BRIHANMUMBAI MUNICIPAL CORPORATION

Mumbai Sewage Disposal Project
Stage II - Priority Works
Priority Sewer Tunnel – Phase 2

BID DOCUMENT

FOR

PRIORITY SEWER TUNNEL – PHASE 2

Design and Build Contract

Bid No. – 7200036535

VOLUME – II

EMPLOYER'S REQUIREMENTS

EMPLOYER

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Municipal Head Office Building,
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India

CONSULTANT

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SEPTEMBER 2022

PRIORITY SEWER TUNNEL PHASE - 2

DESIGN-BUILD CONTRACT

LAYOUT OF THE DOCUMENTS

This volume is one of several that comprise the documents.

	Instructions to Tenderers
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1 DEFINITIONS

Drawings – The Employer's design, as provided in Volume IIB 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

KPI – Key Performance Indicators

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 contains the Employer's Requirements for the 'Priority Sewer Tunnel – Phase 2' Contract. The Contractor shall ensure that the Works are in accordance with the Employer's Requirements.

The general technical specifications are included in the General Specification (Volume IIA) and describe the general requirements of non-tunnelling works. Volume IIC contains the Contract drawings (herein defined as 'the Drawings'). By reference in this clause, Volumes IIA and IIC form part of the Employer's Requirements.

The work shall be executed in accordance with the best modern practices using special techniques and conforming to relevant IS codes.

If there is a conflict between the specific requirements of this Volume II and the general technical specifications and drawings in Volume IIA and IIC, then the specific requirements of this Volume II take precedence.

2.2 Background to the Contract

This contract forms part of the Mumbai Sewage Disposal Project Stage II - Priority Works. The basic objective of the project is to provide a healthier and improved environment for the people of Mumbai by improving the quality and reliability of wastewater collection, treatment and disposal, whilst minimizing the impact of wastewater on the environment.

The sewage collection system, the wastewater treatment, and the effluent disposal systems in Mumbai comprise seven zones, each operating independently and comprising a sewage collection network, pumping stations, rising mains and wastewater treatment facilities.
Zone 5 of Mumbai's sewage collection system includes a collector sewer under Link Road and pumping stations at Vallabhnagar, Gorai, Shimpoli, Charkop, Goregaon and Malad, which deliver flows to Malad Wastewater Treatment Facility (WwTF).

The Priority Sewer Tunnel project has been designed to increase capacity of the existing sewage collection system in Zone 5, while permitting the decommissioning of existing pumping stations by delivering sewage flows by gravity to the proposed Malad Influent Pumping Station (IPS) at Malad WwTF. The Priority Sewer Tunnel is intended to act as a deep collector sewer for all sewage flows on Link Road; it shall be constructed using trenchless technology and carried out in two phases:

'Priority Sewer Tunnel – Phase 1' ('the Contract) includes a 3,200mm diameter sewer tunnel on Link Road from Don Bosco Junction to Malad Pumping Station with a 1,000mm diameter branch sewer tunnel from Gorai Pumping Station, and a 3,200mm diameter sewer tunnel from Malad Pumping Station to the proposed Malad IPS at Malad WwTF, plus associated shafts and upstream connections. This will reduce flows entering the existing collector sewer and permit the decommissioning of the Employer's existing pumping stations at Gorai, Shimpoli, Charkop and Malad. The Phase 1 Works will be the subject of a contract carried out by others.

'Priority Sewer Tunnel – Phase 2' is a 2,600mm diameter sewer tunnel on Link Road from Goregoan Pumping Station to Infiniti Mall and onwards to the proposed Malad IPS via a 2,600mm diameter sewer tunnel. This will reduce flows entering the existing collector sewer and permit the decommissioning of the Employer's existing pumping station at Goregaon.

Sewage flows will be diverted to the Priority Sewer Tunnel – Phase 2 under the 'Malad IPS' contract, which includes construction of a new pumping station at Malad WwTF and screening facilities at existing pumping stations adjacent to the Priority Sewer Tunnel. This contract will be the subject of contract carried out by others.

2.3 Responsibility for Design

The responsibility for design of the Works is split between the Employer and the Contractor in accordance with the following allocation of responsibility:

Party	Design Responsibility
Employer	• General Arrangement of Tunnel Shafts and Screen Chamber • Hydraulic design of the Permanent Works
Contractor	• All other works

2.4 Description of the Works

The Works required under the Contract includes the supply of material, labour, equipment, permits, consumables, Temporary Works, site offices, and all other requirements necessary for the construction of the Permanent Works shown on the Drawings, and in accordance with the Employer's Requirements.

The Permanent Works consist of a number of sewers to be constructed using trenchless technology, which shall be segmental tunneling, and associated structures.

The word tunnelling in this Contract shall be interpreted as the installation of formed segmental lining pipelines by using a 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 comprises the following:

a) Design and construction of 2600mm Internal Diameter (ID) tunnel by segmental lined bored method from Tunnel Shaft S08 (Existing Malad WWTF) to Tunnel Shaft S12 (Goregaon PS on Link Road), of total estimated length 4.75 km.

b) Design and construction of 1,800mm ID tunnel by microtunnelling/Pipe Pushing and Jacking method from Tunnel Shaft DS12 to Tunnel Shaft S12 (Goregaon Bus Depot) of estimated length 60m and 1,400mm ID from DS09 to S09 at Malad bus depot of estimated length 30m.

c) Structural design including detailing of reinforcement for the Permanent Works.

d) Design and Construction of all Permanent Works (and any temporary works provided by the Contractor), to the general arrangement and levels shown on the Drawings.

e) Design & Construction of two (2) Drop Shafts no. DS09 and DS12. Numerical modelling of DS09 shall be done by contractor

f) Design & Construction of seven (7) permanent Segmental Tunnel shafts no. S08, S08A, S09, S09A, S10, S11 and S12.

g) Design and construction of Assembly and tail tunnel based on design & methodology of construction.

h) Design & Construction of Four (4) screen chambers S08/SC08, SC09, SC11 and SC12.

i) Design and Construction of all upstream feeder sewers ,manholes, Diversion chambers etc by open-cut method, microtunnelling or pipe pushing & jacking or conventional tunnelling as shown in drawings Volume IIC.

j) PU coating shall be provided in all shafts and all Screen Chambers.

k) Design, Procurement, Installation and commissioning of all Motorised Bar Screens and Sluice Gates, Electric Hoist, Flap Gates, Manual Bar Screens, Belt Conveyor along with electrical works required for successful completion and commissioning of the project.

l) Design, construction, testing and commissioning of 5m ID tunnel by NATM (New Austrian Tunneling Method) as shown on drawing.

m) Design, construction, testing and commissioning of 3m ID tunnel (both horizontal and vertical combined)- by NATM (New Austrian Tunneling Method) as shown on drawing.

n) 1200mm ID stub pipe of length 10m shall be provided at shaft S08A to connect future microtunnel along Lagoon road.

o) Design, construction of Screen operator cabin for screen chambers S08/SC08, SC09, SC11 and SC012.

p) Identification and confirmation of the line and level of existing sewers at each Tunnel Shaft location to facilitate future connections.

q) Identification and protection or diversion of all utilities (including communications, electrical HV and LV cables/chambers, water mains, storm water drainage channels and pipelines etc) within each work site as required. Utilities marked if any on the drawings are indicative only.

r) Provision of temporary power for construction period and Tests on Completion, including all commissioning.

s) Ensuring 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.

t) Restoration of work sites.

u) Conducting all Tests on Completion in accordance with these Employer's Requirements.

v) Submission of as-built documentation and any other documents as required by the Contract.

w) Handover of the completed Works to the Employer.

x) Contractor shall carry out the work of tunnel boring operation with high precision where tunnel alignment is passing very close to existing Metro II piles.

y) The dimensions like length, dia etc. of proposed upstream sewer lines given in tender drawings Volume IIC are indicative only. Exact dimensions shall be determined by the contractor during execution and work of the same shall be completed in the contractors quoted price.

The Works are located along an extremely busy road (Link Road), with approximately 0.4 km of tunnel passing under environmentally sensitive mangroves.

The works proposed within shaft sites and in the proposed tunnel corridor are in close proximity to private properties, adjacent to metro corridor and below ground services as indicated in the Drawings. Services shown on the Drawings should not be considered complete and accurate representation of all services and the Contractor must carry out its own 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.

The wet commissioning of the project will be undertaken by a separate contract approximately two years after Handover of the completed Works to the Employer. Prior to this the Permanent Works will be idle other than any correction of defects by the Contractor during the Defects Notification Period.

2.5 Deleted

2.6 Other Contracts

2.6.1 Mumbai Sewage Disposal Project Contracts

The Employer intends to progress other contracts 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 he carries out his activities with minimal impact on these other contracts.

(a) Priority Sewer Tunnel - Phase 1

As described in Section 2.2, Phase 1 is the northern section of the Priority Sewer Tunnel and is to be constructed between Don Bosco Junction on Link Road and Existing Malad WwTF. The type of construction work will be similar to Phase 2.

(b) Malad Influent Pumping Station

The scope of this contract is to provide a new influent pumping station (IPS) that will lift flows from the Priority Sewer Tunnel to the preliminary treatment section of a new wastewater treatment facility (WwTF) to be constructed under a separate contract.

2.6.2 Mumbai Metro Line 2

Mumbai Metropolitan Region Development Authority (MMRDA) is presently constructing the Mumbai Metro Line 2 on overhead piers along Link Road with piers located along the centreline and edges of the road. The Tunnel alignment is also proposed along the metro alignment as shown in Volume IIC (Tender drawings). Contractor shall carry out the work of tunnel boring operation with high precision where tunnel alignment is passing very close to existing Metro line-2 piles. In addition contractor shall take all care by continuous monitoring of the tunnel alignment so that the tunnel progresses without deviations and surface settlements.

The Contractor should allow for liaison and sharing the workspace with the Mumbai Metro Line 2 contractor. The Contractor shall minimise the work overlap of the tunnel with the metro works and the Contractor shall be responsible for ensuring there are no clashes between the tunnels Works and the construction of the Metro II contract. When requested to the Contractor and the Engineer shall communicate all relevant details to MMRDA/DMRC throughout the design and construction of the works.

2.7 The Site

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 the 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.

In addition to the tunnels, the Site includes seven (7) tunnel shafts and and two(2) Drop Shafts and four (4) screen chambers.

The route of the tunnels predominantly consists of busy trafficked streets together with approximately 0.4km of tunnelling work below an area of mangrove, where access is restricted, in addition to one site owned by the Employer and part of a site is located within a bus depot owned and operated by the transportation wing of Brihanmumbai Electric Supply and Transport Undertaking company (BEST).

The Contractor's attention is drawn to the fact that the work sites are located on or adjacent to busy trafficked public roads, passages, private rights of way and access passages, where access must be maintained.

When carrying out 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 Contractor shall ensure that the Works are carried out as per the Employer's Requirements.

3 PARTICULAR REQUIREMENTS

3.1 Tunnel Alignment

The position, location and size of the permanent shafts, described in Section 3.12, may vary slightly in the contractors final alignment. If any change in location of shaft/alignment of tunnel due to Metro 2A alignment, no extra cost shall be paid to the contractor.

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.

The Contractor may if he wishes install further temporary or permanent tunnel shafts. 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 contractor cost.

Segmental tunnelling and microtunnelling, pipe pushing & jacking and conventional tunnelling are the methods of construction.

The tunnels shall only be constructed within the right of way under the public roadway and footpaths, shaft areas identified on the Drawings, and the right of way identified between S10 and S12 on the Drawings. Further restrictions to the right of way may be enforced following the Contractor's pre-construction survey of existing structures along the alignment, as detailed in Section 14.4.2.

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.

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.

Completion works at temporary shafts shall be carried out as per drawing Volume IIC and as agreed with the Engineer.

3.4 Deleted

3.5 Structural Design of the Permanent Works

Reinforced concrete for tunnel segmental linings, jacking pipes and all permanent structures shall comply with Sections 15 and 16 of this Employer's Requirements. The tunnelled sewer system is designed to normally operate with partial flow conditions, ie, 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, ie, to a maximum of approximately 20m 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 fly ash 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):	550
Maximum Water Cement Ratio:	0.35
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

Clear cover of concrete to all structural members shall be 50mm minimum except for footpath and pedestrian pathways. The foundation shall be provided with 75mm minimum clear cover if directly provided on soil without mud mat.

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

M–40: - Pavements

M–20: - PCC bedding, benching etc. as per IS 456

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

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.

Skin frictional force shall not be considered for the uplift check in design of all permanent structures.

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

Minimum thicknesses of the permanent concrete structural elements shall be provided as specified below, even if not required from a structural design point of view.

Shaft Wall	- 400 mm
Shaft Bottom Slab	- 500 mm
Shaft Top Slab	- 300 mm
Precast Tunnel Segment	- 200 mm
NATM Tunnel Lining	- 300 mm

3.6 Polyurea'-

Poly urea coating shall be provided to all shafts and screen chambers.

Polyurea Coating

3.6.1 General

Where specified Polymer urea (Polyurea) coat of suitable approved makes conforming to the relevant ASTM/BIS standards and the technical properties stated therein.
Application methodology shall be as per the manufacturer's specifications or as approved by Employer
The internal or external concrete surfaces where ever required to be coated shall be coated with the Polyurea coating to a minimum 1.5mm thickness. The protective coating shall be Polyurea, a 100% solids, flexible, two components, rapid curing, pure Polyurea coating system providing high corrosion, abrasion and thermal shock resistance.

3.6.2 Technical properties

The Polyurea coating shall meet the following technical properties:

1	Solids by volume	100%
2	Density at 25deg C	1.01 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.

3.7 Feeder Sewers

The Contractor shall construct the upstream feeder sewers, manholes, diversion chambers, outfall channel, outfall chamber etc. The diameters, lines and levels of these are detailed on the drawings associated with the individual site areas described in Section 3.12. They shall be constructed with precast concrete pipes, by microtunneling , pipe jacking and pushing or by open trench excavation. The contractor shall lay the cross feeder sewers in between the metro piers by keeping safe distance from the metro piles.

Where the feeder sewers are to be installed by open trench excavation the precast concrete pipes shall be NP3 grade and in accordance with the General Specification (Volume IIA).

Where the feeder sewers are to be pipe jacked the precast concrete pipes shall be manufactured in accordance with Section 16.2 of the Employer's Requirements.

3.8 Stub Pipes

Stub pipe shall be provided at shaft S08A. They shall be constructed with precast RCC pipes by open trench excavation and the precast RCC pipes shall not be lower than 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 as shown on the Drawings, and as detailed on drawing Volume IIC

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 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 covers shall be as shown on drawing Volume IIC . 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, as 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 7.8.1.

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 7 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 and 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 a number of bridges on Link Road. It is understood that all of these bridges are constructed as RCC box culverts, but no additional details have been provided. Prior to commencing his tunnelling works the Contractor shall confirm the location of these bridges and obtain structural details and inform the same to the Engineer

3.12.2 **Work Site S12 & SC12**

The Works at Work Site S12, DS12 & SC12 include Tunnel Shaft S12, screen chamber SC12. Drop shaft DS12 and upstream sewers, manholes, diversion chambers, auxiliary works etc. as shown on the Drawings.

The location of Work Site SC12 is shown on drawing Volume IIC. The Site includes an area within the Employer's Goregaon Pumping Station site.

The location of Work Site S12 is shown on drawing Volume IIC. The Site includes an area within the Goregaon bus depot site adjacent to Link Road. *It is a tentative location, MCGM requested BEST for giving space in the Depo for shaft construction.*

The Employer's existing pumping station is adjacent to the construction works and to the west of the Site are single storey residential / commercial buildings. The Contractor shall take this into account when designing his temporary works and shall monitor settlement throughout construction to ensure there is no damage to the Employer's facilities and to private property.

The location of the Permanent Works has been selected to permit continuous operation of the existing sewage system until commissioning of the Priority Sewer Tunnel.

Details of the existing pumping station site and the limits of the Contractor's site are shown on the existing site layout drawing Volume IIC.

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. The temporary barrier shall be of equal height to that which is to be demolished.

The Contractor shall permit the existing pumping station to remain in operation, throughout the construction works and Tests on Completion.

Reinstatement of cement concrete/asphalt roads, footpaths etc. after completion of permanent and temporary works.

The existing structures to be removed shall be demolished down to 2m below ground level and backfilled with compacted selected earth of 98% Standard Proctor Density.

The Contractor shall remove trees found during survey of the site area which directly interfere with the construction activity. The Contractor shall be responsible for the protection of all trees within the area. Tree cutting/ transplantation / relocation of trees shall be done as per Tree Authority Guidelines and Section 5.6 as well in consultation with the Employer. The permission for tree cutting shall be obtained by the contractor from Tree Authority of MCGM.

The Contractor shall note the existing underground utilities as indicated in Drawings and shall protect them. The Contractor shall divert the existing utilities encountered during construction as per Technical Specifications (Section 6.15 6.16 and 6.17). However if additional underground utilities are discovered during construction work the Contractor shall divert the existing utilities as per Technical Specifications (Section 6.15 6.16 and 6.17).

3.12.3 **Work Site S11**

The Works at Work Site S11 include Tunnel Shaft/ screen chamber S11/ SC11 and upstream sewers, manholes, diversion chambers, auxiliary works etc. as shown on the Drawings.

The location of Work Site S11 is shown on drawing Volume IIC. The site is located in a in Mahada plot, with undeveloped private land immediately adjacent to the site. *It is a tentative location, MCGM requested MHADA for giving space for shaft construction.*

The location of the Permanent Works has been selected to permit continuous operation of the existing sewage system until commissioning of the Priority Sewer Tunnel.

Reinstatement of cement concrete/asphalt roads, footpaths etc. after completion of permanent and temporary works.

The existing structures to be removed shall be demolished down to 2m below ground level and backfilled with compacted selected earth of 98% Standard Proctor Density.

The Contractor shall remove trees found during survey of the site area which directly interfere with the construction activity. The Contractor shall be responsible for the protection of all trees within the area. Tree cutting/ transplantation / relocation of trees shall be done as per Tree Authority Guidelines and Section 5.6 as well in consultation with the Employer. The permission for tree cutting shall be obtained by the contractor from Tree Authority of MCGM.

The Contractor shall note the existing underground utilities as indicated in Drawings and shall protect them. The Contractor shall divert the existing utilities encountered during construction as per Technical Specifications (Section 6.15 6.16 and 6.17). However if additional underground utilities are discovered during construction work the Contractor shall divert the existing utilities as per Technical Specifications (Section 6.15 6.16 and 6.17)

3.12.4 **Work Site S10**

The Works at Work Site S10 include Tunnel Shaft S10 and upstream sewers, manholes, diversion chambers, auxiliary works etc. as shown on the Drawings.

The location of Work Site S10 is shown on drawing Volume IIC. The site is located in at Infinity mall junction.

The location of the Permanent Works has been selected to permit continuous operation of the existing sewage system until commissioning of the Priority Sewer Tunnel.

Reinstatement of cement concrete/asphalt roads, footpaths etc. after completion of permanent and temporary works.

The existing structures to be removed shall be demolished down to 2m below ground level and backfilled with compacted selected earth of 98% Standard Proctor Density.

The Contractor shall remove trees found during survey of the site area which directly interfere with the construction activity. The Contractor shall be responsible for the protection of all trees within the area. Tree cutting/ transplantation / relocation of trees shall be done as per Tree Authority Guidelines and Section 5.6 as well in consultation with the Employer. The permission for tree cutting shall be obtained by the contractor from Tree Authority of MCGM.

The Contractor shall note the existing underground utilities as indicated in Drawings and shall protect them. The Contractor shall divert the existing utilities encountered during construction as per Technical Specifications (Section 6.15 6.16 and 6.17). However if additional underground utilities are discovered during construction work the Contractor shall divert the existing utilities as per Technical Specifications (Section 6.15 6.16 and 6.17).

3.12.5 **Work Site S09**

The Works at Work Site S09 consists of Tunnel Shaft S09, drop shaft DS09 and screen chamber SC09 and upstream sewers, manholes, diversion chambers, auxiliary works etc. as shown on the Drawings.

The location of Work Site S10 is shown on drawing Volume IIC. The site is located at Malad bus depot.

The location of the Permanent Works has been selected to permit continuous operation of the existing sewage system until commissioning of the Priority Sewer Tunnel.

Reinstatement of cement concrete/asphalt roads, footpaths etc. after completion of permanent and temporary works.

The existing structures to be removed shall be demolished down to 2m below ground level and backfilled with compacted selected earth of 98% Standard Proctor Density.

The Contractor shall remove trees found during survey of the site area which directly interfere with the construction activity. The Contractor shall be responsible for the protection of all trees within the area. Tree cutting/ transplantation / relocation of trees shall be done as per Tree Authority Guidelines and Section 5.6 as well in consultation with the Employer

The Contractor shall note the existing underground utilities as indicated in Drawings and shall protect them. The Contractor shall divert the existing utilities encountered during construction as per Technical Specifications (Section 6.15 6.16 and 6.17). However if additional underground utilities are discovered during construction work the Contractor shall divert the existing utilities as per Technical Specifications (Section 6.15 6.16 and 6.17).

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3.12.6 **Work Site S08/SC08**

The Works at Work Site S08 consists of Tunnel launch Shaft S08 which will also act as screen chamber to proposed Malad IPS as shown on the Drawings.

The location of Work Site S08 is shown on drawing Volume IIC. The site is located at existing Malad WwTF.

The location of the Permanent Works has been selected to permit continuous operation of the existing sewage system until commissioning of the Priority Sewer Tunnel.

Reinstatement of cement concrete/asphalt roads, footpaths etc. after completion of permanent and temporary works.

The existing structures to be removed shall be demolished down to 2m below ground level and backfilled with compacted selected earth of 98% Standard Proctor Density.

The Contractor shall remove trees found during survey of the site area which directly interfere with the construction activity. The Contractor shall be responsible for the protection of all trees within the area. Tree cutting/ transplantation / relocation of trees shall be done as per Tree Authority Guidelines and Section 5.6 as well in consultation with the Employer

The Contractor shall note the existing underground utilities as indicated in Drawings and shall protect them. The Contractor shall divert the existing utilities encountered during construction

as per Technical Specifications (Section 6.15 6.16 and 6.17). However if additional underground utilities are discovered during construction work the Contractor shall divert the existing utilities as per Technical Specifications (Section 6.15 6.16 and 6.17).

Upon completion of the works at this site the site will be handed over to the Employer.

The details of the finishing at the Employer's site shall be as per the General Specification (Volume IIA).

3.12.7 **Identification of Existing Sewers**

The Contractor is required to identify and confirm the line, level and internal diameter of existing sewers as given in the below table and as indicated on the Drawings.

Tunnel Shaft	Upstream manhole reference	Downstream manhole reference	Upstream manhole invert level (m THD)	Downstream manhole invert level (m THD)	Internal diameter of sewer (mm)
S09	14334501	14334502	23.15	22.91	1,800
S11	14313903	14323001	23.72	23.42	1,200
S12	14303405	Wet well 1	T.B.C.	T.B.C.	T.B.C.
	14302302	Wet well 2	19.80	T.B.C.	T.B.C.

The Contractor is required to carry out the above survey and submit the results to the Engineer prior to completion of his Temporary Works and Permanent Works designs.

3.12.8 **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 as detailed in drawing . All backfilling of excavations and trenches shall be subject to the acceptance of the Engineer.

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 Engineer. Site grading and surface reinstatement at the Employer's sites shall not be included in the Contract because it is intended that upon completion of the Contract the 'Malad IPS' contractor will move onto the Site to commence his works.

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.

Additional Employer requirement

(a) 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.

(a) 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., Mumbai Metro and 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.

(b) 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.

(b) 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.

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

(d) 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.

(e) 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.

(f) 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.

(g) 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.

(h) 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.

(i) 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.

(j) 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.

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

(l) 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.

(m) 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.

(n) 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.

(o) 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.

(p) 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.

(q) No extra or additional payment will be made to the contractors for backfilling and reinstatement of the pits (Jacking, Receiving and pits excavated for manholes etc.) which may be required to be closed before upcoming monsoon and for re-opening of the same pits after monsoon.The contractors shall programme/plan the work accordingly.

~~(r)~~ The contractor should provide sufficient number of security guards on site for 24 x 7 till the completion of work. The contractor should make arrangement for safeguarding / filling the cavities which may occur at the time of execution of work and Soil stabilization work wherever necessary.

(s) The tenderer should not stack or deposit the materials including the excavated materials on the footpaths, road which will affect the day to day cleanliness of the roads/footpath. If it is found that the materials stacked / deposited by any of the M.C.G.M. agencies, a heavy fine, as per the Bye-Laws "construction, Demolition, Desilting Waste (Management & Handling) Rules-2006" including the other penalties will be imposed.

(t) If it is observed that, the contractor carrying out the work fails to comply with the instructions given by the Engineer /agency appointed by Employer for supervision of the work during execution of work, penal action will be taken against him and if necessary the work will be carried out at the risk and cost of the contractor.

(u) If during the execution of work of tunneling, TBM gets stuck then contactor shall be responsible for taking out the machine and commence the work at the earliest.

(v) Field Laboratory

Contractors shall set up a laboratory at site before commencement of work at their cost for performing various tests and at least the following machines and equipments shall be provided therein –

a. Set of Sieves as per I.R.C. /I.S.
b. Compressive Testing Machine (For new works)
c. Oven, Electrically Operated
d. Weighing Balance (20 kg capacity)
e. Sieve shaker
f. First Aid Box
g. Measuring Jar (for silt content)
h. Other Machines/apparatus as may be directed by the Engineer
i. Vernier Caliber
j. Level / Theodolite
k. Any other testing equipment required for execution of work.

All the test records shall be maintained in the site office and made available as and when required. The laboratory must be established within 30 days from the date of receipt of the orders from Engineer.

The contractor shall install testing equipment at site. The contractor shall ensure and certify the calibration of the equipment so installed and shall maintain the same in working order throughout the period of construction. The contractor shall also provide necessary technically qualified experienced trained staff for carrying out such tests for using such equipment. The tests shall be carried out under the supervision of the Engineer. The calibration shall be checked every twelve months as directed by Engineer-in-charge.

(w) Contractor shall install CCTV camera at each work site in progress and ensure that they are in working condition.

(x) Contractor shall protect trees nearby work site to the extent possible.

(y) Loads of asphalt mix brought on dumpers shall be fully covered with tarpaulin.

(z) While laying asphalt mix layers on the existing road surface, care shall be taken to ensure that no manhole or chamber covers of drainage, etc. are buried or kept higher than road surface. They shall be first identified and raised or lowered to be flushed with final asphalt surface.

(aa) Field Density test shall be taken in Asphalt mix, W.M.M.,D.B.M and GSB. In case of failure of field density of Asphalt mix, the area represented by the sample has to be removed and redone

(bb) Contractor is required to send at least one sample per day up to 50 M.T. and at the rate of one sample for every additional 50 M.T or part thereof per day for asphalt mixes to the laboratory for testing.

(cc) The samples of asphalt mix shall be sent to the Testing Laboratory within 4 days from the date of laying, of Asphalt mix on site. If the samples of the Asphalt mixes are not sent for testing, next interim payment shall not be made.

(dd) In case of less% (percentage) of bitumen in the bitumen mix beyond specified limit, the area represented i.e. work carried out related to sample has to be removed and redone.

(ee) All the specifications laid down by IRC and as detailed in the relevant clauses of MORTH-(2013 as amended) Manual on Specifications for Road and Bridge Works in respect of

Construction of Drainage Layer, Wet Mix Macadam, Dry Lean Concrete and other road works shall be strictly followed

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 Engineer, 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.

xvi) 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

xvii) 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;

xviii) 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.

xix) 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;

xx) 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;

xxi) 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;

xxii) 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.

xxiii) All movement of vehicles to and from the sites shall comply with the Traffic Management Plan described in Section 7.8 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"
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 Void

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 Engineer 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 Engineer 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 Engineer. 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 Engineer 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), or in the case of S14 where there are no SWDs into the existing WwTF outfall channel that discharges into Malad Creek. . 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 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 Engineer 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.

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**
S12	**Commercial**	**Commercial**	**65**	**55**
S11	**Commercial**	**Commercial**	**65**	**55**
S10	**Commercial**	**Commercial**	**65**	**55**
S09	**Commercial**	**Commercial**	**65**	**55**
S15	**Mangroves / Industrial**	**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 MECHANICAL, ELECTRICAL, I&C WORKS

6.1 Sluice Gate Specifications

Scope of supply:

A. Supply, installation, testing and commissioning of Electrically actuated sluice gates with rising spindles at Inlet and Outlet of the screens. (3 Number at SC08, 2 Number at SC09, 2 Number at SC11, 2 Numbers at SC12) as specified in the datasheet and drawings.
B. The Drawings, Datasheets and Specifications are intended to set the acceptable minimum standard. Ensure that the installed equipment is trouble-free and meets performance requirements.

General:

Codes and Standards

1	IS 13349	Cast Iron Single-Faced Thimble-Mounted Sluice Gates
2	AWWA C560	Standard for Cast-Iron Slide Gates
3	BS 7775	Specification for penstocks
4	IS 9338	Cast Iron Flush-Bottom Sluice Gates

A. Where provisions of the pertinent codes and standards conflict with these Specifications and Drawings or with each other comply with the more stringent provisions.
B. Use the latest issue of Standards.

Products:

Materials and Design for Sluice Gates:

A. All materials shall conform to the codes and standards Listed below in or better.

1	Wall thimble, frame, gate wedge, stem guide, lifting operator	IS: 210 Gr FG 260
2	Seating face of frame and gate, stem, stem coupling, stem extension, stem nut, drive nut, all fasteners and anchor bolts/nuts.	AISI-Gr 316 Stainless Steel
3	Lift Nut	IS:318-LTB-2 Bronze
4	Resilient seal for flush-bottom gate	ASTM D 2000 EPDM rubber

B. All castings shall be of uniform thickness with plane faces without any casting defects such as blow holes etc. Welding of any defects will not be allowed. Casting shall be properly machined to give smooth operating faces.
C. All gates shall be thimble mounted to be embedded in concrete walls.
D. All gates shall be with rising spindles.
E. Sluice gates shall be rectangular or circular in shape as specified in the data sheet.
F. Sluice gates having seating or unseating heads and maximum operating head for each gate shall be as specified in the data sheets.
G. Sluice gates with flush-button seals shall be as specified in the data sheets.
H. The seating and unseating pressure head shall be as per datasheet (which is the difference between maximum water elevation and gate center line elevation).

Wall Thimbles for Gates:

A. Provide each gate with a wall thimble with water stop puddle flange having a machined

surface flange to suit gate frame fastening. Thimbles shall have threaded holes for frame fixing bolts/studs.

Frame, Guides and Gate Slide:

A. Flat back frame shall be for mounting on the face of wall thimble. The mating surfaces of frame and thimble shall be fine machined to give leak proof joint. The frame flange shall have accurately drilled holes to match those on thimble flange for fixing with studs and nuts.
B. Extension guides shall extend above the frame, designed to guide and hold the gate in the open position.
C. Provide suitable thick continuous hard neoprene rubber gasket between the thimble and frame.

Gates:

A. Gates shall be of rugged design with suitable ribs to prevent distortion and to withstand the specified water head. Cast integral heavy section pocket shall be provided on the gate top to house the stem connecting block for lifting.

Sealing Faces:

A. Wear resistant metal seals shall be embedded in machined dovetail grooves and screwed in sealing face of frame and slide gate to give watertight seal with smooth operation and long life.
   Permissible leakage through the door seals shall be as per AWWA – C 501-92, C501-92/ BS 7775/ IS 13349 standards.

B. Flush Invert seal:
   For flush invert gates resilient seal of ethylene propylene dimethyl (EPDM) or better-quality material for durability in sewage and resistance to grit abrasion shall be provided in the frame invert member. The sides and top seals will be metal to metal embedded in dovetail grooves.

Wedges:

A. All wedges shall be individually adjustable. The gates with seating water head shall have side wedges.
B. The unseating head gates shall be provided with wedges on all four sides of the gate. Flush bottom gates shall not have wedges on the bottom edge.

Stems and Guide Brackets for Sluice Gates:

A. The stem length shall be suitable for mounting the gate operator at the operating platform. The depth of gate invert to the operating platform is given in the data sheets. The length of stem threads shall be minimum 400 mm longer than the gate opening height.
B. The stem shall be provided with suitable couplings for connecting stem lengths between the gate and the gate operator.
C. Stem guide brackets shall be provided at suitable lengths to prevent buckling.

Stem Protectors for the Sluice Gates:

A. Provide clear plastic or acrylic stem covers complete with stem position indication for each stem. Diameter and length to be recommended by gate manufacturer.

Gate Operators:

A. All operators shall be provided with a vertical flanged mounted stand/pedestal of heavy duty CI or 304 stainless steel.

B. Electrically-operated gates shall have integral gearing with easily fixed/removable hand-wheel to allow the gate to be operated manually without removing actuator.
C. Hand wheel operators shall be approximately 900 mm above the floor.
D. All hand wheels shall have an arrow indicating direction of operation for raising/lowering.

Execution:

Delivery, Receiving and Storage of Equipment:

A. The Contractor shall arrange to deliver all equipment supplied under this Contract to the site and co-ordinate supply of items which are required to be embedded during concreting.
B. Supervise the receiving, unloading and storage of the equipment.
C. The Contractor shall notify the Engineer four weeks in advance of delivery and provide four copies of complete and itemized shipping lists. Each item shall be clearly marked, identified and referenced to the shipping lists.
D. Each component shall be adequately packed and crated to provide protection during shipping, handling and storage.

Installation and Commissioning:

A. Obtain required installation instructions from the manufacturer to ensure the correctness of the equipment installation.
B. Gates shall be installed at the locations indicated on the Drawings and as specified.
C. The manufacturer shall verify that the mounting surface for the gate frame is flat and is of suitable finish for mounting the frame. The Contractor shall ensure the proper alignment of the gate.
D. Have the manufacturer provide the services of experienced, factory trained representatives to supervise the installation and the commissioning of the equipment as well as during any testing required.
E. As part of the commissioning, the manufacturer's representative shall instruct plant staff in the proper care and operation of the equipment.

Inspection:

A. Provide the services of the manufacturer's technical representative to certify that the gate assembly with the gate operates correctly is complete and in the proper operating condition after installation, before it is put into service and that it operates without undue effort.

Testing:

A. The completed sluice gates shall be tested as follows:
a) Movement tests, under no-flow conditions for workability and torque required.
b) Hydrostatic and leakage tests, in closed unseating head position at specified pressures and finally a differential pressure of one a half times the specified pressure. No leakage or deformation is permitted.
c) Completed Sluice Gate along with its Actuator shall be Factory Tested.

6.2 Sluice Gate Datasheet

Sr. No.	Description	Unit	Required	Proposed by Tenderer
	Design and testing code		IS 13349	
	Operating Conditions	-		
1	Fluid	-	Municipal sewage	
2	Fluid Temperature	Deg. C	20 to 40	
3	Sp. Gravity	-	1.02	
4	Fluid Viscosity	Centipoise	1	
5	pH	-	6.5 to 8	
6	Class	-	Annexure -6.2.1	
7	Type	-	Thimble mounted, Rising stem	
8	Size of opening W X H	mm X mm	Annexure -6.2.1	
9	Quantity	Nos.	Annexure -6.2.1	
10	Operation	-	Electric with Manual override	
11	Platform Level	m	Annexure -6.2.1	
12	Invert Level	m	Annexure -6.2.1	
13	Wall thimble type	-	*	
	Make	-	As per the LIST OF APPROVED MAKES	
	Model No	-	*	
	Material of Construction	-		
1	Wall thimble, Frame	-	Cast Iron : IS: 210 Gr FG 260	
2	Gate Wedge	-	Cast Iron : IS: 210 Gr FG 260	
3	Lifting operator	-	Cast Iron : IS: 210 Gr FG 260	

Sr. No.	Description	Unit	Required	Proposed by Tenderer
4	Seating face of frame and gate	-	AISI-Gr 316, Stainless Steel	
5	Stem, stem coupling, stem extension, stem guide	-	AISI-Gr 316, Stainless Steel	
6	Stem nut, drive nut	-	AISI-Gr 316, Stainless Steel	
7	Fasteners and anchor bolts/nuts	-	AISI-Gr 316, Stainless Steel	
8	Lift Nut	-	Bronze IS: 318 Type LTB-2	
9	Resilient seal for flush bottom gate	-	ASTM D 2000, EPDM	
10	Handwheel	-	*	
	Actuator			
1	Type	-	Electrical+ manual override	
2	Supply Voltage	V	415	
3	Make	-	As per the LIST OF APPROVED MAKES	

ANNEXURE -6.2.1

Sr No.	Service	Size (mm)	Pl (m)	Cl (m)	SE (m)	USE (m)	Class Of Gate	Quantity	Actuation
1	Upstream from SC07 (at location SC08)	3200 X 3200	25.4	10.18	-	0.96	Class 1	01	MOTORIZED
2	Upstream from S09A (at location SC08)	2600 X 2600	25.4	10.79	-	0.78	Class 3	01	MOTORIZED
3 (Refer Note 4)	Downstream to Proposed Malad IPS (at location SC08)	5000 X 5000	25.4	11.08	1.5	-	Class 1	01	MOTORIZED
4	Inlet of Screens (Upstream from MH14335101-B) at SC-09	1400 X 1400	28.75	23.21	-	0.42	Class 3	01	MOTORIZED
5	Outlet of Screens (Downstream to DS09) at SC-09	1400 X 1400	28.75	23.11	0.52	-	Class 1	01	MOTORIZED
6	Inlet of Screen SC11(Upstream from MH14313903A)	1200 X 1200	28.22	21.02	-	0.36	Class 1	01	MOTORIZED
7	Outlet of Screen (Downstream to SC-11)	1200 X 1200	28.22	21.02	0.36	-	Class 1	01	MOTORIZED
8	Inlet of Screen (Upstream from MHGORE-1) at SC-12	2000 X 1800	28.5	20.25	-	0.6	Class 1	01	MOTORIZED
9	Outlet of Screen (Downstream to DS-12) at SC-12	1800 X 2000	28.5	20	-	0.44	Class 1	01	MOTORIZED

Where:
* indicates Vendor to provide the details.
CL indicates Center Line
PL indicated Platform Level
SE & USE indicates Seating and unseating pressure head.

Note:

1. Dimensions of Gates shown, as per Drawings, are Tentative. Contractor to Modify Equipment Basis to Suit Equipment Supplied.

2. Levels provided in Data Sheet may vary slightly during execution.

3. Considered Max Water Level Approximate 80% of Tunnel Diameter for Calculating Seating and Unseating Head.

4. For Sr. No 3 (5000mm X 5000mm) due to Size Constraint if CI MOC is not available then Vendor can select the MOC which is compatible with Sewage application.

6.3 Electric actuator:

General

Codes and Standards:

A. Electrical motor operated actuators to be in accordance with IS 9334
B. Where provisions of the pertinent codes and standards conflict with these Specifications and Drawings or with each other, comply with the more stringent provisions.
C. Use the latest issue of Standards.

Products

A. Electrical actuators shall be procured through gate manufacturer only.

Service Conditions:

A. Actuators shall be with IP 65 protection.

Construction Details:

A. General
   a) The actuator shall be suitable for use on nominal 415 V, 3 phase, 50 Hz power supply and shall incorporate motor, integral reversing contactor, local control facilities through Local Push Button Station.
   b) The actuator motor control circuit shall include a device to ensure that motor runs with the correct rotation for the required direction of gate travel irrespective of three phase connection sequence of the power supply.
   c) Setting of the torque levels position limits and configuration of the indication contacts etc. shall be carried out with the removal of actuator covers. Provision shall be made for the protection of configured actuator settings.
   d) The actuator shall be of OPEN-CLOSE duty type wherein normal gate positions are end positions OPEN and CLOSED. After receipt of local/remote command, the actuator shall operate the gate to one of the end positions or if necessary to a pre-set intermediate position as specified.

Actuator Sizing

   a) The actuator shall be sized to guarantee gate closure at the specified differential pressure.
   b) The motor power available with safety margin, for seating and unseating the gate, shall be sufficient to ensure limit switch trip at the extreme end position of gate, with supply voltage 10% below normal.
   c) The operating speed shall govern gate closing and opening at approximately 250 -300 mm per minute unless otherwise stated.
   d) Enclosure: Actuators shall be O-ring sealed, watertight to IP68 and shall at the same time have an inner watertight and dustproof O-ring seal between the terminal compartment and the internal electrical elements of the actuator. The motor and all other internal electrical elements of the actuator shall be protected from ingress of moisture and dust when the terminal cover is removed at site for cabling.
   e) Enclosure must allow for temporary site storage without the need for electrical supply connection.
   f) All external fasteners shall be of stainless-steel type.

Motors:

a) Motors shall be squirrel cage induction motors with minimum insulation class 'F' and temperature rise restricted to class 'B' limit.
b) Motors shall be specifically designed for gate actuator operation, which is characterized by high starting torque, low stall torque & low inertia. All motors shall be high starting torque type to facilitate unseating of gate.
c) Motor shall be capable of a minimum 60 of starts per hour.
d) It shall be possible to separate the motor from the lubricant filled gearing of the actuator allowing easy replacement of motor without releasing any lubricant regardless of mounting position.

Limit switches:

a) The actuator shall be provided with following limit switches.
    1. Two limit switches each with 2 NO + 2 NC contacts as changeover (2 for open and 2 for close direction) for end of travel and interlock purposes.
    2. The limit switch shall enable switching off the actuator when reaching defined gate positions, usually end positions. The gate travel shall be measured by mechanical counter gear mechanism which when reaching the set switching points shall operate the electrical limit switching by cams. The setting accuracy shall be minimum 1/10 of the turn of actuator output shaft. Two train counter gear shall be used along with two limit switches.

Local Position Indicator:

a) The actuator shall include a position indicator for fully open and fully closed condition.

Remote Actuator Status Indication:

a) One set of the two (2) NO/NC contacts of OPEN and CLOSED position Limit Switches and Torque Switches shall be hardwired to respective Gate actuator MCC control circuit for power cut-off purpose and another set of NO/NC contacts shall be interfaced with PLC for HMI/ SCADA indication/ interlock.

Gear:

a) The actuator gearing shall be totally enclosed in a grease or oil-filled gear case suitable for operation at any angle. All drive gearing and components must be of metal construction and incorporate a lost-motion hammer blow feature. For rising spindle gates, the output shaft shall be hollow to accept a rising stem and incorporate thrust bearings of the ball or roller type at the base of the actuator. The design shall permit the opening of the gear case for inspection or disassembly without releasing the stem thrust or taking the gate out of service.

Reduction gear unit:

a) Reduction gear unit shall be used for mechanical/digital position indication, remote position indication and for operation of intermediate switches.

Bevel Gear Set:

a) The actuator shall have the provision or inbuilt gear set to reduce the manual effort with the help of a side mounted hand wheel instead of standard hand wheel.

The Drive Bushing:

a) The actuator shall be furnished with a drive bushing easily detachable for machining to suit the gate stem or gearbox. Thrust bearings, when housed in a separate thrust base should be of the sealed-for-life type.

Anti-Condensation Heater:

a) Anti-condensation heaters shall be supplied to maintain the interior of the actuator enclosure above the dew point on all actuators installed indoors or outdoors. Heaters shall be sized and located to prevent condensation of moisture during shutdown periods.
b) Heaters shall be unaffected by the accumulation of moisture and shall have terminals adequately protected against moisture under severe weather conditions. Heaters shall be mounted on non-combustible material and shall operate without thermal damage to the actuator or themselves.

Motor protection:

a) The motor shall be de-energized in the event of a stall when attempting to unseat a jammed gate.
b) Motors shall have three thermostats connected in series, one in each phase of stator winding, for protection against overheating.

Manual operation:

a) In case of power failure or during emergency operation there shall be provision of manual operation by a hand wheel. The manual drive shall be engaged by means of a lever when the motor is declutched. When the motor is in operation, the manual drive shall be disengaged immediately, and the hand wheel shall not rotate.
b) The hand wheel drive must be mechanically independent of the motor drive and any hand wheel gearing shall permit emergency manual operation in a reasonable time. Clockwise operation of the hand wheel shall give closing movement of the gate unless otherwise stated.
c) Hand wheels shall be able to withstand hammer blows made to open jammed or rarely operated gate.

Performance:

a) Rated Output
    1. The required torque requirement shall be calculated, and design calculations shall be submitted to the Engineer's representative for information.
b) Power Loss
    1. The power loss in actuators and accessories shall not exceed the value specified in relevant standards.
c) Permissible overload
    1. The maximum permissible overloads with regard to voltage, current and reactive output shall conform to relevant IS.

Wiring and Terminations:

a) Internal wiring shall be tropical grade PVC insulated stranded cable of appropriate size for the control and 3-¬phase power. Each wire shall be clearly identified at each end. The terminals shall be embedded in a terminal block of high tracking resistance compound.
b) The terminal compartment shall be separated from the inner electrical components of the actuator by means of a watertight seal and shall be provided with a minimum of three threaded cable entries with provision for a minimum of four. All wiring supplied as part of the actuator to be contained within the main enclosure for physical and environmental protection. External conduit connections between components are not acceptable. A durable terminal identification information nameplate / card showing plan of terminals shall be provided attached to the inside of the terminal box cover indicating
    1. Serial number
    2. External voltage values

3. Wiring diagram number
4. Terminal layout
5. Inscribe cable core identification alongside terminal numbers on the (nameplate / card).
6. Coloured sleeves shall be provided on the termination for identification purposes.
7. Crimping type copper lugs shall be used as termination.
8. Terminals shall be suitable for termination of wires of size 2.5 mm2 (maximum) for control and 4 mm2 (maximum) for power connections. Fixed terminals of power circuit shall be of thermosetting compound. Material of power terminals shall have excellent resistance to deformation, optimum dimensional stability and strong resistance to surface discharge.
9. Two grounding terminals shall be provided on either side of the motor.

Nameplates:

a) The lettering shall be engraved with white letters on black background on the panel surface

Execution

Installation:

A. Ensure that the supplied equipment is factory assembled.
B. Mount the actuators as shown on the Drawings. Where not shown, mount as recommended by the manufacturer.
C. Ensure that operating lights and push buttons are readily visible and accessible.

6.4 Mechanical bar screens:

Scope of Works:

A. Supply, installation, testing and commissioning of Mechanical Coarse Bar Screens. (1 Number at S08, 1 Number at Screen Chamber (SC12) as specified in the datasheet and drawings.
B. The Drawings, Datasheets and Specifications are intended to set the acceptable minimum standard. Ensure that the installed equipment is trouble-free and meets performance requirements.

General:

Codes and Standards:

A. The Design of the screens shall be as per Manufacturer's standard. The design, manufacture and performance of screens and accessories shall comply with all currently applicable statutory, regulations and safety codes in the locality where the system will be installed. Nothing in the specification shall be construed to relieve the VENDOR of this responsibility
B. Where provisions of the pertinent codes and standards conflict with these Specifications and Drawings or with each other comply with the more stringent provisions.
C. Use the latest issue of Standards.

Products:

General Design Data:

A. Provide all mechanical bar screens, accessories and control panels from a single supplier who shall be responsible for all equipment of this section.
B. Provide 25% margin on BKW of the Drive.
C. Provide mechanical bar screens having operating characteristics as specified in the data sheet.

D. Provide mechanically-operated, self-cleaning vertical bar screens of the chain-operated rake type, designed to retain and remove floating matter and other debris from a channel flow. The screenings are to be cleared by an ascending series of rakes positively engaging the bar rack from the upstream side or downstream side, starting at the channel invert and traveling upwards to the chute where screenings are discharged on the downstream side of the screen into a suitable receptacle.
E. Screens shall be suitable for continuous operation in a highly corrosive atmosphere. The screen shall be installed by lowering down in the channel with the main side supports bolted/ anchored in the channel side walls and base. All components will be constructed from stainless steel 316L or better quality materials for corrosion and wear resistance, strength and long useful life. All fasteners including anchor bolts for assembly and installation will be supplied with the screen and shall be in grade 316 stainless steel.
F. All replaceable and wearing parts shall be of standard, accurate dimensions. Complete bar screen shall be factory tested prior to delivery at site.
G. The equipment shall require the minimum maintenance, repair or replacement. Components needing periodic maintenance should be easily accessible from the operating level.
H. Stainless Steel Finishes:
    a) All the Stainless steel surfaces shall be short blasted, pickled and passivated.
    b) Dead plate and discharge chute: Smooth polished finish. Add to the discharge chute top surface, a coating of Teflon or 1.5mm thick Teflon sheeting, riveted in place.
I. Non-sparking Materials:
    a) Provide the screens of non-sparking materials, especially components that may contact each other.
J. The conveyor belt shall be provided with Drop box canopy.
K. Minimum approach velocity in the bar screen channel is 0.45 m/s to prevent grit deposition.
L. Maximum velocity between the bars is 0.9 m/s to prevent washout of solids through the bars.

Mechanical Bar Screen:

A. Frame and Supports:
    a) Provide screens with a side frame width to match the channel width designed for bolting to the concrete walls of the channel. Recessed frames cast into the concrete are not acceptable.
    b) Framework of screen shall be constructed of Grade 316L stainless steel with a minimum thickness of 5mm. Various parts fastened by welding or bolting shall be braced as necessary to ensure a rigid structure. The side frames shall be minimum 5mm thick formed to a U channel profile. The frame shall include cross-connect support beams with U channel-profile with a minimum thickness of 5 mm on the front above the maximum water level.
    c) The frame shall include horizontal supports at the operating floor level. The horizontal supports shall extend beyond the walls of the concrete channel. The horizontal supports shall be designed to allow at least 100mm horizontal distance between the vertical face of the channel wall and anchor bolts.
    d) The base part of the frame shall be of the flush-bottom type with a minimum 8mm thick flat plate resting directly on the channel invert.
    e) The top of the frame shall be provided with at least four heavy duty lifting lugs/eyelets, permanently attached.
B. Bar rack:
    a) Screen bars shall be constructed of continuous 316L stainless steel bars.
    b) The bars shall be trapezoidal in width minimum 12 mm > 6 mm or teardrop in design minimum 12 mm, and 50mm deep.

c) Bars shall extend from the bottom of the screen grid at the channel invert to at least 1000 mm above the maximum water level where they will be fastened to the lower side of the dead plate.

C. Dead Plate:

a) Dead plate fabricated from minimum 5 mm thick 316L stainless steel plate with stainless steel reinforcement on the down stream side. The plate to extend from the top of the rack bars up to the top of the discharge chute.

D. Chute:

a) A discharge chute with side panels shall be provided to divert screenings discharged from the screen to a container. The discharge chute shall be fabricated from minimum 4mm thick 316L stainless steel plate and shall be mounted at an angle of not less than 30 degrees to the vertical. Panels to be positioned on both sides to protect from splashing.

b) Easily removable transparent covers of 6mm thick impact resistant long lasting polycarbonate material shall be provided to prevent screenings from flying out from the chute.

E. Rake:

a) The multi rake screen capacity shall be as specified in data sheets.

b) The screen rakes shall be of shovel shaped design such that screening will not wrap around its tines or the stationary bars and will not fall back into the channel during the cleaning cycle.

c) Screenings transported to the top of the screen shall be discharged positively by means of a scraper mechanism to the discharge chute.

d) The rakes shall run in guides on both sides to ensure proper engagement. The rake shall be fabricated in 316L stainless steel a minimum 12 mm thick with minimum 6 mm thick reinforcement profiles and 10 mm thick side plates. The raking tines shall have the tooth profile precision cut from a single piece of sufficient thickness and depth to ensure adequate stiffness and strength to cope with the loads and forces encountered.

e) The rake tines shall penetrate into the screen bar spacing to ensure that screenings are completely cleared during each lifting operation. Rake tines shall be mechanically engaged into the screen bars. During each cleaning stroke, the raking tines shall engage into the bottom of the bar screen grids at the channel invert.

F. Rake Drive Mechanism:

a) The mechanism for up and down travel of the rake and engaging and disengaging the rake with bar rack will be located in the side frames. The machined components such as shafts, sprockets, chains, guided bearings etc shall be of corrosion-resistant steel duly hardened and stress relieved.

b) The drive design shall be such that the movement of the rakes is smooth and the engagement of tines with the bar rack and dead plate is firm and uniform along the width of rake throughout the rake travel without requiring frequent adjustments.

c) The rakes, drive chains, chain guides, chain sprockets, bearings and axles shall be fully replaceable without having to remove the screen from the channel.

d) The drive mechanism shall consist of:

1. The drive shaft shall be 316L stainless steel having high corrosion resistance, tensile and torsion strength.
2. The upper and lower sprockets shall be solid single piece sprockets with tooth width of minimum 25 mm. The submerged Sprocket shall have ceramic bushes.

3. The chain shall be roller type with minimum 125 mm pitch. The 316L stainless steel rollers shall have high corrosion and wear resistance properties. The chain links shall be in grade 316L stainless steel. The ultimate strength of the chain shall be minimum 140 KN.
4. The chain tightening frame, with heavy duty tensioning screw having Acme threads, shall house flange type grease lubricated heavy duty bearings for the upper shaft. The frame assembly shall be fabricated in 316L stainless steel.
5. Each of the lower sprockets, mounted on two separate single piece stub shafts with bonded ceramic collars, will have self lubricating bearings of high wear resistant material such as polyethylene or better and will be suitable for being submerged in sewage.
6. The chain guide shall be of minimum 65 x 35 x 5 mm L-section in 316L hardened stainless steel to withstand wear and abrasion shall be fixed to the screen frame for full height of travel.

G. Scraper:
   a) Scraper mechanism, with scraper blade of wear resisting, strong synthetic material, shall positively discharge the screenings from the rake, at the top of the screen dead plate, to the chute.

H. Screen Side Panels:
   a) Where moving parts of the screen are accessible from the operating floor level, 316L stainless steel cover panels shall be provided for maintenance access. The panels shall be removable or hinged.

I. Elevated Platform:
   a) Where certain components of the screen, such as the motor, drive system, electrical parts etc are 3.0m or greater above the operating floor level, Provide an elevated work platform for maintenance access to those areas. The platform to be provided with its own support system, hand railing, chequer plate and access ladder. All material shall be of 316L stainless steel.

Electrical Motor and Drive:

A. The Equipment shall be VFD compatible. The motor specifications shall be as per specifications of Electric Motor (LT) in Electrical specifications.
B. Provide all electrical components (i.e. junction boxes, terminal boxes, conduit/wiring, etc) mounted on the screen.
C. The electrical drive motor shall be TEFC, premium efficiency design for 415 volt, 3 phase, 50 Hz electric supply with IP55 protection. The drive motor shall be an inverter duty rated motor with a 1.0 service factor, rated for continuous duty.

Controls and Control Panel:

A. A free-standing control panel shall be provided suitable for an outdoor wet weather location and padlockable. The Control panel shall be floor mounted with IP 54 protection. The control panel shall include all equipment required to operate and control the bar screen with suitable shade. Control panel shall be prefabricated and shall comprise rigid welded structural frames enclosed completely of specially selected smooth finished, SS 316L.Panel light shall be provided with door lock switch.

The design of panels shall ensure adequate ventilation and air circulation without permitting the entry of vermin and dust.

Sufficient reinforcement shall be provided in order to provide resistance to vibrations and provide sufficient rigidity during transportation and after installation.

B. A rated ultrasonic differential level sensor system shall be provided complete with 316L stainless steel mounting for installation in channel. The sensors shall form part of the automated controls of the screen operation. The sensor shall be suitable for flange or bracket mounting as required and shall be environmentally protected to IP 68. It shall have ambient temperature compensation, adjustable datum setting facilities. The accuracy of the sensor shall be ± 0.25% or better. The design and application of ultrasonic level meters shall take into account the vessel or channel construction, the material, size, shape, environment, process fluid or material, the presence of foam, granules, size etc. The installation shall avoid any degradation of performance from spurious reflections, absorption, sound velocity variations, sensor detection area, temperature fluctuations, specific gravity changes and condensation.

C. A VFD (variable frequency drive) and a PLC (programmable logic controller) shall be provided inside the control panel along with other components as specified herein. VFD shall have solid state overload integral and shall include discrete and analogue input and outputs.

D. Operation Control and Instrumentation-
   a) Provide the control panel with a main 3-way selector switch for Auto/ Manual/Stop modes of operation. In the Auto mode there shall be a sub-selector switch provided for Auto Level Differential Mode or Timer Mode.

E. Automatic Level Differential Control System:
   a) In this mode, PLC shall control the VFD to operate the screen for variable torque loads at two speeds and through the automatic reversing/forward shuttle sequence.
   b) The rake drive will start operating at low speed in the forward direction when a preset differential in the upstream and downstream levels across the bar rack is sensed by the ultrasonic level sensors.
   c) If the level differential reaches the higher set point the drive will move at higher speed.
   d) When an obstruction is encountered in the rake operation and over-current is detected, the rake drive shall move to low speed then stop and then run in reverse for set distance and again move forward to clear the obstruction. This forward reverse cycle shall repeat twice and if the obstruction is still not cleared, the drive shall stop and the alarm shall sound. Mechanical over-load sensing for initiating the alarm shall not be acceptable. If the obstruction is removed in forward/reverse operation the screen shall resume operation in the normal forward mode.

F. Timer Control System:
   a) In the timer mode, the screen will operate at preset intervals for set time durations and stop for a fixed time period. The on/off times shall be adjustable and set depending on the rate of accumulation of screenings.
   b) In this mode of operation, when an obstruction is encountered the automatic reversing operation will occur as described above.

G. Manual Control System:
   a) In the manual mode a 3-way sub selector switch is to be provided for forward-stop-reverse operation.

H. Control Equipment:
   a) Control Panel will include not be limited to following:
      1. Heavy duty power On/Off switch
      2. Programmable controller, relays, necessary transformer starters, two solid state timers.

3. Main Selector switch for Auto/Manual/ stop
4. Sub-selector switch for level differential/timer/ with indicating light
5. Sub-selector switch for manual mode: forward/reverse/stop
6. Indicating light: Auto
7. Indicating light: Manual
8. Indicating light: Level differential control
9. Indicating light: Timer control
10. Indicating light: Forward operation
11. Indicating light: Reverse operation
12. Indicating alarm: High water level
13. Indicating alarm: Drive overload
14. Alarm horn
15. Alarm silence button push type
16. Emergency stop mushroom push button (red colour).
17. Ultrasonic differential control

Fasteners:

A. All fasteners, bolts, nuts, washers, screws, anchors etc shall be 316 stainless steel.

Execution:

Installation:

A. Install the screens and other accessories as per manufacturer's instructions and in the presence of a qualified representative of the manufacturer. Ensure the configuration of the equipment, when installed, will operate efficiently.

Painting:

A. Shop and field painting and protective coatings to all components other than stainless steel.

Inspection and Field Testing:

A. Provide the services of an authorized factory trained technical representative to:
   a) Certify completeness of installation
   b) Certify equipment performance throughout the operating range.
   c) Provide training sessions for the operation staff
B. Upon successful completion of the field tests, submit to the MCGM, a report presenting findings of the inspection, testing and any adjustments made.

6.5 Mechanical Bar Screen Data Sheet

Sr. No.	Description	Unit	Required	Proposed by Tenderer
	Quantity	No	Annexure -6.5.1	
	Operating Conditions	-		
1	Fluid	-	Municipal sewage	

Sr. No.	Description	Unit	Required	Proposed by Tenderer
2	Fluid Temperature	Deg. C	20 to 40 Deg. C	
3	Fluid Sp. Gravity	-	1.02	
4	Fluid Viscosity	Centipoise	1	
5	pH	-	6.5 to 8	
	Make	-	As per the LIST OF APPROVED MAKES	
	Model No	-	*	
	Screen Description	-		
1	Type		Mechanical (Motorized)	
2	Flow rate	m^3/hr	Annexure -6.5.1	
3	Maximum water level	m	Annexure -6.5.1	
4	Screen channel width	m	Annexure -6.5.1	
5	Width of rectangular bars	mm	*	
6	Clear spacing between bars	mm	Annexure -6.5.1	
7	Screen inclination with horizontal	Deg	Annexure -6.5.1	
8	Screen channel invert level	m	Annexure -6.5.1	
9	Screen operating platform level	m	Annexure -6.5.1	
10	Wheel barrow floor level	m	*	
11	Screen chute discharge level	m	*	
12	Screen top level	m	*	
13	Screen frame width	m	*	
14	Screen effective width	m	*	
15	Sprocket tooth width	mm	*	
16	Pitch	mm	*	
17	Distance between rakes	m	*	
18	No of rakes/ screen	m	*	
19	Conveyor Belt (Motor driven endless)		As per IS 11592	
20	Width of conveyor belt	mm	600	
	Material of Construction	-		
1	Fixed Bars	-	SS 316L	
2	Side frame /channels	-	SS 316L	

Sr. No.	Description	Unit	Required	Proposed by Tenderer
3	Rake	-	SS 316L	
4	Discharge chute	-	SS 316L	
5	Drive chain	-	SS 316L	
6	Scraper	-	SS 316L	
7	Drive shaft	-	SS 316L	
8	Drive & bottom sprocket	-	SS 316L	
9	Belt of Conveyor	-	Two ply nylon with minimum 3 mm neoprene	

ANNEXURE -6.5.1

Sr No.	Service	Flow Rate (m3/hr)	Max Water Level (m)	Channel Width (m)	Platform Level (m)	Angle of Inclination (Degree)	Bar Spacing (mm)	Invert Level (m)	Qty
1	Upstream of S09A at location S08	15917	11.57	2.6	25.4	85	50	6.71	01
2	Screen at Screen Chamber (SC12)	9125	20.69	2	28.5	75	100	19.25	01

Note:

1. Dimensions of Screens provided in Data Sheets are Tentative and shall be suitable to Vendor Design.

2. Screen Height shall be 1m above Maximum Water Level provided.

3. * indicates Vendor to provide the details.

6.6 Manual Bar Screen Specification

Scope of Works:

C. Supply, installation, testing and commissioning of Manual Coarse Bar Screens (J Type). (1 Number at SC12, 2 Numbers at SC09, 2 Numbers at SC11, 2 Numbers at S08) as specified in the datasheet and drawings.
D. The Drawings, Datasheets and Specifications are intended to set the acceptable minimum standard. Ensure that the installed equipment is trouble-free and meets performance requirements.

General:

The manual bar screen is used in the by-pass channel or upstream of fine screen.
The manual bar screen SS 316Lshall be designed to operate smoothly in two stainless steel 316L grade channels embedded and anchored in walls of the concrete channel. The stainless steel channels shall be straight, smooth and without any joints wherever possible.
The manual bar screen shall be fully constructed from minimum 5mm thick grade 316L stainless steel. It shall have fully welded rugged frame with smooth finish without any warpage. The stainless steel bars shall be welded to the screen frame with clearance of 100 mm between bars.
The screen shall have a debris lip, welded along the along its length at bottom. The debris lip shall be fabricated from thick stainless steel 316L plate strengthened underneath with gussets. It shall have a number of drain holes for free drain of water while retaining debris collected over it. At the top of screen frame shall be a lifting arrangement for conveniently lifting the screen with a hoist hook.

Codes and Standards:

A. The Design of the screens shall be as per Manufacturer's standard. The design, manufacture and performance of screens and accessories shall comply with all currently applicable statutory, regulations and safety codes in the locality where the system will be installed. Nothing in the specification shall be construed to relieve the VENDOR of this responsibility
B. Where provisions of the pertinent codes and standards conflict with these Specifications and Drawings or with each other comply with the more stringent provisions.
C. Use the latest issue of Standards.

General Design Data:

A. The screen is mounted at an angle of 90 Degree from horizontal.
B. Bars are 1 cm thick, 5.0 cm wide.
C. Minimum approach velocity in the bar screen channel is 0.45 m/s to prevent grit deposition.
D. Maximum velocity between the bars is 0.9m/s to prevent washout of solids through the bars.

6.7 Manual Bar Screen Data Sheet

Sr. No.	Description	Unit	Required	Proposed by Tenderer
	Quantity	No	Annexure -6.7.1	
	Operating Conditions	-		
1	Fluid	-	Municipal sewage	
2	Fluid Temperature	Deg. C	20 to 40 Deg. C	
3	Fluid Sp. Gravity	-	1.02	
4	Fluid Viscosity	Centipoise	1	
5	pH	-	6.5 to 8	
	Make	-	As per the LIST OF APPROVED MAKES	
	Model No	-	*	
	Screen Description	-		
1	Type		Manual bar screen (J Type)	
2	Flow rate	m^3/hr	Annexure -6.7.1	
3	Maximum water level	m	Annexure -6.7.1	
4	Screen channel width	m	Annexure -6.7.1	
5	Width of rectangular bars	mm	*	
6	Clear spacing between bars	mm	Annexure -6.7.1	
7	Screen inclination with horizontal	Deg	Annexure -6.7.1	
8	Screen channel invert level	m	Annexure -6.7.1	
9	Screen operating platform level	m	Annexure -6.7.1	
10	Wheel barrow floor level	m	*	
12	Screen top level	m	*	
13	Screen frame width	m	*	
14	Screen effective width	m	*	
	Material of Construction	-		
1	Fixed Bars	-	SS 316L	
2	Side frame /channels	-	SS 316L	
3	Fasteners	-	SS 316	
4	Lifting Lugs	-	SS 316	

ANNEXURE -6.7.1

Sr No.	Service	Flow (m3/hr)	Max Water Level (m)	Channel Width (m)	Screen Height	Platform Level	Angle of Inclination (Degree)	Bar Spacing (mm)	Invert Level (m)	Qty
1	Screen Chamber (SC12) - Goregoan	9125	22.29	2	1.8	28.5	90	100	20.85	01
2	Screen at Screen Chamber (SC09) Inlet	5458	23.63	1.4	1.5	28.75	90	100	22.41	02
3	Screen at Screen Chamber (SC11) Inlet	1333	21.38	1.2	1.5	28.22	90	100	20.12	02
4	Screen at location (S08)	47292	12.58	2	5	25.4	90	50	6.71	02

Note:

1. Dimensions of Screens provided in Data Sheets are Tentative and shall be suitable to Vendor Design.

2. * indicates Vendor to provide the details.

6.8 Electric Hoist Specification

Scope of Works

A. Supply, installation, testing and commissioning of Electric Hoist (1 Number at SC08, 1 Number at SC09, 2 Numbers at SC11, 1 Number at SC12) as specified in the datasheet and drawings.
B. The Drawings, Datasheets and Specifications are intended to set the acceptable minimum standard. Ensure that the installed equipment is trouble-free and meets performance requirements.

Codes and Standards:

A. The following applicable standards established by the Bureau of Indian Standards govern the materials and workmanship employed for the work under this section.

1	IS 2266	Specification for steel wire ropes.
2	IS: 807	Code of Practice for design, manufacture erection and testing (structural portion) of crane and hoists.
3	IS: 3938	Electric wire rope hoists.

B. Where provisions of the pertinent codes and standards conflict with these Specifications and Drawings or with each other comply with the more stringent provisions.
C. Use the latest issue of Standards.

Products

General:

A. Monorail hoists shall be controlled from a pendant push button station and be furnished complete with all required safety devices and overload protection. The power supply shall be through a tagline system. The rail shall be a standard I-beam with stops, securely anchored to the structure.
B. Construction: The monorail hoist shall be designed as follows:
   a) Hoist: Single-speed, rope-type for parallel lug mounting from a geared trolley, with upper and lower limit switches to prevent over travel, (automatic reset type)
   b) Gear: Fully-enclosed, oil-lubricated spur gear.
   c) Drum: Steel, with machine-cut grooves and flanges, to accommodate entire cable in one layer.
   d) Bearings : Anti-friction type, lifetime pre-lubricated and sealed.
   e) Motor and Drum Shaft: Grease-lubricated, with ball or roller bearings
   f) Brakes: Mechanical load brake and separate electric motor brake, each adjustable and capable of supporting the full load.
   g) Cable: Of high strength plow steel, flexible, with min. 5:1 safety factor, for maximum lift plus 2 wraps on drum.
   h) Load Block: Heavy-duty with ball bearing sheave and forged steel swivel hook with anti-friction bearings and safety spring latch.
   i) Motor: Totally-enclosed, single speed
   j) Trolley: Motor-driven, with 4 wheels, spur gear, magnetic brake, ball or roller bearings.
C. Power Supply: 415V, 50Hz
D. Controls: Control equipment shall be mounted in an enclosed compartment which forms an integral part of the hoist and shall include a transformer for control circuit. The pendant pushbutton station shall be suspended from the control compartment and shall be provided with a supporting chain or cable, to locate the station 1 metre above the operating floor level.
E. Each pushbutton shall be clearly marked to indicate its function and sufficient buttons shall be provided to control operations of hoists and trolley.

Execution

Installation:

A. Be fully responsible for work of unloading, storing as necessary, erecting, assembling, adjusting and testing of the materials and equipment specified. Supply shims as required.
B. Provide the services of manufacturer's representatives to supervise the unloading, handling, erecting, assembling and testing of the cranes and to instruct operating personnel in its proper operation and maintenance.

Operation and Load Testing:

A. After erection has been completed and before being placed into service, the crane machinery shall be fully tested.
   a) Running Test:
      1. All clearances and alignments shall be in order; gearing sufficiently quiet and lubrication is adequate.
      2. Operation of each controller switch, contactor, relay and other control devices is satisfactory; all limit switches operate correctly under the most unfavorable conditions.
      3. All circuits, inter-locks and sequence of operation are correct.
      4. All protective devices operate satisfactorily.
      5. Each motion of the crane operates satisfactorily.
   b) Load Test:
      1. The crane shall have each motion tested under the full rated load (loads to be provided by Contractor).
      2. 25% Overload: During this test the specified speeds need not be attained, but the crane shall show itself capable of dealing with the overload without difficulty.
   c) Rated Load: During these tests the specified speeds are to be attained provided that the current supply to the crane is correctly maintained.
   d) Brake Test:
      1. All brakes shall be tested under full load conditions, from maximum speed to rest, three times in quick succession without overheating.

6.9 Electric Hoist Data Sheet

Sr. No.	Description	Unit	Required	Proposed by Tenderer
	Quantity	No	Annexure -6.9.1	
	Operating Conditions			
1	Capacity	Tons	Annexure -6.9.1	
2	Operation	-	Overhead	
	Make	-	As per Approved Makes List	
	Model No*	-	*	
	Crane Specifications			
1	Type	-	Annexure -6.9.1	
2	Clear Lift	m	Annexure -6.9.1	
3	Span	m	Annexure -6.9.1	
4	Hoist Speed	m/min	3-5 (vendor to confirm)	
5	Cross Traverse speed	m/min	12-18 (vendor to confirm)	
6	Long Travel speed	m/min	NA	
7	Micro speed for all the motions through VVVFD	m/min	NA	
8	Location		Indoor	
9	Long travel distance (m)		NA	

Sr. No.	Description	Unit	Required	Proposed by Tenderer
10	Duty		Class II as per IS 3938	
11	Applicable standard		IS 3938	
12	Operation		Rope suspended Pendant push button	
13	Hoist design		IS 3938	
14	Steel wire ropes		as per IS 2266	
15	Rope fall		*	
16	Rope drum Material		Deep grooved type, Steel construction made out of seamless pipes with flanges as per IS 3177.	
17	Gear box MOC		Fabricated out of MS plates and stress relieved	
18	Material (Gear and Pinion)		Helical & straight spur: Hardened and tempered alloy or Carbon steel.	
19	Hardness		Gears – 200 BHN (min) Pinion – 250 BHN(min)	
20	Gear box Lubrication		Oil lubricated	
21	Rope sheave Material		Medium carbon steel	
22	Compensating sheave Material		Medium carbon steel	
	Motors for all the motions:			
1	Type and number		Squirrel Cage induction type in IEC frame sizes and shall have 6 poles / 8 poles as per IS 12615, TEFC motor with VVVF drive, terminal box to be located on top	
2	Mounting		Foot / Flange Mounting type.	
3	Voltage/phase /frequency		415V / 3-phase / 50 Hz, AC supply	
4	Voltage variation / frequency variation		-10 to +10% / ±5 %	
5	Rating (KW)		*	
6	Duty / Duty factor		Heavy duty reversible crane service/ 40% CDF	
7	Starts / hour		150	
8	Class of insulation		Class F Limited to Class B temperature raise	
9	Frame size / Protection class		* / IP 55	
10	Motor make		ABB, Siemens, Crompton, Bharat Bijlie, Kirloskar	
	Brakes: (To be installed on gear box input shaft)			
1	Type / Quantity		Hoist: Electromagnetic Shunt (shoe) brake. Brake to hold any load up to & equal to 125% of rated hoist capacity at any position of lift when power supply fails. CT : Double shoe brake	

Sr. No.	Description	Unit	Required	Proposed by Tenderer
2	Type and details of limit switches		Hoist: Gravity & one counter weight operated back-up limit switch CT : Lever type	
3	Type of bearings		Antifriction Ball / Roller Bearings	
4	Trolley frame MOC		Fabricated steel	
5	Trolley drive wheels		Open geared type bearing mounted assembly	
6	Wheels Material (CT)		Forged	
7	Wheel Hardness		320 BHN (min) with 10mm depth of hardness. Counter case-hardened track wheels to be provided with high hardness wear resistant surface supported by tough ductile core.	
8	Details of trolley power feeding arrangement		Festoon cable system using I beam track with four wheel cable trolley	
9	Lubrication provided for wire ropes		Grease	
10	Buffer		Crane shall be provided with spring / Hydraulic buffers on ends of the bridge and trolley motion.	

ANNEXURE -6.9.1

Sr No.	Service	Capacity (Ton)	Lift (m)	Span (m)	Qty
1	Electric Hoist Trolley Mounted at Screen Chamber (S08)	3	20	10	01
2	Electric Hoist Trolley Mounted at Screen Chamber (SC09)	2	8	5	01
3	Electric Hoist Trolley Mounted at Screen Chamber (SC11)	2	10	4.3	02
4	Electric Hoist C/W SS wire rope hooked at Screen Chamber (SC12)	2	9	8.6	01

Note:

1. Dimensions (Span of Monorail I Section, Capacity -Ton, Lift) provided in Data Sheets are Tentative and shall be suitable to Vendor Design and Actual Load of Equipment to be Lifted.

2. * indicates Vendor to provide the details.

6.10 SPECIFICATIONS FOR FLANGE MOUNTED CAST IRON FLAP GATES

Scope of Works

A. Supply, installation, testing and commissioning of Flap Gate (4 Number at S09A) as specified in the datasheet and drawings.
B. The Drawings, Datasheets and Specifications are intended to set the acceptable minimum standard. Ensure that the installed equipment is trouble-free and meets performance requirements.

General

1.1 The construction of Cast Iron Flap gates shall be in accordance with the specifications mentioned hereunder. The Flap gates shall be capable of performing the duties set out in this specification without undue wear or deterioration. They shall be constructed so that maintenance is kept to a minimum.

1.2 Cast Iron Flap gates should be designed so that they open automatically to allow discharge through sewer lines or conduits or channels even with a small differential pressure on the upstream side of flap. When the water level on downstream side of flap is more than that on the upstream side the flap should close automatically to prevent back flow into the sewer lines or conduit or channels. A clear fall of at least 1 meter will be provided on the downstream of its installation.

1.3 Cast Iron Flap gates shall be designed for water tightness for seating water head as per the actual site requirement.

1.4 The Flap gate will be offered from an approved manufacturer who has sufficient experience in its manufacture and is ISO-9001: 2015 certified.

1.5 All the stainless steel material used on the assembled product shall be checked for correct chemical composition using Positive Material Identification equipment. This shall be re-verified at the time of inspection in presence of client / client representative / third party inspection agency.

1.6 After manufacturing the gates will be shot blast cleaned to remove any surface contamination and thereafter the gates shall be epoxy painted as per painting specification.

Design and Constructional Details

The constructional features and details of components of the required types of Flap gates are to be as under:

Frame

a) The frame will be made from Cast Iron and shall be sufficiently rigid to withstand the designated water head as well as the effects of pulsating motion. The frame shall be flange back type to suit the designated water head in meters.

b) Back flange of the gate aperture frame to be precisely machined flat and drilled to engage with the Pipe Flange mounted in the wall.

c) The frame shall be provided with proper sealing arrangement to enable seating of flap on the seal while closing due to head from downstream and achieve reasonably leak tight closure.

d) The frame will be provided with adjustable hinge bolts to enable secure the flap on to the frame via hinge pins. The hinge bolts and hinge pins shall be made of corrosion resistant material as specified elsewhere.

Flap

a) The Flap will be made from Cast Iron and shall be sufficiently reinforced with matrix to withstand the designated water head in meters.

b) The Flap will be provided with hinge brackets to connect it with the frame. The hinge bracket will be hinged on the frame as well as on the flap to increase the sensitivity of operation.

Seating/Sealing Faces

a) Materials : These should be of made of SS.

b) Fitment : The resilient seating faces shall be secured in machined plain surfaces.

c) Finish : The mating sealing faces on the frame and flap shall be precisely finished for proper contact. They should be so finished that the clearance or gap, if any, between the mating sealing faces, in flap closed position, does not exceed 0.1mm.

Safety Stop

a) The Flap shall be provided with a safety stop to prevent the chances of its opening while handling or while installation. This shall be removed only after installation and prior to field testing.

Finishing and Painting: Following painting procedure shall be adopted for Cast Iron components of flap gates:

- Surface Preparation: shot blast cleaned to near white metal finish.
- Finish painting for gate assembly: 2 coats of black coal tar epoxy paint for gate assembly. Total paint thickness inclusive of priming 250 microns.

Shop Testing: Following shop tests at manufacturers place will be conducted.

a)	Dimensional Check	Important Dimensions shall be checked with reference to approved GA drawing.
b)	Seat clearance check	With the flap in closed condition 0.1 mm thick feeler gauge should not pass through between mating sealing faces.
c)	Material Test Certificates	Material tests certificates for all important components of Flap gates such as Frame, Flap/Shutter, Seat Facings etc. will be furnished at the time of inspection.
d)	PMI Test	Positive Material Identification (PMI) test to be conducted for all stainless steel material.

6.11 FLAP GATES DATA SHEET

Sr. No	Description	Requirements
1.	**Make**	As per Approved Make List with ISO-9001:2015 Certified
2	**Design Code**	As per Manufacturer's Standard
3	Position	Mounted at Flanged DI Pipe (Diameter - 1000mm), Flange Drilling as per PN 10
4	Quantity	04
5.	**Material of Construction**	
5.1	Frame, Shutter/Flap	Cast Iron IS: 210 grade FG 200
5.2	Seat facing	Stainless Steel ASTM A240 Type 304
5.3	Hinge Pins, Adjustable Hinge Bolts	EN-8 / Stainless Steel ASTM A276 Type 431
5.4	Hinge bracket	Ductile Iron with bronze bush at both ends
5.5	Gate Assembly Fasteners, Nut & Bolts and studs	Stainless Steel ASTM A276 Type 304
5.6	Painting	Black Coal Tar Epoxy Paint
6	**Operating Head (m)**	0.25
7.	**Design Head (m)**	1.5
8.	**Testing**	
	Dimensional Check	Required as Specified in Technical Specifications above

6.12 SPECIFICATIONS FOR DUCTILE IRON PIPES

Scope of Works

A. Supply, installation, testing and commissioning of Ductile Iron Pipe - Diameter 1m, Length 1m , Quantity 4 Number at S09A as specified in drawings.
B. The Drawings, Datasheets and Specifications are intended to set the acceptable minimum standard. Ensure that the installed equipment is trouble-free and meets performance requirements.

General

The pipes will be centrifugally cast (spun) Ductile Iron pipes for Water confirming to the IS 8329: 2000 / ISO 2531-1998 /BS EN 545 (latest). The pipes used will be with Flanged joints with Drilling as per PN 10. The class of pipe to be used shall be of the class K-9.

The pipes shall be externally coated with bitumen as per appendix C of IS 8329 and have factory provided cement mortar lining in the inside as per the provisions of Appendix B of the IS 8329. The flanged joints will conform to the Clause 6.2 of IS 8329/ISO Standard.

Marking

All pipes will be marked as per Clause 18 of IS 8329 and shown as below:

- Manufacturer name/ stamp
- Nominal diameter
- Class reference
- A white ring line showing length of insertion at spigot

Packing and Transport

The pipes should be preferably transported by road from the factory and stored as per the manufacturer specifications to protect damage.

Factory test reports & Hydro test reports shall be submitted along with supply.

6.13 SPECIFICATIONS FOR DEWATERING SUBMERSIBLE PUMPS

Scope of Works

Supply, Installation, Testing and Commissioning of Portable Submersible Dewatering Pump Set (1 Number at each Screen Chambers).

- Pumps shall be supplied with a vertical bottom inlet and a horizontal discharge.
- Pump casing/volute with discharge connection shall be of gray cast iron construction, ASTM A-48 Class 35B / IS 210 FG 260, with smooth finish.
- Pump impeller shall be of stainless steel CF 8M (SS 316) dynamically balanced, semi open impeller non clog design. The impeller shall be capable of handling solids, up to 100 mm size. The impeller shall be firmly connected and locked to the motor shaft and dynamically balanced to ISO-10816 standards for smooth vibration-free operation.
- The Pump shall be provided with SS 316 Flexible Hose to Discharge/De-water Sewage at Desired Location.
- The pump shaft shall be a solid continuous extension of the motor shaft and shall be AISI 431 / 410 stainless steel. The shaft shall be designed to meet the maximum torque required at the start-up or any operating point through the pumping range.
- Wear ring/plate shall be provided for Impeller and Casing to allow small running clearance between impeller and pump casing without causing wear of impeller and casing material.
- The shaft shall be of mono block type and Pump sealing shall be provided with Tandem type i.e. with Double Mechanical Seal. The shaft seal shall be located in lubricant chamber, with Silicon Carbide/Silicon Carbide or Tungsten Carbide/Tungsten Carbide inner and outer seals.
- Pump bearings shall be lubricated for life and shall have a life of minimum 100,000 run-hours and be designed and spaced to transfer all radial and axial loads to the pump housing and to minimize shaft deflection.
- Suitable lifting arrangement with chain shall be provided to lift the Pump. Each pump shall have a heavy duty certified lifting chain (SS 316) for raising and lowering the pumps. Safety factor for lifting chains and accessories shall be considered 2.0. The length of each chain should be at least equal to the depth of the wet well from the operating floor plus 2000 mm.
- Inspection and Testing – The contractor shall offer inspection and testing at Factory in presence of Engineer.

6.14 DATA SHEET FOR DEWATERING SUBMERSIBLE PUMPS

SL. NO.	ITEM	UNIT	Description
1.0	**GENERAL**		
1.1	DESCRIPTION		Portable Submersible Pumps
1.2	NUMBERS REQUIRED	Nos.	04
1.3	OPERATION		INTERMITTENT
1.4	LOCATION		INDOOR
2.0	**DESIGN DATA**		
2.1	LIQUID PUMPED		SEWAGE
2.2	pH		6.5 - 8
2.3	LIQUID TEMPERATURE	^{0}C	20 to 40 Deg. C
2.4	VISCOSITY		1
2.5	SPECIFIC GRAVITY		1.03
2.6	MAXIMUM SIZE OF SOLID	mm	100
2.7	DESIGN CAPACITY	m^3/hr	200
2.8	TOTAL HEAD	MLC	25
2.9	DESIGN PRESSURE	MLC	EQUIVALENT TO PUMP SHUT OFF PRESSURE
2.10	DESIGN TEMPERATURE	^{0}C	50
2.11	MAXIMUM SPEED	RPM	*
2.12	PUMP EFFICIENY	%	*
2.13	PUMP BKW	Kw	*
2.14	NPSH AVAILABLE	MLC	AMPLE
2.15	DESIGN CODE		ISO 10816-1, IS 9283, ISO 9906, IS 5120
3.0	**CONSTRUCTION FEATURES**		
3.1	TYPE OF PUMP		NON CLOG, SUBMERSIBLE PORTABLE TYPE
3.2			
3.3	TYPE OF IMPELLER		SEMI OPEN
3.4	SHAFT		MONOBLOCK
3.5	MECHANICAL SEAL		DOUBLE SEAL (BELLOW / BALANCED TYPE)
3.6	DISCHARGE PIPE ORIENTATION		VERTICAL
3.7	BEARING TYPE		RADIAL / THRUST
3.8	BEARING LUBRICATION		GREASE
3.9	COOLING ARRANGEMENT		YES / NO

SL. NO.	ITEM	UNIT	Description
3.10	OPERATION		MANUAL
3.11	FLANGE DRILLING STANDARD		AS PER MANUFACTURER'S STANDARD (COMPANION FLANGE TO BE PROVIDED)
3.12	FLANGE FACE		SOFF / SORF
3.13	DRIVE TRANSMISSION		DIRECT
4.0	**MATERIAL OF CONSTRUCTION**		
4.1	CASING		CAST IRON WITH SUITABLE COATING
4.2	IMPELLER		SS 316 (CF 8M)
4.3	SHAFT		SS 431 / 410
4.4	SHAFT SEAL		SS 316 WITH CERAMIC SEAL FACE
4.5	CASING RING		CAST IRON WITH SUITABLE COATING
4.6	IMPELLER RING		SS 316
4.7	FLEXIBLE HOSE		SS 316
4.8	LIFTING CHAIN		SS 316
5.0	**ACCESSORIES**		
5.1	DRY RUN PROTECTION		YES
5.2	TEMPERATURE SENSOR		NO
5.3	MOSITURE / SEAL SENSOR		YES
5.4	OVERLOAD PROTECTION		YES
5.5	LEVEL CONTROL SYSTEM		NO
5.6	CONTROL PANEL		YES
5.7	VIBRATION MONITORING SYSTEM		NO
5.8	SUCTION PRESSURE GAUGE		NO
5.9	DISCHARGE PRESSURE GAUGE		NO
5.10	SUCTION STRAINER		NO
5.11	DISCHARGE PIPE		NO
5.11.1	CONNECTION		HOSE
5.11.2	LENGTH	m	AROUND 40
5.12	GUIDE SYSTEM WITH ACCESSORIES		GUIDE WIRE / ROPE
5.13	COUPLING CONNECTOR UNIT WITH FOUNDATION PLATE		NOT APPLICABLE
5.14	COMPANION FLANGES WITH NUTS BOLTS, GASKETS		YES
5.15	FOUNDATION BOLTS		NOT APPLICABLE
5.16	SPARE PARTS		NO
5.17	MAINTENENCE TOOLS & TACKLES		NO

SL. NO.	ITEM	UNIT	Description
6.0	**PERFORMANCE GUARANTEE**		**(AS PER ISO 9906)**
6.1	CAPACITY	m^3/hr	(±) 8%
6.2	DIFFERENTIAL HEAD	MLC	(±) 5%
6.3	POWER CONSUMPTION	KW	(+) 5% OR (-) 2.5%
7.0	**TESTS AND INSPECTION**		
7.1	HYDROTEST DURATION / PRESSURE		30 MIN / 1.5 TIMES MAX DISCHARGE HEAD OR TWICE DIFFERENTIAL HEAD WHICHEVER IS HIGHER
7.2	MATERIAL TEST CERTIFICATE		CASING / IMPELLER / SHAFT / COUPLING
8.0	**MOTOR**		
8.1	Mounting		Integral with Pump
8.2	Voltage/Phase/Frequency		415V ± 10% / 3 Phase / 50 Hz ± 5%
8.3	Insulation Class		F
8.4	Degree of Protection		IP 68
8.5	Motor Rating	**KW**	*

Note:

1. Pump Exact Head to be Verified During Detail Engineering based on Pump Installation Depth and Distance to which Sewage to be Pumped.

2. SS 316 Flexible Hose and Cable of 40m length shall be considered, exact length shall be Verified during Detail Engineering.

3. * indicates Vendor to provide the details.

6.15 Electrical Works

General

Electrical works covered herein form part of the civil works for the tunnels. Conditions of contract in Volume - I will therefore be applicable for these works also. In case of conflict between the conditions/requirements covered herein and those covered elsewhere, the latter shall govern. This specification covers requirements in respect of design, manufacture, inspection at manufacturer's works, supply, delivery, installation, testing at site (field testing) and commissioning of electrical works described in subsequent clauses. Liaison with Electricity Supply Company for identifying nearest available source of power, obtaining power supply for temporary (construction) and permanent connection and other related works shall be the Contractor's responsibility. Specification drawings shall be used by the Bidder only for guidance and for assessing the quantum of supply and installation items involved in the works, whether specifically mentioned or not.

Scope

Electrical works shall essentially include supply, installation, testing and commissioning of the following systems:

a) Power supply distribution as per single line diagram.

b) 415V switchgear panel, proposed to be located inside control room / screen operator cabin.

c) Lockable Field cabinet

d) Lighting inside the shaft, in screen operator cabin and outside the electrical crane area.

e) Cabling and earthing protection systems.

f) Accessories such as conduits, supports, all consumables and hardware etc. as necessary.

Location wise scope of work

S08/SC08 – Bald Patch near Malad WwTF, SC09 – Malad Bus Depot, SC11 – Mahda Colony, SC12 – Goregaon IPS

- 415 V panel as per single line diagram having outgoings to, Sluice Gate Electrical Actuator, Mechanical bar screens, Dewatering Pump, Electrical Hoist, APFC Panel, instrumentation load , lighting and receptacles feeders.
- Lighting inside the shaft, in screen operator cabin and outside the electrical crane area Earthing system
- Cabling system

Power supply to the 415V panel shall be 3ph-N, 415V, drawn from the nearest available source of the utility company. The meter of the Utility Company shall be located inside the lockable field cabinet inside separate module owned and operated by the Utility Company.

Electricity

Contractor shall make provision of permanent power supply from Utility company for operation of electrical works of screen chamber.

Standards

All equipment, materials and installations shall comply with the requirements of the latest editions of standards and codes of practice published by the Bureau of Indian Standards and IEC, wherever applicable.

Materials

All material to be supplied / used by the Contractor shall be new, of high quality, free from imperfections and selected for long life and minimum maintenance. Supply items shall be selected from the preferred makes indicated subsequently, items for which preferred makes are not indicated, shall be subject to approval of the Corporation prior to procurement.

Interchangeability

All identical equipment and corresponding parts shall be fully interchangeable without any modification to ensure easy replacement. Non-interchangeable components and equipment are liable for rejection

Clearance from Statutory Authorities

The Contractor shall be responsible for obtaining statutory clearances from all relevant bodies such as electrical inspector, fire officer, factory inspector, insurance authorities, etc. Payment in terms of fees, deposits, etc. of such bodies are required to be made by Contractor, which would be reimbursed by MCGM at actuals on production of documentary evidence. MCGM may assist the Contractor in obtaining such clearances expeditiously by way of issue of introductory letters only to relevant bodies.

Contractor's Licence

It will be the responsibility of the Contractor to obtain necessary Licence / Authorisation permit for work, from licensing board of the state. The persons deputed by the Contractor's firm shall also hold valid permits issued or recognised by the Licensing Board of the state.

Workmanship

The Contractor shall ensure workmanship of good quality and shall assign qualified supervisors / engineers and competent labour who are skilled, careful and experienced in their trades. The Engineer shall reserve the right to reject non-competent persons employed by the Contractor, if the workmanship is not of good quality.

Drawings / Literature

The drawings enclosed with the tender specifications are for guidance only. After award of Contract, the Contractor shall furnish the following minimum drawings for approval of the Engineer:

Single Line diagrams for electrical system at each location, based on the system requirements and actual rating of the loads to be supplied

Equipment layout inside control room

Lighting layout- indoor and outdoor

Earthing layout, including details of earth pit etc.

Cabling layout

Cable schedule

Manufacturer's data sheets and drawings for 415V switchgear panel and other electrical items as applicable.Technical catalogues for components, as applicable.

Tests

The 415 V switchboards shall be offered for inspection after complete assembly. During inspection, the equipment shall be subjected to routine tests as per the applicable standards and test certificates shall be furnished for the Engineer's approval, prior to despatch of material. For all the other electrical equipment like field cabinets, lighting fixtures, cables etc. covered in this specification, test certificates shall be submitted for review / acceptance. Material / equipment shall be despatched only after receipt of shipping clearance.

Completeness of Equipment

Equipment offered shall be complete with all necessary components that are essential for

their satisfactory operation. Such components shall be included in Contractor's Scope whether specifically mentioned or not.

415 V Switchgear Panel (switchboard)

The 415 V switchgear panel shall be provided with separate modules for each circuit. The incoming and outgoing circuits shall cater to the various loads, broadly described below. Spare modules (minimum one of each rating) shall also be provided. It shall be the Contractor's responsibility to design and supply the 415V switchboard, to cater to all the power requirements at each site. Drawings clearly showing number/ rating/ arrangement of modules etc. shall be submitted for approval, after award of contract. Specifications for sheet metal work, components and other general constructional features shall conform to relevant subsequent clauses. The switchboard shall be rated for continuous current and short circuit withstand as indicated on the tender purpose drawings. Incomer to the board shall be MCCB. Outgoing feeders may be MCB/ MCCB/ SFU, as suitable. The panel shall have following design features:

a) Single front, non draw out, modular type, fully compartmentalised, suitable for free standing on floor (for smaller panels, wall mounting is acceptable). The height of the panel shall be 1900 mm (max). However, height of operating devices shall not exceed 1700 mm. Panel shall be suitable for front access. Enclosure shall provide degree of protection not less than IP54 as per relevant Indian Standards.

b) Cable Entry

Incomer and all outgoing modules shall have bottom cable entry.

c) Bus Bars

The panel shall be provided with three phase and neutral bus bars of Electrolytic Copper. The bus bars shall be air insulated and housed in a separate compartment. Direct access to or accidental contact with bus bars and primary connections shall not be possible. Bus bars shall be provided with PVC sleeving throughout the length, which shall be suitable for withstanding rated line to line voltage for 1 minute between bus bar and line for object on the exterior of covering.The bus bar shall be supported on non-hygroscopic material like hylum and nuts & bolts used for fixing busbars shall be brass.

d) Cable Glands

The panel shall be supplied complete with double compression type brass cable glands of adequate size to suit all the incoming and outgoing cables. Removable gland plates shall be provided for fixing the glands.

e) Earthing

The panel shall be provided with an earth bus of 25 x 6 mm Copper strip running its entire length. The earth bus shall be located at the bottom on the rear side. Two earthing terminals shall be provided at the two ends of the earthing bus for connection to external grid. Positive connection of all the frames of equipment mounted on the switchboard to the earth bus shall be maintained through suitably sized earth conductors. All doors shall be earthed. All instruments and relay coils shall be connected to earth bus bar by means of 1100V grade, PVC insulated, 1.5 sq.mm copper conductor looped through the case terminals.

All the metallic parts shall also be bonded to the earth grid. This shall include metallic frames, doorsill.

f) Sheet Metalwork for Switchgear Panel

Sheet steel used for fabrication shall be cold rolled and of minimum 2 mm thickness. Separate compartments shall be provided for incoming / outgoing circuits, bus bars / cables. The panels shall comprise rigid welded / bolted structural frames made of structural steel or pressed and formed sheet steel. The frames shall be enclosed by steel sheets, smoothly finished, levelled and free from flaws. Stiffeners shall be provided

wherever necessary.

Lifting eyes shall be of removable type and shall be replaced by bolts after installation.

All doors, removable covers and gland plates shall be gasketed all around.

All panel edges shall be reinforced against distortion by rolling, bendings or by addition of welded reinforcing members.

All doors shall be removable and supported by strong hinges of the disappearing or internal type and braced in such a manner so as to ensure freedom from sagging, bending and general distortion of panel or hinged parts. The hinges should be in such a fashion that door once hooked in upper hinge, automatically slides in the bottom hinge. Front access doors shall open at least through 120 degrees and shall be provided with stoppers to arrest further movement.

The panel shall be provided with a 75 mm high channel base frame.

g) Painting of 415 V Switchgear Panel

Powder coating shall be provided on the panel after 7-tank process. The paint shade shall be 692 (smoke grey) and 631 (admiralty grey) of IS:5 for indoor and outdoor equipment respectively. The paint thickness shall be minimum 50 micron.

MCCBs, MCBs & RCCB

MCCB/ MCB selected shall be suitable for the application (Motor switching/ lighting/ capacitor bank switching etc.). Miniature Circuit Breakers (MCBs) shall have min. 10 kA breaking capacity. Residual current circuit breakers (RCCB) shall be current operated and comply with relevant IS. The tripping current shall be 30 mA. It shall operate to trip all phases including the neutral. RCCBs shall be provided on all receptacle circuits.

Current Transformer (CTs)

Current transformer shall be cast resin type and shall have polarity markings indelibly marked on each transformer and at the lead terminations at the associated terminal block.

Current transformer shall be able to withstand the thermal and mechanical stresses resulting from the maximum short circuit and momentary duties of the switchgear.

Identification labels shall be fitted giving type, ratio, rating, output and serial numbers, duplicate rating labels are to be fitted on the exterior of the mounting chamber, suitably located to enable reading, without the removal of any cover or metal sheet forming part of the structure of the switchgear.

Indicating Instruments

Digital type Indicating instruments (ammeter, voltmeter, power factor meter and energy meter) shall be provided on the incomer to the 415V switchgear panel. Multi-function type instruments are acceptable.

Selector switch for ammeter and voltmeter shall be an integral part of the indicting instrument.

Indicating instruments shall be mounted flush on the panels with only flanges projecting outside the panel. Instruments shall conform to relevant Indian Standard.

All meters shall be of accuracy class 1.0.

Indicating Lamps

Indicating lamps shall be of the cluster LED type, with low watt consumption. Indicating lamps shall be of the double contact, bayonet cap type rated for operation on 240V AC system as applicable. These should be capable of withstanding 10% over-voltage continuously. Lamps shall be provided with translucent lamp covers of appropriate colours. Bulbs and lenses shall be interchangeable and easily replaceable from the front.

Space Heaters

Adequately rated anti condensation space heaters shall be provided in each cable alley of the switchgear panel. The space heaters shall be of the strip type, and shall be suitable for operation on a 240V, 1-phase, 50 Hz AC system.

Each space heater shall be complete with metallic type toggle switch, HRC fuse in the phase, link in the neutral and a control thermostat of range 30-60°C. The switch shall be located in the cable alley.

Cubicle Lighting

Each cable alley of 415V switchgear panel shall be provided with interior lighting by means of a 11 W compact fluorescent lamp along with metallic type toggle switch. The lamp shall be suitable for operation on a 240V, 1 phase, 50 Hz ac supply. Fuse shall be provided in the power supply circuit for protection. The switch shall be located in the cable alley. Alternative type of lighting, if required, shall be subject to Engineer's approval.

Wiring for Control, Protective Circuits and Power Circuits

All wiring for control, protective, alarm, and indicating circuits shall be carried out using 1100V grade, 1.5 sq.mm stranded copper conductor PVC insulated, wires. CT wiring shall be with minimum 2.5 sq.mm. copper conductor. All wiring shall be run on the sides of the panels and shall be neatly bunched and cleaved without affecting access to equipment mounted in the panel.

All wiring shall be taken to terminal blocks without joints or tees in their runs.

All wiring shall be colour coded as follows:

Instrument transformer	Red, yellow or blue determined by the phase with which the wire is associated or grey wire with indicating respective phase colour sleeves at both ends.
AC Phase wire	Red, yellow or blue determined by the phase with which the wire is associated.
Control circuit	Grey
Earth connections	Green

Engraved core identification ferrules, marked to correspond with the wiring diagram shall be fitted to each wire and each core of multicore cables terminated on the panel, devices etc. Ferrules shall fit tightly on the wires, without falling off when the wire is removed. Ferrules shall be of yellow colour with black lettering. Unused cores of multicore cables shall be ferruled U1, U2, etc. at both ends and connected to spare terminals.

Spare auxiliary contacts of all electrical devices shall be wired to terminal blocks.

Labels

All labels shall comprise black lettering on a white background.

Labels shall be made of non-rusting metal, anodised / electroplated with engraved letters and numbers or labels shall be perspex or other approved plastic with letters and numbers rear engraved and filled with black paint and white paint background.

All labels shall be properly fixed by screws. All components mounted on the Panel fronts shall be identified by labels. Equipment / components mounted within the Panel shall also be identified using labels. Switchgear Panel shall have a designation label.

Control Wiring Terminal Blocks

Terminal blocks shall be of 650V grade, stud type. Brass studs with fine threads shall be used and securely locked within the mounting base to prevent turning. Insulated barriers shall be

provided between adjacent terminals. Not more than two wires shall be connected on any one stud. Where duplication of terminal blocks is necessary, suitable solid bonding links of copper shall be incorporated in the design of the terminal blocks. Connections to the terminals shall be at the front.

Terminals shall be numbered for identification and grouped according to function. Labels of specified type shall be provided on the terminal blocks describing the function of the circuit.

All the terminals shall be shall be shrouded. Terminal blocks at different voltages shall be segregated into groups and distinctively labelled.

Current transformer secondary leads shall be brought to terminal blocks where a facility shall be provided for automatic short circuiting and grounding the secondary.

Terminal blocks shall be arranged with at least 100 mm clearance between any two sets. Minimum 20% spare terminals (with a minimum of 2 numbers) shall be provided in each set of terminals.

Separate terminal stems shall be provided for internal and external wiring respectively.

Ancillary Articles

Following ancillary articles shall be supplied with switchgear panel:

i. 750 mm wide vulcanised black colour safety rubber mat running the entire length of the panel. The upper surface shall have a fluted pattern. The thickness of the mat shall be not less than 65 +/- 0.05 mm at the root of the pattern. The rubber mat shall conform to relevant Indian Standard and shall be subjected to approval by the Engineer. The rubber mat shall bear 'ISI' mark.

ii. 2 pairs of rubber gloves to suit voltage class of switchgear. Gloves shall conform to relevant IS.

iii. First aid box, First aid chart, Shock treatment chart etc. – 1 set.

iv. Fire protection equipment as per the requirement of IE Rules shall be included.

Cables

a) Cables shall be 1.1 kV grade, XLPE insulated, sheathed and armoured. Cables shall conform to latest revision of IS 7098. Power cables shall be with minimum 4 sq.mm aluminium conductor. Control cables shall be with minimum 1.5 sq.mm. copper conductor. All conductors shall be stranded.

b) The estimated lengths of cables of various sizes are indicated in the schedule of prices. The Contractor shall be responsible to supply actual lengths required at site for satisfactory completion of work. Cable procurement action shall be initiated by the Contractor after approval of cable routes by the Engineer.

Cable Terminations

a) Tinned copper lugs of crimping type shall be used for termination.

b) Entries of cables at the switchgear shall be rendered vermin proof.

c) The individual cores of cables shall be neatly dressed and supported at regular intervals within the switchgear, before connecting them to the relevant terminals.

Cable Trays / Supports

Cable trays and supports shall be epoxy painted. Cable trays shall be GI, 2mm thick. Contractor shall provide insert plates of 150x150x5 during civil works (at intervals of about 1000 mm) for supporting cable trays. If insert plates as above are not provided, the plates shall be fixed by anchor fasteners. The charges for this activity shall be included in the rate for cable tray installation and no extra charges shall be payable for the same.

Chequered Plates

Chequered plate required to cover floor opening around the switchgear shall be supplied and

installed by the Contractor.

Chequered plates shall be minimum 6 mm thick. Stiffeners of adequate size shall be welded to the plates to suit the design requirements. The chequered plates shall be epoxy painted after fabrication, cutting to size, carrying out drilling operations etc.

Lighting Fixtures

Lighting fixtures and accessories shall conform to applicable Indian Standards. The lighting fixtures shall be suitable for operation on 240 Volts, single phase, 50 Hz AC supply. Lighting fixtures to be used in outdoor areas shall be of weather-proof design and shall suit outdoor installation.

All fixtures shall be supplied complete with reflectors, lamps / tubes, control gear, capacitors etc., as applicable, for their satisfactory operation.

The ballasts shall have copper windings. Types oflighting fixtures shall be LED and CFL type.

Light Control Switches & Receptacle Units

a) Light control switches shall be 5A decorative types.

b) Receptacle units shall consist of socket outlet associated with a switch of same rating. Decorative type receptacles shall be of 5 / 15 A rating and of 5 pin type, with 15A switch. Industrial type receptacles shall be of 16 A rating and of 3 pin type, with 16A MCB. Industrial receptacles in out door/ semi out door locations shall be of weatherproof type with IP 55 degree of protection (min.).

The receptacles shall become live only when the associated switch is 'ON'. Receptacles shall be housed in sheet steel enclosure of 16 SWG thick. The boxes shall be epoxy painted.

c) The switches and receptacles shall be suitable for use on 240 V, 1 phase, 50 Hz supply. Switches and sockets shall conform to relevant I.S.

Junction Boxes / Switch Boxes

All junction boxes / switch boxes required for works associated with cabling / lighting system shall be fabricated from 16 SWG sheet steel and shall be epoxy painted. The boxes shall be suitable for mounting on walls, columns, poles, steel structures etc.; boxes proposed to be located outdoor shall be of weather proof construction. Each box shall be provided with an earthing terminal. Size and design of junction box shall suit number of cable / conduit terminations at each location, number of switches / receptacles to be installed at each location.

Earthing System

a) Earthing system shall be provided to ensure equipment and personnel safety. Earthing system shall conform to latest revision of IS 3043.

b) Provision of earthing leads / bonds to all equipment, metallic enclosures of electrical equipment, cable trays, metallic conduits etc. shall be Contractor's responsibility.

c) i. Earth Electrode & Pits

Electrodes shall be made from 40 ∅ (nominal bore), 3000 long, heavy-duty GI pipe. Plate electrode in place of pipe electrodes may be accepted, where difficulties are experienced in installation of pipe electrodes, decision of Engineer, however, shall be final in this regard. The pipe electrodes shall be located in treated earth pits.

ii. Conductors for Earthing System

- 25 x 6 mm GI flat for main grid conductor and equipment earthing connections
- 8 SWG GI wire for earthing field cabinets, miscellaneous panels etc.

d) The estimated quantity of earthing conductors of various sizes is indicated in the

schedule of prices. The actual quantity shall be finalised in consultation with the Engineer, procurement action shall be initiated subsequently.

e) Supply, installation, testing & commissioning shall be carried out in accordance with relevant Indian Standards, Code of Practice, Indian Electricity Rules, Fire Insurance, factory inspector, requirement of Electrical Inspector etc. as required.

f) Lightning spike for lightning protection shall be provided on the roof which will be connected to a separate earth pit for instrumentation system.

Power Factor Improvement System

a) An automatic power factor (APFC) improvement (indoor) with Capacitor Banks (APP Type) as per IS 13925, type tested according to IEC 61439-1&2,IEC 61921 shall be provided as part of the 415V Switchgear panel.

b) Capacitor switching, and automatic power factor correction panel shall be designed in such a way that power factor of minimum 0.995 lagging shall always be maintained.

c) All panels of capacitor banks shall be provided with MCCBs, Contactor, minimum 8 stage automatic power factor correction relay.

d) The feeder shall be rated for 10% over voltage and 40% over current.

e) Each capacitor unit shall be individually protected by a MCCB Breaker suitably rated for load current and short circuit capacity, so that a faulty capacitor unit shall be disconnected by the breaker without causing the bank to be disconnected. Thus, the breaker shall disconnect only the faulty unit and shall leave the rest of the units undisturbed.

f) Contactors used for control of capacitors – for switching 'On' & 'Off' – shall be suitable for 'capacitor duty'.

g) Calculations for capacitor sizing shall be submitted by the contractor, after award of contract, taking into consideration the final loads on the 415V bus.

h) APFC Panel shall comprise of:

- Power capacitor shall be housed in the lower/rear compartment and capacitor controls in the top/front compartment.
- Bus bars shall be of Copper conductor and high conductivity.
- Sequencing devices, timer and auxiliary relays for automatic sequential switching of the capacitors in and out of circuit.
- Auto-Manual selector switches
- Microprocessor based Automatic Power Factor Correction (APFC) Relay
- Push buttons for switching 'On' and 'Off' of individual capacitor units in manual mode.
- Red and green lamps for capacitors ON/OFF indication.
- Protective numerical relays to protect the healthy capacitor units when one unit fails in a series connection
- Space heater and cubicle lighting as per the requirements

Installation Requirements- General

The Contractor shall carry out installation work in accordance with the Manufacturers' Instruction Manuals, Specification Drawing, Specifications covered herein and as stipulated in Code of Practice for Electrical Wiring installations (System voltage not exceeding 650 volts). Miscellaneous supply items, whether specifically mentioned or not, required for satisfactory installation, shall be covered in Contractor's scope.

In addition to the above, the installation shall also conform to any other relevant standard,

codes of practices, Indian Electricity Rules, Fire Insurance Regulations, factory inspector, requirements of Electrical Inspector etc. as applicable.

The installation work shall be inclusive of but not limited to provision of supporting accessories, consumables etc.

Provision of steel members in floor cut out for supporting the switchgear panel, field cabinets, other devices shall form part of switchgear installation work.

Installation of Earthing System

a) Each equipment suitable for operation on 415 V system shall be earthed by two separate earthing conductors. Equipment which operate on 240 V systems shall be earthed by one earthing conductor.

b) Earthing conductors shall be suitably buried in ground at a depth of 600 mm in outdoor areas and shall be embedded in floor slab with min. 50mm tile cover in indoor areas. Earthing conductor around the building shall be buried in earth at a depth of 600 mm and at a minimum distance of 1500 mm from outer boundary of the building.

c) Installation of conductors buried in ground shall include excavation in ground upto 600 mm depth and 450 mm width, laying of conductor at 600 mm depth, welding of conductors as required and backfilling. Backfilling shall be done in layers of 150 mm, uniformly spread along the excavation and tampered to achieve original surface. The backfill shall be free from stones.

d) Spacing of 6000 mm between adjacent electrodes shall be kept to the extent possible.

e) Installation of electrodes shall include fixing of earth electrodes in constructed pits and connection to earth grid.

f) Unless otherwise stated, earthing conductors shall be laid minimum 300 mm below underground services, where they are required to cross such services.

g) All connections in the main earth conductors buried in earth shall be of welded type. Connections between main earthing conductor and earth leads shall also be of welded type.

h) Connection between earth leads and equipment shall be of bolted type, unless specified otherwise, these connections shall be of the two bolt type.

i) Damaged surfaces of GI conductors shall be touched-up with zinc rich paint after cutting, drilling, bending, welding, etc.

j) Metallic conduits / pipes and cable trays used for cable laying shall be bonded to the earthing system.

GI pipes shall be provided for entry of earth conductors into building. Cost of these pipes shall be included in the installation rate for earthing system.

Installation of Lighting System Items

Installation work shall include mounting of lighting fixtures, receptacle units, switches etc. All work and supply items including civil items required for mounting shall be included in the Contractor's scope. Contractor shall submit lighting layout drawings for approval. Cable and conduit routes shall be finalised in consultation with the Engineer.

Point Wiring of Fixtures

a) <u>Conduit Wiring</u>

The work shall cover wiring from Switchgear Panel in suitably sized (minimum 25 mm) GI conduits, supported on walls, ceilings, etc., at an interval not exceeding 1000 mm, installation of light control switches and receptacles housed in epoxy painted steel boxes, earthing with 16 SWG copper wire run along the conduits and clamped at every 1000 mm interval, termination of wires (including earthwire) at Switchgear Panel, light control switches, receptacles, lighting fixtures, etc., as required.

Supply of all the items for the work detailed above such as 1100 Volt grade, Cu conductor PVC insulated wires, 5A / 15A switches, GI conduits and accessories (such as junction boxes, tees, elbows, etc.,), suitable epoxy painted sheet steel boxes fabricated from 16 SWG sheet and complete with gasket, knockouts for conduit entries, earthing terminal with bolt, nut and washer, copper earthing wire, flexible conduit, etc., shall be included in Contractor's scope. All work necessary for fixing of boxes, conduits, etc., together with supply of necessary hardware, shall also be included in Contractor's scope.

All light control switches and/ or 5A / 15A receptacle units (connected on the same phase) shown at one location shall be housed in one common box (separate boxes for individual items shall not be used in such cases).

Receptacles shall be wired on separate circuits.

Wiring shall be colour coded using red, yellow and blue colour wires for phase and black colour wire for neutral, green wire for earthing. The wiring throughout the installation shall be such that there is no break in neutral wire in the form of switch or fuse unit.

Wire size shall be min. 1.5 sq. mm. for light fixtures and 2.5 sq.mm. for 5/15A receptacles. Stranded wires shall be used.

The conduits shall be bonded effectively on either end of coupling and other termination points. Conduits shall be grounded at the ends adjacent to switchgear by a grounding conductor connected to an earth clip.

Installation of Cables

Exterior cables shall be laid directly buried in earth 750 mm below finished ground level. Contractor's scope of work shall include excavation, laying, backfilling, fixing, jointing, bending and terminating the cables. The Contractor shall supply materials necessary for installation, jointing and terminating of the cables which shall include but not be limited to items such as glands / lugs, terminating accessories, hardware, consumables, RCC pipes (for cable entry into building) / GI pipes, saddles / spacers, cable identification tags, protective bricks, civil materials etc. All items of work such as chipping, making pockets / holes etc. associated with installation shall be included in Contractor's scope.

Directly buried cables shall be laid on a 50 mm riddled earth bed. The cables shall then be covered on top and on side with riddled earth to a depth of about 150 mm. This is then gently pulled down to a depth of about 100 mm above the top of uppermost cable to provide bedding for the protective earthenware cable covers, which are placed centrally over the cables. Markers shall be provided along the route of the cable.

For the passage of cables through floor or wall openings or other partitions, pipe sleeves of appropriate size shall be provided by the Contractor.

At road crossing 150 mm dia hume pipes, at a depth of 600 mm, for passage of cables shall be provided. Sharp bending, twisting and kinking of cables shall be avoided. The bending radii for power cables shall not be less than 12D, unless specifically approved by the Engineer.

Cable identification tags fabricated from 1.6 mm thick GI flat shall be attached at each end of the cable.

Cable terminations shall be made in a neat, workmanlike and approved manner by skilled personnel specialised in this class of work.

Cables shall be laid on exposed trays/ in floor chases/ shallow trenches with cover, as suitable. Layout drawings and cable schedules for outdoor and indoor cabling arrangement shall be submitted by the contractor for approval, after award of contract. Procurement action for cable trays, tray supports etc. shall be initiated after approval of layout drawings and cable schedule.

Commissioning

After completion of installation works, the Contractor shall arrange to carry out checks / tests on all equipment to prove that the system is in accordance with the design, specifications, Indian Standards, Code of Practice and Electricity Rules.

6.16 I & C Works

Differential Ultrasonic Level Transmitter Data Sheet

Sr. No.	Description	Required	Proposed By Bidder
1	Type and material	Ultrasonic, Pulse Time of flight Stainless steel PVDF/ EPDM seal Flanged or un-flanged as per site requirement, Suitable for Hazardous Areas	
2	Power supply	24V DC	
3	Output	Frequency	
4	Range	Suitable for 0 to 15 m	
5	Beam Angle	6º	
6	Accuracy	±0.25% of range or better	
7	Resolution	Minimum 2 mm or 0.1% of measuring range	
8	Ingress protection	IP 68	
9	Enclosure	ABS Plastic / Polycarbonate or better	
10	Application	Measurement of differential level across Mechanical bar screen in screen Channel	
	Level Transmitter cum Indicator		
11	Mounting	Panel	
12	Display	Digital display with readout in engineering units, Alphanumeric backlit LCD, 2½ digits, Microprocessor based electronics	
13	Input signal	From 2 nos. transducer	
14	Output signal	4-20 mA DC HART (equivalent to level differential)	
15	Output voltage	24V DC suitable for transducer	
16	Accuracy	Within ± 0.25% of range	
17	Power supply	input 230 V AC ± 10%, 50 Hz	
18	Protection	IP 54	
19	Ambient Temp	Maximum 65°C	
20	Reset Facility	Shall be provided	
21	Digital output	2 NO + 2 NC	
22	Communications	Retransmission 4-20 mA signal for connection with PLC	
Note : Level sensor shall be installed at suitable locations in a channel considering beam angle and allowed clearance for non-interference of ultrasonic signal due to channel wall Differential Ultrasonic Level Transmitter arrangement shall be consider for Each Screen Chamber.			

6.17 WHEEL BARROW SPECIFICATIONS

GENERAL

Work Included:

A. Supply of HDPE wheel Barrows 2 nos. at each screen chamber for waste collection.

B. The Drawings, Datasheets and Specifications are intended to set the acceptable minimum standard. Ensure that the installed equipment is trouble-free and meets performance requirements.

Codes and Standards:

C. The applicable standards established by EN 840-2 govern the materials and workmanship employed in the work under this section.

D. Where provisions of the pertinent codes and standards conflict with these Specifications and Drawings or with each other comply with the more stringent provisions.

E. Use the latest issue of Standards.

PRODUCTS

General Design Data:

F. Volume - 660Litres and payload 250 kg min.

G. Overall dimensions: max. L = 1.275m, W = 0.78m, H = 1.2 m.

H. Body - High density polyethylene.

I. Wheels – Four with rubber tyres.

J. All replaceable and wearing parts shall be of standard, accurate dimensions. Complete wheelbarrows shall be factory assembled and tested prior to delivery.

K. The equipment shall be designed for minimum maintenance, repair or replacement.

Structure:

L. Body, tyres and wheels

1. Body to be made from shock-absorbent high–density polyethylene, stabilized against degradation due to ultra-violet radiation and suitable for use in ambient temperatures.
2. Smooth rounded interior to allow rapid discharge of contents and easy cleaning.
3. Internal ribs of approximate 5 mm thickness on front and back inside wall for additional strength.
4. Provide drain with plug at the lowest point to drain water after cleaning.
5. Provide weatherproof cover fitted with the body to check odours and keep away flies and vermin. The covers shall open automatically when tilted for discharging contents.
6. Provide strong upper rim for safe mechanical lifting suitable for use with any type of lifting mechanism based on international norms.
7. Provide easy-to-turn castor wheels with directional castor locks. Provide brakes on two wheels.

6.18 Equipment Makes List

S. No.	Equipment	Vendors
1.	Sluice Gates	M/s Jash M/s Ham Baker M/s Parchure Engineers Pvt. Ltd.. M/s Armco Sluice Gate
2.	Mechanical / Manual Screen	M/s Jash M/s Aqseptence M/s Parchure Engineers Pvt. Ltd. M/s Huber M/s Johnson M/s Auricent
3.	Electric Hoist	M/s Eddy Cranes M/s Electromech M/s Brady Morris M/s SMACO
4.	Submersible Pumps	M/s KSB M/s Xylem M/s KBL M/s Grundfos M/s Kishor
5.	Flap Gates	M/s Jash M/s Vag M/s Orbinox
6.	Switchgear Components	M/s L&T M/s Siemens M/s Schneider M/s GE Power
7.	Lighting Fixtures	M/s Philips M/s Bajaj M/s Crompton M/s Wipro

8.	Miniature Circuit Breakers & Earth Leakage Circuit Breakers	M/s Merlin Gerin M/s MDS Legrand M/s Siemens M/s Hager M/s Schneider M/s Indokopp
9.	Capacitors	M/s Siemens M/s L&T M/s ABB M/s CG Power system
10.	Cables	M/s CCI M/s Universal M/s Finolex M/s RPG M/s Nicco M/s Polycab M/s Gemscab M/s KE
11.	Ultrasonic Level Transmitter	M/s Emerson M/s ABB M/s Siemens M/s Endress+Hauser M/s Krohne Marshall
12.	Electric Actuator	M/s Auma M/s Limitorque M/s L Bernard M/s Rotork
13	Wheel Barrow	M/s Nilkamal M/s Plastic Omnium Urban Systems M/s Linpac
14	DI Pipes	M/s Kejriwal Castings Limited M/s Rashmi Metallik M/s Tata Metallik M/s Electro Steel

6.19 Odour Control Equipment

Contractor shall design, supply, install, test and commission Odour control equipment in all screen chambers.

7 GENERAL CONSTRUCTION WORKS

7.1 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.

7.2 Electricity

The Contractor shall be responsible for making the provision of permanent power supply from the Utility Company required for the operation of screen chamber facility . For the execution of the constructional works at site the Contractor shall be responsible for procurement of power either through the local Electricity Company 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

7.3 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.

7.4 Vechicle Arrangement for Employer Staffs.

The contactor shall provide 3 nos. of vehicles for Employer site staff.

7.5 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.

7.6 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.

7.7 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.

7.8 Working in Public Roads

7.8.1 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.

7.8.2 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.

7.8.3 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

7.8.4 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.

7.9 Geotechnical Investigations

Geotechnical investigation reports are enclosed for General Guidelines of Bidders. Bidder shall make their 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. MCGM shall not entertain claims of whatsoever nature arising out of this at any stage of the work.

7.9.1 Employer's Investigation Programme

During the Employer's design of the works a programme of exploratory drilling was carried out to provide geotechnical data for the Contractor. The data resulting from the programme is available to the Contractor and can be found in the following locations:

1) Report on Investigations:

A report in two volumes has been prepared covering the following records made during the investigation:

Borehole Logs

Insitu Tests

- Packer Tests
- Pressuremeter tests
- SPT Tests
- Groundwater elevation

Laboratory Tests

- Unconfined compressive strength
- Point Load Tests
- Tensile Tests
- Quartz Content / petrography
- Moh's hardness
- Cerchar abrasivity

2) Contract Drawings:

The Drawings include the locations of the boreholes and summaries of what rock types were encountered.

3) Cores:

The cores from the boreholes are available for inspection by arrangement with the Employer.

7.9.2 Additional Subsurface Investigation

Once appointed, the Contractor may carry out whatever additional geotechnical investigations he deems necessary to facilitate completion of the works. The Contractor's attention is drawn to the importance of establishing the subsurface ground conditions and their range of variability along the pipeline 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 pipeline 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.

7.9.3 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 pipeline or tunnel route. The Contractor shall submit the Geotechnical profile along the route of the pipeline or 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.

7.9.4 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.

7.10 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.

7.11 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.

7.12 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.

7.13 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). For all setting out work the Contractor shall use the THD within the Employer's site of Shimpoli Pumping Station, which is benchmark number 166 / RN at a height of 29.357m.

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 / pipeline 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.

7.14 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.

7.15 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.

7.15.1 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 pipes 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

7.16 Diversion of Existing Sewers

7.16.1 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.

7.16.2 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 western 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.

7.16.3 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.

7.17 Diversion of Water Mains

In addition to the requirements given in Section 7.15 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.

7.18 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.

7.19 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

7.20 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.

7.21 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.

7.22 Explosives and Blasting

Control Blasting may be allowed for shaft no S08 & S08A and for NATM Tunnels of ID 5.0m & ID 3.0m at existing Malad STP. For all other locations of project, control blasting is not allowed. Contractor shall obtain all the statutory permissions/approvals before carrying out the activity. Contractor shall involve and get the entire scheme of control blasting (No, dia, location, charge of hole etc) from CWPRS Pune along with the necessary supervision during actual blasting operation.Contractor shall be fully responsible for carrying out operation of control blasting and shall indemnify the owner for any mishap. Any delay on account of this activity will not compensation in terms of cost and time.

Blasting shall be controlled to ensure that the peak particle velocity at any adjacent/ nearby structure is within safe limits as determined by the seismologist. The information on drilling and blasting pattern requires to be furnished to the Engineer. For this purpose, the Contractor may conduct trial blast in the shafts/ tunnel proper and arrive at a blasting pattern in line with the recommendations of Central Water & Power Research Station (CWPRS) according to which the peak particlevelocity shall not exceed 2.5 mm persecond.

7.23 cost and timeFees 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.

7.24 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 as per the policy of MCGM and is inclusive of royalty. However, the cost is exclusive of supervision charges which will be charged extra at 10%.

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.

7.25 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.

7.26 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
- 10 years minimum for LT switchgear panels
- 15 years minimum for Electrical Cables and Cable Trays
- 25 years minimum for Mechanical Rotating Machinery and Complex Equipment

7.27 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.

7.28 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.

7.29 Progress Photographs 0

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.

7.30 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.

7.31 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 (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.

7.32 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.

7.33 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.

7.34 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.

8 CONTRACTOR'S DOCUMENTS

8.1 General

8.1.1 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.

8.1.2 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.

8.1.3 Programme

The Programme to be submitted within the times specified in Section 10, 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 Microtunnelling systems/ 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

8.1.4 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.

8.1.5 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.

(i) 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.

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

8.1.6 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

8.1.7 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.

8.1.8 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.

8.1.9 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

8.1.10 Traffic Management Plan

The Contractor shall submit his draft Traffic Management Plan in accordance with the Traffic Management Requirements described in Section 7.8 and as agreed with the Traffic Police.

8.1.11 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 7.33. 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.

8.2 Design

8.2.1 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 3.12.7.

8.2.2 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.

8.2.3 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.

8.2.4 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 pipejacking 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.

8.2.5 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.

8.2.6 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.

8.3 Construction

8.3.1 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.

8.3.2 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.

8.3.3 Submission on Tunnelling / Microtunnelling System

8.3.3.1 General

The Contractor shall furnish complete details of the tunnelling/microtunnelling 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 and microtunnelling 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.

8.3.3.2 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 / microtunnelling 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.

8.3.4 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 14.4, microtunnelling requirements in Section 16.3.13.

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.

8.3.5 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.

8.4 Handover

8.4.1 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

8.4.2 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.

9 LICENCES AND CONSENTS

9.1 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.

10 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.	Submission of all licenses, consents, clearances, NoCs, etc required for commencement of Construction Work	By end of week 20
8.	Submission of construction stage documents (excluding method statement)	No later than three weeks prior to commencement of that element of work
9.	Submission of construction and installation method statements	No later than three weeks prior to commencement of that element of work
10.	Submission of plant delivery documents	No later than two weeks prior to commencement of that element of work
11.	Submission of Tests on Completion method statement and programme	No later than 6 weeks prior to commencement of the Tests on Completion
12.	As-built documents submission	No later than 2 weeks prior to commencement of the Tests on Completion
13.	Commencement of Tests on Completion	No later than 2 months before the date for completion
14.	Final approved as-built documents	No later than the date set out in the Taking Over Certificate in accordance with Conditions of Contract Sub-Clause 10.1, or 28 days after completion of the Tests on Completion whichever is the earlier
15.	Time for Completion	As stated in the Particular Conditions Part A - Contract Data

11 TESTS ON COMPLETION/TESTS AFTER COMPLETION

11.1 General

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

11.2 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.

11.3 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 watertightness 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.

12 QUALITY ASSURANCE

12.1 General

Further to the requirements of Section 8.1.5 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.

12.2 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.

12.3 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.

13 EXCAVATION WORKS FOR SHAFTS AND TUNNELS

13.1 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.

13.1.1 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.

13.1.2 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.

13.1.3 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.

13.2 Ground Treatment for Ground Stabilisation and Groundwater Control

13.2.1 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.

13.2.2 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 microtunnelling 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.

13.2.3 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.

13.2.4 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.

13.2.5 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.

13.2.6 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.

13.2.7 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.

13.2.8 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.

13.3 Piling

13.3.1 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 8.3.2 of the Employer's Requirements.

13.3.2 Tolerances

13.3.2.1 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.

13.3.2.2 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 13.3.12 of the Employer's Requirements.

13.3.3 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.

13.3.4 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.

13.3.5 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.

13.3.6 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.

13.3.7 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.

13.3.8 Requirements for Reinforced Concrete in Piles

13.3.8.1 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.

13.3.8.2 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.

13.3.8.3 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.

13.3.8.4 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.

13.3.8.5 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.

13.3.8.6 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.

13.3.8.7 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.

13.3.8.8 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.

13.3.9 Bored Cast In-situ Piles

13.3.9.1 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.

13.3.9.2 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.

13.3.9.3 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.

13.3.9.4 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.

13.3.9.5 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.

13.3.9.6 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.

13.3.9.7 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.

13.3.9.8 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.

13.3.10 Drilling Fluid

13.3.10.1 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.

13.3.10.2 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.

13.3.10.3 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/m2 or 4.0 - 40.0 N/m2	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.

13.3.11 Concreting and Extraction of Casing

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

13.3.11.1 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.

13.3.11.2 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.

13.3.12 Secant Pile Walls

13.3.12.1 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.

13.3.12.2 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.

13.3.12.3 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.

13.3.12.4 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.

13.3.12.5 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.

13.3.13 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.

13.4 Cast In-situ Secondary Concrete Lining of Shafts

13.4.1 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.

13.4.2 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.

13.4.3 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.

13.4.4 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.

13.4.5 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.

13.4.6 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.

13.4.7 Concrete Replacement and Repair

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

13.4.8 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.

13.4.9 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.

13.4.10 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.

13.5 Shotcrete Lining of Shafts

13.5.1 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.

13.5.2 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.

13.5.3 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.

13.5.4 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.

13.5.5 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.

13.5.6 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.

13.5.7 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

13.5.8 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.

13.5.9 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.

13.5.10 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 35ºC, sprayed water curing shall be required

13.5.11 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.

13.6 Cavity Grouting

13.6.1 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 tunnel 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.

13.6.2 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.

Primary grout shall be injected through grout holes provided in the linings. 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.

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.

13.6.3 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.

13.6.4 Deleted

13.6.5 Cement Grout for Cavity Grouting

13.6.5.1 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.

13.6.5.2 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.

13.6.5.3 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.

13.6.5.4 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.

13.7 Waterproofing System for Shafts

13.7.1 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.

13.7.2 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.

13.7.3 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

13.7.4 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.

13.7.5 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.

13.7.6 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.

13.7.7 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.

13.7.8 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/mm^2 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.

14 TUNNELLING SYSTEMS

14.1 Tunnel Boring Machines (TBMs) and Shields

14.1.1 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 submit the specifications, standards, requirements of TBM complying with the Employers Requirement and obtain Engineers concurrence before procurement of TBM for the project.

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.

14.1.2 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.

14.1.3 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.

14.1.4 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.

14.1.5 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.

14.1.6 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.

14.1.7 Guidance

14.1.7.1 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.

14.1.7.2 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.

14.1.8 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.

14.1.9 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.

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.

14.1.10 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.

14.1.11 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.

14.1.12 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.

14.2 Slurry and Earth Pressure Balance (EPB) Machines

14.2.1 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.

14.2.2 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.

14.2.3 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.

14.2.4 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.

14.2.5 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:

d) Face pressure gauges
e) Machine position, inclination and roll
f) Cutterhead rotation speed, direction, torque and thrust
g) Cutterhead door aperture status (where fitted)
h) Ram thrust pressures, stroke and speed singly and in combination
i) Slurry flows and pressure (slurry machines)
j) Screw rotation speeds and pressure drop (EPBMs)
k) Electrical power
l) Means of measuring and recording the volume of material excavated per ring of advance
m) TBM advance rates
n) Ram extension
o) If required by the Contract, provisions shall be made for data logging of all the above functions
p) Grout quantity
q) Volume of soil conditioning constituent materials including air, water, foaming agents and polymers.

14.3 Operation of Tunnelling Machines and Shields

14.3.1 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.

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.

14.3.2 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.

14.4 Monitoring of Works

14.4.1 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.

14.4.2 Ground Movement Monitoring

14.4.2.1 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.

14.4.2.2 Monitoring Methodology

In particular, settlement monitoring points are to be established between Tunnel Shafts S08 and S12 where the tunnel is below DP Road and Link Road.

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.

14.4.3 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.

14.4.4 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 jacking pipes (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.

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).

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

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 $m \geq 0.8D$	Nuts with $0.5D \leq m < 0.8D$	Nuts with $m \geq 0.8D$	Nuts with $0.5D \leq m < 0.8D$
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/mm^2	400	400	600	800	1000
Yield stress R_e min. N/mm^2	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/mm^2	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 Portland Slag Cement (GGBS shall be maximum of 30% of the cement content)

The minimum cementitious content shall be 400kg/m3 and the maximum cementitious content shall be 500kg/m3.

The maximum free water/cementitious material (w/c) ratio shall be 0.35.

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 SO3 shall not exceed 4.0% SO3 by weight of cementitious content.

The alkali content of the concrete expressed as sodium oxide (Na2O) equivalent shall not exceed 3.5kg/m3, 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/m3) 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 13.6.

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 **Error! Reference source not f ound.** 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 14.4 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 Tests on Precast Concrete Segments

Contractor shall conduct the below mentioned tests on precast concrete segments

15.5.1 Pullout Test

15.5.2 RCPT

RCPT shall be conducted as per ASTMC 1202.

It is used to measure ingression of chloride ions in concrete.

RCPT Ratings : ASTM C 1202

charged passed (coulombs)	Chloride Ion Penetrability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very Low
<100	Negligible

15.5.3 WPT

WPT shall be conducted as per DIN 1048

It is used to measure depth of water penetrate in concrete. It should not be more than 10mm as per DIN 1048.

16 MICROTUNNELLING/PIPE JACKING WORKS

16.1 General

Microtunnelling is a process of accurately excavating, non-man entry tunnels for installing underground pipelines, using laser guided remote controlled shields and installing product pipelines by jacking technique as the tunnelling goes on simultaneously. The term microtunnelling is generally applied to small-diameter tunnels and pipelines installed by pipejacking methods behind a remotely controlled tunnel boring machine.

Pipejacking is defined as the installation of a tunnel lining by jacking pipes behind a shield, tunnelling machine or auger boring machine. It is customary to call the process of microtunnelling and pipejacking together as only microtunnelling wherein pipejacking is an obvious integral component.

The microtunnelling machine shall be selected with regard to the ground conditions, length of drive and other relevant factors.

The Contractor shall be fully responsible for the selection, design, supply, operation and maintenance of tunnelling machines, shields, ancillary equipment, consumables, and any materials whatsoever required for the construction of the tunnels.

Microtunnelling machines shall comply generally with the provisions of Section 14 covering TBMs, shields, slurry and earth pressure balance machines.

The supplementary system required for microtunnelling and pipejacking operation shall include muck disposal system and slurry separation system, automatic pipe lubrication system, grouting system, guide rails, entrance and exit seals. The entrance and exit seals shall be capable of withstanding anticipated hydrostatic loads plus the pressures exerted by the pressurized systems. Man entry requirements stated in Section 13 are only applicable for internal diameters of 1,200mm or greater.

16.1.1 Jacking System

The jacking system comprises high thrust hydraulic jacks mounted in a jacking frame capable of exerting the required jacking force against a purpose built thrust wall to push the pipes and the shield forward through the ground. The jacking force is transferred evenly to the jacking pipe through a push ring connected to the pipe.

16.1.2 Pull-back or telescopic Station

To permit tool changing on TBM's for 1,200mm tunnel ID or greater, a steel cylinder shall be located directly behind machine powerpack with either two or four 100t jacking cylinders, each with 1200mm stroke powered from the machine powerpack and fitted with stroke and pressure sensors on one cylinder to indicate on the main operators screen. This shall be with gripper devices to allow the machine to be retracted. Note when using this it is necessary to secure all the lead pipes as there is a tendency to pull the machine off the end of the pipe. The main use of this is to ensure that even force can be applied to the cutters, in long distance pipejacking the pipe packers tend to compress and a springing effect can occur whereby the machine jumps into the face causing shock loading to cutter bearings and shattering cutter discs.

16.1.3 Guidance System.

The guidance system shall meet the requirements of Section 14.1.7. The device shall be installed in the jacking shaft and the beam is set to the desired level, gradient and alignment. The microtunnelling machine shall have photo sensitive cells on the target panel located at the rear of the shield which converts the laser position into digital data. The data are then

electronically transmitted to the operator's control panel where digital readout of the location can be made.
On curved alignments additional laser stations inside the jacked pipeline are provided to ensure correct transfer of positional data.

The laser source or theodolite shall be firmly supported in the jacking pit so that it is independent of any movement that may take place during the jacking operation requiring reaction from the shaft walls.

16.1.4 Remote Control System

All microtunnelling systems rely on remote-control capability. The control system monitors and controls the steering of the shield, spoil removal system (slurry or augur or vacuum), jacking system and guidance system, and shall meet the requirements set out in Sections 14.1, 14.2 and 14.3.

The control cabin shall be located near to the jacking pit so that the operator can visually monitor the activities in the pit. Where it is not possible to locate the control cabin near to the pit due to space limitations, a CCTV camera system shall be set up in the pit to allow the operator to monitor the activities in the pit.

16.1.5 Jacking Shafts (Jacking Pits)

A Jacking Shaft or Jacking Pit is a temporary structure from where a jacking operation is performed. The shaft can be rectangular or circular in shape and shall be securely supported to ensure safety of persons working inside as well as the equipment. The size of the shaft shall be such that it is capable of accommodating the jacking equipment (and also the shield), jacking pipe and other paraphernalia or enable construction of manhole or chamber as needed.

It shall be the responsibility of the Contractor to design the jacking shaft, its supporting dewatering system, access system for personnel and materials and ventilation systems, besides all other functional requirements to allow it to function as a jacking shaft on a microtunnel system. Due consideration shall be given to the depth, hydrostatic and earth as well as surcharge loads due to equipment/ vehicles plying in vicinity of the shafts.

The shafts shall be provided with appropriate means of entry of workmen and staff which shall be separate from the hoists or lifts for the purpose of lowering of pipes, materials or equipment etc. The size of the shaft shall duly account for these requirements making due allowance for available working space on site.

16.1.6 Receiving Shaft (Receiving Pit)

A Receiving Shaft or Receiving Pit is a purpose built temporary structure to receive and remove the tunnelling shield after its completion of a tunnel drive. The shaft can be rectangular or circular in shape as per requirement. The size shall be sufficient enough to accommodate the tunnelling shield when it emerges into the shaft after completion of a tunnel drive or construction of a chamber.

It shall be the responsibility of the Contractor to design the receiving shaft including the number of such shafts required considering the drive strategy he intends to employ, its supporting, dewatering system besides all other functional requirements to allow it to function as a receiving shaft on a microtunnel system. Due consideration shall be given to the depth, hydrostatic and earth loads as well as surcharge loads due to equipment/vehicles plying in vicinity of the shafts.

The Contractor shall be responsible to ensure minimum number of temporary shafts and he will be required to erect any permanent structures at such locations as acceptable to the engineer at no extra cost to the Employer.

16.1.7 Thrust Wall

The thrust wall is a temporary concrete structure built within the jacking shaft to transfer the jacking force to the ground during jacking operation. The jacking shafts may often have more than a single thrust wall and each thrust wall shall be perpendicular and square to the pipeline to be jacked. The thrust walls shall be in good contact with the soils/ rock behind or anchored into bottom so that wall can transmit the jacking force effectively to the ground without affecting the shoring system and to provide the required jacking force.

16.1.8 Entrance Ring

A steel flange fitted with a rubber seal (a 10mm to 20mm thick circular rubber gasket whose outside diameter is the same as that of the steel flange and the inside diameter is smaller than that of the jacking pipe) installed perpendicular to the pipeline at the entrance. The purpose of the rubber seal is to prevent the slurry or ground water from entering into the shaft through the pipe entrance.

16.1.9 Exit Ring

This is similar to the entrance ring except that the internal diameter of the rubber seal is much smaller than that of the jacking pipe and is installed to prevent the slurry or ground water from escaping the tunnelling machine when it emerges at the receiving shaft.

16.1.10 Jacking Frame

To facilitate placing of the microtunnelling machine and pipes in the jacking shaft, a jacking frame) shall be carefully set up in the shaft to correct alignment and gradient so that the pipe when placed on it stays in line with and square to the pipeline alignment. The jacking frame assembly shall be such that it is not disturbed due to jacking force exerted onto the thrust wall.

16.1.11 Thrust Pressure Plate

The thrust pressure plate is usually a 50mm or 100mm thick steel plate installed between the jacks assembly and the thrust wall. The pressure plate enables the concentrated jacking load from the jacks to be transmitted evenly to the thrust wall.

16.1.12 Jacking Ring

Jacking ring or thrust plate is a purpose made structural fitting which shall be installed between the jacking assembly and the jacking pipe to transfer the point loads from the individual jacks into evenly distributed jacking force to the pipes being jacked. The ring shall be fabricated and machined, if necessary, so that it fits exactly onto end of the jacking pipe.

16.1.13 Automatic Water sprinkling system

An automatic water sprinkling system shall be provided by the Contractor to wet the jacking pipes immediately prior to the pipes being lowered down the jacking shaft.

16.1.14 Automatic Lubrication System

In order to maintain the frictional forces and resultant jacking forces to minimum, automatic lubrication system capable of operating the injectors in sequential or selective manner shall be provided with the system. This lubrication system must be integrated with the drive control system in the operator's console.

16.1.15 Intermediate Jacking Station

For longer distance jacking, intermediate jacking stations, comprising a telescopic type jacking pipe assembly (usually made of steel), are used with a set of inter jacks and push ring installed around the inner side of the female pipe of the telescopic pipe assembly.

The intermediate jacking station shall be installed at appropriate pre-planned chainages with correct anticipation of the requirement for the same and jacked-in along with the other jacking pipes.

Whether the alignment is made up of a series of straight sections or it will follow curvatures, it will be appropriate to be ready with Intermediate Jacking Stations to be inserted in the pipe train in a planned manner whether operated or not. Interjacks shall be designed to minimize the jacking forces. The pipe manufacturer must have the capability to fabricate interjack pipes as necessary.

Interjacks need to be inserted into the drive at least 100m behind the machine and every 100m thereafter or as frequently as considered necessary by the Contractor considering his drive strategy and equipment.

The interjack can either be of steel construction or purpose built pipes. Exact circularity tolerances shall be strictly adhered to for ensuring a good working seal for the life of the drive.

A double seal arrangement shall be used on the lead pipe spigot fitting to the rear tail skin of the interjack section.

Lubrication shall be provided to maintain a good lubrication of the sliding joint, an adjustable seal shall also be used as with the articulation seal on the machine. The cylinders shall be fitted with a stroke measuring device to indicate in the main control screen.

16.2 Products

16.2.1 Jacking Pipes

The reinforced concrete pipes shall be sufficiently reinforced with steel to withstand all stresses induced by handling, jacking, earth and water pressure and all working loads at the depths at which they are to be used without cracking, spalling or distortion.

Provision shall be made for the injection of lubricating fluid or grout through pre-formed holes in the pipe walls. Lubrication holes shall be fitted with non-return valves.

Every pipe made shall be clearly and indelibly marked upon it an identification number, class, batch of concrete, diameter and date of manufacture. Every finished pipe shall be tested for dimensional conformity and non-destructive testing with Schmidt Hammer or any other method as agreed with the Engineer. Full records are to be maintained of each pipe test and for each individual pipe the date manufactured, cleared after testing and supplied.

All pipes shall be handled, unloaded and stacked in such a manner as to prevent damage to the pipes, in accordance with the manufacturer's recommendations.

Jacking pipes will be required to undergo a third party certified Quality Assurance and control programme to ISO 9000.

16.2.2 Analysis and Design

The Contractor shall be responsible for design of the jacking pipes as per the drive strategy intended to be adopted by him.

The pipes shall be designed to account of the anticipated curvature.

Precast concrete pipes shall be designed against internal and external loadings including: Jacking forces, ground pressure, water pressure and handling forces.

The precast concrete pipes shall be sufficiently reinforced to withstand all stresses induced by the loads mentioned, without cracking, spalling and distortion.

16.2.3 Manufacturing of Precast Concrete Pipes

Concrete jacking pipes shall comply with the provisions of BS EN 1916 and BS 5911-1 or JSWAS A2. The pipes must be manufactured using a vertical vibration casting facility.

Strength test requirements of precast concrete pipes shall meet the requirements of NP4 class pipes under IS 458, Concrete strength class used in precast concrete pipes shall be minimum M50 according to the Indian Standard IS 456 (Plain and Reinforced Concrete Code of Practice).

Cement used for manufacture of precast concrete pipes shall conform to one of the following standards: IS 269, IS 455, IS 1489 (part 1), IS 1489 (part 2), IS 8041, IS 8043, IS 8112, IS 12269, IS 12330

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

Aggregates used for manufacture of concrete pipes shall conform to IS 383.

The maximum size of aggregates shall not exceed one third of pipe thickness or 20mm whichever is smaller.

Water used for mixing of concrete and curing of pipes shall conform to IS 456, Section 5.4. Chemical admixtures in concrete pipes shall conform to IS 9103.

16.2.4 Concrete Specification for Precast Jacking Pipes

Concrete shall be grade C40/50 in accordance with BS 8500 or grade M50 in accordance with IS 456 and Portland Slag Cement (GGBS shall be maximum of 30% of the cement content)

The minimum cementitious content shall be 400kg/m3 and the maximum cementitious content shall be 500kg/m^3.

The maximum free water/cementitious material (w/c) ratio shall be 0.35.

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.

16.2.5 Inspection, Sampling and Testing

Inspection and sampling of concrete pipes shall conform to minimum requirements outlined in IS 458, Section 11 subject to the following-

One pipe out of every 100 pipes or part thereof manufactured for each diameter shall be tested at the Contractor's expense using a Three Edge Bearing Test in a laboratory or institution approved by the Engineer.

Every pipe shall be subjected to dimensional conformity tests and the tolerance shall be within limits as per the Standard adopted

After the satisfactory completion of testing and acceptance of the pipes by the Engineer the pipes shall be stored at factory premises during the period awaiting delivery.

If the pipes are to be procured from a manufacturer, the Contractor shall make arrangements for visits of the Engineer for inspection and testing as and when deemed necessary by the Engineer. All expenses in connection with such visits shall be borne by the Contractor. 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.

Pipes delivered with visible cracks, scars, chips, or any damage in excess of the limitations specified, shall not be used. Damaged or defective pipes shall be marked as rejected and shall be promptly removed from the working site.

The Engineer shall have full authority to inspect any material or finished product and reject the same if found not conforming to the standard

16.2.6 Pipe Joints

The jointing arrangement for the jacking pipes is crucial in terms water-tightness, flexibility and smooth transmission of jacking force. Spigot ended jacking pipe with a recess to receive rubber rings and steel or stainless steel couplings (collars) or other acceptable joints shall be used in pipejacking application. The spigot and socket joints shall be flush on the outside as well as on the inside. The Contractor shall submit joint details to the Engineer for acceptance.

Special design precautions must be taken for the design of joints in cases where curved alignments are planned or likely to be required.

16.2.7 Joint Rubber Rings (Gaskets)

The joint rubber rings supplied and installed shall be of the Cornelius rubber ring type or similar accepted and shall be capable of accommodating 2 degree deflection at each joint.

The testing of the rubber ring shall conform to IS. 3400 and also IS. 5382.

Gaskets for pipe jack joints shall provide a seal against the ingress of groundwater during jacking and in the permanent condition. Gasket material shall comply with the requirements of BS EN 681-2, including resistance to chemical attack and microbiological degradation.

The gasket shall be lubricated with a product recommended by the manufacturer and agreed with the Engineer.

The Contractor shall indicate the grade of rubber rings he intends to use and submit samples for acceptance prior to incorporation in the Works. The grade, type or source of supply of rubber rings shall not be changed without the written agreement of the Engineer.

16.2.8 Pipe Couplings (Collars)

Pipe couplings (collars) shall be made of stainless steel Grade 304. The steel coupling shall be of such dimension and thickness so that when inserted into the pipe, it fits exactly into the recesses in the pipe. The joint so formed shall be watertight. The joint details shall be agreed with the Engineer. Before fitted to the pipes, the collars shall be coated with anti-abrasive and anti-corrosive materials such as polymorphic resin or other materials as accepted by the Engineer.

16.2.9 Compressible packers

Suitable compressible packers shall be used at the joints for distributing the jacking force evenly through the wall of the jacking pipes. Uneven transfer of jacking force from one pipe to another shall result in concentrated and excessive stresses in the pipe which can cause the pipe to crack. The Contractor shall submit details of the compressible packers for the Engineer's acceptance.

The average modulus of elasticity of the packer material shall be 150 MPa.

The packing material shall be resilient and shall distribute pipe stresses arising from jacking loads. The packing material dimensions and installation shall be agreed with the Engineer prior to commencement of jacking operations.

The manufacturer shall provide, on request, a statement of the allowable distributed and deflected jacking loads. Details of the characteristics used in the assessment of the allowable jacking loads shall be included in the statement.

The thickness of the packer shall take the degree of curvature in account.

16.3 Construction Works

16.3.1 Construction of Jacking and Receiving Shafts

Thrust and reception pits and shafts shall be designed and constructed to allow the safe operation of plant, equipment and handling of materials and to withstand all loadings imposed by ground pressure, superimposed loads from surface structures and the maximum anticipated thrust forces. Where Permanent Works accommodate the thrust arrangements, these shall be designed to ensure that the Permanent Work is not damaged.

Before work may start on any thrust pit, it shall be demonstrated that the design will withstand the maximum jacking force of which the jacks are capable.

In all cases the Contractor shall submit his proposals including calculations to the Engineer for his agreement as required.

If applicable, the jacking equipment shall have a jacking capacity of 20% greater than the maximum calculated allowable jacking load required to install the pipe. The jacking system shall develop a uniform distribution of forces on the end of the casing and / or pipe by the use of cushioning material and / or thrust rings.

A pipe lubrication system shall be used to lower friction developed on the surface of the pipe / casing during jacking as detailed in Section 16.1.14.

The thrust block shall be designed to safely withstand the maximum jacking pressure to be used, with a factor of safety of at least 2.0 without excessive deflection or displacement.
Each shaft shall have a separate means of access or ladder bay for access which shall be isolated from the part of the shaft used for hoisting materials. The shaft support system shall be watertight and shall prevent any pressurised slurry from the tunnel face reaching the shaft.

The shaft shall be kept dry at all times and shall have a drainage sump to pump out the ingress water. The Contractor is deemed to be fully aware of the serious consequences to the tunnelling equipment and other accessories if the shaft is flooded. He shall take every precaution to avoid flooding in the shaft. The shaft shall be well protected against surface runoff getting into the shaft. The Contractor shall be solely responsible for any consequential delays and expenditure arising as a result of flooding the shaft.

The shaft floor shall be designed to withstand the load of the tunnel machine and other accessories.

The Contractor shall be solely responsible for providing and subsequent removal of shoring to the shafts or pits and ensuring stability of the sides of such excavations and safety of adjoining structures.

16.3.2 Design Loads

The design shall take at its minimum the following loads-

a) Full hydrostatic pressure (water table assumed at surface) in combination with zero internal pressure (i.e. tunnel drain down)
b) Ground loading according to standard practice
c) Dynamic loading as a result of earthquake forces.
d) Transportation, handling and installation forces for pipes.
e) Installation stresses- i.e. stresses due to driving or due to intentional and non-intentional curvatures

16.3.3 Construction of Thrust Wall

The thrust wall shall be designed and constructed by the Contractor to the agreed details. The thrust wall shall be reinforced or unreinforced concrete constructed against the wall of the jacking shaft. The Contractor shall ensure that the thrust wall is constructed as an independent structure and it shall not interfere with the jacking shaft or the floor when jacking force is applied on to it. Contractor shall indicate in his Documents the construction details of the thrust wall showing details on how the wall be made independent of the jacking shaft structure.

The Contractor shall ensure that the thrust wall and the soil behind are in complete contact and there is no gap between them. The Contractor shall further ensure that the thrust wall shall effectively transfer the jacking force on to the soil behind and that the ground behind is capable of withstanding the jacking force.

In the event that there is gap between the thrust wall and the soil behind, the Contractor shall arrange the gap to be filled with accepted cement grout before loading the thrust wall.

The thrust wall shall be demolished fully or partly after completion of the jacking operation involving that wall.

16.3.4 Jacking Frame

The Contractor shall provide a jacking frame in accordance with the microtunnelling equipment manufacturer's details and install it firmly onto the floor of the jacking shaft. He shall ensure that the Jacking frame is installed to the correct grade, levels and alignment. It shall be also square to the pipeline alignment at all times and not disturbed due to forces arising from the jacking operation. The Contractor shall arrange with the Engineer to check the level, alignment etc. of the guide rail and obtain the Engineer's endorsement before commencing the pipejacking work.

16.3.5 Entrance and Exit Arrangement

One of the most critical microtunnelling operations is the launching and retrieval (entry and exit) of the microtunnelling machine. It is critical that the Contractor implements adequate engineering measures including stabilisation of unstable soil by grouting or other means to prevent soil and water inflows into the shaft.

An elastomeric seal shall be provided in the entrance and exit ring. The seal is to prevent the flow of ground water or lubricant through the shield/pipe entry opening on the shaft wall.

An exit ring must be provided without exception if the strata at the level of exit happens to be loose.

The Contractor shall plan this work well in advance and fabricate the fittings and rubber seal as per agreed method and details.

16.3.6 Soil Stabilisation at the Tunnel Entry and Exit

In addition to the seal, it may be necessary to stabilise the soil behind the entrance wall or exit wall. Chemical grouting, cement grouting, jet grouting, piles, ground freezing or temporary shoring are some methods commonly used by the Contractors to prevent the soil flow into the shaft.

16.3.7 Cement Grouting

The Contractor shall be fully responsible for preventing the occurrence of voids outside the pipe and if they occur he shall fill them with cement grout in accordance with Section 13.6 of the Employer's Requirements. Immediately following the jacking operation the Contractor shall pressure grout the jacked section to fill all voids existing outside of the pipe. Grouting shall be from the interior of the pipe through grouting holes as specified.

Systems of standard pipe, fittings, hose, and special grouting outlets embedded in the pipe walls shall be provided by the Contractor. Care shall be taken to ensure that all parts of the system are maintained free from dirt. Grout composed of cement, sand and other accepted compounds and water shall be forced under pressure into the grouting connections at the invert and shall proceed until grout begins to flow from upper connections. Connections shall then be made to these holes and the operation continued to completion.

Apparatus for mixing and placing grout shall be of a type accepted by the Engineer and shall be capable of mixing effectively and stirring the grout and then forcing it into the grout connections in a continuous uninterrupted flow.

After grouting is completed, pressure shall be maintained by means of stop cocks, or other suitable devices until the grout has set sufficiently. After the grout is set, grout holes shall be completely filled with dense concrete and finished neatly without evidence of voids or projections.

16.3.8 Jacking System

The hydraulic jacking system shall be installed against a purpose built thrust wall in the jacking shaft. The substantial force required for jacking pipes and the tunnelling machine shall be provided by high pressure jacks driven by hydraulic power packs. The ram diameter and stroke of the jacks may vary according to individual Contractor's technique and to suite site conditions.

The jacks shall be mounted on jacking frames as detailed in Section 16.3.4 so that the jacks are square to the pipe alignment. The jacking frame shall be firmly supported to the floor so

that it does not move during jacking operation. A push ring shall be used to transmit the jacking force evenly to the pipe.

16.3.9 Jacking Force

The Contractor shall calculate the expected jacking load for each microtunnel drive well ahead of designing the jacking pipes. Accurate estimation of the jacking load is necessary to determine the pipe wall thickness, the need for intermediate jacking stations and lubrication requirements, types of jacking system and thrust block design. The overall jacking force depends on the type of surrounding soil, depth of cover, pipe materials, diameter and the overall length of the pipeline.

The total jacking force essentially consists of two components, "Frictional force around the pipeline" and the balancing force at the tunnel face called "Face Pressure". The Contractor shall use appropriate geo-mechanics formulae and guidelines for computing the jacking force. The Contractor shall calculate the anticipated jacking force for each drive and submit his calculation to the Engineer for acceptance.

The Contractor shall be solely responsible to ensure that the pipes are not subjected to excessive jacking force or torsional force so as to crush them. If such thing occurs the Contractor shall have to remedy the situation at his risk and cost.

In case the anticipated jacking force is expected to be higher intermediate jacking stations must be inserted in the jacked pipeline in a planned manner. For this purpose special interjack stations and interjack pipes shall be provided as specified considering the drive strategy adopted by the Contractor.

16.3.10 Pipe Lubrication System

The boring machines shall be designed to overcut around the external diameter of the pipeline to the required minimum extent only. The Contractor shall carefully monitor the jacking force and use an appropriate automatic lubrication system, in accordance with Section 16.1.14, to bring down the jacking force within the allowable jacking force for the pipe.

16.3.11 Operation

All key personnel shall be experienced in the pipejacking process and hold relevant skills accreditation.

Before any particular pipe jack length commences, sufficient pipes and, if required, intermediate jacking station assemblies shall be available to ensure continuous operation.

The agreement of the Engineer shall be sought for inclusion in the Permanent Works of repaired pipes.

The jacking force applied by the thrust pit jacks, or an intermediate jacking station shall not exceed the allowable distributed or deflected design load for any pipe being jacked.

Thrust loads shall be transferred to pipes through a thrust ring which shall be sufficiently rigid to ensure even distribution of the load.

Changes to line and level shall be gradual. The manufacturer's stated permitted draw or angular deflection on any individual joint shall not be exceeded.

Intermediate jacking stations shall be inserted to a predetermined plan. Operation shall commence when loading reaches a predetermined level, which shall be less than the allowable distributed and deflected jacking loads as determined by the manufacturer.

To avoid excessive loading it may be necessary to undertake continuous jacking until completion of the drive. Where this is necessary the Contractor shall put in place appropriate measures to minimise noise and disturbance.

Where necessary means shall be provided to ensure that the pipeline remains stationary when face balance pressure is maintained and when any jacking rams are retracted.

Installed joints shall be prevented from opening when the jacking loads are removed.

Pipes which have been jacked through a pipe jack shall not be used elsewhere on the Works. Cut pipes shall not be jacked.

The annular space between the sides of the excavated tunnel and the jacking pipes shall be constantly filled with an appropriate lubricant as agreed with the Engineer as part of the operational method statement. This lubricating fluid shall be maintained under pressure until completion of the drive. The lubrication injection points shall consist of a minimum of three holes equally spaced around the circumference of the pipe.

Where necessary, the lubricant may contain an accepted additive to limit water loss.

Daily records of the quantity of lubricant used for each length of pipe thrust and the point at which the lubricant was injected shall be kept.

Where the quantities of lubricant injected significantly exceed the theoretical volumes, this shall be investigated and reported to the Engineer.

On completion of pipe jack, the annulus shall be filled by displacing the lubricant with grout. All lifting holes and grouting holes shall be sealed.

On completion of the drive, intermediate jacking stations shall be left fully closed. All jacks, props, thrust rings and packing shall be removed, the ends of the pipes cleaned, and a new packing ring glued to the receiving face. An 'O' ring seal shall then be inserted into the sliding joint and the joint jacked fully closed. The order of closing the stations shall be from the tunnelling shield working back.

16.3.12 Level and Alignment Accuracy

The pipes shall be installed into place, true to line and level. Pipejacking shall be carried out in accordance with the following alignment tolerances:

- Line +/- 50mm
- Level +/- 25mm
- The maximum angular deflection between the pipes shall not exceed 0.5 degrees or the maximum deflection recommended by the manufacturer of the pipes at the jacking force necessary for construction of the tunnel

The pipes shall be installed within the above tolerances from the proposed sewer elevations and locations provided on the Drawings.

Notwithstanding the specified alignment tolerances, the rate of change of direction in any plane, or combination of planes, shall be agreed with the Engineer, taking into account the pipe length, diameter, over-cut, jacking loads, and the manufacturer's recommendations.

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.

16.3.13 Monitoring of Microtunnelling Works

In addition to the requirements of Section 14.4 the Contractor shall monitor and maintain site records of jacking loads, line and level measurements, the distance moved, the jacking forces and quantity, type, consumption and pressure of injected lubricants. Where applicable,

hydraulic pressure of interjacks shall be monitored and recorded by the Contractor. Line and level monitoring shall be carried out in conjunction with monitoring of the pipe deviation angle.

A graphical relationship between the jacking force and the distance moved shall be produced to ensure that the necessary measures are taken to avoid exceeding the maximum permitted jacking forces.

The jacking force instrumentation shall be calibrated for each drive by the Contractor. The calibration certificate shall be made available to the Engineer.

Copies of all records shall be available to the Engineer at intervals to be agreed.

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 jacking pipes
- Reinforcement drawings
- Concrete mix details
- Structural calculations for jacking pipes, 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

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.

5. Concept and Objective

6. Stage 3 Safety Audit (Completion of Detailed Design) (as per IRC:SP:88-2010 'Manual on Road Safety Audit')

7. Necessity of Alternate routes.

8. Current Status of Alternate route

9. Max. Carrying Capacity, overall traffic scenario

10. 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

11. 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

12. Dual Carriageway Road

- Use of Hard Shoulder
- Use of Narrow Lanes
- Contra Flow Operation
- Cross Over

13. Emergency Procedures

14. Traffic Route Safety Control Measures

15. Trespassing onto site

16. Route Signage

17. Parking on Site, contractors vehicles

18. 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.1 Accommodation

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.2 Office 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
Coat hooks	30 Nr
A3/A4 high speed photocopier	1 no.
fax machine	1 no.

E.3 IT EQUIPMENT

The following IT equipment shall be provided by the Contractor and fitted out in the accommodation. It shall all be brandnew and from a source to be approved by the Employer's Representative and the Contractor shall take out a Maintenance Contract for all of the supplies equipment for the duration of its life on Site. The Maintenance Contractor shall report only to the Employer's Representative.

 4 No. high specification modern laptops complete with large capacity hard disc drive and 16GB RAM, large colour monitor, mouse, fax modem, DVD/CDRW drive, USB drives etc.

 4 No. high specification modern desktops complete with large capacity hard disc drive and 32GB RAM, large colour monitor, mouse, fax modem, DVD/CDRW drive, USB drives etc.

 file server with networking software, large capacity network storage and associated backup device.

 All computers shall be provided complete with standard software including Microsoft Windows and latest MS Office Suite. Additionally 2 Nos of the desktop computers shall be provided with AutoCAD 2017 and one of the laptops shall be provided with Primevera.

 The Contractor shall be responsible for cabling, setting up, configuring and maintaining the network.

 Network Printers, scanners and copiers (All Printers to contain approved Network card connected to all office computers)

 2no. Laser A4/A3 Colour

 3no. Laser A4

Other Items
The Contractor shall be responsible for the provision of high speed broadband connection (20 mbps) for E-mail/Internet access at all office computers for the durationof the Design Build period.

E.4 Equipment

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.5 Protective 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.6 Kitchen 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.7 Stationery & 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