install glands and valves to withstand the pressures envisaged.

All machines and shields (except those used exclusively for pipejacking) shall be self-propelled. Where propulsion is by means of hydraulic rams thrusting off previously constructed segmental lining, ram shoes and facings shall be designed to distribute the thrust without causing damage to the constructed lining. Ram shoe pads shall be adequately secured. Propulsion rams shall be capable of operating individually or collectively in any combination. They shall permit the insertion of a key closing segment, if used, in any location.

Where open shields are to be equipped with face rams for the support of excavation they shall be capable of operating individually or collectively in any combination. Face rams shall be designed to accommodate the loads necessary to make the face secure. The operation of face rams shall be interlinked with that of the propulsion rams.

Arrangements for extraction, transport and disposal of spoil shall be appropriate for the material to be handled.

All operating functions of TBM or shield, including rate of advancement, shall be accessible to the TBM or shield driver.

The machine tailskin shall be fitted with an adequate tail seal to prevent the ingress of water and/or grout. The tail seals shall be replaceable from within the tunnel. A grout seal, located at the rear of the tail shield, shall be considered to limit grout migration along the shield towards the cutterhead.

All closed face machines shall be designed to maintain pressure on the excavated ground at all times. The pressure shall at least balance the in situ ground and hydraulic pressures making up the total overburden pressure and shall be capable of varying the face pressure as the overburden pressure changes. The design shall also take into account the ground type, density, gradation, strength and abrasiveness.

All closed face machines shall incorporate a two compartment air-lock for man access to the cutter head and face.

The machine operation panel shall monitor and where appropriate control the following:

a) Forward thrust

b) Ram pressure

c) Main bearing grease and oil lubrication pressure flow and temperature

d) Alignment and altitude of shield

e) Electrical load characteristic

Depending on the type of machine chosen the following items shall be monitored and recorded:

a) Face pressure

b) Slurry pressure and flow rates

c) Archimedean screw pressure

d) Compressed air pressure in module

e) Volume of soil removed

Where sledges drawn by the TBM or shield arc used, they shall be designed such that they do not damage the permanent or temporary lining.

13.1.3 Cutter Head

Tunnelling equipment selected for the project shall have appropriate cutter head equipped with suitable cutter bits to excavate soils and rock below the water table. The cutter head shall be appropriately designed for the type of ground it is anticipated to tunnel through including the variability of the ground strata. The tunnelling equipment shall be capable of balancing the ground water pressure supporting the excavated tunnel face at all times.

The tunnelling machine shall be equipped with a crushing chamber behind the cutter head with powerful crusher to crush the excavated rocks into smaller pieces. Moreover, the machine shall be capable of exerting a large thrust force/torque on to the tunnel face to facilitate excavation of rock.

The speed of rotation, torque, bit arrangement (and its structural and mechanical characteristic to withstand rock excavation for longer drive) of the cutter head and the thrust force the tunnelling machine is capable of exerting on to the rock face are important features to consider when selecting machines for tunnelling in rock.

The cutter head of TBMs and closed face machines shall be capable of clockwise and anticlockwise rotation and shall only be able to excavate the ground whilst the hydraulic rams are being actuated. The design of the machine shall ensure that the cutter head can be retracted back from the unexcavated ground to minimise the risk of the machine jamming and to facilitate maintenance.

Where the TBM diameter exceeds 1,800mm the cutting head discs/picks shall be able to be renewed from the rear of the cutter head and be interchangeable.

Where boulders could occur on the tunnel face, the machine head shall permit a minimum 300 mm boulder to be pushed through the cutterhead. The machine shall have the capability to handle, break up as required and remove such boulders through the screw conveyor or slurry discharge aperture without special procedures.

13.1.4 Automated Spoil Removal System

This system conveys the excavated spoil from the tunnel face to the ground surface for disposal. The spoil removal rate and the speed of the shield are fully or semi-automatically controlled in such a way to achieve minimal heave or settlement. There are three systems available for the conveyance of the spoil and they are slurry system, augur system, and vacuum system.

13.1.5 Cyclone Separators for Slurry Separation

Considering high volumes of muck likely to be removed, cyclone separators shall be deployed instead of vibrating screens in the slurry separation tanks. This shall ensure efficient slurry handling and shall increase the productivity of tunnelling. Solids coming from slurry TBM / Microtunnelling machine shall be removed from bentonite slurry using soil separation plant.

Cleaned bentonite suspension shall be used again for the tunnelling process. Sufficient buffer of bentonite slurry has to be stored using boxes with sufficient capacity.

Soil separation plant shall be equipped with double stage hydrocyclone system with sufficient bentonite slurry capacity in order to thread maximum slurry circuit volume of TBM in any case on time. Each separating stage shall be designed to thread full slurry capacity.

Hydro-cyclone size of desilter stage shall be 3" in order to guarantee a solids cutoff point of approx. 25 µm.

Water content of separated soil shall be less than 25%.

Drilling slurry containing smaller solids than approx. 25µm shall be removed from bentonite slurry circuit using centrifuges with sufficient capacity in order to maintain bentonite slurry density in proper level.

The system shall be capable of handling 400 m^3/hr would be a minimum for (DN1800 - DN2500) and 600 m^3/hr for higher microtunnels.

De-sanding may be necessary where sand content is high. This can only be verified upon further detailed geotechnical investigations within the Contractor's scope.

If the rock behaves as a silt stone there is a strong possibility that fines will remain suspended in the slurry which will increase the density and hamper the pumping capacity.

Slurry shall be monitored for density. The specific gravity of returning slurry from the machine shall be no higher than 1.25. The need for addition of bentonite to the slurry is not envisaged unless a loose soil formation such as gravels or sands is encountered.

13.1.6 Airlocks

Consideration for airlocks shall be shown as necessary where the pipe/tunnel is of sufficiently large cross section to allow the Contractor to incorporate an access envelope 0.9m wide by 2.0m high within the pipe/tunnel and clear of services including ventilation duct and spoil conveyor.

13.1.7 Guidance

13.1.7.1 General

An adequate guidance system shall be installed on tunnelling machines with a display to show the position and altitude of the machine relative to the design alignment. The display shall be visible to the machine driver at all times.

A secondary means such as a plumb-bob or other apparatus shall be used to check inclination, and to indicate roll. Shields shall be furnished with a means of controlling orientation.

Detailed guidance information shall be checked against the tunnel alignment control at regular intervals as agreed with the Engineer.

The system operation shall vary from totally manual to fully automated. Using the information from the laser system and other sensors, the operator controls various functions of machine like cutter head RPM, thrust, directional steering, slurry operations, lubrication etc. to ensure drive as per designated alignment.

The operator shall monitor all the information and continuously feed into the control panel as necessary. He shall be alert at all time and shall observe the crew's activities and other site activities, evaluate the information and make appropriate operational decisions. The Operator shall monitor and keep record of line and grade of the machine, cutter head torque, jacking thrust, RPM, steering pressures, slurry flow rate, pressures of slurry systems and rate of advancement.

13.1.7.2 Laser Guidance System

Conventional laser guidance systems may be adequate for individual drive lengths up to 400m and in straight alignment. However, for curved and longer drives properly designed guidance system must be used. It shall be suitable for curved and long distance drives and be independent of the machine manufacturer if possible.

Anti-roll protection shall be with an external sensor giving fast reaction times to prevent machine roll should the cutterhead 'snag' and cause a roll.

Moving station can be used which has a 3 stage installation, stage one launches the machine with the laser in the shaft as usual, after approx 80m the station must be moved to the tunnel together with a rear reference station laser checking back to a reflector mounted on the original shaft laser station tunnel and uses a reference station mounted in the normal shaft laser position.

13.1.8 Fire Protection

Provisions shall be made throughout the length of the machine for the detection and automatic suppression of fires. The system shall be maintained in an efficient operating condition at all times.

Fire protection and fire-fighting arrangements as required by the relevant standards shall be incorporated on all shields and tunnelling machines. The equipment shall include, but not be limited to:

- Fire extinguishers
- Sprinkler systems
- A high-density foam drencher system.

A warning signal both audible and visual shall be provided.

Tunnel boring machines, other than remote control machines, shall also be equipped with the following:

- Significant electrical items protected by direct injection of extinguishant into enclosures from a fixed system
- A fixed extinguisher system discharging foam or powder over hydraulic pumps, motors and storage tanks
- Water spray curtain at the rear end
- Additional fire protection as appropriate to size and layout of the tunnelling machines.

Hand held fire extinguishers shall be sited at suitable locations.

The Contractor shall use liquid in the shields which is nontoxic and of low flammability to minimise to the utmost the risk of an oil fire.

13.1.9 Erection of Shield

Before commencement of the tunnelling works, the shield shall be completely assembled adjacent to the first launch shaft with all necessary equipment installed so that it is in working order for inspection and checking by the Engineer. Sample tunnel lining segments shall be available to demonstrate the erection.

The Contractor shall supply all necessary information to the Engineer to enable him to observe the commissioning inspection of the shield at the manufacturer's factory, to ensure that the design and manufacture is in accordance with the specification.

The shield shall be erected to the required grade and line as specified by the manufacturer.

13.1.10 Inspection and Testing

The Contractor shall be responsible for the quality of materials used or present within the TBM or shield and must ensure that all materials used or present are adequate for the task they are to perform.

The Engineer shall be permitted at any stage during manufacture to inspect, examine and test on the manufacturer's premises the materials, workmanship and performance of all plant and components to be supplied under the Contract. Such inspections, examination or testing shall not release the Contractor from any obligation as specified under the Contract.

13.1.11 Personnel and Training

The Contractor shall ensure that all key personnel who are responsible for driving, maintenance and controlling the machine have received the necessary training in the duties that they are required to perform. Preferably the training shall be done within a system of national vocational qualifications. Such training shall include emergency procedures.

The Contractor shall provide and maintain a complete list of the names of persons, and their duties, responsible for the operation of the machine, who have completed the appropriate training to an accepted standard.

13.1.12 Dismantling of Shield

On completion of the drive, the shield shall be able to be dismantled within the tunnel/shaft.

If the shield is required for another drive, the shield shall be cleaned, refurbished and tested before the further drive begins.

13.2 Slurry and Earth Pressure Balance (EPB) Machines

13.2.1 General

A slurry machine is a tunnel boring machine with a bulkhead located behind the face to form a pressure chamber. Slurry or other medium is introduced into the chamber under appropriate pressure to equalise ground pressure and to be mixed with material excavated by rotary cutter wheel. The resultant slurry is removed by pumping.

An earth pressure balance machine (EPBM) is a tunnel boring machine with a pressure bulkhead located behind the face to form a pressure chamber. The excavated material is retained in the

pressure chamber under pressure and is extracted by means of a screw mechanism in an operation integrated with excavation. Liquids and additives may be admitted to the chamber to mix with excavated material.

13.2.2 Machine Characteristics

The machine shall be fitted with a pressure bulkhead capable of withstanding the total pressure envisaged plus an adequate working and safety margin. Where machine size permits, this bulkhead shall include provision for a means of access to the pressure chamber.

The pressure control system shall maintain the required pressure on the face at all periods when the machine is advancing, and when standing. Control shall be such that the pressure can be adjusted to suit changing face conditions and maintain stability at all times.

Pressure sensors capable of working in air, liquid, spoil/liquid and spoil media shall be mounted on the pressure bulkhead or slurry pipework with pressure gauges in the control cabin reading the pressure in the chamber.

All tools on the cutter head including the copy and gauge cutters shall be of robust and durable construction in order to minimise the need for replacement during the drive. Excavation tools shall be replaceable from the chamber. A system to indicate wear of the tools shall be provided.

If the machine requires the application of low-pressure compressed air to gain access to the pressure chamber, air locks and bulkheads shall comply with the provisions of BS EN 12110.

Propulsion rams and shoes shall be designed to take account of the additional forces required to propel the shield forward with the face pressurised. The load from anyone rams or combination of rams shall be limited to avoid damage to the lining.

The tail skin shall be of a length to ensure that the tail seals are fully engaged on the last ring built after shoving, or on a pipejacking lead pipe.

Tail seals shall be designed to withstand the maximum pressure at the tunnel invert, plus additional operational pressures from propulsion and grouting, with an adequate safety margin. They shall prevent ingress of water, slurry, grout and other materials into the tunnel. Tail seals are to be; replaceable and accessible for maintenance during operations. The type of seal is to be fully compatible with the tunnel lining used.

An emergency tail seal shall be available in the event of a significant breach of the main seals.

13.2.3 Grouting

Slurry and EPB Machines shall be designed for and equipped with a supplemental ground stabilisation system. This system shall comprise regularly spaced grout ports built into the shield for grouting the ground ahead of the tunnel face. The location and number of ports shall be adequate for implementation of face stabilisation measures needed for access to the face in all ground conditions. All ports shall be readily accessible and fitted with valves.

13.2.4 Spoil Removal

The excavation and disposal arrangements shall be capable of dealing with the full range of materials expected. Generally the disposal system shall accommodate material produced by the cutting equipment. A trap may be provided for the retention of pieces of material which would otherwise cause damage to or stop up the disposal system.

Slurry machines shall be provided with means of accurately controlling and adjusting the density and viscosity of the medium supplied to the pressure chamber and introducing additives where required. Pipework, pumps and separation plant shall be designed to accommodate the

maximum rate of advance at which the machine will be progressed. The separation plant shall be such that an assessment of the nature and volume of excavated material can be made.

Earth pressure balance machines shall be provided with a screw conveyor of sufficient length that the face pressure can be dissipated along its length. Injection points shall be incorporated into the screw conveyor for the introduction of additives.

13.2.5 Instrumentation

The monitoring and control instrumentation shall be grouped in suitable panels allowing good visibility and communications within the working area.

Instruments and controls shall include, but not be limited to the following:

a) Face pressure gauges

b) Machine position, inclination and roll

c) Cutterhead rotation speed, direction, torque and thrust

d) Cutterhead door aperture status (where fitted)

e) Ram thrust pressures, stroke and speed singly and in combination

f) Slurry flows and pressure (slurry machines)

g) Screw rotation speeds and pressure drop (EPBMs)

h) Electrical power

i) Means of measuring and recording the volume of material excavated per ring of advance

j) TBM advance rates

k) Ram extension

l) If required by the Contract, provisions shall be made for data logging of all the above functions

m) Grout quantity

n) Volume of soil conditioning constituent materials including air, water, foaming agents and polymers.

13.3 Operation of Tunnelling Machines and Shields

13.3.1 General

The Contractor shall take full responsibility for the performance of the tunnelling machines and shields engaged on the Works. He shall employ personnel who are trained in, and have experience of, the type of machine or shield used.

The Contractor shall operate and maintain the shield to the satisfaction of the Engineer and in accordance with the manufacturer's recommended operating and maintenance instructions.

The Contractor shall plan his excavation processes, especially at the commencement and completion of drives, in such a way as to prevent ground movement which might adversely affect the permanent work and existing structures. The Contractor shall present a detailed method statement to the Engineer for his agreement. This statement shall include but not be limited to:

a) The proposed method of transportation and erection of tunnelling machines or shields

b) The proposed method of commencing the tunnel drives until all the ancillary equipment is installed, including

c) Any ground treatment or dewatering required; temporary thrust arrangements shall be detailed

d) The method of determining ground conditions ahead of the face and the assessment of the risk of altered ground conditions

e) The proposed method for controlling volume loss from tunnelling

f) The proposed method for reconciling the volume of material excavated with the volumetric rate of advance of the tunnel

g) The proposed method of junctioning including dismantling the machines or shields

h) The method of ensuring that any voids created during the excavation process are adequately grouted as soon as practicable after excavation.

Before tunnelling commences, the Contractor shall ensure that all machine systems are operational including all temporary and permanent ground support systems.

Before the shield is dispatched to the tunnelling site, it shall be completely assembled with all necessary equipment installed so that it is in working order for inspection and checking by the Engineer. Sample tunnel lining segments shall be available to demonstrate the erection.

The Contractor shall supply all necessary information to the Engineer to enable him to observe the commissioning inspection of the shield at the manufacturer's factory, to ensure that the design and manufacture is in accordance with the specification.

The Contractor shall store on site replacement parts and maintenance materials which shall include (where relevant) but not limited to:

a) One complete set of discs, picks and cutters

b) Special hydraulic rams, hydraulic hoses and components

c) Spoils removal system rollers, bearings and bolts

The shield operators and the Contractor's chief mechanic/s shall be trained by the shield manufacturer prior to the start-up of the shield. A technical representative from the shield manufacturer knowledgeable in the assembly, operation, maintenance and repair of the shield shall be incorporated with the Contractor's staff at the construction site for the whole duration of the tunnelling works.

During each shift the Contractor shall survey the position of the shield and verify the guidance system readout is correct.

13.3.2 Excavation

Machines and shields shall be moved forward and excavation made for one unit of the tunnel excavation and lining at a time and only after completion of the previously erected support. The method used shall ensure correct alignment at all times without imposing excessive loads on the tunnel supports, lining or on the surrounding ground. Careful control of the working face shall be maintained to prevent overbreak and loss of ground.

Where linings are constructed behind a shield without a tail skin, excavation shall not commence until a complete ring of lining is available at the erector. Ring erection shall commence immediately after advancement of the shield is complete.

When tunnelling under or near existing structures or utility infrastructure, a specific method statement shall be submitted to the Engineer for agreement.

13.4 Monitoring of Works

13.4.1 General

The Contractor shall be required to monitor closely the progress of the tunnelling/ jacking and drilling operation. Daily manual logs or site records of thrusting pressures, torque, lubricant injection rate and the line and level measurements shall be properly maintained in addition to any computerised data logging and shall be available to the Engineer at all times. Such records shall be duly signed by the Contractor. If the Contractor fails to maintain and produce such details before the Engineer on site, the Engineer may order suitable steps including suspension of the work without prejudice to any other rights of the Engineer. The Contractor shall be solely responsible for such actions ordered by the Engineer.

The Contractor shall appoint within his site team an experienced Monitoring Engineer who shall lead the Contractor's monitoring team and issue instructions to the operator as necessary.

The Contractor's Site Manager shall attend monitoring review meetings if requested by the Engineer.

The accuracy and precision of the measurement required will depend on the purpose of the monitoring and shall be as agreed upon considering methodology.

Assessments shall be carried out to establish the zone of influence due to tunnelling works and to determine the likely damage that will occur to existing above-ground and subsurface infrastructure.

The outcome of the assessments shall determine the type and amount of monitoring that will be required.

13.4.2 Ground Movement Monitoring

13.4.2.1 General

Prior to the Works commencing, a photographic survey shall be carried out of all existing 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 existing structures, or their representative, prior to the start of construction. Existing pipelines, tunnels and services shall also be regarded as structures.

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.

The Contractor shall monitor the effects of excavation and tunnelling works 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.

The Contractor shall provide all monitoring equipment and instruments 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.

Monitoring shall be referenced to stable reference 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 regular intervals during the duration of the Works.

The Contractor shall observe, record and analyse the readings to establish trends in movement and reconcile movements measured with those predicted.

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.

Monitoring of settlement, scheduled defects and defects arising during the course of the works shall continue at agreed intervals throughout the Defects Notification Period.

13.4.2.2 Monitoring Methodology

Settlement monitoring reference arrays comprising 9 reference points, centred on, and perpendicular to the tunnel line are to be placed at 100m centres. Monitoring is to be undertaken to ensure the stability of readings prior to and after tunnelling has been completed, and at intervals to identify any trends in readings that demonstrate that ground movements are in accordance with predictions and control of the stability of works.

Monitoring shall be in the form of precise levelling unless otherwise instructed by the Engineer. Monitoring points shall be established at least 40m in advance of the face and measurements undertaken to establish base readings. When the face has passed the array readings shall be undertaken on a daily basis for 7 days. Thereafter readings shall continue on a weekly basis for 4 weeks or until ground movements have ceased or as directed by the Engineer.

Settlement monitoring reference points shall comprise 50mm long masonry nails in road pavements, or 10mm diameter 50mm long stainless steel round head bolts with stainless steel washers in steel tamp in anchors with lead sleeves in structures. Settlement monitoring reference points in verges and other non-paved areas shall comprise 1.5m long 20mm diameter deformed steel bar driven into the ground. If these systems are not acceptable to the owners of the structure, other systems are to be proposed by the Contractor for acceptance by the Engineer.

The zone of influence of the tunnel shall be as determined by an established empirical prediction method using the worst credible values for face loss predicted for the proposed method of working. The minimum value of face loss to be used in determining this zone of influence is 2.0%. The Contractor shall carry out settlement assessment and appropriate monitoring of any structures that he identifies to be at risk from settlement. The extent of monitoring coverage may need to be increased if uncontrolled groundwater ingress occurs.

13.4.3 Monitoring of Tunnel Excavation

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.

Where shields and machines are employed the Contractor shall monitor per unit advance, the altitude of the shield or machine. Information to be recorded includes rate of advance, line, level, square, plumb, roll. Where applicable, face pressure, slurry density, slurry viscosity, slurry level, slurry flow, cutter speed, rotation direction, torque screw conveyor speed, air pressure, and to the degree of accuracy applicable, volume of material excavated.

Where grouting is carried out, the type, volume and pressure of grout shall be recorded.

All information recorded by the Contractor shall be provided to the Engineer on a daily basis unless another interval has been agreed.

Where the Contractor considers that any corrective action he may take will exceed the tolerances in the Contract, he shall so inform the Engineer and obtain his agreement.

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.

All significant groundwater ingress shall be recorded and monitored.

All atmospheric testing shall be recorded and monitoring for all gases carried out in accordance with BS 6164.

The Contractor shall keep copies of all recent face records at the workface for the information of supervisory personnel.

13.4.4 Contingency Measures and Emergency Procedures

The Contractor shall determine contingency measures to deal with potential hazards that may affect the Works. The Contractor shall submit for acceptance 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.

Hazards to be addressed include:

a) Changing ground conditions

b) Excessive movement of the linings

c) Excessive ground movement

d) Excessive settlement of the existing structures

e) Unplanned stoppages

f) Mechanical excavation plant failure

g) Insufficient labour resources

h) Failure of services to underground works (air, light, power, etc.)

i) Incidents within underground works

j) Delay in supply of sprayed concrete (SCL)

k) Delay in supply of segments (TBM).

In underground construction works, changes tend to be progressive with evidence of structure or ground behaviour 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.

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.

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.

14 MICROTUNNELLING/PIPE JACKING WORKS

Deleted

15 SEGMENTAL LINING WORKS

15.1 General

Precast concrete segments for linings shall be supplied by the Contractor from an agreed manufacturer, or manufactured in a purpose-built factory, for erection in the Works in accordance with the Employer's Requirements.

Segments of the lining shall be designed to withstand handling, storing and erection stresses as well as permanent loads. The Contractor shall provide to the Engineer copies of calculations and drawings to demonstrate adequacy of the designs.

Lining segments may be cast in existing moulds and be a manufacturer's standard design or be a particular design to suit the requirements of the project and tunnelling plant.

Concrete shall be in accordance with the Employer's Requirements and have a minimum strength class of M50 (characteristic cube compressive strength of 50 MPa).

Segments shall be reinforced with steel. Steel reinforcement shall either be in the form of bars with cages formed by welding or tying in accordance with Section 15.2.15, or alternatively the Contractor is permitted to reinforce the segments with steel fibres in accordance with Section 15.2.14.

All segmental lining pieces shall be coated internally using Polymer urea coat of Fosrac, Myk or equivalent conforming to relevant ASTM/BIS standards and must meet the specifications as per Attachment-III. Application methodology shall be as approved by Engineer at no extra cost to MCGM. Contractor shall consider the pricing of this coating under "Pricing Schedule A1.3-Tunnels item reference 3.5".

Concrete segments shall have a minimum thickness of 200mm and their design shall comply with IS 456 and IS 3370.

15.2 Manufacture of Segments

Manufacturing facilities for segmental lining systems will be required to show:

a) A certified Quality Assurance and control programme to BS EN ISO 9001 agreed with the Engineer.

b) Compliance with the Employer's Requirements regarding materials, mixing and placing, curing and storing of concrete constituents, concrete segments and fixings.

The manufacturer's premises and methods shall be open to inspection by the Engineer for the purpose of checking the quality of manufacture. The Contractor shall ensure that all necessary assistance is provided to the Engineer on each visit.

Prior to segment production the Contractor shall provide a Method Statement of the proposed method of manufacture, curing handling, storing and delivery of the precast segments containing:

a) The location of manufacture, testing and storage of the units.

b) A programme of trial mixes, design and manufacture of moulds and casting of prototype units.

c) General arrangements of the production lines and typical mould details.

d) Types, sources and quality of cement, aggregate, water and reinforcement.

e) Types and sources of admixtures proposed.

f) The proposed methods of compaction, curing and protecting the units during storage.

g) The proposed quality assurance arrangements.

h) The proposed method of handling the units, transport arrangements and logistics.

No work shall start until this method statement is accepted by the Engineer.

15.2.1 Moulds

Moulds shall be robustly constructed, tightly jointed and properly maintained such that the dimensions of the segments are always within the specified tolerances.

Where new moulds are being manufactured, the fabrication drawings shall be submitted to the Engineer for agreement.

Details of the moulds to be used for casting concrete segments shall be supplied to the Engineer for his agreement before prototype segments are cast. Trial segments may be made for the Engineer's inspection. Samples shall be marked indelibly and set aside for reference purposes.

Worn moulds shall be replaced before they reach the stage where out of tolerance segments are produced.

15.2.2 Tolerances for the Manufacturing of Bolted Segments

15.2.2.1 Segments

Dimensions of individual precast concrete special segments shall be within the following tolerances:

(a) circumferential length	±1mm
(b) thickness	+3mm, -1.5mm
(c) width	±1mm
(d) square	diagonal dimension ± 1 mm from theoretical dimension
(e) bolt holes: size	+1mm, -0.2mm
(f) bolt holes and dowel position	1mm
(g) sealing gasket groove: dept	+0.5mm, -0.0mm
(h) sealing gasket groove: width	±0.5mm
(i). sealing gasket groove: position	±1.5 mm from specified position
(j) longitudinal joints in a plane generally along the axis of the tunnel (longitudinal)	0.3 mm from theoretical plane with rate of deviation not exceeding 0.6 mm/m
in a radial plane	0.1 mm from theoretical plane with rate of deviation not exceeding 0.6 mm/m
(k) circumferential faces	0.5 mm from theoretical plane with rate of deviation not exceeding 1 mm/m
(l) smoothness of other faces back face front face	 smooth float ±1.5 mm formed face ±1 mm
(m) mismatch of sealing groove at corners	<0.5 mm

15.2.2.2 Rings

At least two test rings shall be erected on a flat and level base, in a form and sequence representative of the construction arrangement to be agreed with the Engineer. All designed longitudinal packings are to be removed from both rings. The following dimensions shall be checked:

(a) internal diameter (adjusted for packer removal where necessary)	±0.2% ID or 6mm maximum
(b) lip between adjacent segments on internal diameter	<3 mm
(c) gap between longitudinal segment joints (packings removed and bolts tightened)	1mm feeler gauge not passing

15.2.3 Tolerances for the Manufacture of Expanded Segments

15.2.3.1 Segments

Dimensions of individual precast concrete segments shall be within the following tolerances:

(a) circumferential length	±1.0mm
(b) segment thickness (on backs)	±1.5mm
(c) width	±1.5mm
(d) regularity of surfaces:	
straight edge applied in any position parallel to axis of ring on extrados, intrados and cross-joint faces, and normal to axis on longitudinal joint and cross-joint	
joints:	0.25 mm feeler gauge not passing
extrados; intrados:	1.25 mm feeler gauge not passing

15.2.3.2 Rings

At least two test rings shall be erected on a flat and level base, in a form and sequence representative of the construction arrangement to be agreed with the Engineer. All designed longitudinal packings are to be removed from both rings. The following dimensions shall be checked:

(a) internal diameter with key in its design location	0.2% ID or 6mm maximum
(b) lip between adjacent segments on internal diameter	1.5 mm
(c) gap between longitudinal segment joints	0.5 mm feeler gauge not passing

15.2.4 Marking of Segments

As a minimum all segments except solid key shall have marked with indented upper case lettering the following information on the inner face:

a) Internal diameter of lining

b) Type of segment referenced to the detailed drawings

c) A unique mould identification any special information to indicate the position or orientation of the segment in the ring

d) The weight of segment in kilograms

e) Date of casting.

15.2.5 Joint Packing

Where shown on the drawings a minimum 2 mm thick strip of stress distribution packing is to be incorporated in each longitudinal joint covering at least 80% of the joint surface area.

15.2.6 Gasket Grooves

Where shown on the drawings, gasket grooves shall be provided around all joint faces of each segment and key in accordance with the dimensions recommended by the gasket manufacturer.

15.2.7 Concrete Cover

Concrete cover shall be as stated in the Employer's Requirements.

Precast segmental lining systems shall be designed in accordance with IS456 for cover and concrete mix requirements.

15.2.8 Grout holes

Where specified, grout holes shall be provided in every segment excluding the key, and shall be a nominal 50 mm diameter or greater. They shall be either plain or threaded, and provided with a non-return valve.

15.2.9 Curing

Segments shall be cured in accordance with the provisions of ENV 13670-1.

All precast concrete segments shall be cured using moist curing, curing compounds or steam curing, or a combination of these systems to the acceptance of the Engineer.

Immediately after compaction and thereafter for the curing time, concrete shall be protected against harmful effects of weather, including rain, rapid temperature changes, frost, and from drying out. The method of curing shall prevent loss of moisture from the concrete.

The method of curing used shall minimise temperature gradients and differences within the concrete. The Contractor shall demonstrate to the Engineer that the temperature differential across the segment shall not exceed 15°C (at any time).

15.2.9.1 Moist Curing

The segments shall be water cured by ponding or continuous agricultural type spraying for a minimum of 7 days. The water used for curing shall be sufficiently warm to prevent thermal shock to the concrete. The segments may then be stored in a stockpile prior to delivery to Site. The segments in the stockpile shall be kept wet by spraying with curing water. Curing methods (d) and (e) from Clause 6.6.3 of BS 8110: Part 1 (IS: 456 Section 2 Clause 13.5) will be acceptable.

The requirements for curing water shall be the same as those specified for water for production of concrete as specified in BS EN 1008.

Where moist curing is used all exposed concrete surfaces shall be covered with Hessian or similar fabric kept thoroughly wet throughout the process. Alternatively a fog spray may be used or polythene sheet laid in contact with the wet concrete. Other proposals may be made by the

Contractor for the acceptance of the Engineer but the adopted method shall keep the surface of the concrete continuously moist until demoulding.

Moist curing shall be accomplished in such a way that excess water shall be available to the concrete throughout the curing process. It shall be carried out in an enclosed environment that protects the segments from the drying effect of wind and sun and shall continue for a minimum period as required.

15.2.9.2 Steam Curing

Steam curing may be used to accelerate the initial strength gain of the concrete with the agreement of the Engineer. The maximum temperature of the concrete during the curing cycle shall not exceed 75ºC.

The method of curing used shall minimise temperature gradients and differences within the concrete. The Contractor shall demonstrate to the Engineer that no temperature gradient within the segment shall be allowed to exceed 15ºC.

For low pressure steam curing sufficient steam jets or steam-entry points shall be provided to ensure that a substantially uniform temperature is maintained under the steam covers (such that the difference in temperature between any two points adjacent to the concrete mass is not more than 10 ºC).

Under no circumstances during steam curing shall steam jets be allowed to impinge upon any part of the concrete mass or of a test specimen or of their formwork or moulds nor shall any steam delivery pipe be attached directly to any formwork or moulds in such a manner as may cause localised overheating of the concrete.

Where steam curing is to be used the steam covers shall be placed over the concrete mass immediately following the concrete finishing operations to prevent drying out. The concrete shall remain undisturbed and shall not be exposed to steam until it has reached a minimum initial stiffness of 0.5 N/mm^2 penetration. During this period the temperature at the surface of the concrete mass shall not exceed 35 °C. All concrete shall have an initial maturity of 1 hour before steam may be admitted to the steam covers except that, where necessary, a small amount of steam may be used to maintain the concrete at the temperature at which it was placed.

The maximum rate of temperature rise under the steam covers shall be such that the temperature at any time does not exceed the temperature which would be predicted at that time for a uniform increase in temperature at the rate of 24°C/h. In addition, the temperature rise in any one 15-minute period shall not exceed 6°C.

15.2.10 Treatment of Formed and Unformed Surfaces

The maximum local irregularity acceptable shall be rounded protrusions of 0.5 mm height above the general concrete surface. Larger irregularities may be accepted if they are abraded back giving no clear transition to the surrounding surface.

The general surface irregularity acceptable is 1.0 mm from maximum height protrusions to maximum depth indentations.

If the extrados of the segments is not formed with a shutter it shall comply with the following:

a) The maximum local irregularity shall be rounded protrusions of 3 mm height above the general concrete surface.

b) The maximum surface irregularity over an area of 500 mm by 500 mm shall be 5 mm from maximum height to maximum depth.

15.2.11 Stripping Moulds and Lifting Segments

Formwork shall be removed in a manner not to damage the concrete, and at times to suit the requirements for its curing.

The segments shall be left in the moulds until they have attained sufficient strength that the mould stripping will not damage the surface of the concrete.

The Contractor shall show, to the satisfaction of the Engineer, that the strength of the concrete is sufficient that the proposed method of lifting will not induce deleterious effects upon the concrete.

15.2.12 Handling, Stacking and Transport

The method of lifting and handling, the type of equipment and method of transport shall not damage the segments. Segments are to be stacked in a manner agreed with the Engineer.

Segments shall not be transported to site or incorporated into the works until they have achieved the 28-day compressive characteristic strength, and in the case of fibre-reinforced segments their flexural or tensile strengths.

If the grout hole is to be used for segment handling, the Contractor shall ensure that this has been catered for in the design.

15.2.13 Repairs

Cosmetic repairs to imperfections in the finish of a segment or of minor damage may be accepted provided that the repair procedure gives strength and durability characteristics equivalent to the sound concrete, using a method agreed by the Engineer.

Where the Engineer considers defects or damage to be extensive, structural repairs shall not be carried out. Segments not accepted shall be clearly marked as such and removed from the general stockpile and destroyed.

Agreed procedures for repairing damage to segments shall take into account the nature and location of the damage, the time at which it occurs after casting and the location of the segment when damaged.

15.2.14 Segments Reinforced with Steel Fibres

Fibres shall have an aspect ratio in the range of 30-150 for lengths of 12.7-63.5 mm.

Steel-fibre-reinforced concrete shall generally be designed to "Technical Report No. 63, Guidance for the Design of Steel Fibre Reinforced Concrete (The Concrete Society)".

Fibre type and dosage shall be selected such that the performance requirements specified in the Employer's Requirements are achieved. This shall be demonstrated by laboratory trials undertaken and agreed with the Engineer prior to commencement of segment casting.

Fibre type and dosage shall be selected for ease of use in the batching, mixing and concrete placement processes proposed as demonstrated by site trials.

Fibres may be collated with a fast-acting water-soluble glue, or may be uncollated individual fibres.

Fibres which tend to form fibre balls during batching shall not be used.

Steel fibres shall be added during the production process in a manner which does not interrupt or disrupt the normal mixing cycle.

Automatic fibre dosing equipment shall be capable of monitoring and recording steel fibre usage during the production process.

Production testing shall continue throughout segment casting to demonstrate that the specified performance is being achieved.

Steel-fibre-reinforced concrete flexural performance shall be determined and monitored in accordance with ASTM C 1609/ C 1609M or JSCE-SF4 as agreed with the Engineer.

Steel-fibre-reinforced concrete tensile performance shall be determined and monitored in accordance with ASTM C496 or BS EN 12350 as agreed with the Engineer.

Fibres shall be added and mixed in a manner to produce a homogeneous distribution within the concrete matrix, and com-pacted and finished to ensure that fibres do not protrude from non-formed surfaces. Testing of concrete shall demonstrate that the fibres are being uniformly distributed throughout the concrete mix.

15.2.15 Segments Reinforced with Steel Bars (Reinforcement Cages)

Reinforcement shall be cut and bent according IS 456, to the tolerances given in the Employer's Requirements. Rebending of incorrectly bent bars shall not be permitted.

Prior to cutting, bending or fixing any reinforcement the Contractor shall obtain the acceptance of the Engineer for his proposals for fabrication of reinforcement cages. The proposals shall include the use and assembly of jigs and prefabrication of sections as necessary to ensure rapid accurate assembly with a positive means of achieving dimensional stability. All reinforcement shall include a Fusion Bonded Epoxy coating conforming to IS 13620:1993.

The number, size, form, cover and position of all reinforcement shall be in exact accordance with the Employer's Requirements.

Prefabricated sections shall be kept clean and dry and shall be stored such that no deformation takes place.

Bars may be welded by an agreed electrical process which maintains the compliance of the bar with the tensile test criteria specified in the appropriate British or Indian Standard. Before any such welding is carried out the Contractor shall submit test results for the acceptance of the Engineer.

There shall be sufficient welds in the cage for any segment to ensure that every bar is electrically connected to every other bar in the cage.

The Contractor shall only use qualified welders; copies of welders certificates shall be given to the Engineer.

The Contractor shall bear the costs of all testing.

Concrete spacers shall be fixed so that the reinforcement is held firmly in the correct position within the formwork with all the cover as specified. The spacers shall be rigidly fixed to the reinforcement to prevent displacement. If the spacers are wired on, the ends of the wires shall be turned into the unit.

The Contractor shall demonstrate to the satisfaction of the Engineer that the reinforcement cage can be lifted without damage or distortion.

The spacers shall be used as little as possible with bonding bars used as much as possible to this end. Spacer blocks may only be used with the agreement of the Engineer. Plastic spacers will not be permitted if heated concrete or steam curing is used.

Before any welded joints are made for the Works, The Contractor shall arrange a trial of his proposed procedure for the Engineer to satisfy himself of the suitability of the equipment and

method proposed. The trial will also establish the cleanliness of the bars to be joined. The Contractor shall obtain the acceptance of the Engineer for any cleaning method proposed for the steel.

Six welded joints shall be tested for strength as specified above. If one joint fails by less than ten percent of the specified strength then two further tests shall be made. If one weld fails by more than ten percent of the specified strength or more than one joint fails then the selected welding method will not receive acceptance.

15.2.16 Gaskets

15.2.16.1 Compression Gaskets – General

Gaskets for precast concrete segmental lining shall be supplied by a specialist supplier certified to ISO 9001 or equivalent quality standard.

The gasket cross-section shall be dimensioned as detailed for the mating surfaces of the segmental tunnel linings. Gasket manufacturing tolerance shall be ±0.5mm width and +0.5/-0.0mm for thickness. Prototype gaskets shall be fit-tested to assess stretch characteristics.

The material from which gaskets are to be manufactured shall withstand any aggressive response from the ground of groundwater and, where the tunnel is to carry effluents of liquids, the medium contained in the tunnel. In particular the gasket material shall withstand chemical attach and biological degradation such that the gasket functions properly for the design life of the facility.

15.2.16.2 Compression Gaskets – Testing

Gaskets shall be tested in accordance with the agreed quality procedure.

The test rig for assessing water tightness shall simulate a range of conditions of displacement and joint gap, including the worst combination to be encountered in the completed structure, and the type of joints to be constructed in the tunnel. In each test the water pressure shall be increased in increments of 0.5 bar and held at each value for 5 minutes. The final test pressure shall be agreed with the Engineer or shall be the maximum of:

1. At least 1 bar in excess of the maximum hydrostatic pressure to which the structure may be subjected.
2. Two times the maximum hydrostatic pressure to which the structure may be subjected.

This pressure shall be maintained for 72 hours during which no leaking shall occur at the gasketed faces. Tests shall be carried out at normal ambient temperature.

The gasket shall function under all combinations of packing and displacement encountered in the completed structure including permissible tolerances.

Based on accelerated aging tests, the projected residual compressive stress in the gasket material at the end of the design life shall not be less than 65% of the short-term compressive force for the fresh material. Where the residual compressive stress is less than this value, the test pressures in the watertightness test shall be reassessed.

The manufacturer shall provide details of the maximum load to fully compress the gasket in the groove.

15.2.16.3 Hydrophilic Gaskets

Hydrophilic gaskets shall not be used.

15.2.16.4 Elastomeric Gaskets

Elastomeric gaskets shall comply with the requirements of BS EN 681-2 and have an IRHD (international rubber hardness degrees) between 60 and 75. The material shall consist of a compound able to withstand the long term stresses and strains, groundwater and internal chemical conditions without detriment to the specified performance.

The gasket cross-section shall be dimensioned to suit the groove as detailed for the mating faces of the segmental tunnel linings. Manufacturing tolerances shall be ±0.5 mm width and +0.5/-0.0 mm for thickness.

The extruded section shall be joined to form a rectangular gasket that is a stretch fit into the grooves of the concrete segments. The corner joint shall be shot moulded and the corner pieces shall be of a different section from the extruded lengths in order that the watertightness characteristics described in the Employer's Requirements may be achieved and to avoid excessive load on the corners of the concrete segments.

Gaskets shall be fixed into the groove cast in the segmental tunnel linings prior to erection. The adhesive shall be as recommended by the manufacturer of the gasket.

Gasket faces shall be lubricated prior to erection with a product recommended by the gasket manufacturer and agreed with the Engineer.

15.2.16.5 Composite Gaskets

Composite elastomeric and hydrophilic gaskets shall be tested to the same requirements as elastomeric gaskets. A time allowance for the expansion of the hydrophilic portion of the gasket shall be allowed for in the test where appropriate.

The gasket cross-section shall be dimensioned to suit the groove as detailed for the mating surfaces of the segmental tunnel linings. Manufacturing tolerances shall be ±0.5 mm width and +0.5/-0.0 mm for thickness.

Gaskets shall be manufactured from extruded solid sections with appropriate spaces within the section to enable the gasket to be fully compressible within the groove formed in the concrete segments. The gasket shall still be capable of further compression when its top surface is level with the top of the groove.

The extruded section shall be joined to form a rectangular gasket that is a stretch fit into the grooves of the concrete segments. The corner joint shall be shot moulded and the corner pieces shall be of a different section from the extruded lengths in order that the watertightness characteristics described in the Employer's Requirements may be achieved and to avoid excessive load on the corners of the concrete segments.

Gaskets shall be fixed into the groove cast in the segmental tunnel linings prior to erection. The adhesive shall be as recommended by the manufacturer of the gasket.

Gasket faces shall be lubricated prior to erection with a product recommended by the gasket manufacturer and agreed with the Engineer.

15.2.16.6 Gaskets - General

Gaskets shall be fitted into the grooves provided in the edges of the segment to be sealed in the manner recommended by the gasket manufacturer. The gasket dimensions shall be compatible with the groove profile, subject to the specified tolerances.

Gaskets shall be fitted to segments before being taken into the tunnel and shall be protected from damage during transport.

Care shall be taken to avoid displacing the gaskets during segment handling. No deleterious material shall be permitted in the groove or on the gasket.

Compression and hydrophilic rubber gaskets shall be bonded in position in the groove provided in the edges of the segment in accordance with the manufacturer's instructions.

Hydrophilic and composite (compression/hydrophilic) gaskets shall be protected from the effects of rain or accidental wetting. Segments with hydrophilic or composite gaskets shall not be erected in standing water.

Gaskets to be cast into the concrete segment shall be securely held in place in the mould during casting, and shall not be damaged during the demoulding process or cause damage to the segment.

15.2.17 Segment Bolts in Tunnel Linings

15.2.17.1 General

Segment bolts in the bored tunnel linings may be removed at any time after completion of annular grouting following liner installation, or they may be left in place provided the bolts and all associated fittings have a high level of corrosion resistance in accordance with the requirements set out below.

Details of the proposed bolts dismantling method if any, shall be issued to the Engineer prior to the commencement of work.

15.2.17.2 Manufacturing

All segment bolts and cast-in sockets shall be purchased as an assembly and shall be of proprietary design. Details of the manufacturer of the segment bolt system shall be submitted to the Engineer for approval.

15.2.17.3 Dimensions

Dimensions of steel bolts and nuts shall comply with the requirements of:

BS 3692:2001 - ISO metric precision hexagon bolts, screws and nuts — Specification

or

BS 4190:2001 ISO metric black hexagon bolts, screws and nuts — Specification

Nuts shall be normal nuts not thin nuts.

The length of each bolt shall allow for steel washer, sealing washer or grummet and for all adjustments required in the alignment of tunnels. All bolts for the precast concrete segments shall be fitted with sealing washers under the nut or bolt head.

15.2.17.4 Bolts and fittings to be left in place

Bolts

Bolts left in place shall be made of Grade A4-80 stainless steel to BS EN ISO 3506-1 or an equivalent to be approved by the Engineer. Required mechanical properties from the standard are:

Steel Group	Steel Grade	Property Class	Tensile Strength *R*m a min MPa	Stress at 0.2% permanent strain *R*p0, 2[a] Min MPa	Elongation after fracture A[b] min mm
Austenitic	A1, A2	50	500	210	0.6*d*
	A3, A4	70	700	450	0.4*d*
	A5	80	800	600	0.3*d*

a The tensile stress is calculated on the stress area

b This is determined on the actual screw length and not on a prepared test piece

Minimum tensile strength for bolts is 800 N/mm^2.

Design of bolts

To avoid problems with a loss of material strength of Grade A4-80 steel due to the manufacturing process, spear bolts shall be manufactured as a threaded stud with a nyloc nut or similar fitted at one end, and to be approved by the Engineer. The same shall apply to curved bolts.

Nuts

Nuts to be of Grade A4-80 stainless steel to BS EN ISO 3506-2 or an equivalent to be approved by the Engineer. Required mechanical properties from the standard are:

Steel group	Steel grade	Property Class		Stress under proof load S_p Min MPA	
		Nuts with m ≥ 0.8D	Nuts with 0.5D ≤ m < 0.8D	Nuts with m ≥ 0.8D	Nuts with 0.5D ≤ m < 0.8D
Austenitic	A1, A2,	50	025	500	250
	A3, A4	70	035	700	350
	A5	80	040	800	400

Minimum tensile strength for nuts is 800 N/mm^2.

Steel Washers

The steel washer under the head of the bolt shall be Grade A4-80 stainless steel to BS EN ISO 3506-2 or an equivalent to be approved by the Engineer.

Plastic washers

Plastic washers shall be of the dimensions shown on the drawings and shall be made of Low Density polyethylene.

15.2.17.5 Bolts and fittings to be removed

Bolts

Bolts to be removed shall be Grade 8.8 steel bolts to BS 4190:2001 Table 7 and be either hot dip galvanised in accordance with BS 7371-6, or sherardised to BS 7371-8 Class S1. Strength grade designations for steel bolts and screws are:

Strength grade designation	4.6	4.8	6.8	8.8	10.9
Tensile strength R_m min, N/mm²	400	400	600	800	1000
Yield stress R_e min. N/mm²	240	320	480	640	900

Nuts

Nuts shall be Grade 8 steel bolts to BS 4190:2001 Table 8 and be either hot dip galvanised in accordance with BS 7371-6, or sherardised to BS 7371-8 Class S1, the same as for the bolts. Strength grade designations for steel nuts are:

Strength grade designation	4	6	8	10	12
Proof load stress N/mm²	400	600	800	1000	1200

Washers

Washers shall be to BS4320.

15.2.18 Packings

All forms of packing shall be of a shape commensurate with the lining, provided with bolt holes where required and of a width which does not prevent the proper operation of any gasket or seal included in the joint.

Timber packings shall be knot-free softwood, or plywood, sawn to shape with bolt holes where applicable. They shall be treated to retard rot and fire, and shall be available in all necessary thicknesses.

Stress distribution packing for longitudinal joints in concrete rings shall be cut from an accepted bituminous felt fibre based sheet to the shape required with bolt holes where applicable. Alternative materials to bituminous felt shall be agreed with the Engineer.

Steel packings shall be machined and provided in thicknesses of not less than 2 mm. They shall be protected from corrosion in the manner specified for mild steel segments.

Packings shall only be used where agreed with the Engineer.

15.3 Concrete for Segments Production

15.3.1 General

Concrete shall be grade C40/50 in accordance with BS 8500 or grade M50 in accordance with IS 456 and the Portland Slag Cement shall have a GGBS content of between a minimum of 66% and a maximum of 80% as per IS455 and BS 6699.

The minimum cementitious content shall be 400kg/m_3 and the maximum cementitious content shall be 500kg/m_3.

The maximum free water/cementitious material (w/c) ratio shall be 0.40.

The maximum shrinkage rate shall be 0.04%.

The penetration limit shall be 8 mm as measured in accordance with BS EN 12390 Part 8, and the water absorption limit shall be 1.6% to BS 1881 Part 122.

The total water soluble chloride content of the concrete arising from all the mix constituents shall not exceed 0.4% expressed as a percentage of ion by weight of cementitious content.

The total acid soluble sulphate content of the concrete arising from all the mix constituents expressed as SO_3 shall not exceed 4.0% SO_3 by weight of cementitious content.

The alkali content of the concrete expressed as sodium oxide (Na_2O) equivalent shall not exceed 3.5kg/m^3, when calculated in accordance with BS 8500.

The requirements for the production of precast concrete tunnel segments, whether manufactured in a plant or in temporary field plant production, shall be in accordance with the requirements of BS 8500 and EN 206 (IS 456) unless otherwise required by the Employer's Requirements.

Any changes in the source of material, in mix proportions (except changes in cement content of not more than 10kg/m^3) or in production methods shall be subject to the prior agreement of the Engineer.

15.3.2 Concrete Constituent Material

The Contractor shall obtain certificates of compliance with the relevant current Indian and British standards and all other requirements of the Employer's Requirements from the producers of the constituents of the concrete for the acceptance of the Engineer prior to use. Any change in materials or materials supplier shall require new certificates of compliance, which shall also be submitted to the Engineer for acceptance.

15.3.3 Cement

The cement shall be Strength Class 52.5 Portland Cement CEM 1 conforming to BS EN 197 Part 1 (IS12269) or Portland blast furnace slag Cement CEM 111 conforming to BS EN 197 Part 1 (IS 455).

The quality of the cement is to be determined on the basis of its conformity to the performance characteristics given in the respective Indian Standard Specification for that cement. All cement shall be tested in accordance with BS EN 196 and shall be certified by the manufacturer as being in accordance with the appropriate standard specification. All cement Suppliers shall hold valid ISO 14001 and ISO 9002 certification.

The Engineer may order additional tests on cement and the Contractor shall draw the necessary samples from the stocks at the precast plan and have them tested at a laboratory accepted by the Engineer.

Supplementary Cementing Materials shall conform to IS 456: 2000.

All cement shall be tested in accordance with BS EN 196 and shall be certified by the manufacturer as being in accordance with the standard.

The specific surface, when tested in accordance with EN 196, shall be not less than 275 m^2/kg. The results of all testing shall be submitted to the Engineer for acceptance.

Cement shall be stored in bags in dry weatherproof sheds with raised floors.

Each consignment of bagged cement shall be stored separately and labelled so as to be identifiable and shall be used in order of delivery. Different brands or types of cement shall be

stored separately and shall not be mixed together for use in the works, excepting where specified. Portland cement and slag cement, which have been deleteriously affected by moisture shall not be used in the works and shall be immediately removed from the site. No hooks or other sharp implements shall be used to lift or move cement bags. Any bags that are punctured shall not be used in the works and shall be removed immediately from the site.

All cement shall be supplied from a single source. If the source of material changes it shall be fully tested and test certificates detailing compliance with the requirements of the Employer's Requirements shall be submitted to the Engineer.

Batches of cement shall be used in order of their delivery to the site.

15.3.3.1 Aggregate

All aggregates shall comply with the requirements of BS EN 12620 (IS383), unless otherwise required by the Employer's Requirements.

Only accepted aggregates whose source contains a sufficient quantity of aggregate to complete the job shall be used in the works. The following information shall be submitted to the Engineer for acceptance prior to the commencement of the works:

a) The name and location of the pit or quarry.

b) Groups classification in accordance with BS EN 932-3

Marine dredged aggregate shall not be used.

The 'ten percent' fines value for the coarse aggregate, determined in accordance with BS EN 933, shall be greater than 10kN.

The water soluble chloride levels of the aggregate, determined in accordance with BS EN 1744 shall not exceed the following values:

a) 0.06% by weight of fine aggregate.

b) 0.03% by weight of coarse aggregate.

The acid soluble sulphate content of the aggregate when determined in accordance with BS EN 1744 shall not exceed the following values:

a) 0.40% by weight of fine aggregate.

b) 0.40% by weight of coarse aggregate.

The drying shrinkage of the aggregate when determined in accordance with BS EN 1367 Part 4 shall be less than 0.075%

Any aggregate that is known to be alkali reactive shall not be used. Aggregates proposed for use shall be tested for potential reactivity by full petrographic examination, for soluble silica (in accordance with ASTM C289-81) and by the recommended procedure for the 'gel pat test' as described in the National Building Studies Research Paper No. 25: Part VI. If the testing shows the aggregate to be other than wholly non-reactive it shall not be used.

Aggregates that contain calcitic dolomitic limestone shall be tested for alkali-carbonate reactivity in accordance with ASTM C586-69. If the testing shows the aggregate to be other than wholly non-reactive it shall not be used.

The water absorption of the combined aggregate shall not exceed 3% when determined in accordance BS EN 1097 Part 3

All aggregates shall be kept free from contact with deleterious matter with adequate provision for drainage, and shall be stored and handled so as to avoid segregation and loss of fines prior to its incorporation into the concrete.

The overall grading of the aggregates shall be such as to produce concrete of the specified quality that will work readily into position without segregation.

The overall grading shall be controlled throughout the work so that it conforms closely to that assumed in the selection of the mix proportions. Each delivery shall be inspected and, if required by the Engineer, tested in accordance with BS EN 933-1.

The moisture content of the aggregate shall be consistent at the time of batching and shall be included in the quantity of water to be added to the concrete.

Copies of the results of routine control tests carried out by the aggregate producer shall be retained by the Engineer for inspection by the Purchaser on demand.

15.3.3.2 Admixtures

Admixtures may be used to improve the properties of the concrete, e.g. to reduce water demand by using super plasticisers, to enhance resistance to chloride ion penetration; and to reduce water permeability, subject to the agreement of the Engineer.

Admixtures used in the concrete shall comply with BS EN 934 (IS 9103) with the following requirements:

a) The quantity and method of adding admixtures shall be in accordance with the manufacturers' recommendations and in all cases shall be subject to the acceptance of the Engineer.

b) Any admixture which contains a chloride ion content in excess of 2% by weight of admixture or 0.03% by weight of the cementitious content shall not be used.

c) Calcium chloride in any form shall not be used.

d) Air entraining admixtures shall not be used.

e) Admixtures shall be stored and used in accordance with the manufacturers' recommendations. The shelf life of any admixture shall not be exceeded. Any admixture which has exceeded its shelf life shall be immediately removed from the precasting plant.

f) The Contractor shall demonstrate the action of any proposed admixture by means of trial mixes.

Where admixtures are used the Contractor shall provide the Engineer with the following information.

a) The typical dosage and details of the detrimental effects of under dosage and over dosage.

b) The chemical name(s) of the main active ingredient(s) in the admixture,

c) Tests shall be carried out on, or certificates shall be provided for each delivered batch of admixture in accordance with BS EN 934: Part 3 for at least:

   i. Dry material

   ii. Ash content

   iii. Relative density

   iv. Chloride ion content

d) Whether or not the admixture leads to the entrainment of air when used at the admixture manufacturer's recommended dosage.

Any change in materials source or variation in material properties will require new evidence of compliance, according to the provisions of the Employer's Requirements.

Admixtures shall be stored in accordance with the manufacturer's recommendations in containers which shall be clearly marked to show the contents.

15.3.3.3 Water

Water shall be potable and comply with the requirements of Appendix A of BS EN 1008.

Where water for use in the works is not available from a public utility it shall comply with the following requirements:

a) The initial setting times of cement, determined from a test block manufactured using the proposed water and a control test block manufactured using distilled water, tested in accordance with BS EN 196: Part 3 shall not differ by more than 30 minutes.

b) The average compressive strength of test cubes manufactured using the proposed water and control test cubes manufactured using distilled water tested in accordance with BS EN 196 Part 1 shall be at least 90% of the average compressive strength of the control cubes.

The water shall be clean and free from industrial wastes and other deleterious material. Water which is highly coloured or which has a pronounced odour or in which algae is growing shall not be used.

The pH value shall be numerically greater than 6.

15.3.4 Trials

The Contractor shall give sufficient notice to enable the Engineer to be present at the making of trial mixes and the preliminary testing of cubes. The Contractor shall prepare trial mixes, using samples of material typical of those he proposes to use in the works, for the concrete, to the satisfaction of the Engineer before the commencement of production.

Sampling and testing procedures shall comply with BS EN 12390 and IS 456: Section 2: Clause 15.

The concreting plant and means of transport employed to make trial mixes and to transport them representative distances shall be similar to the corresponding plant and transport to be used in the Works. A clean dry mixer shall be used and the first batch discarded. Test cubes shall be taken from trial mixes as follows. For each mix a set of six cubes shall be made from each of three consecutive batches. Three cubes from each set of six shall be tested for compressive strength at an age of 7 days and three at an age of 28 days. The tests shall be carried out at a laboratory approved by the Engineer.

The Contractor shall make a trial using the moulds proposed for use in segment production to establish the minimum stripping time, such that, removal of the mould will not damage the surface of the concrete.

Trials shall be undertaken to determine the optimum quantities of admixtures required to obtain the desired properties of the concrete.

15.3.5 Batching and Mixing

The quantities of cementitious material, fine aggregate and coarse aggregate shall be measured by weight.

Separate weighing machines shall be used for cementitious materials. Alternatively, cementitious materials may be measured by using a whole number of bags in each mix.

The quantity of water shall be adjusted to make allowance for the free moisture content of the aggregate. All dry admixtures shall be measured by weight. Liquid admixtures may be measured by volume.

The batch weight of aggregate shall be adjusted to allow for the free moisture content of the aggregate being used.

All measuring equipment shall be maintained in a clean and serviceable condition. The accuracy of measuring equipment shall be checked over the range to be used and maintained thereafter. Weekly checks on the accuracy of the weight batching equipment shall be made unless otherwise agreed by the Engineer.

The accuracy of the equipment shall fall within the following limits.

- Measurement of water ± 3% of the quantity of water in each batch
- Measurement of aggregate ± 3% of the total quantity of aggregate in each batch
- Measurement of admixture ± 5% of the quantity of admixture in each batch

The mixer shall comply with manufacturer's requirements for the mixer. Care shall be taken to ensure that all components are thoroughly mixed and in particular any admixtures are uniformly distributed throughout the batch.

The mixing blades of pan mixers shall be maintained within the tolerances specified by the manufacturer of the mixer and the blades shall be replaced when it is no longer possible to maintain the tolerances by adjustment.

The quantities of all of the constituents, the temperatures of the cement and water when added to the mix, the time of mixing and the temperature of the mixed concrete immediately before discharge shall be recorded for each batch.

The temperature of the cement when added to the mix shall not exceed 30oC. The temperature of the mixed concrete shall not exceed 32oC.

Adequate standby equipment shall be available so that in the event of a breakdown of mixing plant, critical concreting operations will not be interrupted.

Remixing of partially hardened concrete with or without additional cement, aggregate or water is prohibited.

The mixing time shall be established during the trials but shall not be less than that recommended by the manufacturer, subject to the Engineer's acceptance of the trial mixes.

Mixers that have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed. The first batch of concrete through the mixer shall then contain only two-thirds of the normal quantity of coarse aggregate.

15.3.6 Concrete Compliance

15.3.6.1 General

All sampling and testing of constituent materials shall be carried out in accordance with the appropriate British or Indian Standards. In particular, sampling and testing of fresh and hardened concrete shall comply with BS EN 12930 (IS 456) unless this is at variance with the Employer's Requirements.

If fresh concrete does not comply with the workability requirements then it shall not be used without prior acceptance of the Engineer.

15.3.6.2 Strength Control

Compliance with the specified characteristic strength shall be in accordance with BS 8500 (IS 456 Section 2 Clauses 15 and 16). Where steam curing is to be used, the cubes shall be cured in the same manner as the segments before being put in the curing tanks.

Unless otherwise directed by the Engineer, the rate of sampling shall be one sample for each 10m3 of concrete, but not less than one set of samples shall be taken on each day that concrete is produced.

The action required in the case of non-compliance shall be determined by the Engineer, but may include the in-situ testing of segments to prove compliance or rejection of the segments. All additional testing or remedial work shall be at the Contractor's expense.

15.3.6.3 Workability

The workability of the fresh concrete shall be such that the concrete is suitable for the conditions of handling and placing so that after compaction it surrounds all reinforcement and completely fills the moulds. Workability shall be measured by slump for each batch in accordance with BS EN 12350-2.

Concrete which does not comply with the required workability shall not be used in the permanent Works.

15.3.7 Transportation, Placing and Compacting Concrete

The methods of transporting and placing concrete shall be agreed with the Engineer and shall be in accordance with BS 8110, (IS 456) unless otherwise required by the Employer's Requirements. These methods shall be fully described in the Contractor's Method Statement for segment production and shall be in accordance with the following requirements:

Concrete shall be so transported and placed that contamination, segregation or loss of the constituent material does not occur.

All moulds into which concrete is to be placed shall be clean and free from standing water immediately before the placing of the concrete.

The placing and compaction of concrete shall be carried out in such a way as not to cause displacement or other disturbance to the reinforcement cage or moulds or to damage the faces of the moulds.

Concrete, when deposited, shall have a temperature of not less than 10ºC and not more than 32ºC.

Concrete shall be thoroughly compacted by vibration, during the operation of placing, and thoroughly worked around the reinforcement around embedded fixtures and into corners of the formwork to form a solid mass free from voids. When vibrators are used to compact the

concrete, vibration shall be applied continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner that does not promote segregation of the ingredients.

Surfaces upon which concrete is to be placed shall be clean and free from standing water.

A sufficient number of vibrators in serviceable condition shall be on site to ensure that spare equipment is always available in the event of breakdowns.

Where vibrators of the immersion type are used, contact with reinforcement and all inserts shall be avoided as far as is practicable. Internal vibrators shall operate at not less than 10,000 cycles per minute and external vibrators at not less than 3,000 cycles per minute. Vibration shall not be used as a means of distributing heaped concrete into position.

Whenever vibration has to be applied externally, the design of moulds and disposition of vibrators shall ensure efficient compaction and the avoidance of surface blemishes.

15.4 Construction of Segmental Tunnel Lining

15.4.1 General

The Contractor shall agree with the Engineer all details for the method of construction of linings and support systems including transport, handling and erection.

Before erection of each ring of segmental lining, any loose material or other obstructions shall be removed from the ring building area.

All faces of all tunnel lining segments shall be thoroughly cleared of foreign matter and debris prior to placing of the segment.

Where the lining is to be grouted, the shape of the ring shall be maintained until the ring is stabilised.

Erection of segmental linings shall be by purpose-made mechanical system or be manual, aided by mechanical means, in such a way as not to damage the lining. Manual erection will only be permitted by specific agreement with the Engineer after submission of assessments under the Manual Handling Operations Regulations 1992 (as amended). The erection of linings shall follow the agreed method at all times.

The Contractor shall be responsible for ensuring that the segments are not damaged. He shall take the greatest care in the design, detailing, manufacture and construction of the linings and in the provision of packings in the joints to ensure that the completed tunnel lining remains uncracked at working loads and fit for its purpose.

15.4.2 Segmental Erection Systems

Segment erection systems shall be capable of picking up and placing segments safely and accurately. Lifting and gripping systems shall be designed to handle the loads with an adequate factor of safety and without damaging segment sealing systems. If required, erection systems shall be capable of compressing joint gaskets.

The erector shall be in clear view of the operator. A safety device shall be fitted to avoid accidental release of segments during handling and placing.

The machine shall be designed to enable the void behind the segments to be grouted from the shield automatically and continuously as the shield is propelled forward. The design shall enable the grouting pipes to be cleaned or replaced in the event of a blockage.

15.4.3 Erection of Bolted Lining

The segmental lining shall be erected in the tail of the shield in such a way that the plane of the rings shall always be consistent with the altitude of the shield within the constraints of the tapered lining. The ovality of the build shall be kept to a minimum and the joints between segments shall remain true.

The erection of each ring will normally commence with the invert segments and proceed by building and bolting subsequent segments on alternative sides where possible up to the key or top segment at the predetermined position. Segment positions shall be maintained during erection and after completion of the ring build. Lubrication of the gasket shall be undertaken to reduce friction effects and the likelihood of damage to the gasket.

The radial joint bolts shall be tightened at the time each segment is positioned to maintain joint faces in contact and to maintain compression of the gaskets where used.

The first segment placed shall be maintained in its correct position and the circumferential joint bolts of all remaining segments shall be located and loosely secured to allow correct formation of the ring shape.

After completion of the build and before excavation for the subsequent stroke, all circumferential joint bolts shall be tightened. Further retightening of the bolts shall be performed after completion of the subsequent stroke and prior to erection of the next ring.

The roll of the lining shall be maintained in accordance with the limitations of bolt hole clearances to ensure full circumferential bolting of the lining to be achieved.

Where proprietary forms of segment fixings and fastenings are used, methods of erection shall follow the segment manufacturer's recommendations.

15.4.4 Tapered Segmental Lining

Tapered rings shall be used to negotiate horizontal and vertical curves and to correct for line and level. Variable width packings shall not be used for this purpose except to the extent allowed for in the design and testing of the sealing strips and gaskets.

Where tapered rings are used they shall be erected in such orientation as may be necessary to produce the specified alignments and grades of the tunnel.

The orientation of the taper shall be decided after each excavation cycle prior to erection of the next ring.

15.4.5 Grouting of Bolted Lining

Grouting of linings shall be in accordance with Section 12.6.

Bolt holes shall be filled flush with the surrounding concrete using a freshly prepared non-shrink cement and fine aggregate paste. The Contractor shall ensure that the measures adopted shall not impair the water tightness of the structure.

15.4.6 Packing

Where specified, packings of form and type set out Section 15.2.18 shall be inserted between the circumferential faces of segmental lining, to assist in distributing machine or shield thrust ram forces.

Packing shall be used for the correction of minor deviations in line and level and for segmental plane error corrections and also for ring plane alignment correction. Packing shall not in general exceed 6 mm thickness, or half the sealing capacity of the gasket, whichever is the lesser.

Packings greater than 6 mm required for designed alignment control shall be subject to the agreement of the Engineer.

Packings shall not be used in radial joints, unless agreed with the Engineer.

Packing at any point in the circumferential joint shall be feathered out to zero in steps of not more than 3 mm.

15.4.7 Level and Alignment Accuracy

The segments shall be installed into place, true to line and level and in accordance with the following alignment tolerances:

- Expanded segmental linings: line and level +/- 25mm
- Grouted segmental linings: line and level +/- 35mm

The maximum lipping between the edges of adjacent segments shall not be greater than 5mm.

The plane of each segmental ring shall not depart at any point from the plane surface normal to the longitudinal axis by more than 10mm.

Where the tunnel diameter is greater than 2m, the maximum and minimum measured diameters in any one ring shall be within 1% of the theoretical design diameter of the ring.

Notwithstanding the specified alignment tolerances, the rate of change of direction in any plane, or combination of planes, shall be agreed with the Engineer.

No combination of tolerances resulting in a reverse fall will be permitted where the invert of the tunnel is required to convey sewage by gravity flow.

15.4.8 Defective Work

Any segments which are damaged or defective prior to erection shall be indelibly marked and removed from site.

The Contractor shall be responsible for ensuring that the segments are not damaged. He shall take the greatest care in the design, detailing, manufacture and construction of the linings and in the provision of packings in the joints to ensure that the completed tunnel lining remains uncracked at working loads and fit for its purpose.

Any part of the tunnel lining which does not comply with the required tolerances or quality immediately after erection shall be rectified. Advancement of the face shall be suspended until the Contractor's proposals for rectification have received the Engineer's agreement.

Any segment found to be cracked or spalled in the stockpile, during transportation or erection will be rejected. Any segments cracked or spalled after erection and built into the tunnel shall be repaired to the acceptance of the Engineer except when the damage is sufficient to compromise the integrity of the lining, when the Contractor shall then propose his remedial works to the Engineer. Should the Engineer deem the segment in a state beyond repair then the Contractor shall remove it from the permanent lining and replace it with a suitable segment.

The Contractor shall submit proposals for the repair of any rings built into the Works for the agreement of the Engineer.

15.4.9 Re-alignment of Out-of-Tolerance Lining

The Contractor shall propose immediate remedial actions to bring the tunnel drive into tolerance. The Engineer shall exercise a stop work order in the event the tunnel drive is out of tolerance and no satisfactory remedial action is proposed.

The Contractor may propose a re-alignment to correct an out-of-tolerance tunnel drive. In exercising this option, it is the responsibility of the Contractor to demonstrate that:

a) The required minimum falls are maintained

b) Where the tunnel is required to carry sewage by gravity flow a reverse fall has not been created

c) The re-alignment does not deteriorate the intended operational characteristics of the sewer.

15.4.10 Pointing and Caulking

15.4.10.1 Caulking

Segment joints to be caulked shall be cleaned of all grout, dust and deleterious matter so as to leave the recess to be caulked clean and undamaged. Caulking tools with widths as close as practicable to the widths of the recesses shall be used. Caulking materials shall be forced into the joints so that the full depth is filled. No visible leaks shall remain on completion.

Lead for caulking shall comply with BS EN 12588:1999. Lead shall be supplied in rod or strip of widths appropriate to the segment joints, or as lead wool. Cementitious caulking compound cord shall be asbestos free.

15.4.10.2 Pointing

Segment joints to be pointed shall be cleaned of all grout, dust and deleterious matter so as to leave the recess to be pointed clean and undamaged. In the case of circumferential joints containing packings, cleaning and pointing shall extend at least to the packing or a minimum of 20 mm. The pointing material shall be pressed into the joints so that they are completely filled and then given a steel trowel finish flush with the inside periphery of the ring.

Mortar for pointing shall be cement: sand (1:3) or otherwise agreed with water sufficient only to provide a workable consistency which can be rammed into the joint. Mortar shall be used within 1 hour of mixing. Cement and sand shall comply with the General Specification (Volume IIA) and be of a grading commensurate with the work.

Additives and proprietary mixes may be used with the Engineer's agreement.

15.4.11 Monitoring of Segmental Lining Works

In addition to the requirements of Section 13.4 the Contractor shall undertake survey checks pertinent to the accurate erection and position of segments during each ring build and keep daily records during construction of the line, level and profile of the lining and of the roll, plane, square and plumbness of rings.

Before the commencement of each tunnel drive and thereafter daily during the course of the drive the Contractor shall submit for the consent of the Engineer his proposals for setting out and correcting deviations of line, level and plane.

Copies of all records shall be available to the Engineer at intervals to be agreed.

15.5 Polyurea Lining

15.5.1 General

All segmental lining pieces shall be coated internally using Polymer urea (Polyurea) coat of Fosrac, Myk, BASF or VIP conforming to the relevant ASTM/BIS standards and the technical properties stated in the Employer's Requirements.

Application methodology shall be as approved by Engineer at no extra cost to MCGM. Contractor shall consider the pricing of this coating under "Pricing Schedule A1.3- Tunnels item reference 3.5"

All inner faces of segmental lined tunnels shall be coated with the Polyurea coating to a minimum 1.5mm thickness. The protective coating shall be Polyurea, a 100% solids, flexible, two component, rapid curing, pure Polyurea coating system providing high corrosion, abrasion and thermal shock resistance.

15.5.2 Technical properties

The Polyurea coating shall meet the following technical properties:

1	Solids by volume	100%
2	Density at 25deg C	g/ml sprayed film
3	Tensile Strength ASTM D-412	19 Mpa
4	Tear Strength ASTM D624C	90 +/- 4 (N/mm)
5	Elongation ASTM D412	>300%
6	Shore –D ASTM D2240	46
7	Abrasion (1kg, H22 wheels) ASTM D4060	0.4 mg/1000 cycles
8	Abrasion (1kg, CS17 wheels) DIN En ISO 5470	10 mg/1000 cycles
9	Abrasion (1kg, H22 wheels) ASTM D4060	36mg/1000 cycles
10	Service temperature	-30deg C +/- 135deg C
11	Modulus 100/200/300 % D412	>9/13/16 Mpa (Nmmsq) ASTM

The Contractor shall submit test certification from the manufacturers for approval by the Engineer.

15.5.3 Application Methodology

The Polyurea coating shall only be applied to the segmental lining upon installation of the segments within the tunnel and after the relevant section of the tunnel has been cleared of construction materials and plant.

The Contractor shall grout any bolt holes in the RCC segments in accordance with Section 15.4.5 of the Employer's Requirements using a freshly prepared non-shrink cement and fine aggregate paste.

The Contractor shall then prepare the concrete surface by pressure washing and cleaning to ensure a good bond between the coating and the substrate.

Upon completion of the preparation works the Contractor shall seal off the section of tunnel and install dehumidifiers to reduce the relative humidity at the surface to 75% or less when

measured with a hygrometer to BS 8201 Appendix A, for the duration of the application process and in accordance with supplier guidance.

When the relative humidity at the surface is achieved the Contractor shall apply primer, if required, and Polyurea conforming to the specified standards utilizing high pressure, heated two component spray proportioning equipment with an application pressure between 2000-2500 PSI.

Polyurea should be applied to achieve a minimum required thickness of 1.5 mm. A coverage rate of 3 litres/m^2 is the maximum permitted coverage rate for a single coat application.

The proportioning equipment utilized must be capable of supplying correct pressure and heat for the appropriate hose length on a consistent basis.

The Contractor shall submit the application methodology for approval of Engineer.

15.5.4 Quality Control Requirements:

A sample panel must be prepared for guidance and as reference panel for the project. This sample panel is to be prepared on a full RCC segment ring installed in the tunnel for a length of 3m to include segment joints in both planes. This sample panel shall be prepared within the constructed tunnel after surface preparation and dehumidifying as detailed above. The sample panel must be step down to show each coat/ procedure. All work standards will be measured against this approved sample.

Product batch numbers must be recorded on delivery together with the compilation of certificates of conformity.

16 INSPECTION, TESTING AND COMMISSIONING REQUIREMENTS

16.1 Inspection and Testing during Manufacture

16.1.1 General

16.1.1.1 All inspection and testing shall be carried out in accordance with the Specification and in absence of Specification, relevant Indian Standard, or internationally approved equivalent standard. After award of contract, the Contractor shall furnish a QA Plan (QAP) for approval by the Employer. The QAP shall include testing for incoming supply of raw materials and bought out items, stage inspections, and tests on finished products at manufacturer's works / appropriate testing station. The QAP shall clearly indicate tests which are intended to be witnessed by the Contractor alone and those by both Contractor and Employer.

16.1.1.2 Inspection and test schedule shall be as follows;

- Manufacture tests;
- Acceptance inspection / quantity checking;
- Install /site inspection;
- Site acceptance test;
- Tests on Completion;
- Process Wet Tests (by raw sewage);
- Operation Test (Tests After Completion);
- Complete performance tests after designated Operation Service period (before plant handing over); and
- Test furnished as per IS Code/manufacturer QAP.

16.1.1.3 The Contractor shall carry out inspection of equipment at the place of manufacture, as per approved QAP.

16.1.1.4 The Employer and/or duly authorised and designated representative(s) shall be entitled to attend the aforesaid inspection and/or tests.

16.1.1.5 The Employer and his duly authorised representative shall have access to the Contractor's premises at all times to inspect and examine the material and workmanship of the mechanical and electrical plant and equipment during its manufacture there. If part of the plant and equipment is being manufactured on other premises, the Contractor shall obtain permission for the Employer or his duly authorised representative, to inspect as if the plant and equipment was manufactured on the Contractors own premises. Testing (including testing for chemical analysis and physical properties) shall be carried out by the Contractor and certificates submitted to the Engineer who will have the right to witness or inspect the above-mentioned inspection /testing at any stage desired by him. Where inspection or testing is to be carried out at a subcontractor's works, a representative of the Contractor shall be present.

16.1.1.6 The Contractor shall provide test procedure, pre-factory test results, and calculation sheet, photo in advance and provide all of test results with necessary documents including its data and photo to show the Engineer that the test is carried out in a proper condition. Construction material shall be tested by the Contractor at the approved laboratory.

16.1.1.7 The procedure for the testing and inspection to be carried out during or following the manufacture of the materials to ensure the quality and workmanship of the materials and to further ensure that they conform to the Contract in whatever place they are specified shall be

as described below.

i) The Contractor shall give the Employer at least 21 clear days' notice in writing of the date and the place at which any plant or equipment will be ready for inspection/testing as provided in the Contract. Prior to notice, the Contractor shall submit pre-factory test results The Employer or his duly authorised representative shall thereupon at his discretion notify the Contractor of his intention either to release such part of the plant and equipment upon receipt of works tests certificates or of his intention to inspect. The Employer shall then give notice in writing to the Contractor, and attend at the place so named the said plant and equipment which will be ready for inspection and/or testing. As and when any plant shall have passed the tests referred to in this section, the Engineer shall issue to the Contractor a notification to that effect after obtaining clearance from the consultants.

ii) The Contractor shall forward to the Employer 6 duly certified copies of the test certificates along with characteristics performance curves/tables if any for all equipment obtaining dispatch clearance from the consultants/Engineer

iii) If the Engineer(s) fails to attend the inspection and/or test, or if it is agreed between the parties that the Engineer(s) shall not do so, then the Contractor may proceed with the inspection and/or test in the absence of the Engineer and provide the Employer with a certified report of the results thereof as per (ii) above.

iv) If any materials or any part of the works fails to pass any inspection / test, the Contractor shall rectify or replace such materials or part of the works and shall repeat the inspection and/or test upon giving a notice as per (i) above. Any fault or shortcoming found during any inspection or test shall be rectified to the satisfaction of the Engineer before proceeding with further inspection of that item. Any circuit previously tested, which may have been affected by the rectification work, shall be re- tested.

v) Where the plant and equipment is a composite unit of several individual pieces manufactured in different places, it shall be assembled and tested as one complete working unit, at the manufacturer's works.

vi) Neither the execution of an inspection test of materials or any part of the works, nor the attendance by the Engineer (s), nor the issue of any test certificate pursuant to (iii) above shall relieve the Contractor from his responsibilities under the Contract.

vii) The test equipment, meters, instruments etc., used for testing shall be calibrated at recognised test laboratories at regular intervals and valid certificates shall be made available to the Engineers at the time of testing. The calibrating instrument used as standards shall be traceable to National/International standards. Calibration certificates or test instruments shall be produced from a recognised/Laboratory for the Engineer's consent in advance of testing and if necessary instruments shall be recalibrated or substituted before the commencement of the test.

viii) Items of plant or control systems not covered by standards shall be tested in accordance with the details and programme agreed between the Engineer and Contractor's Representative. If such materials or works are found to be defective or not conforming to the Contract requirements, due to the fault of the Contractor or his sub-contractors the Contractor shall defray all the expenses of such inspection and/or test and of satisfactory reconstruction.

ix) Tests shall also be carried out such that due consideration is given to the Site conditions under which the equipment is required to function. The test certificates shall give all details of such tests.

x) The Contractor shall establish and submit a detailed procedure for the inspection of

materials or any part of the works to the Employer for approval within the date indicated in the Programme Details. The detailed procedure shall indicate or specify, without limitation, the following:

xi) Applicable code, standard, and regulations;

xii) Fabrication sequence flow chart indicating tests and inspection points;

xiii) Detailed tests and inspection method, indicating the measuring apparatus to be used, items to be measured, calculation formula, etc.;

xiv) Acceptance criteria;

xv) Test report forms and required code certificates and data records;

xvi) Method of sampling, if any sampling test to be conducted; and

xvii) Contractor's or Employer's witness points.

xviii) The Contractor shall not pack for shipment any part of the Plant until he has obtained from the Employer or his authorised representative his written approval to the release of such part for shipment after any tests required by the Contract have been completed to the Employer's satisfaction.

xix) The following Inspection and Testing procedures shall be carried out for the equipment as per approved QAP.

16.1.1.8 The detailed procedure shall indicate or specify, without limitation, the following:

- Raw Material;
- Visual Inspection/Appearance;
- Chemical and Mechanical Property Tests;
- Dimension Checking;
- Dynamic Balancing for all Rotating Parts;
- Stage Inspection;
- Hydrostatic / Leak Testing for all Pressure Parts, Pneumatic Leak Test Wherever Applicable;
- Repair Procedure;
- Operation Check;
- Procedure Qualification Record (PQR); Welding Procedure Qualification (WPQ) And Welders Qualification Report (WQR);
- Material Test;
- Assembly/Connection; and
- Documentation.

16.1.1.9 The Contractor shall maintain proper identification of all materials used, along with reports for all internal / stage inspection work carried out, based on the specific job requirement and or based on the datasheets / drawings / specifications.

16.1.1.10 The expenses incurred during inspection shall include, but not be limited to all travelling, boarding, lodging expenses.

All expenses incurred by the Engineer or his representative or persons nominated by the Engineer including third party in attending inspection / re-inspection and tests of Plant carried out within India and abroad shall be borne by the Contractor.

A maximum of two persons from the Employer's side will witness the inspection and testing along with the Contractor's representative.

The expenses incurred during inspection shall include, but not be limited to all travelling, boarding, lodging including visa charges etc.

16.1.1.11 Witnessed testing will normally be waived on standard types of equipment such as small motors made by approved manufacturers, individual standardised instruments, small mass produced components used in the manufacture of Plant items, small bore pipework and fittings, minor installation materials and low voltage cable. For clarity, this shall not relieve the Contractor of his obligation under the Contract to ensure that all Plant is tested at the manufacturer's works prior to delivery to Site.

16.1.1.12 As a guide to the Contractor the Employer reserves the right to witness testing of the following but not limited to the following Plant items:

Electrical;

- 415 V Metal Enclosed Switchgears (PCC / MCC);
- 415 V Power Capacitor and Control Panel;
- Diesel Standby Generator with AMF Control Panel;
- Battery, Battery Charger and DC Distribution Board;
- Variable Frequency Drives;
- Non-Segregated Bus Duct;
- Power & Control Cables; and
- Lighting System;

Mechanical;

- Valve and Penstock Actuators;
- Valves;
- Pipes;
- Sluice Gates;
- Expansion/Dismantling Joints;
- Weir Gates;
- Screens;
- EOT Cranes and Hoists;

Instrumentation and Control;

- Level Measuring System;
- Pressure Gauges;
- Pressure Transmitter;
- Flow Measuring System;
- Temperature Measuring System;
- Instrumentation and Control Cables;
- Instrument Control Panel;
- Programmable Logic Controller;
- HMI System;
- Uninterruptible Power Supply System;
- Wireless GPRS Gateway Testing; and

- FAT & SAT for complete ICA system

16.1.1.13 All destructively tested samples shall be replaced with new.

16.1.1.14 The Employer reserves the right to be present during the testing and inspection of all Plant items.

16.1.2 Materials, Plant, and Equipment

The Contractor shall place orders for the material and the equipment only after approval of the QAP by the Engineer. The Contractor shall submit the detailed technical information and its drawings, unpriced copy of the Contractors order for the Plant item / equipment / material from the approved manufacturer and the procedure of submission, review and revision shall be as specified herein below. The Contractor shall inform the Employer about the likely dates of manufacturing, testing, and dispatching of any material and equipment to be incorporated into the Permanent Works. The Contractor shall notify the Employer for inspection and testing, at least twenty-one (21) days prior to packing and shipping and shall supply the manufacturer's test results and quality control certificates. The testing and approval for dispatching shall not absolve the Contractor from his obligations for satisfactory performance of the plant.

Dispatch Clearance

All mechanical/electrical/instrumentation equipment shall be tested at their respective factory which will be witnessed by tri parties (Contractor, Client /Consultant inspecting team) in line with approved QAP and Equipment Data sheet.

The test observation sheets, material tests certificates (chemical and mechanical test at laboratory) and joint inspection report shall be signed by the Contractor, Client/Consultant officials after successfully completion of tests.

The Contractor shall forward all original reports to the Client and copy to the Consultant for verification and issuances of Dispatch Clearance Certificates. No Dispatch Clearance Certificate will be issued at the factory itself by the inspecting agency.

16.1.3 Factory Acceptance Test (FAT) Document

Fifty Six (56) days prior to commencement of inspection of each Plant item / equipment, the Contractor shall supply a Factory Acceptance Test (FAT) Document for approval. This shall comprise four copies of the following:

- Unpriced copy of the Contractors order for the Plant item / equipment concerned;
- details of the inspection and test procedures to be carried out; and
- Pre-factory test results and its photos.

The FAT Plan shall provide comprehensive details of the tests to be carried out, the purpose of each test, the equipment to be used in carrying out the test and the methods to be adopted in carrying out the tests. The FAT shall provide space within the documentation for results of the tests to be added and for each test and for the FAT as a whole to be signed off by the Contractor and the Engineer.

On completion of the tests the Contractor shall provide four copies of all test certificates, curves, etc. for the inspected Plant item. To remove doubt, test certificates shall be provided for the Plant item as a whole plus certificates for the relevant component parts such as:

- Motors;
- Pumps and Blowers;
- Instruments;
- Gear Boxes;
- Electrical Switchgear;
- Integral Control and Switchgear Panels;
- Valve Gear;
- Castings;
- Actuators;
- Cranes and Hoists;
- Screens;

16.1.4 Inspection and Testing Programme

The Contractor shall submit to the Engineer not later than 56 days prior to the commencement of the first inspection and test during manufacture a programme detailing the inspection dates for all Plant. Those items of Plant that the Engineer has specifically identified for witness testing test shall be highlighted in the programme.

The Contractor shall keep the Engineer informed of any changes to the programme.

The Engineer shall not be requested to inspect an item of Plant until the Contractor has satisfied himself that the equipment meets all requirements of the Employer's Requirements.

The Contractor shall inform the Engineer in writing at least 21 days in advance regarding readiness for carrying out inspection of equipment/material etc. at manufacturer's works or at places of inspection. The programme for inspection shall be finalised by the Engineer after the receipt of the above case equipment/material, etc. If it is found not to comply with the specification, dates for re- inspection shall be finalised and expenses incurred by the Employer for such visits shall also be recovered from the Contractor. Contractor's Representatives shall essentially be present during all inspections of Plant items. The following information shall be given in the inspection call letter mentioned above:

- Name of manufacturer/supplier;
- Address of place where inspection is to be carried out;
- Proposed date/s and equipment to be inspected;
- Name/s of contact personnel at manufacturer's/ supplier/s works with their telephone and fax numbers;
- Name of Contractor's Representative who will be present during the inspection; and
- Confirmation that internal testing has been completed. Submission of internal testing report for review before visiting the plant.

The Contractor shall provide all the necessary instruments, test facility, water / electric power, test piece, samples, engineers/ workers, all cost and others to carry out the tests after assembly. All instruments used for such tests shall be calibrated and certified by and approved by an independent testing authority not more than one year prior to the tests in which they are used. Calibration certificates with expiry date and name of authorisation agency for instruments used

for such tests shall be produced for the approval of the Engineer and if necessary, instruments shall be recalibrated before the commencement of the tests.

No material shall be delivered to the Site without Dispatch clearance certificate having been carried out or waived in writing by the Engineer.

If during or after testing, any item of plant fails to achieve its intended duty or otherwise proves defective, it shall be modified or altered as necessary and retested and re-inspected as required by the Engineer.

16.2 Tests at Manufacturer's Premises – Mechanical Equipment

16.2.1 Motors

(a) Routine Tests

All routine tests shall be carried out on all motors as per the latest edition of IS 325.

(b) Acceptance Tests

Full load test to determine efficiency, power factor and slip shall be conducted on all the motors.

(c) Type tests

The following type tests shall be carried out on one motor of each rating above 10 kW:

- Isolation resistance test;
- Temperature rise test;
- Momentary overload test;
- Vibration measurement test;
- Noise level test;
- Over speed /over load test; and
- Starting current, starting torque, and pull out torque at reduced voltage.

16.2.2 Valves and Expansion Joints

(a) During testing there shall be no visible evidence of structural damage to any of the valve components.

(b) Motorised valves shall be tested with their job actuator, with a differential head equivalent to their maximum working pressure, to prove that the actuators are capable of opening and closing the valves under maximum unbalanced head condition within the specified opening or closing period.

(c) Hydrostatically tested shall be as per relevant IS/BS standard for each type of valve.

(d) The following tests shall be carried out for sluice valves, knife gate valves:

- Seat Leakage Test;
- Body Hydrostatic Test;
- Valve Operation;
- Dimensional Check; and
- Visual Inspection.

(e) The following tests shall be carried out for non-return valves:

- Seat Leakage Test;
- Body Hydrostatic Test;
- Valve Operation;
- Dimensional Check; and
- Visual Inspection.

(f) The following tests shall be carried out for expansion joints:

- Leakage Test;
- Body Hydrostatic Test;
- Displacement Range;
- Dimensional Check;
- Visual Inspection.

16.2.3 Pipe-work

Testing of pipes and fitting shall be carried out in accordance with relevant Indian Standard and internationally approved standard. Pipes, fittings and expansion bellows shall be hydrostatically tested for 1.5 times the rated pressure. The following tests shall be carried out for pipelines:

- pressure test;
- leakage test;
- LP test for welding pipeline;
- welding beat check;
- dimensional check; and
- visual inspection.

16.2.4 Crane & Hoists

The cranes shall be completely assembled in the Contractor's or Subcontractor's Works and shall be subjected to the tests as specified in IS 807/IS 3177 or relevant internationally approved standard. The Contractor shall provide the test weights.

Hoists and lifting equipment shall be assembled and tested at the place of manufacture in accordance with IS 3938.

Each and every rotating part/assembly/sub-assembly shall be dynamically balanced as per grade G16 of ISO 1940/1 - 1986.

16.2.5 Sluice Gates

(a) Seat Clearance Check

With the gate fully closed, the clearance between seating faces when checked with the filler gauge, shall not exceed 0.1 mm.

(b) Movement Tests

Each gate shall be shop operated manually/electrically three times from the fully open position to the fully closed position and return to fully open, under no flow conditions to demonstrate that the assembly is workable.

(c) Leakage Tests

With the gate in closed position, design pressure shall be applied for a period not lesser than 5 minutes to the unseating side of the sluice gate and the leakage shall not exceed the maximum leakage permissible as per IS 13349.

(d) Hydrostatic Tests

Finally, a differential of one and a half times the design pressure shall be applied to the unseating side of the gate. Under these tests no part shall show any deflection of deformation.

16.2.6 Screens

a. All screens shall be checked for overall dimensions, assembly, and clearance between the bars / space between a rake and bar surface / aperture size and its material as well as painting works. Moreover, motion of rake/drum and wiper/self-cleaning arrangement shall also be tested at works.

b. Conveyor shall be checked for dimensions and physical conditions, belt joint portion, travelling accuracy of belt, motors and its power consumption, and performance of safety device.

c. At least one screen of each type shall be tested for efficiency and operation by employing screenings. For screens having a depth of channel more than 3 metres, testing with reduced depth is acceptable.

16.2.7 Reinforced Cement Concrete Pipes

Testing

a) All pipes for testing purposes shall be selected at random from the stock of the manufacturer and shall be such as would not otherwise be rejected under the criteria of tolerances as mentioned in IS:458.

b) The Contractor shall provide laboratory test /analysis results of cement and aggregate components and cement vs. aggregate vs. water mixing ratio and concrete mixing time and mixing method.

c) During manufacture, tests on concrete shall be carried out as per IS:456. The manufacturer shall supply, when required to do so by the Engineer the results of compressive tests of concrete cubes and split tensile tests of concrete cylinders made from the concrete used for the pipes. The manufacturer shall supply cylinders or cubes for test purposes required by the Engineer and such cylinders or cubes shall withstand the tests prescribed as per IS:458. Every pressure pipe shall be tested by the manufacturer for the hydrostatic test pressure. For non-pressure pipes, 2 percent of the pipes shall be tested for hydrostatic test pressure.

d) The specimen of pipes for the following tests shall be selected in accordance with relevant clause of IS:458 and tests in accordance with the methods described in IS:3597:

- Hydrostatic Test;
- Three Edge Bearing Test;
- Absorption Test;
- Dimension and Colour of Surface; and

- Damage.

16.2.8 Sampling and Inspection

- In any consignment, all the pipes of same class and size and manufactured under similar conditions of production shall be grouped together to constitute a lot. The conformity of a lot to the requirements of this Employer's Requirements shall be ascertained on the basis of tests on pipes selected from it.
- The number of pipes to be selected from the lot for testing shall be in accordance with Table 15 of IS:458.
- Pipes shall be selected at random. In order to ensure randomness, all the pipes in the lot may be arranged in a serial order and starting from any pipe, every r-th pipe be selected till the requisite number is obtained, r being the integral part of N/n where N is the lot size and n is the sample size.
- All pipes selected shall be inspected for dimensional requirements, finish and deviation from straight. A pipe failing to satisfy one or more of these requirements shall be considered as defective.
- The number of pipes to be tested shall be in accordance with column 4 of Table 15 of IS:458. These pipes shall be selected from pipes that have satisfied the requirements mentioned in the above clause.
- A lot shall be considered as conforming to the requirements of IS:458 if the following conditions are satisfied:
    - The number of defective pipes shall not be more than the permissible number given in column 3 of Table 15 of IS:458;
    - All the pipes tested for various tests shall satisfy corresponding requirements of the tests;
    - In case any pipes do not satisfy the requirements of any one or more tests, one or two further samples of same size shall be selected and tested for the test or tests in which the failure has occurred. All these pipes shall satisfy the corresponding requirements of the test; and
    - All destructively tested samples shall be replaced to new.

16.2.9 Steel Cylinders Pipes and Specials

Testing

1) Welding beat check - Remove all scale on the welding points and welding beat and its thickness shall be checked by the Engineer.
2) Penetration Test
3) A suitable penetrating liquid (kerosene oil/dye) is applied to the surface of the portion under examination and is permitted to remain there for sufficient time to allow the liquid to penetrate into any defects open at the surface. After the penetrating time, the excess penetrate, which remains on the surface is removed. Then a light coloured powder absorbent called a developer is applied to the surface. This developer acts as a blotter and draws out a portion of the penetrant which had previously seeped into the surface openings. As the penetrant is drawn out it diffuses into the coating of the developer, forming indication of the surface discontinuities or flaws.

4) Each steel cylinder shall be subjected before lining/coating to a hydrostatic test under a water pressure equivalent to the test pressure in accordance with Clause 10 of IS:1916 and relevant provisions of IS:3597, provided that the whole of the area of the calculated reinforcement is used in the steel cylinder. In the case of pipes where a part of the principal reinforcement is provided in the cage, the steel cylinder shall be subjected to proportionately less hydrostatic test pressure.
5) Manufacturer's standard specials shall be hydrostatically tested before lining/coating. Where feasible, other specials shall be hydrostatically tested (before lining/coating) at factory. However, when this is not practicable, at the discretion of the Engineer, the unlined specials shall be tested by penetration test as per IS:3658 or other approved means.
6) The contractor shall submit QA/QC and methodology for welding works
7) Approval of welding rods
8) Welders qualification test.

16.2.10 Cast Iron / Ductile Iron Pipes

Mechanical Tests

Mechanical chemical tests shall be carried out during manufacture of pipes and fittings as specified in relevant IS codes. The results so obtained shall be considered to represent all the pipes and fittings of different sizes manufactured during that period and the same shall be submitted to the Engineer. The method for tensile tests and the minimum tensile strength requirement for pipes and fittings shall be as per relevant IS codes.

Brinell Hardness Test

For checking the Brinell hardness, the test shall be carried out on the test ring or bars cut from the pipes used for the ring test and tensile test in accordance with IS:1500.

Retests

If any test piece representing a lot fails in the first instance, two additional tests shall be made on test pieces selected from two other pipes from the same lot. If both the test results satisfy the specified requirements, the lot shall be accepted. Should either of these additional test pieces fail to pass the test, the lot shall be liable for rejection.

Hydrostatic Test

For hydrostatic test at works, the pipes and fittings shall be kept under test pressure as specified in relevant IS codes; they may be struck moderately with a 700 g hammer. They shall withstand the pressure test without showing any leakage, sweating or other defect of any kind. The hydrostatic test shall be conducted before coating the pipes and fittings.

16.3 Mechanical Equipment

All mechanical equipment shall be tested at site as per the following items:

a) The test shall verify any damage/missing parts, No. of equipment to be installed, material, location as specified in drawing, levelling, centreline, solid installation and condition of installation to be fitted in levelling of pipeline and valves;

b) Testing run will be conducted for verifying rotation direction, vibration, noise, and stability and any leakage, if possible;

c) The test will be verified to check maintenance space and ease of equipment maintenance work; and

d) The testing shall be performed in full compliance with the latest version of the applicable standard testing protocol. These tests shall be witnessed by the Engineer as per procedures set forth for witnessing elsewhere in this document.

16.4 Tests at Site

a) In addition to progressive supervision and inspection by Engineer, the Contractor shall offer for inspection to the Engineer, the completely erected plant/part of Plant on which tests are to be carried out. After such inspection, each equipment/sub-system shall be tested by the Contractor in accordance with the applicable standards in the presence of the Engineer. Such tests shall include but not be limited to the tests specified in the following clauses.

b) The Contractor shall possess during the entire working period the Electrical Contractor's licence of appropriate class from the concerned statutory authorities governing the area of work place. The Contractor shall fully comply with the relevant statutory rules and regulations. On completion of the installation or at intermediate stages, if required by the statutory authorities, the Contractor shall arrange for inspection and obtain approval from the concerned statutory authorities. If any fees are to be paid to statutory authorities for testing, inspection and calibration, these shall be paid by the Contractor and shall be included in his erection and commissioning charges.

16.5 Piping and Valves

a) The erected pipe work shall be subjected to a hydraulic test at 1.5 times the maximum pressure or twice the working pressure whichever is higher to test the soundness of the joints. Provision of the necessary pumps, gauges, blank flanges, tappings, etc. for carrying out these tests shall be included in the Contract. All gas piping shall be air tested to twice normal working pressure.

b) Leakage tests shall be carried out on all erected pipework and valves immediately after erection and where possible before being built in.

c) Operating tests shall be conducted on valves.

16.6 Motors

Condition of winding insulation shall be tested and insulation values shall be restored to required level by suitable heating arrangements locally.

16.7 Cranes

The crane and lifting tackle shall be tested to 125% of the safe working load. The Contractor shall arrange the test load. The Contractor shall also arrange for the appropriate certificates from the concerned authorities before regular use of the cranes and other lifting equipment.

16.8 Screens

After erection, all screens shall be tested for smooth operation and capability to handle typical wastewater solids including stringy materials. Clearance between the dead plate and tines shall be checked as applicable.

16.9 Gates and Penstocks

a) Leakage test shall be performed by the Contractor after installation of all gates.

b) Under the design seating head and unseating head, the leakage shall not exceed the limit specified in IS:13349, for shop testing.

16.10 Reinforced Cement Concrete Pipes

a) After laying and jointing of RCC pipes is completed, the pipe line shall be washed out with sufficient water and be tested at the work site as per the Employer's Requirements and as directed by the Engineer. All equipment for testing at the work site shall be supplied and erected by the Contractor. Water for testing of pipes shall be arranged by him. Damage during testing shall be the Contractor's responsibility and shall be rectified by him to full satisfaction of the Engineer. Water used for the test shall be removed from pipes and not released to the excavated trenches.

b) After the joints have thoroughly set and have been checked by the Engineer and before back filling the trenches, the entire section of the sewer or storm water drain shall be proved by the Contractor to be water tight by filling in pipes with water to the level of 1.5m above the top of the highest pipe in the stretch and heading the water up for a period of one hour.

c) The apparatus used for the purpose of testing shall be approved by the Engineer. If required by the Engineer, the Contractor shall dewater the excavated pit and keep it dry during the period of testing. The loss of water over a period of 30 minutes shall be measured by adding water from a measuring vessel at regular 10 minute intervals and noting the quantity required to maintain the original water level. For approval of this test the average quantity added should not exceed 1 litre/ hour/100 linear metres / 10mm of nominal internal diameter. Any leakage including excessive sweating which causes a drop in the test water level will be visible and the defective part of the work shall be removed and made good.

d) In case of pressure pipelines, the completed stretch of pipeline shall be tested for site test pressure. The site test pressure shall not be less than the maximum operating pressure plus the calculated surge pressure, but in no case shall it exceed the hydrostatic test pressure as specified in IS:458.

16.11 Steel Cylinder Pipes and Specials

a) After laying and jointing of steel cylinder pipes and specials with concrete lining and coating is completed, the pipeline shall be washed out with sufficient water and be tested at the work site as per the following Employer's Requirements and as directed by the Engineer. All equipment for testing at work site shall be supplied and erected by the Contractor. Water for testing of pipes shall be arranged by him. Damage during testing shall be the Contractor's responsibility and shall be rectified by him to the full satisfaction of the Engineer. Water used for the test shall be removed from pipes and not released to the excavated trenches.

b) Each section of the pipe line shall be slowly filled with clean water and all air shall be expelled from the pipeline. The pressure in the pipeline shall then be raised and maintained by means of pump to the test pressure. The test pressure shall not be less than 1 1/2 times the working pressure at the lowest point or the static head pressure, whichever is higher. Under the test pressure, no leak or sweating shall be visible at the welded joints. The duration of test shall not be not than 24 hours. Exposed joints shall be carefully examined and all such joints showing visible leaks shall be rewelded. Any cracked or defective pipes and specials in consequences of this pressure test shall be removed and replaced by sound material by the Contractor and the test shall be repeated to the satisfaction of the Engineer.

c) The hydrostatic shop test for pipes and fittings shall be as per the code/standard requirement. After erection at site, complete pipes and fittings shall be hydrostatically tested for a pressure of 1.5 times operating pressure.

d) Where directed by the Engineer, welded joints on pipes larger than 675 mm diameter shall be subject to a nitrogen gas test after welding.

e) A tapped hole (approximately 6 mm diameter) shall be made in the socket end of each pipe by the Contractor and shall be fitted with a suitable non-return valve. Nitrogen, at 400 kPa pressure, shall then be pumped into the annular space between the spigot and socket and the pump disconnected.

f) If no drop in pressure occurs over the ensuing period of 30 minutes, the test shall be deemed to be successful. If the test pressure cannot be maintained for 30 minutes, all defects in the weld shall be cut back and rewelded and the test reapplied until successful. The cost of initial and subsequent testing of defective welds shall be at the Contractor's own expense.

g) The Contractor shall provide all items necessary for the nitrogen tests including compressor, valves, gauges and tubing.

16.12 Cast Iron, Ductile Iron Pipes and Fittings

a) After the pipes and fittings are laid, jointed and the trench partially backfilled except at the joints, the stretch of pipe line as directed by Engineer shall be subjected to pressure test and leakage test after washing the pipe line out with sufficient water.

b) Where any section of the pipeline is provided with concrete thrust blocks or anchorages, the pressure test shall not be made until at least five days have elapsed after the concrete was cast. If rapid hardening cement has been used in these blocks or anchorages, the tests shall not be made until at least two days have elapsed.

c) Each section of the pipe line shall be slowly filled with water and all air shall be expelled from the pipe by tapping at points of highest elevation before the test is made and plugs inserted after the tests have been completed. The specified test pressure based on the elevation of the lowest point of the line or section under test and corrected to the elevation of the test gauge shall be applied by means of a pump connected to the pipe as directed by the Engineer.

d) The duration of test shall not be less than 5 minutes. Exposed joints shall be carefully examined and all such joints showing visible leaks shall be recaulked until water tight. Any cracked or defective pipes and fittings in consequence of this pressure test shall be removed and replaced by sound material by the Contractor at no extra cost to the Engineer and the test shall be repeated to the satisfaction of the Engineer.

e) After satisfactory completion of the pressure test, the section of pipe line shall be subjected to leakage test. The duration of test shall be 2 hours. No pipe installation shall be accepted until the leakage is less than the number of cm^3 /h as determined by the formula:

Where,

$$q_L = \frac{ND\sqrt{P}}{3.3}$$

q_L=The allowable leakage in cm^3/hr

N = Number of joints in the length of the pipeline

D = Diameter in mm, and

P = The average test pressure during the leakage test in Kg/cm^2

f) Should any test of pipe laid indicate leakage greater than that specified above, the defective joints shall be repaired by the Contractor at his own cost until the leakage is within the specified allowance.

g) Necessary equipment and water used for testing shall be arranged by the Contractor at his own cost. Damage during testing shall be Contractor's responsibility and shall be rectified by him at his own cost. Water used for testing shall be removed from the pipe and not released in the excavated trenches.

h) After the tests mentioned above are completed to the satisfaction of the Engineer, the backfilling of trenches shall be done as per the Employer's Requirements specified elsewhere.

16.13 Manufacturer's Works Acceptance Tests on Electrical Equipment

The following equipment / items shall be subjected to inspection, routine /acceptance tests as per latest edition of relevant Indian / International standards in the presence of Employer/ his Engineer:

a) HV/LV transformers;

b) HV metal enclosed switchboards &switchgears;

c) 415 V metal enclosed switchgears (PCC / MCC);

d) Power capacitor and control panel;

e) Diesel standby generator with AMF control panel;

f) Battery, battery charger and DC distribution board;

g) Variable frequency drives;

h) Non-segregated bus duct;

i) Power & control cables;

j) Cable carrier system;

k) Lighting system; and

l) Earthing and lightning protection systems.

Copies of test certificates for the type tests and special tests not later than 5 years conducted as per relevant Indian / International Standards for all the equipment /items of above shall be furnished for the perusal of the Employer / his Engineer. If type tests and special tests have not been conducted on any of these items, the same shall be carried out in the presence of owner/ Engineer at no extra cost.

16.14 Manufacturer's Works Acceptance Tests on ICA Equipment

i. Instrumentation:

Inspection, testing and setting to work:

General

Each item of plant shall be subjected to the manufacturer's own tests which shall be certified.

Each item of plant and its installation shall be subject to inspection and testing at the place of manufacture.

The Contractor shall be responsible for the provision of all necessary test equipment. The Contractor shall demonstrate to the Engineer, the correct operation of any item of plant and the Engineer may witness any test. Tests which, in the opinion of the Engineer, were failed or not performed correctly shall be repeated.

Calibration tests for field instruments and analytical instruments shall be conducted on site after installation and the same should be witnessed by the Engineer.

Before any test is made, the Contractor shall submit to the Engineer a full list of test equipment and test procedures (method statements) to be used. Each item of test equipment shall have a standard of accuracy better than that stated by the manufacturer of the item to be tested. The Contractor shall provide evidence of the condition and performance of any item of test equipment, in the form of test certificates issued by an appropriate authority independent of the Contractor and manufacturer, or as otherwise directed by the Engineer. Test equipment shall be checked frequently during the period of the tests.

The Contractor's staff responsible for supervising and carrying out tests shall be fully conversant with the various items of equipment of other manufacturers and if necessary the Contractor shall arrange for his personnel to attend suitable training courses on his own expense.

Any fault or shortcoming found during any inspection or test shall be rectified to the satisfaction of the Engineer before proceeding with further inspection or testing of that item. Any circuit previously tested, which may have been affected by the rectification work, shall be re-tested.

Preliminary Inspection and Testing at the Place of Manufacture

Field-mounted instruments

After successful completion of the manufacturer's own inspection and testing of instruments supplied under the Contract, similar tests shall be carried out in the presence of the Engineer and the Contractor. Such tests shall include a demonstration that an increase or decrease of the measured value at several points over the full range of the instrument produces a corresponding increase or decrease in the instrument output signal. These tests shall include checks on the specified accuracy of the instrument at all points.

Instrument Panels, Enclosures and Mounting Boards

The manufacturer shall not present instrument panels, enclosures and mounting boards (assemblies) for inspection and testing until the manufacturer's own tests and inspection has been completed. A preliminary inspection and test of these assemblies may then be witnessed by the Engineer. The Contractor shall give not less than 7 days' prior notice in writing that he has completed his tests and inspection and is ready for the witnessed tests and inspection. Where this notice period is different in the Conditions of Contract, the Conditions of Contract shall take precedent.

The witnessed inspection and testing shall include the following:

a) A visual inspection of the panel assembly to show that the design, construction and finish are satisfactory and in accordance with the Specification;

b) A check that equipment is securely mounted, accessible for removal or calibration without damage to or undue disturbance of other components, wiring or piping;

c) That all engraving and labels are correctly positioned, fixed and designated in accordance with the Specification;

d) Panel power-distribution circuits have the correct breaker/fuse rating coordination and designation;

e) Power-isolation facilities meet the Specification;

f) The main incoming supply voltage, frequency and/or pneumatic supply pressure is within the required limits, these being checked at the beginning and end of the test and the results recorded on test certificates;

g) The output of all power supply units again at the beginning and end of the testing with results being recorded;

h) The power supply voltage or air pressure of all component instruments of the assembly(s), these voltages/pressures being recorded on the test certificate;

i) The insulation resistance of all circuits except sensitive electronic equipment which is liable to damage by application of the test voltage, such circuits being disconnected before making the insulation resistance tests and these tests being carried out in accordance with IEE Wiring Regulations; and

j) That the clean earth bar is isolated from main frame of the panel.

Internal lighting and anti-condensation heaters and associated thermostats, isolators, limit switches and wiring shall be checked for compliance with the Specification.

Spare capacity within the panel(s) shall be checked to see that it complies with the Specification. This shall include future equipment space, spare terminals, space in wiring trunkings and provision for additional cable entry.

Functional Testing at the Place of Manufacture

General Requirements

Once the preliminary inspection and testing is complete to the satisfaction of the Engineer, functional testing shall commence. The purpose of the functional tests are to demonstrate that instrument panels enclosures and mounting boards (assemblies) conform with requirements of the Specification.

Not less than 30 days before the commencement of functional tests, the Contractor shall submit to the Engineer, for approval, two copies of comprehensive test procedural documents detailing each test to be carried out. The document shall include results forms on which the results of each test will be entered. The forms shall include spaces for numerical values, where necessary, and witness signatures.

All applicable drawings and data shall be provided at the place of inspection by the Contractor. The Contractor shall provide all test instruments and equipment necessary to test the assemblies in their entirety.

The following is a typical list of the equipment required:

- Switch Boxes;
- Indicator Light Boxes;

- Analogue Signal Sources;
- Dummy Loads;
- Meters;
- Simulators;
- Desk-Top Computers;
- Programmers for DCS or Outstations; and
- Insulation Test Equipment.

ii. Programmable Logic Controller (PLC)

The Contractor shall carry out specified tests as follows in addition to any tests stated or implied by the foregoing sections of this clause.

The tests shall be carried out on the fully assembled control panel containing the PLC and associated equipment to demonstrate correct functional operation of the hardware and software systems.

Factory Acceptance Test (FAT)

The Contractor shall conduct a full programme of tests of the PLC system at the Contractor's testing facility in the presence of the Engineer to verify that all features of the system have been provided, are operating correctly and are in full compliance with the Specification. FAT shall include PLC system for facility and PLC based control system with panel mounted HMI for TSPS(s). Unless otherwise specified or agreed by the Engineer, the entire PLC system shall be assembled and tested together as an integrated system, including all master station equipment, all operators' consoles, all outstations and telemetry equipment, all instrumentation panels and uninterruptible power supplies included in this Specification. The scheduled date for the factory acceptance test shall be as agreed by the Contractor and the Engineer at least four weeks before the test. FAT shall be conducted with a hardwired simulation panel connected to the PLC system. The Contractor shall note the importance of the requirement. No software based simulation testing shall be accepted or allowed.

Not less than one month before the scheduled factory acceptance test, the Contractor shall submit to the Engineer for approval two copies of a comprehensive manual detailing each test to be conducted. The manual shall include a results form on which the results of each test will be entered, including spaces for numerical values where appropriate and witness signatures.

Not less than 7 days before the scheduled factory acceptance test, the Contractor shall give written notification to the Engineer that a complete dry-run of the factory acceptance test has been performed successfully and that, in the opinion of the Contractor, the system exhibits stable operation and is ready for the formal factory acceptance test.

The factory acceptance test will be considered successfully completed only when the system has successfully passed all factory tests. The system shall not be delivered to Site until the successful completion of the factory acceptance test is certified by the Engineer or unless otherwise approved by the Engineer. Delay in delivery of the system due to failure of the factory acceptance test shall not constitute an unavoidable delay. If the system fails the factory acceptance test, the test shall be extended or rescheduled at the discretion of the Engineer.

All hardware to be used in the testing of the system shall have passed an agreed preliminary hardware performance test to ensure known hardware operability before software testing begins.

After successful completion of the factory acceptance test, no software changes shall be made to the system without written authorisation by the Engineer. Any changes to the system which affect the system software documentation, such as input scale modifications or changes to the control logic, shall be entered into the system documentation before delivery of the system to Site. All instruments under IC&A scope shall be tested 100%.

Factory Acceptance Test Procedures

General

The scope of the tests shall include the proving of every aspect of hardware and software operation and functions as detailed below.

Hardware Tests

a) Verify the correct inventory of hardware including cables and printed circuit boards;

b) Demonstrate that all spare-memory, disk-capacity and system-expansion requirements have been met;

c) Demonstrate all hardware and software diagnostics;

d) Verify all power supply voltages are within tolerance;

e) Verify proper earth connections and isolation of instrumentation earth for all equipment; and

f) Demonstrate operation of test simulation and indication equipment and its suitability for adequate functional testing of all system functions.

Software Tests

a) Demonstrate the editing of all system parameters including set-points, timers and the like;

b) Demonstrate system configuration capabilities including the addition and deletion of input and output points, outstations, and all data base parameters; and

c) Demonstrate the addition, deletion and modification of mimic displays and report formats.

Functional Tests

The functional tests shall verify proper operation of every specified system function as an integrated system. These tests shall be conducted in conjunction with functional tests of instrumentation and control panels as specified elsewhere. All failures or discrepancies found shall be documented in the test manual.

Following a failure of any functional test, should software or hardware modifications be required it shall be the decision of the Engineer whether the factory acceptance test is to continue, re-start or be aborted. If testing is allowed to continue, any changes which are required shall be described in a system modification document, signed by both Contractor and Engineer and shall be incorporated into the final factory acceptance test documentation. The failed test shall be re-conducted and the Engineer may require the retest of functions which may be affected by the modification.

The functional tests shall include, as a minimum, the following:

a) Demonstration that the system meets the requirements of the Specification for response time and speed of screen update;

b) Verification of the accuracy of all analogue input points in the system. The procedure shall include applying the appropriate signal to each analogue input at a minimum of three points within the range of the input, checking for expected numerical results, and verifying appropriate update of related mimic displays. Proper sensing and action by the system to high and low out-of-range inputs shall also be verified;

c) Verification of the proper logic sense, pulse accumulation and rate computation where appropriate, of all digital inputs and verifying appropriate update of related mimic displays;

d) Verification of all control and sequencing operations and proper operation of all digital and analogue outputs. The procedure shall include simulation of all related process variables for both normal and abnormal conditions, including instrument and component failure, and demonstration of fail-safe response of the system. System outputs shall be indicated with appropriate lamps and indicators;

e) Simulation of outstation communications errors and failures and demonstration of error detection and handling, failure detection and handling, and appropriate changes to control actions as designed and specified;

f) Verification of fault detection and diagnostics by inducing a sufficient variety of fault conditions in the system to ensure that detection processes and fail-safe operation are adequately tested;

g) Demonstration of proper operation of all mimic displays, help pages, reports, operator procedures and historical data accumulation;

h) Demonstration of proper operation of all outstations following a simulated master station central processor failure; and

i) Demonstration of proper operation of all equipment during both a system wide or isolated power failure, and following power restoration. The procedure shall include the demonstration of battery backup of both master station and outstation for the full length of time specified, and proper operation of power fail, low voltage warning and all associated alarms.

Reliability Test

After successful completion of the functional tests, a 48-hour continuous run of the system shall be performed. The test shall be passed if no system function is lost or no hardware or software failure occurs. Hardware failure is defined for this test as the loss of a major component such as the computer, an outstation, a VDU or a peripheral device. Non-repetitive mechanical failures of loggers, push-buttons and the like are excluded.

During this test, the system shall be exercised with simulated inputs and conditions in a manner which approximates the on-site operational environment. Unstructured testing by the Engineer shall be included during this test. Upon any system failure during this period, it shall be the decision of the Engineer whether the reliability test is to continue or be aborted. If testing is allowed to continue, any changes to the system which are required shall be described in a system-modification document, signed by both Contractor and Engineer and the document shall be incorporated into the final factory acceptance test documentation.

Factory Acceptance Test Documentation

As a minimum, the following information shall be included in the Factory Acceptance Test manual for each test:

- Test identification number;
- Test name and description;
- List of all equipment to be tested including any special test equipment required;
- Description of the test procedure broken down into logical steps;
- Description of the expected system response verifying the completion of each logical step;
- Space for recording the results of the test and the time and date of the test; and
- Space for signatures of the Contractor and the Engineer.

In addition, the Contractor shall provide a method for recording and tracing all problems, discrepancies, queries and suggestions regarding the system and software, and for formalised control of any modifications to the system.

Pre-commissioning Tests

The Contractor shall perform pre-commissioning, or preliminary, testing of the PLC system in accordance with that specified for instrumentation. The purpose of pre-commissioning tests is to confirm readiness of the system for commissioning.

The scope of pre-commissioning tests shall be generally as specified for factory acceptance tests but real field inputs and final control elements shall be used wherever practical to provide inputs to the system and to confirm proper outputs.

Where this is impractical, simulation signals shall be injected as near as possible to their ultimate sources so as to include in the tests as much of the cabling system as possible.

Each process system shall be set to work under manual control and the system tested to confirm proper operation. After proper operation of manual control mode has to be verified, tests of automatic controls of each process system shall be conducted wherever practical.

Commissioning

Site Acceptance Tests (SAT)

The Contractor shall submit all relevant draft operating manuals for the PLC System to the Engineer for approval prior to commissioning tests.

Any faults or failures of the system detected during the previous tests shall be noted and corrected to the satisfaction of the Engineer before commissioning is allowed to commence.

As part of commissioning, the PLC system shall be tested for availability for a continuous period of 60 days. During this period, the system will perform the normal functions according to the procedures described in the SAT documentation approved by the Engineer.

The system shall have passed the SAT if all major components have been free from fault or failure and exhibit full error-free functionality for 100 % of the total duration of the test, unless otherwise agreed by the Engineer. Major components include all master station equipment, outstations, communications facilities and instrument panel components, excluding push-buttons, switches and lamps and any equipment not supplied by the Contractor.

During SAT, no modifications to the system shall be made by the Contractor without the written approval of the Engineer. Erroneous functioning which requires software modifications or re-configuration to correct, other than set-point or parameter changes, shall constitute a failure of the availability test. Any changes to the system which are required and approved shall be described in a system-modification document, signed by both Contractor and Engineer and the

document shall be incorporated into the final test documentation. The test shall be restarted after corrections have been made.

16.15 Manufacturer's Works Acceptance Tests on Uninterruptible Power Supplies

The Contractor shall carry out further specified tests as follows, in addition to any tests stated or implied by the foregoing sections of this clause.

The tests shall be carried out on the fully assembled unit utilising the batteries that are to be supplied with the unit.

The Contractor shall demonstrate the following:

i. change-over from full load with mains present to full load on battery supply;

ii. carry out a discharge test on the system at full load and for the specified duty bridging time period; and

iii. carry out recharge test after operation for the specified duty bridging time at full load. The UPS shall supply the full load during the recharge cycle.

16.16 Inspection at Site

During erection of the Plant, the Engineer will inspect the installation from time to time in the presence of the Contractor's Supervisor to establish conformity with the requirements of the Specification. Any deviations found shall be corrected as instructed by the Engineer.

16.17 Plant Protection on Site

Factory finished plant shall be adequately protected both before and during installation against damage to finished surfaces, fitted components, and the ingress of dust. It may be necessary for structural finishing operations to be carried out in the vicinity of installed plant before it is taken over and the Contractor shall take this into consideration in complying with the requirement of this clause.

16.18 Erection Staff

The Contractor shall provide at least two approved senior English-speaking working erectors to supervise the erection of all Plant in the Contract and in each case to act as the Contractor's Representative as set out in Clause 13 of the general conditions of contract.

In the case of a foreign firm based overseas, the Contractor's Representative shall be thoroughly conversant with the manufacturer's Plant and equipment, and its erection and shall be an expatriate.

The Contractor shall also provide sufficient erectors skilled in electrical, mechanical and instrument engineering, with such skilled, semi-skilled and unskilled labour as are necessary to ensure completion of the various sections of the Contract in the time required. The Contractor shall not remove any supervisory staff or labour from the site without the prior approval of the Engineer.

The Engineer will give the Contractor at least one month's notice in writing of the date on which the erection staff will be required on site, and the Contractor shall confirm the date of arrival in writing to the Engineer. The Contractor shall make all the necessary arrangements to ensure that sufficient plant has been or is about to be delivered to site, so that there shall be no delay to the start of erection.

It shall be the responsibility of the contractor to obtain necessary license / authorisation/ permit for work from the licensing boards of the locality/state where the work is to be carried out. The persons deputed by the Contractor's firm shall also hold valid permits issued or be recognised by the licensing board of the locality/state where the work is to be carried out.

16.19 Erection and Building-in

The installation work shall comply with the latest applicable Standards, Regulations, Electricity Rules and Safety Codes of the locality where the installation is to be carried out. Nothing in this specification shall be construed to relieve the Contractor of this responsibility.

It shall be the Contractor's responsibility to obtain approval/clearance from local statutory authorities including the Electrical Inspector, wherever applicable for conducting of any work or for installation carried out which comes under the purview of such authorities.

The Contractor shall carry out the complete erection of all plant, including the provision of all necessary skilled and unskilled labour, material, transportation, supplies, power and fuel, Contractor's equipment and appurtenances necessary, for the complete and satisfactory erection of the Plant.

The Contractor shall have a separate cleaning gang to clean all equipment under erection and as well as the work area and the project site at regular intervals to the satisfaction of the Employer. In case the cleaning is not up to the Employer's satisfaction, he will have the right to carry out the cleaning operations and any expenditure incurred by the Employer in this regard will be to the Contractor's account.

Erectors

The Contractor's employees shall include skilled erection staff in sufficient number, who shall arrive on the site on or before the respective dates set out in the approved work programmed and prior to delivery of any item of Plant to the Site. The Engineer will not entertain any claim by the Contractor in respect of delayed erection due to a delay in the delivery of any items of Plant to the site.

Contractor's Equipment, Materials and Appurtenances

The Contractor shall have available on the Site sufficient suitable equipment and machinery, as well as all other materials and appurtenances required by him, of ample capacity to ensure the proper erection of Plant and to handle any emergencies such as may normally be expected in work of this character.

The Contractor shall be responsible if any installation materials are lost or damaged during installation. All damages and thefts of equipment/component parts, after takeover by the Contractor, till the installation is taken over by Employer shall be made good by the Contractor to the satisfaction of Engineer.

Workmanship

Plant shall be erected in a neat and workmanlike manner on the foundation and at the locations and elevations shown on the approved drawings and other engineering documents. Unless otherwise directed by the Engineer, the Contractor shall adhere strictly to the aforesaid drawings and no departures there from will be permitted.

All Plant shall be correctly aligned, levelled and adjusted for satisfactory operation and shall be installed so that the proper and satisfactory connection can be made readily between the various units and pipe work and equipment installed under the Contract. The mounting

arrangements for pump sets and blowers shall be such that the alignment offset between motors and the driven equipment shall be well within 0.1 mm.

Building-in

Erection of Plant shall be phased in such a manner so as not to obstruct the work being done by other contractors. Before commencing any erection work, the Contractor shall check the dimensions of structures where the various items of plant are to be installed, and shall bring any deviations from the required positions, lines or dimensions to the notice of the Engineer and shall take such measures as are necessary for their correction.

The Contractor shall take particular care for the correct positioning and alignment of all puddle pipes which are required through concrete structures prior to, and during the pouring of concrete. The Contractor shall pin and plug in the holes prepared, all small clips, plugs, screws, nails, sleeves, inserts, etc., required for fixing electric wires and conduits, small pipe work and all other apparatus.

The Contractor shall align all equipment and holding down bolts and shall inform the Engineer before proceeding with grouting-in the item or item concerned. The Contractor shall ensure that all equipment is securely held and remain in correct alignment before, during and after grouting-in.

The Contractor shall properly bed in cement grout each item of plant or its supporting base resting on foundations, and shall grout-in where required holding down bolts placed in the holes prepared in the foundations. The materials and workmanship used in grouting shall be such as will result in a solid anchoring of foundation bolts and complete filling of the gaps between the Plant or its base and the foundations, without shrinkage or cracking.

During erection of the Plant, the Employer will inspect the installation from time to time in the presence of the Contractor's Site representative to establish conformity with the requirements of the Specification. Any deviations and deficiencies found or evidence of unsatisfactory workmanship shall be corrected as instructed by the Employer.

All plant shall be installed in accordance with the recommendations or instructions of the manufacturer, for the particular application. Each mounting position shall be chosen to give correct operation of the equipment, ease of operation, access for maintenance and servicing and freedom from any condition which could have adverse effects.

Precautions

The approval by the Engineer of the Contractor's proposals for rigging and hoisting of any item of plant into its final position shall not relieve the Contractor from his responsibility for avoiding damage to completed structures, parts or members thereof or other installed equipment. He shall at his own cost make good, repair or replace any damaged or injured items whether structural, mechanical, electrical, architectural, or of any other description, promptly and effectively to the satisfaction of the Engineer.

No plant or other loads shall be moved across the floors of structures without first covering the floors with timber of sufficient size so that applied loads will be transferred to floor beams and girders of steel or concrete. If it is required to reduce bending stresses or deflection, the beam and girders shall be provided with temporary supports. Any movement of Plant and other loads over the floor structures shall be subject to the prior approval of the Engineer.

16.20 Tests on Completion

16.20.1 General

Prior to the commencement of Tests on Completion, the Contractor shall submit for approval the following:

a) As-built drawings;

b) Operation and Maintenance Manuals; and

c) Site test results / data sheet and photo.

Tests on Completion shall not be commenced until the aforementioned documents are approved.

The initial charges of oil, grease, electrolyte, generator fuel / oil, chemical, disposal of cake, etc. necessary for Tests on Completion shall be provided by the Contractor. Raw sewage and electricity required for Tests on Completion shall be provided by the Contractor. If necessary, the Contractor shall create design loading conditions for testing purposes by testing fewer than the total number of installed units of process tanks or equipment at a time. In such cases, multiple tests shall be conducted to ensure that all installed units are tested. In the event that raw sewage/influent wastewater is not available at the plant, the Contractor shall defer testing until such time as sewage becomes available for treatment as described elsewhere in these Bid Documents. The Contractor shall provide adequate notice (this notice period shall be determined by the normal lead time for locally purchased chemicals plus at least 28 days) of his chemical requirements prior to commencement of the Tests on Completion involving their use.

The cost of chemicals used for the Tests on Completion shall be met by the Contractor.

The inspection and tests procedure which will be carried out are provided under the general conditions of contract and shall also consist of the following:

Manual Commissioning Tests (Clause i)

Manual commissioning tests shall be such preliminary trials, tests and retests on individual items of Plant or complete systems as are required by the Engineer to demonstrate that the Plant as a whole is ready to undergo the Manual Operation Tests and that these will take place with a minimum of interruption.

The Manual Commissioning Tests shall demonstrate not only the items of Plant under normal operation, but also their response to abnormal and emergency conditions.

The Engineer will notify to the Contractor which items of Plant will be tested and the extent to which they will be tested in order to fulfil the requirements of the Specification.

Leakage tests at 1.5 maximum working pressure shall be carried out on all erected pipe work prior to the Manual Commissioning Tests.

Pump curves shall be available for the Manual Commissioning Tests and all instruments essential for the tests shall have been calibrated.

Manual Operation Tests (Clause ii)

When the Manual Commissioning Tests have been completed so that the items of Plant have been demonstrated to the satisfaction of the Employer Representative, the Contractor shall commence the Manual Operation Tests.

These tests shall demonstrate the correct operation of the whole Plant whilst using the minimum quantity of automatic control and monitoring equipment. Such equipment shall be at least that required both for the maintenance of safety and for the normal mode of operation of the Plant.

The Plant will be required to demonstrate satisfactory operation at all design flow rates.

The tests shall be of seven consecutive days' duration; if the supply of water should fail or other matters interfere outside the Contractor's control, the tests may be of such number of broken days as the Engineer considers is the equivalent.

The exact date of commencement shall be subject to the approval of the Engineer and shall be dependent on the following conditions having been met:

(1) All relevant items of Plant in approved working order; and

(2) All items of Plant correctly identified with labels.

Automatic Commissioning Tests (Clause iii)

The Automatic Commissioning Tests shall be such preliminary trials, tests and retests on individual items of Plant or complete system as are required by the Engineer to demonstrate that the Plant as a whole is ready to undergo the Tests of Completion and that these will take place with a minimum of interruption.

At least one week before commencement of these tests, the Engineer will notify the Contractor which items of Plant will be tested and the extent to which they will be tested to fulfil the requirements of the specification.

The Tests on Completion shall not be carried out until the completion of the above tests.

1) All pipe work shall be hydrostatically tested at site to a pressure equal to 1.5 times the maximum working pressure likely to be encountered in the system;

2) The Contractor shall carry out all tests on the Plant and shall supply four copies of all test results to the Engineer;

3) All tests shall be to the approval of the Engineer who may require them to be repeated, prolonged or modified as may be necessary to ensure that any or all items of Plant conform to the Contract; and

4) The Engineer shall be permitted to inspect all Plant which is undergoing tests and may himself conduct tests.

Where it is necessary for the Engineer to make arrangements for the supply of water, chemicals, power, etc., for any testing, the Contractor shall not commence the tests until after these arrangements have been made on or after a date agreed by the Engineer, and the Contractor shall make no claim for delay to such testing on this account except as provided for under Clauses 44 of the General Conditions of contract.

If any item of plant fails during or after testing to achieve its intended duty or otherwise proves defective, it shall be modified or altered as necessary and re-tested and re-inspected as required by the Engineer.

Vibration/noise level tests shall be carried out at site which will form basis for acceptance of the equipment. If the Contractor is not in a position to meet the requirements given below as per ISO 10816 – 1995, the equipment may either be rejected or the Contractor shall carry out all necessary modifications to keep vibrations within the acceptable limits specified.

Table 16-1 Acceptable Noise Limits

Equipment	Noise Level (dBA at 1.86 m from equipment)	Velocity of vibration (mm/sec)
All rotating equipment not having reciprocating parts with motor kW less than or equal to 15 kW	85	1.12
All rotating equipment not having reciprocating parts with motor kW more than 15 kW and less than or equal to 75 kW	85	1.8
All rotating equipment not having reciprocating parts with motor kW greater than 75 kW	85	2.8
All equipment having reciprocating parts viz. compressors, dosing pumps sampling pumps	85	-

The Contractor shall have a minimum of three commissioning engineers, one for process and plant and the others for mechanical/electrical/instrumentation works on site during all tests to both demonstrate the Plant and to correct any faults which may occur.

16.21 Dry Test Requirements

As a minimum requirement, the following dry tests shall be carried out as a general requirement:

1) general inspection to check for correct assembly and quality of workmanship;
2) check on the presence of lubricant, cooling medium, electrolyte, etc.;
3) check on adequacy and security of Plant fixing arrangements;
4) general check to ensure that all covers, access ladders, water proofing, guard railings etc. are in place;
5) check on damp-proofing, rust-proofing and vermin-proofing and particularly the sealing of apertures between building structures, chambers, etc. and the outside;
6) Civil and Building Works
7) As a minimum requirement, the following dry tests shall be carried out on the civil engineering and building works:
   - Check for the presence of foreign bodies in pipe work and structures.
8) Mechanical Works

   As a minimum requirement, the following dry tests shall be carried out on the mechanical systems:
   - Carry out preliminary running checks as far is permitted by circumstances to ensure smooth operation of Plant.
9) Electrical Works

   As a minimum requirement, the following dry tests shall be carried out on the electrical systems:
   - Check phasing and polarity;
   - Carry out point to point check on all cables;

- Check on security of cable terminations;
- Check on completeness and adequacy of earthing systems;
- Check setting on protection relays, sizes of fuses and motor overload settings;
- Carry out checks on cabling systems in accordance with the requirements of the relevant standards;
- Check operation of main circuit breakers by secondary injection methods;
- Check rotational direction of Plant;
- Check instrument loop integrity, functionality and calibration;
- Check operation of standby generator installation and mains / generator changeover procedures; a 4-hour load test (using the normal load of the Works) shall be carried out on the generator when the load is available;
- Check plant functionality; and
- Check functionality of the central MMI and its power supply.

16.22 Hydraulic Wet Test Requirements

Hydraulic wet tests shall be carried out on completion of dry tests.

Clear water shall be used for hydraulic wet tests. The purpose of the tests is to prove the hydraulic performance of the Works. To demonstrate this, the Contractor shall ensure that each part of the Works is hydraulically loaded to its rated throughput for a period of at least four hours.

To ensure a sufficient supply of water to carry out these tests, the Contractor shall provide all required facilities, including but not limited to any temporary facilities that may be required for storage and recycle of clear water or facilities for the disposal of the water off Site in an approved manner.

The following tests inter alia shall be carried out:

1) Pressure test all piped systems laid directly in the ground in accordance with the relevant standards;
2) Fill all structures to check for leaks;
3) Fill all storage vessels to check for leaks and distortion;
4) Run all pumped systems to check for;
    - Correct functionality;
    - Absence of leaks;
    - Correct running temperatures;
    - Smoothness of running and the absence of undue vibration or stress; and
    - Check drive running currents;
5) Carry out calibration of instruments where appropriate;
6) Carry out valve operation, diversions, etc. to fully hydraulically load each process element (or where there is a requirement to withstand an overload), overload each process element; and
7) Demonstrate correct functionality of electrical, control and instrumentation systems.

The Contractor shall simulate the conditions that will prevail when operating as a process to demonstrate the correct functionality of process control loops, etc.

During these tests, a check on the performance of Plant shall be made to compare its site performance with the factory test data and to identify any constraints on performance due to site conditions.

16.23 Safety Audit

After satisfactory completion of hydraulic wet tests and prior to introduction of process fluid to the plant, a safety audit shall be carried out to ensure compliance with the necessary requirement for safety and for operation of Plant. The safety audit shall be documented. The safety audit document shall be approved by the Engineer prior to commencement of Plant commissioning.

16.24 Co-operation with other Contractors in the Execution of their Tests

The Contractor shall, where required, assist other contractors in carrying out their tests on completion and or Tests after Completion.

Where this assistance does not constitute part of the Contractors own work associated with Tests on Completion or Tests after Completion, the Contractor shall be reimbursed at the rates approved by the Engineer.

APPENDIX A -TYPICAL DETAILS FOR CONTRACTOR'S DOCUMENTS

A.1 Civil

A.1.1 General

- Site layouts providing information on levels and detailing the location of proposed permanent and temporary works;
- Site layouts at the location of proposed permanent and temporary works providing information on levels and detailing the location of existing:
  - buildings
  - roadways and tracks
  - footpaths
  - drainage
  - buried pipelines
  - cable routes for direct in ground and ducted systems;
- plans, elevations and main sections of all structures and buildings
- general arrangements and main sections of all structures
- permanent and temporary drainage provisions
- general arrangement drawings
- detail drawings of:
  - shafts
  - manholes
  - buildings and architectural details
  - cable and pipework chambers
  - buried pipework
  - pipework connections
  - contract interface
- reinforcement drawings
- bar bending schedules;
- calculations for:
  - structural and civil design

A.1.2 Shaft Temporary Works

- Plan and Elevation / Sectional Elevation drawings showing proposed temporary support systems and construction sequences
- Calculations demonstrating the stability of the support system and the structural loadings on it
- Method statements detailing how the shaft will be constructed

- Details of safety provisions: Handrails, access ladders and walkways, mechanical lift systems and the like

A.1.3 Shaft Permanent Works

- General arrangement drawings, plans, elevations and sections showing the permanent structure
- Reinforcement drawings and schedules
- Structural Calculations
- Detailed drawings showing ladders, handrails, covers, ironwork generally
- Manufacturers technical data for HDPE and Polyurea liners together with supplier / applicator experience and other proprietary items.

A.1.4 Tunnelling

- Drawings of all liner elements for segmental liners or pipes
- Reinforcement drawings
- Concrete mix details
- Structural calculations for liners, including jacking forces and interjack details for microtunnelling
- General arrangement drawings for TBMs
- Full technical data for TBMs
- Technical data for drilling and grouting equipment
- Method statements for excavation

A2 DESIGN SUBMISSIONS - ASSESSMENT PROCEDURES

The Contractor's Design submissions will be assessed by the Employer's Representative within 28 days from the date of submission. The form and detail of the assessment shall be as determined by the Employer's Representative and according approval to a submission will not release or remove the Contractor's responsibility for the design under the Contract. The Submission will return along with the Comment Resolution Sheet (CRS), for the obtaining of a Notice to proceed from the Employer's. The submissions will be coded A or B or C or D or E, whose meaning is listed as below.

i. Code 'A' – Approved
ii. Code 'B' – Approved with comments. Work may proceed subject to incorporation of comments
iii. Code 'C' – Objected. Revise and resubmit. Work may not proceed
iv. Code 'D' – Rejected.
v. Code 'E' – Review not required. Work may proceed

(1) The issue of an approval shall be without prejudice to the issue of any future Notices.
(2) The Contractor shall, prior to the submission of the Design Data, obtain all required 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.

APPENDIX B – TRAFFIC MANAGEMENT PLAN

The Contractor shall submit a draft Traffic Management Plan, which shall form the basis for obtaining approval from the traffic police. The draft Traffic Management Plan shall include the following:

1. Introduction to the Contract
2. Salient Features of the tunnelling work shaft to shaft
3. The Traffic Management Plan shall be as per guidelines illustrated in IRC:SP:55-2001 "Guidelines on Safety in Road Construction Zones" published by the Indian Roads Congress
4. Existing Traffic Scenario
    - Peak hours / Time
    - Street Furniture – signals, stops, electric poles, panel boxes, utility boxes.
    - Junctions – Geometry / traffic
    - Road Condition Survey
    - Road width
    - Central medians
    - Footpaths
    - Encroachments
    - Road side shops / Garages / organized housings
    - Institutions - MCGM Pumping Stations / fire brigade / MTNL / Schools / Colleges / Religion Centres, etc.

1. Concept and Objective
2. Stage 3 Safety Audit (Completion of Detailed Design) (as per IRC:SP:88-2010 'Manual on Road Safety Audit')
3. Necessity of Alternate routes.
4. Current Status of Alternate route
5. Max. Carrying Capacity, overall traffic scenario
6. Design Criteria / Design of the Designated Route
    - Safety Clearances
    - Lane Widths
    - Length of Works
    - Aspects of the area considered in the design
    - Design parameters
    - Speed Control / Temporary Speed Limits
    - Use of Delineators
    - Use of Safety Barriers

- Pedestrian Path
- Pedestrian Barriers
- Pedestrian Crossings
- Temporary Road Markings and Studs
- Warning Lights
- Diversions / Road Closures
- Junctions with Working Areas
- Surface Condition / Maintenance
- Carriageway Edge Conditions (Hard shoulders are used for traffic)
- Works Access and Exit
- Routes for construction vehicles
- Material Storage
- Loading and Unloading of materials
- Installation of Traffic Signal and Maintenance
- Removal of Traffic Management
- Working at Night
- Working in an adverse weather condition

1. Traffic Signs and Road Markings
    - Size and Sitting of Signs
    - Advance cautionary / warning signs
    - Informatory signs
    - End of Road Works Sign
    - Existing signs and markings
2. Dual Carriageway Road
    - Use of Hard Shoulder
    - Use of Narrow Lanes
    - Contra Flow Operation
    - Cross Over
3. Emergency Procedures
4. Traffic Route Safety Control Measures
5. Trespassing onto site
6. Route Signage
7. Parking on Site, contractors vehicles
8. Conclusion

APPENDIX C. PROCEDURES FOR CONSTRUCTION PERMIT

In addition to compliance with the MCGM Guidelines for Trenching Activity, the procedures for obtaining construction permit from MCGM are outlined below:-

*1 Apply for NOC from Tree Authority

*2 Receive inspection from Tree Authority

*3 Obtain NOC from Tree Authority

*4 Request and obtain NOC from Storm Water and Drain Department

*5 Request and obtain NOC from Sewerage Department

*6 Request and obtain NOC from Electric Department

*7 Request and obtain NOC from Environmental Department

*8 Request and obtain NOC from Traffic & Coordination Department

*9 Request and obtain NOC from CFO

*10 Request and obtain completion NOC from Tree Authority

*11 Request and obtain completion NOC from Storm Water and Drain Department

*12 Request and obtain completion NOC from Sewerage Department

*13 Request and obtain completion NOC from Electric Department

*14 Request and obtain completion NOC from Environmental Department

*15 Request and obtain completion NOC from Traffic & Coordination Department

*16 Request and obtain completion NOC from CFO

17 Request and receive competition inspection from BMC

18 Obtain Completion Certificate

* Takes place simultaneously with another procedure

APPENDIX D. ENGINEER'S ACCOMMODATION FOR THE CONTRACT PERIOD

E.1Accommodation

Type	Minimum Area (each)
Engineer's Office (with A/C)	15m^2
Assistant Engineer's Office (with A/C)	12m^2
Secretarial/Admin Office (with A/C)	12m^2
General Offices (Double) 2 Nr. (with A/C)	12m^2
Meeting Room (with A/C)	20m^2
Store Room (with A/C)	4 m^2
Kitchen (with A/C)	12 m^2
WC (2 no.)	4 m^2
Shower Rooms (2 no.)	4 m^2
Changing Rooms (2 no.)	12 m^2

E.2Office Equipment and Supplies

Accommodation to be fitted out as required by the Engineer. All equipment shall be new.

Item	Nr.
Office desk min. size 1.5m x 0.85m with 3 drawers	5
Arm chairs swivel type	10
Swivel chairs (no arms)	5
Table 1.5m x 0.85m	10
Stacking Chairs	10
A0 drawing hangers complete with A0 hangers.	4
Four drawer suspension type filing cabinets	8
Shelving 225mm wide	50m
Plan chest A0 size, 6 drawers	1 no.
15" Rotating Electric fans	10 Nr.
Wastepaper bins	15 Nr.
Boot scraper	1 no.
Boot brush and waist height handle	1 no.
Pin-up boards and pins	5 Nr.
Door mats	5 Nr

Item	Nr.
Coat hooks	30 Nr
A3/A4 high speed photocopier	1 no.

E.3Equipment

The Contractor shall provide the following equipment for the exclusive use of the Engineer and staff for the duration of the Contract Period.

The equipment shall be suitable for use in a tunnel environment.

The equipment shall be new and from an approved supplier. The Contractor shall supply current calibration certificates for survey equipment and shall maintain, calibrate and insure the equipment through the Contract Period to ensure that it is at all times in good repair and adjustment and shall make good any loss or damage howsoever caused.

Item	Nr.
Total Station and ancillaries of approved manufacture	1
Automatic level, tripod and 5m staff of approved manufacture	1
Ranging rods, 2m long and coloured red/white	6
Steel 50m tape	1
Fibre 50m tape	1
5m steel pocket tapes	8
1m spirit level	1
Maximum/Minimum thermometer	2
High powered waterproof battery inspection lamp	2
Hand held noise measurement device and recharging unit, with LAeq. and Max. sound level capabilities	1
Sledge Hammer	1
Lump Hammer	1
Marker paint	
Wooden pegs	
Survey Books	

E.5Protective Clothing

The Contractor shall provide the following protective clothing for the exclusive use of the Engineer and staff.

Item	Nr.
Gortex or equivalent Waterproof coats and leggings	8
Reflective jackets	8
Disposable Overalls	4
Work Boots steel toe capped	8
Wellington or equivalent boots steel toe capped + Sole lined	8
Hardhats	20
Ear plugs, pairs	100
Gloves	20

E.6Kitchen Equipment

The Contractor shall equip the kitchen with the following items:

Item	Nr.
Fully plumbed stainless steel sink and draining board	1
Work top	$3m^2$
Stools	8
Cupboard	1
Refrigerator	1
4 ring gas burner	1
Microwave oven	1
Kitchen Table	1
First Aid box	1
Mugs	20 sets
Plates and cutlery	10 sets
Washing up bowl	1
Tray	1
Dustpan, brush	1
Soft broom	1
Hard Broom	1
Waste Bin	1
Bucket and mop	1

E.7Stationery & General

The Contractor shall provide stationery and general consumable office supplies for the sole use of the Engineer and staff. The cost of providing these items shall be recoverable on verification

of receipts by the Engineer against the relevant provisional sums. The Contractor shall ensure these items are procured at competitive rates from an approved source.

- Postage stamps
- A3/A4 Paper
- Batteries
- Pens/Pencils
- Filing ancillaries
- A4 Refill pads
- A3/A4 Envelopes
- Notebooks
- Washing up liquid
- Hand towels
- Soap
- Hand Cleanser
- Paper towels
- Replacement items for first aid box
- Barrier Cream
- Disinfectant
- Cleaning materials