SCHEDULES

SCHEDULE - A

(See Clauses 2.1 and 8.1)

SITE OF THE PROJECT

1.0 THE SITE

1.1 Project Area

The Project area of the estimated 14.150 km long Zoji La Tunnel including the approaches to the portals is located north-east of the city of Srinagar, on the Srinagar-Leh section of the National Highway 1 (A reference to NH1 in these schedules shall always mean the Srinagar-Leh section of the NH1), in the State of Jammu and Kashmir. The tunnel shall be constructed between Baltal (Approximately 1200 m south west of Km 100 stone on the NH 1) and Minamarg (Km 117 on the NH).

Fig.1: Location of Zojila Tunnel

The Project area of the proposed Zojila tunnel is defined by:-

a) the western (Srinagar side) approach road to the tunnel, with its exit point near KM 95 stone on NH 1,

b) the western portal location at Baltal,

c) the eastern portal location at Minamarg (KM 117 on NH 1)

d) the approach road to the eastern (Leh side) portal of the tunnel, with junction point at approximately Km stone 118 of the NH 1
e) Locations of the three intermediate ventilation shafts along NH 1,and
f) the egress tunnel co located with the main tunnel.

1.2 Site of the Project Highway shall include the land, buildings, structures and road works as described in Annex-I of this Schedule-A.

1.3 An inventory of the Site including the land, buildings, structures, road works, trees and any other immovable property on or attached to the Site shall be prepared jointly by the Authority Representative and the Contractor and such inventory shall form part of the memorandum referred to in Clause 8.2.1 of the Agreement.

1.4 The proposed alignment plans of the Project Highway are specified in Annex-III which has to be followed by the Contractor as a minimum. The Contractor may, however, improve upon the alignment plans and profile and raise the finished roadway level (FRL) with approval from the Authority's Engineer within the available Right of Way.

1.5 The status of the environment clearances obtained or awaited is given in Annex IV.

Annex - I
(Schedule-A)

Site

1. **Site**

1.1 **The Site**

The Project Highway aims at construction of tunnels excluding approaches in general area between KM 100 and KM 119 of the Srinagar-Leh Section of NH 1, as per following details :-

- 14.150 km long two lane bidirectional single tube tunnel with a parallel 14.200 km long egress tunnel on new alignment between Baltal & Minamarg along the existing NH-1 in the State of J&K.
- Access Roads to the Intermediate Construction/Ventilation Shafts –
  - Shaft No1- 0.350 km
  - Shaft No 2- 0.100 km
  - Shaft No 3- 0.070 km

1.2 **Description of the Project**

An index map and location plan of the Project Highway is given at Appendix A-I.

1.3 **Latitudes & Longitudes**

The approximate longitude and latitude of the region is

Western Side: 34°-16' Northing and 75°-22'-40" Easting.

Eastern Side: 34°-19'-37" Northing and 75°-34' Easting.

1.4 **Seismicity**

The Project area of Zojila Tunnel is situated in the seismically active mountain range of the Himalaya and is influenced by active faulting associated with main tectonic features of the Himalayan mountain belt (e.g. Main Central Thrust, Main Boundary Thrust, Kishtwar Fault, etc.). Historical and instrumental data reveal that at least eleven earthquakes with magnitudes $\geq$ 6.0 were recorded in this region from around 1800 to present date. The last significant seismic activity struck the area in October 2005, and with a magnitude of 7.6, it was with catastrophic results throughout the entire region.

According to seismic zoning map of India (BIS Code IS 1893: 2002, Part I: ZWL) the tunnel site is situated in Zone IV, which represents the second most vulnerable zone category. Seismic design parameters relevant for the Project area related to Maximum Credible Earthquake (MCE) and Design Basis Earthquake (DBE) are accelerations of 0.24 g and 0.12 g.

1.5 **Geology :**

The geology as assessed during field investigation is brought out as follows for the guidance purposes only. THE CONTRACTORS ARE REQUIRED TO CARRY OUT THEIR OWN ASSESSMENT OF THE GEOLOGY OF THE PROJECT AREA.

Geological Units

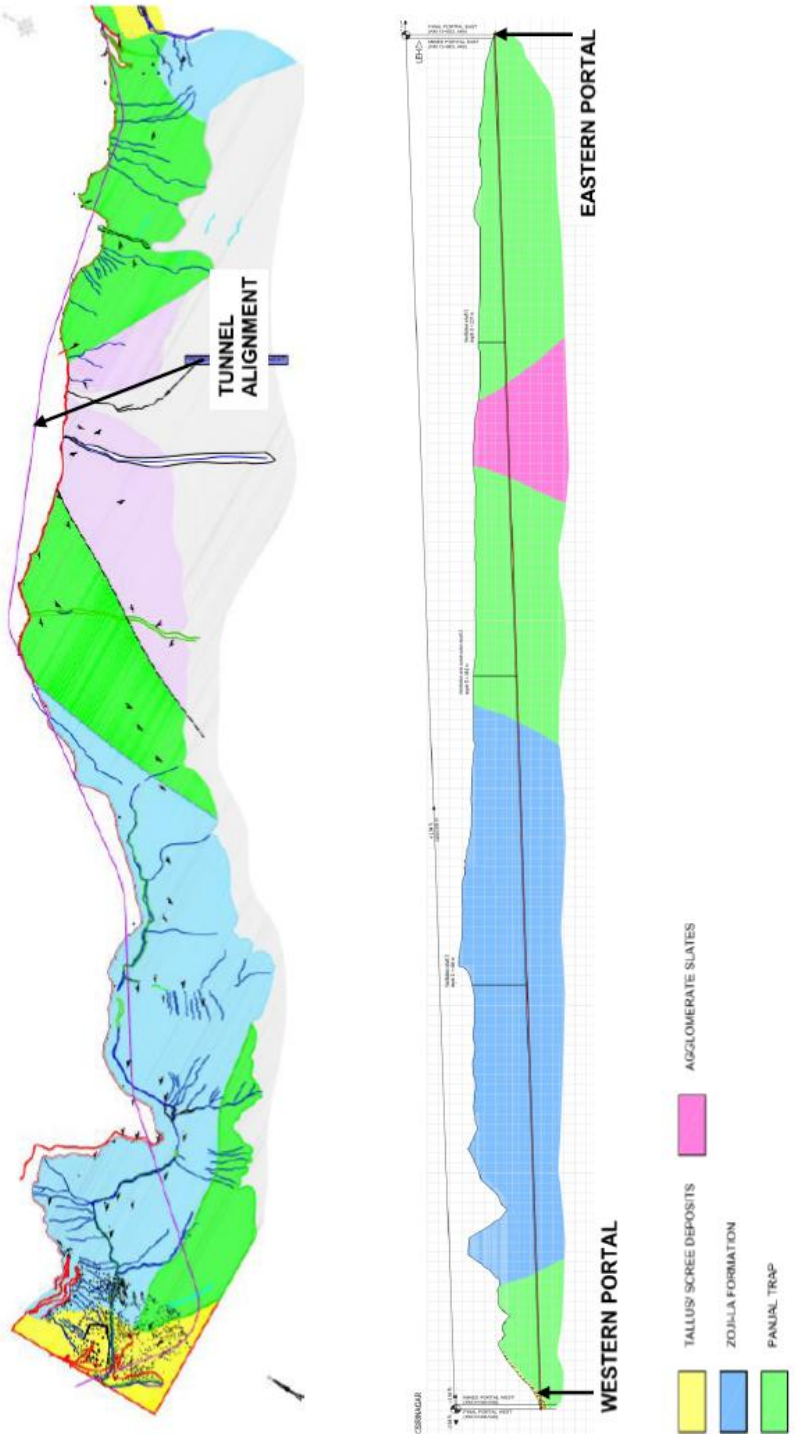
Based on the results of performed geological/geotechnical investigations, the predicted geological units which are relevant for the construction of Zojila Tunnel have been summarized and characterized. These are brought out in the following paragraphs. However it is reiterated that the stated distribution of the geological units is only for guidance and the responsibility of verifying the facts or carrying out geological/geotechnical investigations rests with the Contractor. The Project area of Zojila Tunnel is located in Permo-carboniferous, metamorphic rocks of sedimentary and magmatic origin. The tunnel alignment is in the formations of 'Panjal Trap', Zojila information and Agglomerate Slates as shown in figure on next page.

Rock Fall and Slope Debris (Debris and Talus Material)

Rock fall and slope debris (debris and talus material) are encountered at both portal areas of proposed Zojila Tunnel. The debris material consists mainly of angular rock boulders with varying block sizes (diameters of a few decimetres up to some meters), which are embedded in a (silty-) sandy-gravelly matrix. The rock mass can be described as a composition of 'soil-like' matrix and competent, intact rock blocks of bedrock (metabasite, phyllites, slates). The thickness of the debris accumulations ranges from a few meters up to several decametres at the toe of the valley slopes.

Zojila Formation

This geological unit is encountered in the western section of Zojila Tunnel and consists mainly of dark grey, fine-grained, finely foliated graphitic, partly carbonaceous, phyllites, slates, schists and subordinately marble. Laboratory tests performed with samples collected in the area of proposed Zojila Tunnel and simple manual field index tests indicate a dominance of strong uniaxial compressive strength. Due to intensive foliation and slaty cleavage the rock mass is highly anisotropic. The spacing of the foliation planes is observed as 'very thin' to 'thin' (2-20 cm).



Yellow- Tallus/Scree deposits. **Green**- Panjal Trap **Blue**- Zojila formation, **Magenta**- Agglomerate Slates

Fig: Predicted Geology of Zoji la Tunnel Area

(Plan View & Elevation View)

Tectonic shearing along fracture zones or shear zones increase the degree of fracturing (spacing of foliation planes < 2 cm) and result in clayey coatings or fillings on discontinuities (shear planes). Thick (several decimetres to several meters), continuous zones of fine-grained fault rock (fault gouge) were not encountered during performed site investigations. But due to morphological features the occurrence of bigger shear zones or faults within this geological unit can be assumed.

Panjal Trap

This geological unit consists of metamorphic (green schist facies) volcanic rocks of basaltic-andesitic origin (Metabasite). The mineralogical composition is dominated by Plagioclase and Pyroxene with Amphiboles and Olivine. Volcanic textures and structures like pillow lavas or porphyritic textures are preserved commonly. Younger, low temperature metamorphic conditions led to serpentinization which can be observed along discontinuities.

Generally the Metabasites are a greenish to dark grey, fine-grained, hard and compact rock. Laboratory tests and simple manual field index tests indicate a dominance of very strong uniaxial compressive strength. The rocks are fresh, with slight weathering phenomena (discoloration at surfaces and along discontinuities) near to the surface. The Metabasites are dominated by massive rock mass with thickly (60-200 cm) to very thickly (>200 cm) spaced foliation planes. Additionally, schistose types with thinly to medium spaced (6-60 cm) foliation planes are encountered.

Agglomerate Slate

The 'Agglomerate Slate' formation is found in the eastern part of the tunnel in an anticlinal core. This formation consists of greywacke, slates, phyllites and schists with angular fragments, mainly of quartz-porphyry, granite or slates. Due to its internal fabric the pyroclastic origin of the rocks is indicated.

The rock mass is mainly thinly foliated with foliation spacings varying between 6 and 20 cm. Laboratory tests and simple manual field index tests indicate a dominance of medium strong to strong uniaxial compressive strength.

Rock Mass Classification

The rock mass classification is done based on the Austrian Guideline for NATM tun-nelling (Austrian Society for Geomechanics, 2001, 2008, 2009; Guideline for the ge-otechnical design of underground structures with conventional excavation).

According to the procedure for the geotechnical design of NATM tunnels as given in the guideline mentioned above in a first step ground with similar properties is

classi-fied into a Ground Type. For the Zojila Tunnel 7 Ground Types are defined based on the geological and geotechnical data and the heterogeneity of the rock mass in the Project area. The values for the key parameters of each Ground Type are deter-mined from available information and/or estimated based on experience from tunnel projects in comparable ground conditions.

In the second step Project specific Behaviour Types are defined based on the potential behaviour of the ground. These Behaviour Types represents the determined behaviour of the rock mass due to the excavation of the tunnel without any support measures. To determine the ground behaviour the Ground Types are combined with the predicted ground conditions represented by the influencing factors which are the primary stress condition, the water condition and the orientation of discontinuities. For the Zojila Tunnel 7 Behaviour Types are defined, which can form the basis for the further support design to achieve stable tunnel conditions.

The following table shows the predicted distribution in percentage terms of Ground Types (GT), and Behaviour Types (BT) for the Zojila Tunnel.

		Section					
		1	2	3	4	5	6
Length [m]		76	1640	5551	2217	1112	3487
Ground Types GT		100	0	0		0	0
	G	0	65-85	0	65-85	0	65-85
	G	0	15-30	0	15-30	0	15-30
	G	0	0-5	0	0-5	0	0-5
	G	0	0	30-50	0	50-70	0
	G	0	0	40-60	0	25-45	0
	G	0	0	5-15	0	0-10	0
Behaviour Types BT [%]	B T 1	0	30-45	0	30-45	0	30-45
	B	0	50-60	2-10	50-70	10-20	50-70
	B	0	5-10	25-45	0-5	45-60	0-5
	B	0	0-5	50-70	0-2	25-40	0-2
	BT 7/8/9	100	0	0	0	0	0

The detailed geological description of the site is attached at Appx A-II.

1.6 **Traffic**

Traffic count details are as per the survey conducted by the tunnel feasibility study consultants during the month / year July, 2011 on the Project.

For the conceptual tunnel design, the design traffic for the highway section is considered at 2500 trucks (3 tons and above) and 5000 passenger cars (below 3 tons) per day and for both lanes (traffic projection for year 2024).

Contractors are advised to conduct own traffic study.

2. **Land**

The Site of the Project Highway comprises the land (Total of land already in possession) as described below:

S. No.	Chainage (km)	(New Alignment)	ROW (m)	Remarks
1.	From Approx. 5.00 Km from take off point at km 95.00 of NH1 towards western portal of the proposed Tunnel	To, approx. 0.803 km from take off point at km 118.00 of NH-1 towards eastern portal of the proposed Tunnel	40.00 m	Length of the project highway is approx. 14.31 km i.e. the starting point of loop roads on each portal. Drawing no. : (i)8482B_II ZOT_POR-01-12-00 (ii) 8482B_II ZOT_POR-08-12-00

3. **Carriageway**

The present carriageway of the Project Highway is Two Lane.

4. **Major Bridges**

The Site includes the following Major Bridges:

S.No.	Chainage(km)	Type of Structure			No.of Spans with span length (m)	Width (m)
		Foundation	Sub-structure	Superstructure		
Nil						

5 **Road over-bridges (ROB)/ Road under-bridges (RUB)**

The Site includes the following ROB (road over railway line)/RUB (road under railway line):

S.No.	Chainage (km)	Type of Structure		No. of Spans with span length (m)	Width (m)	ROB/ RUB
		Foundation	Superstructure			
NIL						

6 **Grade separators**

The Site includes the following grade separators:

S.No.	Chainage (km)	Type of Structure		No. of Spans with span length (m)	Width (m)
		Foundation	Superstructure		
NIL					

7 **Minor bridges**

S.No.	Chainage (km)		Type of Structure		No. of Width Spans with span length (m)
		Foundation	Sub-structure	Superstructure	

8 **Railway level crossings**

The Site includes the following railway level crossings:

S. No.	Location (km)	Remarks
NIL		

9 **Underpasses (vehicular, non vehicular)**

The Site includes the following underpasses:

S. No.	Chainage(km)	Type of Structure	No. of Spans with span length (m)	Width (m)
NIL				

10 **Culverts**

The Site has the following culverts:

S. No.	Chainage (km)	Type of Culvert	Span /Opening with span length (m)	Width (m)
Nil				

11 **Bus bays**

The details of bus bays on the Site are as follows:

S. No.	Chainage(km)	Length (m)	Left Hand Side	Right Hand Side
NIL				

12 **Truck Lay byes**

The details of truck lay byes are as follows:

	S. No.	Chainage	(km)	Length (m)	Left Hand Side	Right Hand Side
	NIL					

13 Road side drains

The details of the roadside drains are as follows:

S. No.	**Location**			
	From	**To**	**Type**	**Remarks**
1.	Start of Project Highway	Western Portal	**RCC**	Length 82.5 M

	Eastern Portal	End of Project Highway	**RCC**	**Length 46.2 M**
2.	Start of Tunnel	End of Tunnel	**RCC/Pipe**	**Length 14.2 KM**

14 Major junctions

The details of major junctions are as follows:

S.	**Location**		**At**	**Separated**	**Category of Cross Road**			
No.			**grade**					
	From km	**to km**			**NH**	**SH**	**MDR**	**Others**
NIL								

(NH: National Highway, SH: State Highway, MDR: Major District Road)

15 Minor junctions

The details of the minor junctions are as follows:

S. No.		**Location**		**Type**	
	From km	**From km**	**To km**	**T -junction**	**Cross road**
NIL					

16 Bypasses

The details of the bypasses are as follows:

S. No.	**Name of bypass (town)**	**Chainage (km) From ----to**	**Length (in Km)**	**Carriageway**	
				Width (m)	**Type**

NIL

[17 Other structures]

[Provide details of other structures, if any.]

Annex - II
(Schedule-A)

Dates for providing Right of Way

The dates on which the Authority shall provide Right of Way to the Contractor on different stretches of the Site are stated below:

Sl. No	**From km to km**	**Length (km)**	**Width (m)**	**Date of providing ROW***
1	**2**	**3**	**4**	**5**
Full Right of Way (full width)	For Project Highway (*82.50 m before the project start at km 0.000 as per portal drawing no. 01 on western side and 46.2. m beyond project end at km 14.182 as per portal drawing no. 08 on eastern side)*	14.310 Km	40 meter	ON THE APPOINTED DATE

Annex - III

(Schedule-A)

Alignment Plans

The new alignment of the Project Highway as per the alignment plan indicated below:

The vertical and horizontal alignment drawings attached as Appendix B-I.

Annex - IV

(Schedule-A)

Environment Clearances

The Environmental clearances for the Project Highway are not required.

SCHEDULE - B
(See Clause 2.1)

Development of the Project

1 **Development of the Project Highway**

Development of the Project Highway shall include design and construction of the Project Highway (Zojila Tunnel) as described in this Schedule-B and in Schedule-C.

2 **CONSTRUCTION OF PROJECT**

The construction of project [including Rehabilitation and augmentation] shall include "Construction, Operation and Maintenance of 2-Lane bi-directional Zojila Tunnel with Parallel Escape (Egress) Tunnel excluding approaches on Srinagar-Leh Section connecting NH-1A at Km 95.00 And At Km 118.00 in the State of Jammu & Kashmir on EPC Mode" of the Project Highway as described in Annex-I of this Schedule-B and in Schedule-C.

3 **Specifications and Standards**

The Project Highway shall be designed and constructed in conformity with the Specifications and Standards specified in Annex-I of Schedule-D.

Annexure-I
(Schedule-B)

DEVELOPMENT OF THE PROJECT

1. Description of the Tunnel System

1.1 Portals

1.1.1 Western Tunnel Portal

Final portal elevation	:	2900 m
Final portal location	:	Pos. E : 538871.9 m UTM, Pos. N: 3790008 m
Mined tunnel portal location	:	Pos.E: 538900.9 m UTM Pos.N:3789985.0 m
Cut & Cover tunnel length	:	37 m. Cross section as indicated in Appendix B-I
Ventilation building	:	Situated above the cut & cover tunnel, two axial fans, electrical supply installations
Service and control buildings	:	Floor space of 800 m². To be constructed as per drawings approved by the Authority Engineer.
Allied works	:	Loop roads, Vehicle Parking area, Tunnel Service Building, Ventilation Building and Shafts, Avalanche Protection measures, etc.

1.1.2 Eastern Tunnel Portal

Final portal elevation	:	3310 m
Final portal location	:	Pos. E: 549997.8 m UTM Pos. N: 3797178.5 m
Mined tunnel portal location	:	Pos. E: 549976.0 m UTM Pos. N: 3797157.8 m
Cut & cover tunnel length	:	30 m. Cross section as indicated in Appendix B-I

Ventilation building	:	situated above the cut & cover tunnel, two axial fans, electrical supply installations
Service building	:	Floor space of 800 m².To be constructed as per the drawings approved by the Independent Engineer.
Allied works	:	Loop roads, Vehicle Parking area, Tunnel Service Building, Ventilation Building and Shafts, Avalanche Protection measures, etc.

1.2 Vertical and Horizontal Alignment

The vertical and horizontal alignment is given in the drawing at Appendix B-I.

1.3 Cross Section Width and Height

1.3.1 Cut & Cover Tunnel

The cut & cover tunnel is defined as the tunnel section from the final portal to the mined tunnel portal. The length of the cut & cover section shall be 37 m at the western and 30 m at the eastern portal area. The typical cross sections are given in the drawings attached as Appendix B-I.

A clearance profile with a height of 5.5 m over the carriageway and 2.3 m over the walkway shall be provided.

The width of the cut & cover tunnel shall be 10.8 m with the sections as described below ;-

Table 1: **Cross section elements cut & cover tunnel**

Cross Section Element	Width
Walkway:	1.40 m
Hard shoulder:	0.25 m
Driving lane:	3.50 m
Mountable Median	0.50 m
Driving lane:	3.50 m
Hard shoulder:	0.25 m
Walkway:	1.40 m
Overall:	10.80 m

1.3.2 **Mined Tunnel**

The mined tunnel is defined as section between the mined tunnel portal West and East with a length of 14.083 m. The typical cross sections are given in the drawings attached as Appendix B-I.

A clearance profile with a height of 5.5 m over the carriageway and 2.3 m over the walkway shall be provided. The width of the clearance profile shall be 10.0 m as per the table below:-

Table 2: Cross section elements mined tunnel

Cross Section Element	Width
Walkway:	1.00 m
Hard shoulder:	0.50 m
Driving lane:	3.50 m
Mountable Median	0.50 m
Driving lane:	3.50 m
Hard shoulder:	0.50 m
Walkway:	1.00 m
Overall:	10.50 m

1.4 **Ventilation**

1.4.1 **Concept**

The ventilation system consists of a fully transverse ventilation system with eight ventilation sections, including three intermediate ventilation caverns and three ventilation shafts. The length of the ventilation sections and cross sections of the ventilation ducts are given below. The shaft lengths are not included in the below given values.

Ventilation section length: Section 1 and 2: approx. 2245 m

Section 3 and 4: approx. 1578 m

Section 5 and 6: approx. 1715 m

Section 7 and 8: approx. 1543 m

Ventilation cross section: Exhaust air duct: minimum 10.6 m2

Fresh air duct : minimum 10.6 m2

The exhaust and fresh air duct are situated above the carriageway. The carriageway is separated from the ventilation ducts by an intermediate concrete ceiling. In the

fresh air duct higher air pressure than in the carriageway room is provided. Due to this the fresh air is pressed into the carriageway room through openings (20 x 50 cm every 6 m) in the concrete ceiling. In the exhaust air duct lower air pressure than in the carriageway room is provided, hence the air is sucked into the exhaust air shaft. Exhaust air openings are constructed in the tunnel ceiling every approx. 100 m with a cross section of 3.0 x 4.0 m. The openings can be controlled with electronic equipment (exhaust air dampers) and adjusted to the actual requirements. The exhaust air and fresh air duct are separated by a vertical concrete wall.

1.4.2 **Ventilation Cavern**

The three ventilation caverns are situated perpendicular to the main tunnel at approx. km 4.489, km 7.646 and km 11.076 respectively south of the lay-bye, between the main tunnel and the separate egress tunnel, with a length of approx. 30 m. The main characteristics of each of the three ventilation caverns are as follows.

Cavern excavation height: 15.0 m

Cavern excavation width: 21.0 m

Cavern length: 30.0 m

Excavation cross section: 185 m^2

The ventilation caverns include all electro mechanical installation for the ventilation and power supply system and can be accessed through the main tunnel or the separate parallel egress tunnel.

Rooms for electro mechanical equipment are situated at the level of the carriageway under the side axial fans. Above the E&M facility rooms the four axial fans, two for exhaust air extraction and two for fresh air supply, are installed. All axial fans are located at the same elevation. The fans and the E&M rooms are separated with a reinforced concrete ceiling. The typical layout of the cavern is given in drawings 8482B_II-ZOT_VEN-03-12-00 to 8482B_II-ZOT_VEN-05-12-00 included in Appendix B 1.

In the area of the fans the cavern cross section is heightened to provide enough space for gantry crane and maintenance personnel. The gantry crane is designed to be movable in both, longitudinal and cross sectional, direction of the ventilation cavern to ensure that each part of every ventilation fan is accessible. The gantry crane shall have a capacity of 12.5 tonnes with a span of minimum 20 m (Kone cranes or equivalent).

Below the exhaust air fans openings in the concrete ceiling are designed with 5.0 m length and 3.0 m width, hence the exhaust air fans are lowered through these openings in case of requirement of maintenance work or replacement of an axial fan. The

fresh air fans are replaced through the same openings, due to this one exhaust air fan has to be dismounted prior of fresh air fan replacement. The hydraulic aggregates are installed beside the axial fans in such way that the axial fans have not to be lifted above the hydraulic aggregates in case of axial fan replacement. Due to this the axial fan is only lifted approx. 0.5 m during replacement and the cavern height can be minimized.

The axial fan room is accessible for maintenance personnel through staircase from the E&M facility rooms. The different axial fans can be accessed with ladders and walkway located above the ventilation ducts. Each ventilation duct room can be entered from the axial fan room with fire proof doors.

The exhaust air ducts as well as the fresh air ducts lead to the ventilation shaft in which the ducts lead to the fresh air intake and the exhaust air extraction respectively above ground elevation.

The cavern layout design shall be suitably adjusted in Contractor's detailed design, based on electromechanical and ventilation requirements as well as the actual encountered ground condition.

1.4.3 **Ventilation Shaft**

Three ventilation shafts are required. The ventilation shafts are located above the caverns and connect the cavern to the ground. The shafts are located near km 4.489, km 7.646 and km 11.076 of the tunnel alignment. The shafts have a depth of 484 m, 365 m and 208 m respectively. The shaft 1 and 2 are designed to be additionally used as access shaft during the construction period. These shafts are excavated by conventional drill and blast methods top down. The layout of the construction shafts is given in drawing 8482B_II-ZOT_VEN-01-12-00 included in Appendix B 1. The shaft #1 and #2 has an excavation diameter of 14 m and an excavation cross section of 154 m2 depending on the support category. The shaft #3 is only used for ventilation measures and is constructed with raise boring with a diameter of 6 m and an excavation cross section of 28 m^2.These ventilation/construction shafts will be designed with suitable canopies at top to prevent ingress snow and rain.

Access roads shall be constructed from the National Highway NH-1 to the Ventilation cum construction shaft openings for operation and maintenance purposes. Also, the area has to be protected by providing boundary line with gates for permanent land acquisition. During construction of the main tunnel, the ventilation shafts No 1 and No 2 are planned to be used as intermediate construction access. The details of the approach roads are as follows:-

1.4.4 **Access Roads to Ventilation Shafts**

Access Road to Ventilation cum Construction Shaft No 1- Single lane road. Take off point near Km 106 of NH 1. Length- 350m

Access Road to Ventilation cum Construction Shaft No 2- Single lane road. Take off point near Km 110 of NH 1. Length- 100 m

Access Road to Ventilation Shaft No 3- Single lane road. Take off point near Km 113 of NH 1. Length- 70 m

1.4.5 **Ventilation Shaft Terminal Buildings**

Ventilation shaft terminal buildings are required to be constructed at each ventilation shaft opening locations to house the ventilation operation and maintenance equipment and personnel. The floor area requirement for each of these terminal buildings shall be minimum 400 m2.. The exact layout shall be as per Contractor's detailed design

1.5 **Separate Parallel Egress Tunnel and Cross Passages**

The separate egress tunnel shall be constructed parallel to the main tunnel. Distance between the axes of the main and the egress tunnel shall be maintained at 25 m depending upon the actual ground conditions. The egress tunnel shall have a cross section suitable for emergency vehicle. Additionally the egress tunnel can be used for site traffic during construction of the main tunnel. The typical cross section is given in the drawings at Appendix B-I.

Egress tunnel length: 14.200 km

Clearance profile: 6.0 m width and 3.5 m height

Cross Passages. At every 250 m, cross passages connect the main tunnel with the separate parallel egress tunnel as per following details:-

Drivable cross passages connect the egress tunnel with the main tunnel with interval of 750 m and at lay-bys. The typical cross section of the drivable cross passage shall be equal to that of the egress tunnel.

Pedestrian cross passages connect the egress tunnel with the main tunnel with interval of 250 m. The typical cross section of the pedestrian cross passage is 3.5 m width.

The length of cross passages shall be as per the Contractor's detailed design.

The locations of the cross passages are given in the schematically in the drawing "Tunnel system and installation" in Appendix B-I.

1.6 Lay-by Cabinet

Lay-bys are located on both highway sides (B.H.S.) of the tunnel with interval of 750 m. The lay by shall have a width of 3 m and a length of 40 m. The detailed locations is given in the drawing "Tunnel system and installation" in Appendix B-I.

At each lay by a hydrant cabinet and an emergency telephone cabinet is provided at both tunnel sides. A power supply niche is additionally situated at each lay by except the lay by at ventilation cavern.

1.7 Jet Fan Cabinet

Jet fan cabinets are located with an interval of 400 to 600 m. The jet fan cabinets are situated at both highway sides (B.H.S.) with a length of 30 m (three inner lining block segments). The detailed location is given in the drawing "Tunnel system and installation" in Appendix B-I.

1.8 Emergency Telephone & Communication System

Emergency telephone cabinets are located at the p location is given in the drawing "Tunnel system and installation" in Appendix B-I. Emergency telephones with digital voice transmission allow the road users to directly communicate with the traffic control centre.

Radio rebroadcasting equipment is provided to enable emergency services and staff operating within the tunnel to maintain communication.

To warn, guide and assist the tunnel users public address systems are provided.

1.9 Mountable Median:-

A mountable median of 0.5 m width shall be provided in the centre of the carriageway to divide the two traffic lanes. Other features of the median shall be as per Contractor's detailed design in accordance with relevant codes.

1.10 Final Interior Finish.

The main traffic tunnel shall have a final interior finish of a fire resistant material of suitable surface characteristics as per Contractor's detailed design subject to approval by Authority Engineer.

1.11 Lighting and E&M Facilities-

As per Contractor's detailed design subject to approval by the Authority Engineer.

The main equipment shall consists of switchgears, transformers, power distribution boards, luminaries, safety facilities and associated equipment. Details are given in the relevant drawing in Appendix B-I. For the Zoji la tunnel a high voltage facility with electrical feed from both sides shall be provided. Electrical substations are located at

an interval of 750 m in separated niches at each lay-by and in the ventilation cavern near the middle of the tunnel. However, the Electrical Power Supply Cost shall also be borne by the Contractor during the Operation & Maintenance of the Tunnel System/ Sub-systems.

Tunnel safety facilities such as CCTV-Cameras, traffic lights, variable message signs, traffic loop detectors, emergency communications, alarm push buttons, fire detection systems etc. shall be provided as per Contractors detailed design

An alternative source of power –uninterruptible power supply (UPS) equipment shall be provided to maintain supplies of the essential equipment for duration of 180 minutes.

An adequate modern and intelligent lighting system shall be provided as per Contractor's detailed design The light intensity of the entry and exit zones shall be adapted to the actual outside lighting level according to external conditions (day/night, regulation through measurement of luminous density).

A fire-extinguishing water pipe to be installed at one highway side providing fresh water supply to the hydrants in case of an incident or maintenance measures.

The egress tunnel shall also be equipped with lighting and safety facilities such as CCTV-Cameras, fire detection system etc.

The specifications for the lighting and the fixed operating equipments are brought out at Appendix D-II.

1.12 **Service Buildings** : Tunnel service buildings are to be located close to both tunnel portals with covered/underground passage to egress tunnel. The following equipment and installation, contained in the service buildings, are to be provided as per Contractor's detailed design.

- control room
- facilities for the electrical power supply: main electricity substation, HV switchroom, LV switchroom, UPS room, battery room, space for transformers;
- diesel generator, fuel tanks
- plant rooms for the tunnel maintenance and future requirements, stores;
- staff room and toilet facilities;

1.13 **Drainage And Waterproofing Concept**.

The tunnel shall be designed as a dry and drained tunnel as per contractor's detailed design.

Allowable infiltration in the main traffic tunnel $\leq$ 0.002 gal/sq. ft/day(US Gallon).

The tunnel high point is equal to the eastern portal which leads to a drainage to the lower western portal (Srinagar) with a gradient of 2,89% over the whole tunnel length of 14.150 km.

The tunnel vault is sealed against ground water inflows with a water proofing system. The water is drained along the bottom of the side walls with perforated drainage pipes.

Typical hydraulic concept drawings are included in Appendix B-1

1.14 Construction Concept

The construction of the main and the egress tunnel to include the cross passages only internationally accepted method as proposed in the Technical proposal maintaining the clear profile with prior approval of NHIDCL in consultation with the Authority Engineer. However, the method of construction is Contractor's choice.

The final choice of number of working faces/attack points rests with the Contractor, however as guideline, the Zoji la tunnel may be constructed from both tunnel portals and from the intermediate construction access shafts No 1 and 2 mentioned previously. During winter season, for a period of four months, construction works from the western portal and from construction access shafts No 1 and 2 may not be feasible due to closure of the National Highway NH-1. However construction from the eastern portal will be possible round the year. The Contractor is at liberty to work round the year at all work sites including western portal and Construction shafts with due protection measures with the approval of Authority's Engineer.

The parallel egress tunnel in combination with the drivable cross passages may be used for the construction of the main tunnel.

1.15 Site Installation

Four site installations are visualised . The site installation for the western portal is to be located in the area of Baltal. The site installation for the eastern portal is to be located in the area of Minamarg. Additional installations will be located in the vicinity of the openings of the construction access shafts no 1 and no 2 near Km 106 and 110 of the NH1 and Gagangir close to the National Highway approx.25 km from the western port. After making the assessment of requirement, the Contractor has to ascertain the availability of the land with the local authorities/ NHIDCL.

1.16 Muck Dump Disposal

Muck dump disposal sites are available in the Project area. Upto 20 land pockets have been proposed for muck disposal and these disposal area are located between approx. km stone 90 and Km stone 120 on existing NH 1. Prior to any disposal of muck dump material, necessary permission shall be obtained from the local authorities (Civil administration/Forest/Wildlife) as per law for which the local NHIDCL office will provide necessary assistance. For estimation of capacity of the individual pockets

the Contractors are required to carry out reconnaissance in coordination with local NHIDCL authorities. Muck disposal and management shall be carried out in accordance with the Environmental Laws of State/Central Govt.

2. **Project Facilities**

Project facilities shall be constructed in conformity with Annex-I of Schedule-C.

3. **Alignment Plan and Longitudinal Section**

An alignment plan and vertical profile of the tunnel is given in the drawings at Appendix B-I.

4. **Drainage System**

As per contractors detailed design approved by the Authority Engineer in accordance with the concept described at 1.13 above.

5. **Other Features of Project**

5.1. **Service Road**

No Service Roads has been proposed in this reach of Project, however, the road for loops at both the portals are to be constructed as shown in the drawing.

5.2 **Proposed Right of Way for approaches to Portal**

In view of Shri Amarnath base camp at Baltal, the alignment of the temporary approach road are to be cleared by SASB/ local Authorities. The contractor will be required to construct this temporary approach road including bridge at their own cost.

5.3 **Slope protection**

Slope protection will be constructed depending upon the actual site conditions as per contractor's detailed design. These may be required primarily along the western approach in this reach of the Project.

5.4 Utilities Provision of accommodating utilities shall be made both over as well as underground wherever required,

5.5 **Rainwater Harvesting**

As per Ministry of Environment and Forests Notification, New Delhi dated 14. 01.1997(as amended on 13.01.1998, 05.01.1999 & 6.11.2000), the construction of Rain water harvesting structure is mandatory in and around water crisis area, notified by the Central Ground water Board. State Govt rules shall be complied with.

6. **Specifications and Standards**

6.1 Design Speed: 80 KMPH

6.2 The Project Highway shall be constructed in conformity with the Specifications and Standards specified in Annexure 1 of Schedule-D.

7. **CHANGE OF SCOPE**

The length of the main tunnel, egress tunnel, ventilation shafts and eastern & western portals with associated structures shall be treated as an approximate assessment. The actual lengths as required on the basis of detailed investigations shall be determined by the Contractor in accordance with the Specifications and Standards. Any variations in the lengths specified in this Schedule-B shall not constitute a Change in Scope, save and except any variations in the length arising out of a Change of Scope expressly undertaken in accordance with the provisions of Article 13.

8. **Note to Schedule B**

8.1 Outside the requirements spelt out in this schedule, the Contractor has the design freedom. The detailed design must be done according to the latest international standards and practices for highway tunnels. The minimum functionality to be achieved for the Zoji La Tunnel, shall be as per DPR included in the tender documents.

APPENDIX B-I

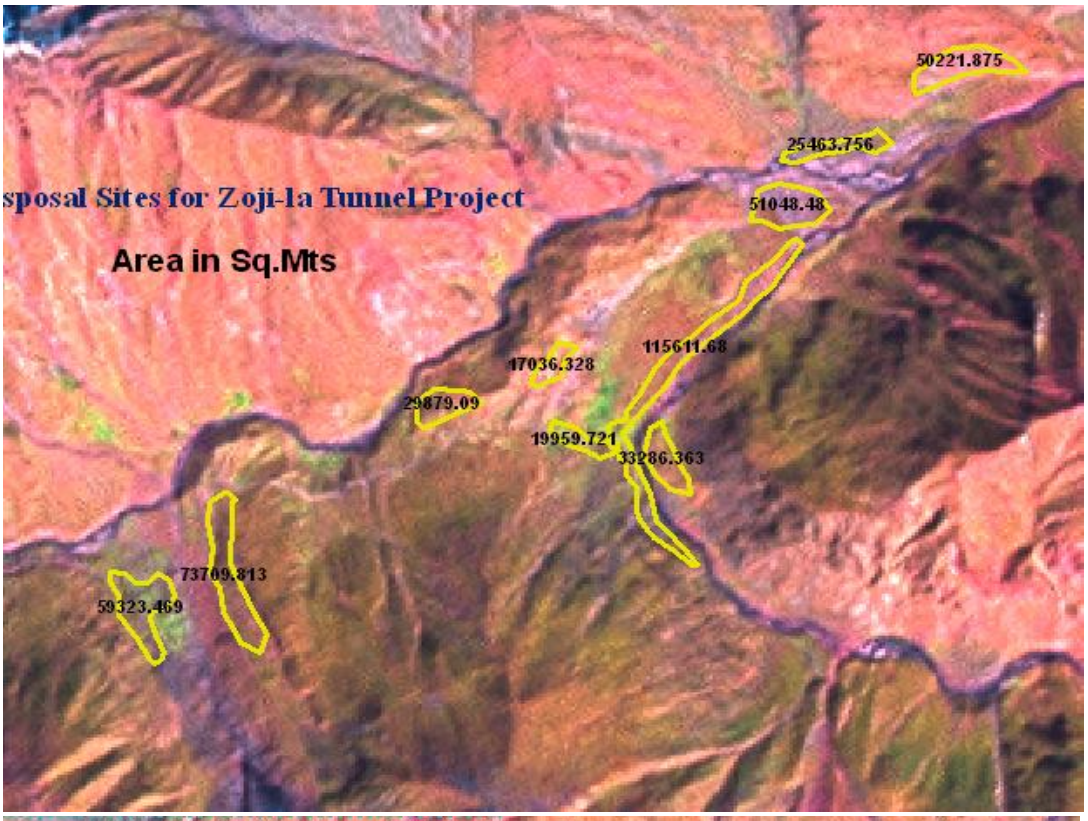
The following drawings are enclosed:

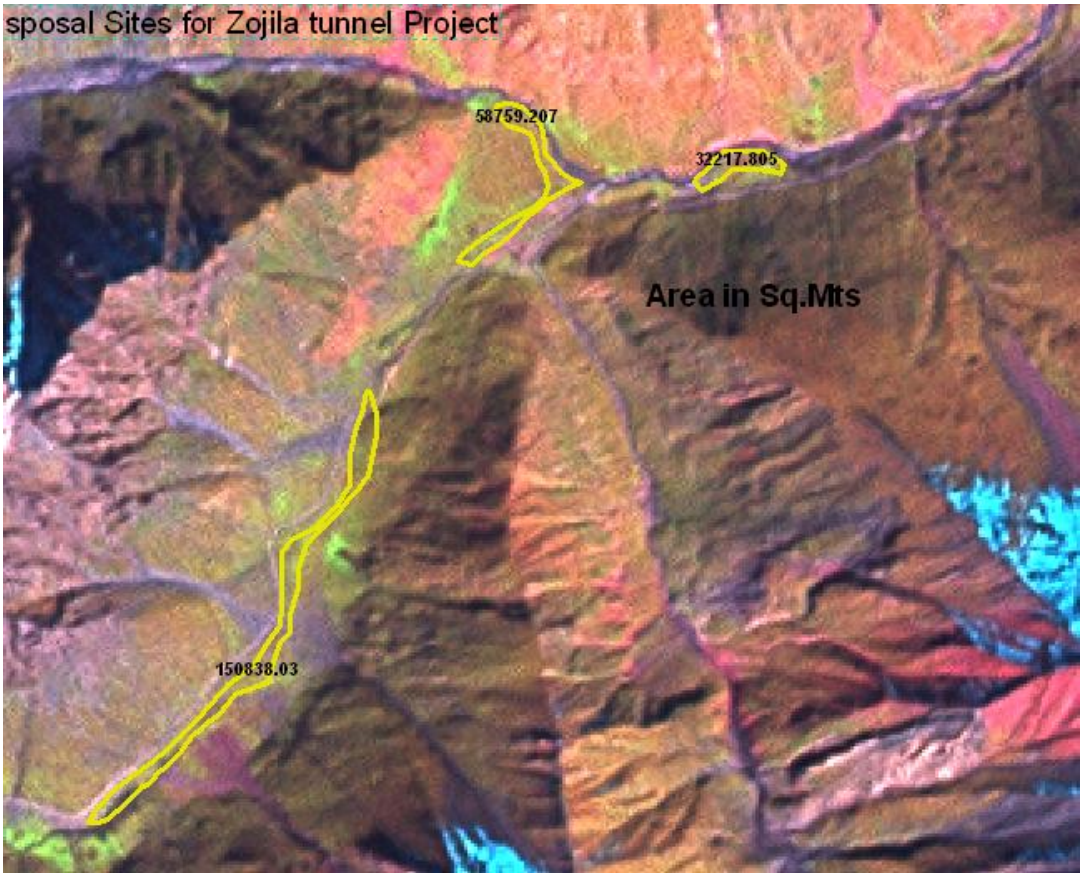
Sl No.	Drawing No.	Description
T1	8482B_II-ZOT_GEN-02-12-00	General Layout Tunnel - Plan View
T2	8482B_II-ZOT_GEN-03-12-00	General Layout Tunnel- Longitudinal Section
T3	8482B_II-ZOT_GEOM-01-12-01	TYPICAL CROSS SECTION, CLEARANCE PROFILE AND INSTALLATIONS WITHOUT INVERT SLAB
T4	8482B_II-ZOT_GEOM-02-12-01	TYPICAL CROSS SECTION, CLEARANCE PROFILE AND INSTALLATIONS WITH INVERT SLAB
T5	8482B_II-ZOT_GEOM-20-12-01	TYPICAL CROSS SECTION, CUT & COVER TUNNEL GENERAL LAYOUT AND CLEARANCE PROFILE
T6	8482B_II-ZOT_GEOM-05-12-00	TYPICAL CROSS SECTION, EGRESS TUNNEL
T7	8482B_II-ZOT_GEN-05-12-00	Tunnel system and installations
T8	8482B_II-ZOT_E&M-01-12-00	ELEMENTARY DIAGRAM OF SAFETY INSTALLATIONS
T9	8482B_II-ZOT_Vent-01-12-00	Typical cross section Ventilation Shaft 1 & 2
T10	8482B_II-ZOT_Vent-02-12-00	Typical cross section ventilation shaft no 3
T11	8482B_II-ZOT_vent-03-12-00	Typical cross section ventilation cavern plan view
T12	8482B_II-ZOT_vent-04-12-00	Typical cross section ventilation cavern longitudinal section
T13	8482B_II-ZOT_hyd-01-12-00	Typical cross section hydraulic scheme plan view
T14	8482B_II-ZOT_hyd-02-12-00	Typical cross section hydraulic scheme general layout western portal
T15	8482B_II-ZOT_hyd-03-12-00	Typical cross section hydraulic scheme general

		layout eastern portal
A16	Appendix A	Detail of approach road (Final detail shall be as per Contractor's design)
A17	Appendix B	Detail of Bridges(Final detail shall be as per Contractor's design)
A18	Appendix C	Detailed Report of SASE
A19	Appendix D	Details of Culverts (Approx.) (Final detail shall be as per Contractor's design)

APPENDIX B-2

MUCK DISPOSAL SITES





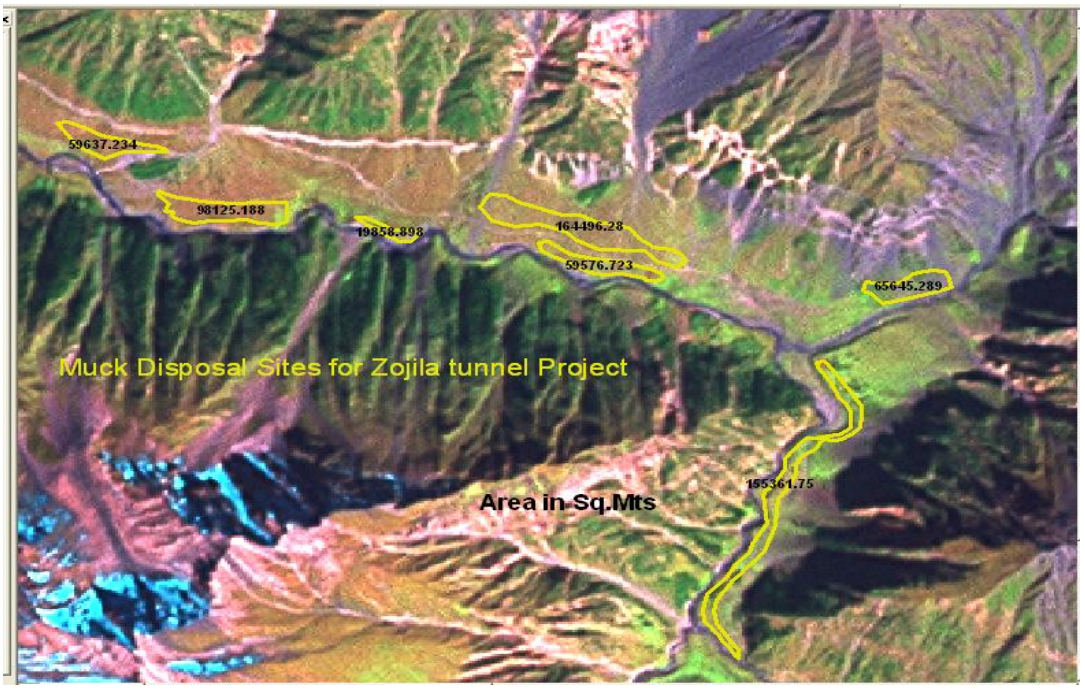


Table: Muck Disposal Sites and Their Capacities

S No	General Area	Pocket	Approx Area In Sq M
	Baltal	B 1	155361.75
		B 2	65645.289
		B 3	59576.723
		B 4	164496.28
		B 5	19858.898
		B 6	98125.188
		B 7	59637.234
	Gumri		
		G 1	150838.03
		G 2	58759.207
		G 3	2217.805
	Machoi-Minamarg		
		M 1	59323.469
		M 2	73709.831
		M 3	29879.09
		M 4	19959.721
		M 5	33286.363
		M 6	17036.328
		M 7	115611.68
		M 8	51048.48
		M 9	25463.756
		M 10	50221.875

Note:- (a) Total number of pockets identified- 20

(b) Total approximate area- 1310057 Sq M

SCHEDULE - C
(See Clause 2.1)

PROJECT FACILITIES

1.0 **Project Facilities**

The Contractor shall construct the Project Facilities in accordance with provisions of this Agreement, Such Project Facilities shall include:

a. Roadside furniture;
b. Street and Tunnel lighting;
c. Pedestrian facilities;
d. Landscaping and tree plantation in loop area;
e. Rest areas;
f. Truck lay-bys;
g. Bus-bays and bus shelters - DELETED
h. Vehicular Underpasses and Pedestrian /Cattle crossings - DELETED
i. Traffic aid posts;
j. Medical aid posts;
k. Vehicle rescue posts;
l. Telecom system; and
m. Highway traffic management system.
n. Facilities for the Authority and the Authority's Engineer
o. Vehicles for the Authority
p. Training
q. Helicopter Services

2.0 **Project Facilities for the Tunnel**

Project Facilities forming part of Tunnel and to be completed as described in Annex-I of this Schedule-C.

Annex - I

(SCHEDULE-C)

PROJECT FACILITIES TO BE PROVIDED ALONGWITH THE TUNNEL

1.0 **Project Facilities**

The Contractor shall construct the Project Facilities at the portal locations in accordance with provisions of this Agreement, Such Project Facilities shall include:

a. Roadside furniture;
b. Pedestrian facilities;
c. Tree plantation;
d. Truck lay-bys;
e. Bus-bays and bus shelters; and
f. Others
   (i) Highway Lighting
   (ii) Highway Patrol
   (iii) Ambulances
   (iv) Cranes
   (v) H.T.M.S.
   (vi) Development of site for wayside amenities;
   (vii) Traffic aid posts;
   (viii) Medical aid posts;
   (ix) Vehicle rescue posts
   (x) Telecom system
   (xi) Project Laboratory.

2.0 **Description of Project Facilities**

Each of the Project Facilities is briefly described below:

a. Road side Furniture

Road side furniture shall be provided in accordance with Manual of specifications and standards.

b. Street and Tunnel Lighting

Street and Tunnel lighting shall be provided in accordance with Manual of Specifications and Standards.

c. Pedestrian Facilities

Pedestrian Facilities shall be provided in accordance with the Manual of Specifications and Standards.

d. Landscaping and Tree Plantation

Landscaping and free plantation shall be provided in accordance with the Manual of specifications and Standards.

e. Rest areas

Rest areas shall be provided in the vicinity of the Western and Eastern portals. They shall include toilets and drinking water facilities.

f. Truck Bays

Truck bays in the vicinity of both the portals shall be provided as indicated by the Authority Engineer / Local authorities during construction.

g. Bus-bays and Bus Shelter – NoBus-Bays and Bus Shelter is proposed

h. Vehicular Underpasses and Pedestrian/Cattle Underpasses

No underpass is proposed.

i. Traffic Aid Posts

Traffic Aid Posts shall be provided out side the Western and Eastern portals to facilitate smooth flow of traffic .

j. Medical Aid Posts

Medical aid posts shall be provided at the Service Buildings.

k. Vehicle rescue posts

Vehicle rescue posts shall be provided at the service building areas in accordance with Specifications and Standards.

l. Telecom system

Telecom posts(at Western and Eastern portal locations) shall be provided for convenience of the users of the Project.

m. Highway traffic management system

Shall be provided in accordance with specifications and Standard.

n. Facilities for the Authority and the Authority Engineer

Facitlities for the Authority and Auhtority's Engineer are to be provided as per Annexure-IA of Schedule-C.

o. Vehicle for Authority.

The vehicles / passenger cars for the project shall be 4x4 SUVs, petrol or diesel driven having cylinder capacity of minimum 1500cc. The hard top SUVs shall be 4 W Drive either petrol or diesel driven and may be Innova/Toyota Fortuner/Jeep Compass/ Scorpio or equivalent. Four number of vehicles are to be provided by the

Contractor with front and rear AC for inspection and liasoning with other departments for 3500 Kms per month..

The Contractor shall provide within one month from the appointed date and shall be provided and maintained until issue of the Taking Over Certificate for the complete work. During Operation & Maintenance stage only 2 vehicles are to be provided for the use of Authority. Initially, new vehicles shall be provided and a vehicle shall replaced with a new vehicle after a maximum run of 75, 000 km or Four years whichever is earlier. All necessary taxes for operating the vehicles shall be fully paid and all necessary papers shall be provided as required by prevailing Motor Vehicles Act with comprehensive insurance cover for the vehicles. The vehicles shall be provided day and night as required by the Authority. The Contractor shall also make available drivers having valid licence at such times and for such duration as instructed by the Authority.

The vehicles shall be maintained in a smooth running condition. All expenses required for keeping the vehicles in smooth running condition such as fuel, lubrication oil and other consumables, necessary service and maintenance, drivers, repairs and replacement etc. are to be met by the Contractor. In the event of any vehicle being off the road for maintenance or on account of breakdown, the Contractor shall provide substitute vehicle(s) immediately. If the Contractor at any time fails to provide vehicle(s) or substitute vehicle(s) as specified above, an amount of Rs. 2500 per day or part thereof for each vehicle (that the Contractor failed to provide) shall be debited to the Contractor's account. Also the number of days for which the vehicle(s) were not provided shall not be included for payment.

p. Training

Training to officers of the Authority for 5 Days (excluding journey time) including all arrangements of Lodging, Food as per 3 star facilities. Training shall include 3 days classroom and 2 days site visit.

Training should be arranged in two batches within one year of Appointed Date, each batch will have 8 participants.

q. Helicopter Services

However, contractor shall provide helicopter (Twin Engines) services from Srinagar airport to zojila project site and return for half day (Four Hours) twice a month on the request of the Autority. Additional or less usage of Helicopter service can be adjusted in subsequent months. The Contractor shall provide the Helicopter service within one month from the appointed date and shall be provided and maintained until issue of the Taking Over Certificate for the complete work.

r. Other Facilities

As per the direction of Engineer-in-charge.

Annexure-IA

(SCHEDULE- C)

1. Facilities for the Authority and the Authority's Engineer

The facilities to be provided for the Authority and the Authority's Engineer, comprehending the Site Offices and Accommodation shall be as follows:

Table 1: Facilities for the Authority and the Authority's Engineer to be provided by the Contractors

Offices	Accommodation for Authority Staff	Accommodation for Auhtority Engineer Staff
Core Office and Work Site offices	- General Manager (GM):…… 1 - Dy. General Manager (DGM)……..2 - Manager /Site Engineer……6 - Office Supporting Staff…….…....9 - Visiting Officials ……..…5	- Team Leader (T/L):.....1 - Other Key Experts.....7 - Sub-Professional Staff.....7 - Office Supporting Staff .....9 - Visiting Experts ……..…3

Note (1): Site Office: The layout shall be prepared by the Contractor and submitted for review and approval by the Authority's Engineer/ Authority. The locations shall be confirmed by the Authority's Engineer/ Authority.

Note (2): Accommodation: Depending upon the Authority's Engineer/ Authority's acceptance, rental of existing buildings by contractor for use of Authority and Authority Engineer will be allowed depending the proximity of the works to the nearby cities or towns, and comfortability.

1.1 Site Office for the Authority and the Authority's Engineer

1.1.1 Construction of Site Offices

The basic layout of each site office shall be prepared by the Contractor and submitted to the Authority's Engineer for review and respective acceptance.

The building shall comply with India's applicable specifications for architectural and structural works for buildings.

a. Basic Layout

The layout shall be prepared in accordance with the number of staff shown in Table-1 to accommodate properly the following (note: the plan area shown below is the minimum requirement to be considered):

(1) Core Office – Office Type 1:

- Minimum Area: 200 sqm for Authority, 150 sqm Authority Engineer and 150 sqm common area.

- The tentative area requirements are given below:

(i) One office room for Team Leader .....25 sqm

(ii) One office room for the GM, NHIDCL.....25 sqm

(iii) Office room for DGM, NHIDCL……..…….20 sqm each

(iv) Office room for Other Key Experts of AE ……..……15 sqm

(v) One office room for Manager/Site Engineer of Authority .....50 sqm

(vi) One office room for Sub-Professional Staff of AE .....50 sqm

(vii) One Meeting/Conference Room (Common) .....40 sqm

(viii) One reception/administration office room (Common) .....50 sqm

(ix) One office room for working tables .....20 sqm

(x) 2 kitchen (Pantry) plan area well equipped with sink, draining board, cupboards, shelving, etc. ..... 10 sqm each

(xi) Male (3) and Female (1) toilets with shower and wash-hand basin facilities for the sole use of the Authority's representative, International Experts, National Experts, and administration staff (office manager and secretaries)..... 4 units

(xii) Male (2) toilets for Sub-Professional and Supporting staff..... 2 units

(xiii) Corridor for connecting all rooms (approx..60 sqm)..... 2m width

(xiv) Parking for the vehicles used by the Authority and Authority's Engineer and visitor's vehicles .....12 veh.

(2) Site Office – Office Type 2: (to be provided at all work sites i.e. both portals, three shaft locations and plant area)

b. Basic Requirements

(i) The Contractor shall, not later than 15 days after the starting date, submit full details of the Design Drawings to the Authority's Engineer, including floor plans, elevations, construction principles and materials, before commencing the erection of the facilities.

(ii) The Contractor shall be responsible for raising the ground (if necessary), grading and drainage in the vicinity of the building(s), with suitable access and walkways. The Contractor shall construct a covered hard-standing parking area, for the exclusive use of the Authority's Engineer and his visitors and respective access road to the parking area. The access road shall be paved and hard enough in order to be transited even during heavy rains. Outside lighting shall be installed around the buildings and the parking area, and appropriate signs shall be erected to indicate the purpose of the facilities.

(iii) All facilities shall conform to current fabrication standards for the required types. The facilities described above shall represent the minimum requirements. The Contractor shall provide all additional incidentals and necessary items, so that the facilities will be completely adequate and

satisfactory in every respect for their intended use. Painting both the exterior and the interior shall be as agreed with the Authority's Engineer.

(iv) The building shall be complete with all services connected with clean water supply by water bowser (including elevated water tank and the tower for capacity of 3,000 liters for Office Type 1), electricity and sewerage. Each room shall be provided with at least four electrical outlet sockets. All power shall be 220V-240V, 50Hz except where otherwise agreed by the Authority's Engineer. All rooms shall be illuminated by fluorescent lighting. Each toilet shall be provided with a flushing toilet and warm water hand washing and shower facilities and extractor fans.

(v) Telephone services (minimum 3 telephone lines and 6 extension lines completed with equipment for the office), including international direct dialing shall be provided. In addition, extra lines shall be provided for facsimile and internet connections. Each office shall be equipped with a telephone connected to the main reception telephone.

(vi) Offices and meeting rooms shall be air-conditioned. The air-conditioning may be either individual units or a central ducted system and shall be adequate to maintain temperature o f neither be more than 24°C (dry bulb) nor less than 15°C. The noise level of the air-conditioning while working should be sufficiently low to allow normal voice level discussions to take place.

(vii) Office rooms shall be capable of providing at all times environmental conditions suitable for the operation of specified electronic office equipment.

(viii) The building shall be weather proof, fire protected, heat-insulated and secured. Windows shall give adequate light and ventilation and be protected with metal mosquito-proof gauze and have security bars and Venetian, or other approved sun blinds. Ceiling height above the floor level shall be at least 2.75 m. All internal walls shall be sound insulated. Floors shall be PVC tile covered. In toilets and other washing areas the floors shall have drains to assist cleaning.

1.1.2 Maintaining and Servicing of the Offices

(i) The construction of the new office building for the Authority's Engineer shall be completed within 60 days since the date of commencement of the Contract and shall be equipped and maintained by the Contractor to the satisfaction of the Authority's Engineer until 3 months after the issue of a Completion Certificate for the Works or such earlier time as instructed by the Authority's Engineer whereupon the furniture shall be removed and any internal partition walls modified as required by the Authority's Engineer.

(ii) The Contractor shall provide all laborers, materials and equipment for maintaining and cleaning offices, furniture and fittings. The Contractor shall replace and/or restore, as directed, any facilities or parts thereof that become damaged, worn out, lost or stolen. The Contractor shall provide an adequate

stock of all expendable and consumable items including refreshments, clean water supply and drinking water, paper towels, toilet rolls, soaps, washing up liquid, brooms/mops and shall ensure proper and continuing functioning of all components and parts of the facilities during the contract period.

(iii) The Offices shall be provided with waste disposal material and these shall be emptied and disposed of daily by the Contractor.

1.1.3 Equipment and Expenses for Running-Off the Offices

The Contractor shall provide the following furniture and equipment to be used by the Authority's Engineer at Site.

Table: Furniture and Equipment for Site Offices (each office)

Item	Unit	Quantity for Core office	Quantity for each of work site office	Remarks
Refrigerator (deodorizer and ..... no-frost sy	unit	2	1	Office Type 1: 300liters' minimum capacity
Deep Freezer	Unit	1	-	
Water Dispenser (19 liters capacity including bottles and 6 spares bottles/gallon)	set	4	2	Office Type 1
Electric Kitchen Stove	unit	2	1	Size and model shall be discussed
Electric Kettle	unit	2	**1**	
Diesel Generator Set	unit	1	-	Office Type 1: 125 KVA

1.2 Accommodation for the Authority and the Authority's Engineer Staff

1.2.1 Accommodation

(1) General

(i) Immediately after the date for Commencement of Works, during the first 3 months or until the permanent installations are prepared and approved, the Contractor shall provide rented houses as per the accommodation for all staff of the Authority's Engineer.

(ii) The accommodation shall be equipped with security grilles and mosquito netting, and shall be fully furnished and equipped with new items by the Contractor to the satisfaction of the Authority's Engineer, including curtains, linen, blankets, glassware, cutlery, crockery and kitchen utensils.

(iii) Each house shall be wired to permit the use of standby generators as well as mains for the supply of electricity. The generators shall be fitted with automatic starting switchgear if so directed by the Engineer. Covered, hard standing areas for positioning generators and storing fuel shall be provided.

(iv) Each house designated for the Engineer's International Experts and National Experts shall be provided with one telephone line and internet connection. Telephone installation shall be made by the Contractor but the cost of calls shall be paid by the Authority's Engineer staff.

(v) Each house shall be provided with a TV (including cable and satellite connection). The installation shall be made by the Contractor but the cost of calls shall be paid by the Authority's Engineer staff.

(vi) Each house shall be provided with hot and cold water in the kitchen and the bathrooms.

(vii) The Contractor shall provide watchmen for security purposes to the approval of the Authority's Engineer.

(viii) The accommodation shall be available and ready for occupation within the number of days approved by the Authority's Engineer after the Commencement Date.

(ix) In the event that the Contractor fails to provide the required accommodation within the time specified or subsequently agreed by the Authority's Engineer, the Contractor shall provide, at no cost to the Employer, suitable hotel accommodation until such time as the accommodation is ready for occupation.

(x) When a house is no longer required by the Authority's Engineer, all furniture, fittings and equipment provided by the Contractor for that house shall become the property of the Contractor.

(2) Housing Types

(A). House for the Authority near to Core Office (GM, NHIDCL)

One residential accomodation, internal floor area approximately 100sqm comprising 1 x sitting room, 1 x dining room, 1 x bedroom with attached bathrooms, 1 additional bathroom, 1 x kitchen, 1 x office, 1 x veranda. Temperature control arrangements to the sitting room, dining room and bedrooms.

(B). Accommodation for the Authority near to Core Office (Other Staff: 1 per 1 person)

Bachelor's accommodation having internal floor area approximately 40 sqm (03 nos.) and other of 25 sqm with attached bathrooms.

(C). Team Leader (Authority's Engineer)

One residential accomodation, internal floor area approximately 100sqm comprising 1 x sitting room, 1 x dining room, 1 x bedroom with attached bathrooms, 1 additional bathroom, 1 x kitchen, 1 x office, 1 x veranda. Temperature control arrangements to the sitting room, dining room and bedrooms.

(D). Other Key Experts and Sub-Proffessional/Suppporting Staff

Bachelor's accommodation having internal floor area approximately 25 sqm with attached bathrooms.

Note: (1) All the residential accomodation must have temperature control facility so that temperature is niether more than 24°C nor less than 15°C.

(3) Maintenance

(i) The Contractor shall be responsible for supplying all utilities, including electricity (whether by mains or generator), water, timber for open fires, drainage and telephone services, and shall meet the cost of these services, except the cost of telephone calls.

(ii) The Contractor shall maintain the accommodation, and all furniture, fittings and equipment, whether supplied by him or not, in good repair and to the satisfaction of the Authority's Engineer as long as such accommodation is occupied by the staff of the Authority & Authority's Engineer for the purposes of the Contract.

SCHEDULE - D
(See Clause 2.1)

SPECIFICATIONS AND STANDARDS

1 The Contractor shall comply with the Specifications and Standards set forth in Annex-I of this Schedule-D for construction of the Project.

Annex - I
(Schedule-D)

Specifications and Standards for Construction

1 **Specifications and Standards**

All Materials, works and construction operations shall conform to the Manual of Specifications and Standards for Two-Laning of Highways (IRC:SP:73-2007), referred to as the Manual, and MORTH Specifications for Road and Bridge Works. For tunnel works including portals section 14 of IRC: SP 84: 2014 and IRC SP:91:2010 (Guidelines for Road tunnels) may be followed. Where the specification for a work is not given, PIARC guidelines/ relevant international codes/ Good Industry Practice shall be adopted to the satisfaction of the Authority's Engineer.

2 **Deviations from the Specifications and Standards**

2.1 The terms "Contractor", "Authority Engineer" and "Contract Agreement" used in the Manual shall be deemed to be substituted by the terms "Contractor", "Authority's Engineer" and "Agreement" respectively.

2.2 [Notwithstanding anything to the contrary contained in Paragraph 1 above, the following Specifications and Standards shall apply to the Project, and for purposes of this Agreement, the aforesaid Specifications and Standards shall be deemed to be amended to the extent set forth below:]

ATTACHMENT-DI TECHNICAL SPECIFICATIONS FOR ROAD TUNNELS - CIVIL WORKS

Annexure (i) to Attachment-DI: "Guideline for Inner Shell Concrete",
Austrian Society for Concrete-and Construction Technology, 2006, Austria.

Annexure (ii) to Attachment-DI: "Guideline for Sprayed Concrete",
Austrian Society for Concrete- and Construction Technology, 2005, Austria.

ATTACHMENT-DII ROAD TUNNELS-E&M, LIGHTING AND OTHER FIXED OPERATING EQUIPMENT (FOE)

Annexure (i) to Attachment-DII
Technical Specification Ventilation Equipment
Annexure (ii) to Attachment-DII
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ATTACHMENT-DI

TECHNICAL SPECIFICATIONS FOR ROAD TUNNELS - CIVIL WORKS

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1 SCOPE OF WORK

The National Highways & Infrastructure Development Corporation Limited (NHIDCL) has been entrusted with the work of construction of Zojila Tunnel excluding approaches located north-eastern of the city of Srinagar at the National Highway NH-1 close to the village of Sonamarg.

2 GENERAL

These Technical Specifications define the technical and quality standards specifically for NATM tunnel construction works in all ground condition.

The construction works shall be executed by the Contractor according to the quality requirements defined in the Specification and to the satisfaction of the Authority's Engineer. Any item of work arising from the execution of the works, not covered by the Technical Specification, shall be according to a Standard as agreed with the Authority's Engineer and the Contractor.

It is the intent of this Specification to define standards for the tendering process as well as for the planning and execution of the work by the Contractor. This includes the definition of quality standards which have to be followed and will be checked during construction by the Authority's Engineer. Deviations from the Specification must be submitted in writing in the tender.

This Technical Specification is based on the "Specification for Tunnelling, Third Edition", British Tunnelling Society, Institution of Civil Engineers, 2010 and "MORTH Specification for Road and Bridge Works", Ministry of Road Transport and Highways, 2000.

2.1 Definition

Behaviour Type (BT) means general categories describing similar ground behaviours with respect to failure modes and displacement characteristics.

Contractor means the person(s) named as contractor in the Letter of Tender accepted by the Employer and the legal successors in title to this person(s).

Contractor's Representative means the person named by the Contractor in the Contract or appointed from time to time by the Contractor who acts on behalf of the Contractor.

Cost means all expenditure reasonably incurred (or to be incurred) by the Contractor, whether on or off the Site, including overhead and similar charges, but

does not include profit.

Day means a calendar day.

Design drawing, final drawing, construction drawing, fit-for-constriction drawing means drawing of detailed design prepared by the Contractor and approved by Authority's Engineer.

Employer means the person named as employer in Contract Data and the legal successor in title to this person.

Authority's Engineer and Engineer means the person appointed by the

Employer to act as Authority's Engineer for the purposes of the Contract and named as such in the Contract Data, or other person appointed from time to time by the Employer and notified as such to the Contractor.

Framework plan means the summary of the Geotechnical Design, including relevant parameters used in the design, and application criteria for the assignment of excavation and support methods.

Ground behaviour means reaction of the ground to the excavation of the full profile without consideration of sequential excavation and support.

Ground Type (GT) means ground, soil or rock, with similar properties.

(Design) Line of excavation means the line of excavation within which no unexcavated ground material shall remain at any time. If due to additional displacements of the ground unexcavated material extend into the line of excavation the Authority's Engineer may order to excavate this material at no additional costs.

Materials means things of all kinds (other than Plant) whether on the Site or otherwise allocated to the Contract and intended to form or forming part of the Works, including the supply-only Materials (if any) to be supplied by the Contractor under the Contract.

Overbreak means the excavation beyond the line of excavation.

Overbreak Line means the line to which overbreak is allowed without any remedial work required.

Plant means the apparatus, machinery and vehicles intended to form or forming part of the Permanent Works.

Site means the places where the Permanent Works are to be executed and to which Plant and Materials are to be delivered, and where the Operation Service is to be provided, and any other places as may be specified in the Contract as forming part of the Site.

System Behaviour (ST) means behaviour resulting from the interaction between ground, excavation profile and support, separated in: system behaviour in the

respective excavation section, system behaviour in the supported section and system behaviour in the final state.

Working Day means a day on which working is performed.

Works means the Permanent Works and Temporary Works or either of them as appropriate and the facility to be operated by the Contractor during the Operation Service Period.

2.2 Work during Bad Weather Condition

All works have to be continued during any weather condition. Difficulties due to low temperature or snow falls in winter times or heat, drought or heavy rain falls in summer time are compensated with the unit prices. No extension of construction time is derived.

It shall be noticed that various parts of the Project Highwayarea do show avalanche risks. The Contractor shall investigate the working areas required for the tunnel construction concerning avalanche risk before establishing site infrastructure.

Parts of the Project Highwayarea are not accessible in winter time due to heavy snowfall and avalanche risk. A closure of the National Highway NH-1 at the area of Gagangir towards Sonamarg can be assumed for approx. 4-5 months from December/January to March/April. The actual date of road closure and opening will be defined by the road owning authority.

2.3 Submittals

The Contractor shall provide description of all works prior to commencement of any work to the Authority's Engineer for approval. The Contractor shall submit the documents in a way that sufficient time is left for approval of the submittals but latest 2 working weeks before start of the relevant works if not specified herein differently or directed by the Authority's Engineer.

The description shall include but not limited to procedure, sequence, materials, equipment, laboratory etc. The Authority's Engineer may request additional data and supplementation of the submittals at any time.

2.4 Standards and Units

Materials, equipment and methods shall comply with the Standards and Codes of Practice indicated using the versions that are current at the date for submission of tenders. The Contractor may propose the adoption of alternative standards and shall provide explanations with any proposals. The use of such standards shall be subject to the agreement of the Authority's Engineer.

Some Indian, European and British Standards and Guidelines are listed in Clause 2.5. The list is provided for information only and does not illustrate all relevant Standards for the Works. All Work shall be in compliance with these Standards and Guidelines. First and foremost the compliance of Indian Standards is required unless defined otherwise in this Specification. International (in the first step European) Standards and Guidelines shall be accessed to when no Indian Standards/Guidelines are available for the specific matter.

References to sources for Standards, Guidelines and Recommendations cited in the contractual documents are provided in Table 1. The list is provided for information only.

Table 1: References to sources of Standards, Guidelines and Recommendation

Abbreviation	Name
ASTM	American Society for Testing and Materials, 100 Bar Harbor Dive West, Conshohocken PA 19429 – 2595, U.S.A.
BSI (BS)	British Standards Institute, 389 Chiswick High Road, London, W4 4AL UK.
DIN	Deutsches Institut für Normung e.V. Beuth Verlag GmbH, Burggrafenstrasse 6 D-10787, Berlin, Germany.
EFNARC	European Federation of Producers and Applicators of Special Building Products, Association House, 235 Ash Road, Aldershot, Hampshire, GU12 4DD, United Kingdom.
EN, ENV	European Committee for Standardisation, Central Secretariat, Rue de Stassart 36 B-1050, Brussels.
IRC	The Indian Road Congress, Jamnagar House, Shahjahan Road, New Delhi- 110011.
IS	Bureau of Indian Standards, Manak Bhavan, 9 Bahdur Shah Zafar Marg, New Delhi – 110002.

ISO	International Organization for Standardisation 1, rue de Varembé CP 56, CH- 1211 Genéve 20, Switzerland.

ÖNORM:	Austrian Standard Institute, Heinestraße 38, 1020 Wien, Austria

RVS (Austrian Code for Road Construction)	Austrian Association on Road, Rail and Transport (FSV), Karlsgasse 5, 1040 Wien, Austria
ÖGG	Austrian Society for Geomechanics, Bayerhamerstrasse 14, 5020 Salzburg, Austria

The units applied are those of SI-System according to ISO 1000. A full stop (.) is used as decimal delimiter. Additionally in the schedule of prices the following abbreviations are applied:

d calendar day

each each

ls lump sum

wd working day

2.5 Listing of Standards

The list is provided for information only.

2.5.1 Indian Standards

ID of Standard	Description
IS 10262-2009	Guidelines for concrete mix design proportioning
IS 1077-1992	Common Burnt Clay Building Bricks
IS 11171-1985	Dry-Type Power Transformers

IS 1199-1959	Methods of sampling and analysis of concrete
IS 12269-1987	53 grade ordinary Portland cement
IS 12330-1988	Specificatioon for sulphate resisting Portland cement
IS 1248	Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories
IS 1278-1972	Filler rods and wires for gas welding
IS 1343-1980	Code of Practice for Prestressed Concrete
IS 1542-1992	Sand for plaster
IS 1554-1988	(Part 1): PVC insulated (heavy duty) electric cables: Part 1 For working voltages upto and including 1 100 V
IS 1566-1982	hard-drawn steel wire fabric for concrete reinforcement
IS 1885-1993	Electrotechnical Vocabulary: Part 32 Electric cables
IS 1651-1991	Stationary cells and batteries, lead-acid type (with tubular positive plates)
IS 8130-1984	Conductors for insulated electric cables and flexible cords
IS 1786-2008	High strength deformed steel bars and wires for concrete reinforcement-
IS 1791-1985	General Requirements for Batch Type Concrete Mixers
IS 1905-1987	Code of practice for structural safety of buildings; masonry walls
IS 2062-2011	Hot Rolled Medium and High Tensile Structural Steel
IS 2116-1980	Sand for masonry mortars
IS/IEC 60947-1-2007	Low-voltage Switchgear and Controlgear :Part 1 General Rules

IS 2180-1988	heavy duty burnt clay building bricks
IS 2309-1989	Code of practice for the protection of buildings and allied structures against lightning
IS 2386-1963	(Part 1 & 8): methods of tests for aggregates for concrete
IS 2502-1963	Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement
IS 2505-1992	Concrete vibrators - Immersion type - General requirements
IS 2514-1963	Concrete vibrating tables
IS/IEC 60947-2-2003	Low-Voltage Switchgear and Controlgear - Part 2 : Circuit Breakers
IS 13118-1991	High-Voltage Alternating-Current Circuit-Breakers
IS/IEC 60947-3-1999	Low p voltage switchgear and controlgear : Part 3 Switches, disconnectors, switch-disconnectors and fuse combination units
IS 269-1989	Ordinary and low heat Portland cement (33 GRADE)
IS 2705-1992	Current transformers
IS 2750-1964	Steel Scaffoldings
IS 2751-1979	Code of Practice for Welding of Mild Steel Plain and Deformed Bars for Reinforced Concrete Construction
IS 280-2006	Mild Steel Wire for General Engineering Purposes
IS 13925-1-2012	Shunt capacitors for ac power systems having a rated voltage above 1000 V Part 1:General
IS 2961-1973	Chrome retan finished upper leather
IS 8130-1984	Conductors for insulated electric cables and flexible cords
IS 3043-1987	Code of practices for earthing
IS 3085-1965	Method of Test for Permeability of Cement Mortar and Concrete
IS 3156-1992	Voltage transformers

IS 3231-1986	Electrical relays for power systems protection
IS 3427-1997	A.C. Metal Enclosed Switchgear and Controlgear for Rated Voltages Above 1 kV and Up to and Including 52 kV
IS 3443-1980	Crane rail sections
IS 3558-1983	Code of practice for use of immersion vibrators for consolidating concrete
IS 3597-1998	Concrete pipes - Methods of test
IS 5578-1984	Guide for marking of insulated conductors
IS 11353-1985	Guide for Uniform System of Marking and Identification of Conductors and Apparatus Terminals
IS 3764-1992	Code of safety for excavation work
IS 383-1970	Coarse and Fine Aggregates From Natural Sources For Concrete
IS 3954-1991	Hot Rolled Steel Channel Sections for General Engineering Purposes - Dimensions
IS 4031-1989	Methods of physical tests for hydraulic cement
IS 4032-1985	Method of chemical analysis of hydraulic cement
IS 4081-1986	Safety code for blasting and related drilling operations
IS 4138-1977	Safety code for working in compressed air
IS 432-1982	Mild Steel and Medium Tensile Steel Bars and Hard-Drawn Steel Wire for Concrete Reinforcement
IS 456-1978	Plain and Reinforced Concrete - Code of Practice
IS 457-1957	Code of Practice for General Constrution of Plain and Reinforced Concrete for Dams and Other Massive Structures
IS 458-2003	Precast Concrete Pipes (with and without Reinforcement)
IS 4756-1978	Safety code for tunnelling work
IS 4880 (Part 1-7)	Code of practice for design of tunnels conveying water
IS 4925-2004	Concrete Batching and Mixing Plant
IS 4988-1968	(Part 1-5): Glossary of terms and classification of earth moving machinery
IS 5082-1998	Wrought aluminium and aluminium alloy bars,

	rods, tubes and sections for electrical purposes
IS 516-1959	Method of Tests for Strength of Concrete
IS 5525-1969	Recommendation for detailing of reinforcement in RCC
IS 5640-1970	Method of test for determining aggregate impact value of soft coarse aggregates
IS 5819-1970	Recommended Short-circuit Ratings of High Voltage PVC Cables
IS 5831-1984	PVC insulation and sheath of electric cables
IS 5878-1971	(Part 1-7): Code of Practice for Construction of Tunnels
IS 5892-2004	Concrete transit mixers & agitators
IS 6430-1985	Mobile air compressor for construction purposes
IS 6461-1972	Glossary of terms relating to cement concrete: Part I Concrete aggregates
IS 6461-1972	Glossary of Terms Relating to Cement Concrete - Part III :
	Concrete Reinforcement
IS 650-1991	Standard Sand for Testing of Cement
IS 694-2010	POLYVINYL CHLORIDE INSULATED UNSHEATHED AND
	SHEATHED CABLES/CORDS WITH RIGID AND FLEXIBLE
	CONDUCTOR FOR RATED VOLTAGES UP TO AND INCLUDING 450/750 V
IS 7098-1988	Crosslinked polyethylene insulated PVC sheathed cables: Part 1
	For working voltage upto and including 1 100 V
IS 7245-1974	Concrete payers
IS 7251-1974	Concrete finishers
IS 7293-1974	Safety code for working with construction machinery
IS 7319-1974	perforated concrete pipes
IS 783-1985	Code of Practice for Laying of Concrete Pipes
IS 7861-1981	(Part 2): Code of pracdtice for extreme weather

	concreting: Part II Recommended practice for cold weather concreting
IS 7861-1981	(Part 1): Code of practice for extreme weather concreting Part 1
	Recommended practice for hot weather concreting
IS 800-2007	General Construction In Steel - Code of Practice
IS 8041-1990	Specification for rapid hardening Portland cement (2nd revision)
IS 8112-1989	High strength ordinary Portland cement (43 grade)
IS 814-2004	Covered Electrodes for Manual Metal Arc Welding of Carbon and Carbon Manganese Steel
IS 816-1969	Code of practice for use of metal arc welding for general construction in mild steel
IS 817-1992	(Part 1): Training of Welders - Code of Practice: Part 1 Manual metal arc welding
IS 818-1968	Code of Practice for Safety and Health Requirements in Electric and Gas Welding and Cutting Operations
IS 2062-2011	Hot Rolled Medium and High Tensile Structural Steel
IS 8623-1993	Low-Voltage Switchgear and Controlgear Assemblies
IS/IEC 60898 -2002	Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations : Part 1 Circuit-breakers for ac operation
IS 9012-1978	Recommended practice for shotcreting
IS 9103-1999	Concrete Admixtures
IS 9284-1979	Method of test for abrasion resistance of concrete
IS 9417-1989	Recommendations for welding cold worked bars for reinforced concrete construction

2.5.2 European Standards

Eurocode 1	Basis of design and actions on structures

Eurocode 2	Design of concrete structures
Eurocode 3	Design of steel structures
Eurocode 5	Design of timber structures
Eurocode 7	Geotechnical design
Eurocode 8	Design of structures for earthquake resistance
BS EN ISO 62:2008	Plastics. Determination of water absorption
BS EN 196:2005	Methods of testing cement
BS EN 197-1:2011	Cement. Composition, specifications and conformity criteria for common cements
BS EN 197-1:2004	Cement – Part 1: Composition, specifications and conformity criteria for common cements
BS EN 206-1:2001	Specification, performance, production and conformity
BS EN 295-7:1996	Requirements for vitrified clay pipes and joints for pipe jacking
BS EN 338:2010	Structural timber. Strength classes
BS EN 450-1:2005	Fly ash for concrete – Part 1: Definitions, specifications and conformity criteria A1:2007
BS EN 471:2004	High-visibility warning clothing for professional use - Test methods and requirements
BS EN 480:2006	Admixtures for concrete, mortar and grout. Test methods
BS EN ISO 527-3:1996	Plastics. Determination of tensile properties. Test conditions for films and sheets
BS EN 681-2:2000	Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Thermoplastic elastomers
BS EN 771-3:2011	Specification for masonry units. Aggregate concrete

	masonry units (dense and light-weight aggregates)
BS EN 772-2:1998	Methods of test for masonry units. Determination of percentage area of voids in masonry units (by paper indentation)
BS EN 791:1996	Drill rigs – safety
BS EN 815:1997	Safety of unshielded tunnelling boring machines and rodless shaft boring machines for rock
BS EN 932-6:1999	Tests for general properties of aggregates. Definitions of repeatability and reproducibility
BS EN 933-1:2012	Tests for geometrical properties of aggregates. Determination of particle size distribution. Sieving method
BS EN 934-2:2009	Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – Definitions and requirements, conformity, marking and labelling
BS EN 1008:2002	Mixing water for concrete – Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete
BS EN 1011-1:2009	Welding - Recommendations for welding of metallic materials - General guidance for arc welding
BS EN 1011-2:2001	Welding. Recommendations for welding of metallic materials. Arc welding of ferritic steels
BS EN 1062-7:2004	Paints and varnishes. Coating materials and coating systems for exterior masonry and concrete. Determination of crack bridging properties
BS EN 1090-2:2008	Execution of steel structures and aluminium structures. Technical requirements for steel structures
BS EN 1097	Tests for mechanical and physical properties of aggregates
BS EN 1367	Tests for thermal and weathering properties of aggregates

BS EN ISO1461:2009	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
BS EN 1537:2000	Execution of special geotechnical work – rock anchors
BS EN 1542:1999	Products and systems for the protection and repair of concrete structures. Test methods. Measurement of bond strength by pull-off
BS EN 1562:2012	Founding. Malleable cast irons
BS EN 1563:2012	Founding. Spheroidal graphite cast iron
BS EN 1744	Tests for chemical properties of aggregates
BS EN 1849-2:2010	Flexible sheets for waterproofing. Determination of thickness and mass per unit area. Plastic and rubber sheets
BS EN 1928:2000	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of watertightness
BS EN ISO 3506-2: 2009	Mechanical properties of corrosion-resistant stainless-steel fasteners - Nuts
BS EN ISO 4624:2003	Paints and varnishes. Pull-off test for adhesion
BS EN ISO 9001:2008	Quality management systems. Requirements
BS EN 10025:2004	Hot rolled products of structural steels
BS EN 10080:2005	Steel for the reinforcement of concrete. Weldable reinforcing steel.
BS EN 10164:2004	General Steel products with improved deformation properties perpendicular to the surface of the product – technical delivery conditions
BS EN 10226-1:2004	Pipe threads where pressure tight joints are made on the threads. Taper external threads and parallel internal threads. Dimensions, tolerances and designation

BS EN ISO 11925-2:2011	Reaction to fire tests. Ignitability of products subjected to direct impingement of flame. Single-flame source test
BS EN 12110:2002	Tunnelling machines – Air locks – Safety requirements
BS EN 12111:2002	Tunnelling machines – Road headers, continuous miners and impact rippers – Safety requirements
BS EN 12310-2:2000	Flexible sheets for waterproofing. Determination of resistance to tearing (nail shank). Plastic and rubber sheets for roof waterproofing
BS EN 12317-2:2010	Flexible sheets for waterproofing. Determination of shear resistance of joints. Plastic and rubber sheets for roof waterproofing
BS EN 12336:2005	Tunnelling machines - Shield machines, thrust boring machines, auger boring machines, lining erection equipment - Safety requirements
BS EN 12350	Testing fresh concrete
BS EN 12390	Testing hardened concrete
BS EN 12504-1	Testing concrete in structures – Part 1: Cored specimens – Taking, examining and testing in compression
BS EN 12588:2007	Lead and lead alloys. Rolled lead sheet for building purposes
BS EN 12620:2002	Aggregates for concrete
BS EN 12878:2005	Pigments for the colouring of building materials based on cement and/or lime. Specifications and methods of test
BS EN 12889:2000	Trenchless construction and testing of drains and sewers
BS EN 13055-1:2002	Lightweight aggregates. Lightweight aggregates for concrete, mortar and grout
BS EN 13139:2002	Aggregates for mortar

BS EN 13263-1:2005	Silica fume for concrete – Part 1: Definitions, requirements and conformity criteria
BS EN 13492:2004(E)	Geosynthetic barriers - Characteristics required for use in the construction of liquid waste disposal sites, transfer stations or secondary containment
DIN EN 13670-1:2011	Execution of concrete structures
BS EN 13791:2007	Assessment of in-situ compressive strength in structures and pre-cast concrete components
BS EN 14487-1:2006	Sprayed concrete – Part 1: Definitions, specifications and conformity
BS EN 14487-2:2006	Sprayed concrete – Part 2: Execution
BS EN 14488-1:2005	Testing sprayed concrete – Part 1: Sampling fresh and hardened concrete
BS EN 14488-2:2006	Testing sprayed concrete – Part 2: Compressive strength of young sprayed concrete
BS EN 14488-3:2006	Testing sprayed concrete – Part 3: Flexural strengths (first peak, ultimate and residual) of fibre reinforced beam specimens
BS EN 14488-4:2005	Testing sprayed concrete – Part 4: Bond strength of cores by direct tension
BS EN 14488-5:2006	Testing sprayed concrete – Part 5: Determination of energy absorption capacity of fibre reinforced slab specimens
BS EN 14488-7:2006	Testing sprayed concrete – Part 7: Fibre content of fibre reinforced concrete
BS EN 14889-1:2006	Fibres for concrete – Part 1: Steel fibres. Definitions, specifications and conformity
BS EN 14889- 2:2006	Fibres for concrete – Part 2: Polymer fibres. Definitions, specifications and conformity
BS EN 15167-1:2006	Ground granulated blast furnace slag for use in concrete,

	mortar and grout – definitions, specifications and conformity criteria
BS EN 60204	Safety of machinery. Electrical equipment of machines
BS EN 61672-1:2003	Electroacoustics. Sound level meters. Specifications
DD CEN/TS 14416:2005	Geosynthetic barriers. Test method for determining the resistance to roots
PD CLC/TR 50426:2006	Assessment of inadvertent initiation of bridge wire electro-explosive devices by radio-frequency radiation. Guide

2.5.3 British Standards

BS 143 and 1256:2000	Threaded pipe fittings in malleable cast iron and cast copper alloy
BS 1134:2010	Assessment of surface texture. Guidance and general information
BS 4190:2001	ISO metric black hexagon bolts, screws and nuts. Specification
BS 4449:2005	Steel for the reinforcement of concrete – Weldable reinforcing steel – Bar, coil and decoiled product
BS 4482:2005	Steel wire for the reinforcement of concrete products. Specification
BS 4483:2005	Steel fabric for the reinforcement of concrete
BS 4921:1988	Specification for sherardized coatings on iron or steel
BS 5228-1:2009	Code of practice for noise and vibration control on construction and open sites. Noise
BS 5228-2:2009	Code of practice for noise and vibration control on construction and open sites. Vibration
BS 5607:1998	Code of practice for the safe use of explosives in the construction industry

BS 5911-1	Concrete pipes and ancillary concrete products. Specification for unreinforced and reinforced concrete pipes (including jacking pipes) and fittings with flexible joints (complementary to BS EN 1916:2002)
BS 5975:2008	Code of practice for temporary works procedures and the permissible stress design of falsework
BS 6100	Building and civil engineering. Vocabulary. (various dates)
BS 6164:2011	Code of practice for health and safety in tunnelling in the construction industry
BS 6319	Testing of resin and polymer cement compositions for use in construction (various dates)
BS 6472:2008	Guide to evaluation of human exposure to vibration in buildings (1–80 Hz)
BS ISO 4866:2010	Mechanical vibration and shock. Vibration of fixed structures. Guidelines for the measurement of vibrations and evaluation of their effects on structures
BS 7385-2:1993	Evaluation and measurement for vibration in buildings. Guide to damage levels from groundborne vibration (Part 2)
BS 7668:2004	Weldable structural steels. Hot finished structural hollow sections in weather resistant steels. Specification
BS 7671:2011	Requirements for electrical installations
BS 7973-1:2001	Spacers and chairs for steel reinforcement and their Specification. Product performance requirements
BS 7973-2:2001	Spacers and chairs for steel reinforcement and their Specification. Fixing and application of spacers and chairs and tying of reinforcement
BS 7979:2001	Specification for limestone fines for use with Portland cement
BS 8102:2009	Code of practice for protection of below ground structures against water from the ground

BS 8500-1:2006	Concrete – Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier
BS 8500-2:2006	Concrete. Complementary British Standard to BS EN 206-1. Specification for constituent materials and concrete
BS 8666:2005	Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. Specification

2.5.4 International Standards

ASTM D 1777	Standard Test Method for Thickness
ASTM D 3776	Standard Test Methods for Mass Per Unit Area (Weight) of Fabric
ASTM D 4491a	Standard Test Method for Water permittivity
ASTM D 4751	Standard Test Method for Apparent opening sizeof a Geotextile
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
ASTM D 3786	Standard Test Method for Bursting Strength of Textile Fabrics-Diaphragm Bursting Strength Tester Method
ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
ASTM D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
ASTM D 4355	Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus
ASTM D 3787	Standard Test Method for Bursting Strength of Textiles-Constant-Rate-of- Traverse (CRT) Ball Burst Test
ASTM D 4157	Standard Test Method for Abrasion Resistance of Textile Fabrics

	(Oscillatory Cylinder Method)
EFNARC-1996	European Specification for Sprayed Concrete
ASTM C-39	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C-78	Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C-94/C	Standard Specification for Ready-Mixed Concrete
ASTM C-172/C	Standard Practice for Sampling Freshly Mixed Concrete
ASTM C-685/C	Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing
EFNARC Three Point Bending Test on Square Panel with Notch 2011	Testing Sprayed Concrete - Flexural tensile strength of fibre concrete on sprayed test specimen.
Austrian concrete society publications	Guide line on shotcrete and testing methods
Austrian concrete society publications	Inner lining concrete
JSCE -2004	Recommendation for design and construction of steel fibre reinforced concrete, Publications of Japan society of civil Authority's Engineers
DIN 67524 (Part1/02)	Lighting of street tunnels and underpasses
DIN 67524-2008	Tunnel illumination
DIN 5035	Artificial lighting
RABT (2006)	Guidelines for equipment and operation of road tunnels

2.6 Materials

All materials supplied to the Works shall conform to all of the following:

- This Specification.
- The appropriate Indian Standard, if no Indian Regulation is available the corresponding European or British Standard shall be adopted.
- Where an industry certification scheme is available, material shall be supplied in accordance with that scheme.
- Materials shall be supplied from a quality assured source, operating a Quality Assurance system in compliance with the relevant part of BS EN ISO 9001.

Where required in the particular Specification or where stated on the drawings, samples should be supplied and the subsequent material shall conform to the samples.

Materials used on site shall be used in accordance with the manufacturer's recommendations and instructions.

All materials should be handled and stored in a way to maintain their integrity and to avoid damage and degradation.

Details of the level of inspection and testing to be adopted in respect of supplied materials shall be agreed with the Authority's Engineer prior to commencement of work. Individual submissions are then restricted to those required by the Quality System.

2.7 Quality Management and Records

The Project Highwayshall be administered using an accredited Quality Management System conforming to BS EN ISO 9001. The individual requirements for agreement by the Authority's Engineer of materials and workmanship throughout this Specification shall be incorporated into agreed self-certification procedures.

The agreed Quality Control arrangements, including hold points and submission of records for the Authority's Engineer's acceptance, shall be set out in agreed Inspection and Test Plans.

References to the agreement of materials, workmanship, methods etc. throughout this Specification shall be interpreted as requiring the agreement of the Employer's Representative.

The Contractor shall maintain all records necessary under this Specification, including quality records as appropriate. Electronic records shall be maintained and backed up on a daily basis to prevent loss of data in the event of failure of electronic data storage.

Copies of all site records shall be available to the Authority's Engineer.

The Contractor shall supply the Authority's Engineer with all information necessary for the Health and Safety File including as-built drawings and records, maintenance schedules, operation and maintenance manuals, within the time specified in the Contract, after substantial completion of the Works. Information shall be provided in the agreed format. The Health and Safety File shall be prepared by the party identified in the Contract

3 SITE INSTALLATION

3.1 General

The Contractor shall be responsible for providing all necessary provisions for the execution of the construction works under this Contract. This includes plants, equipments, materials and laboratories.
The Contractor shall design, furnish, install, maintain and operate at the Project Highway area all temporary works and equipment such as Contractor's camp, offices, stores, workshops, warehouses, assembly areas, machinery, vehicles, material yards, health and safety measures, electric power, telecommunications, illumination, water supply system, concrete and aggregate processing plants, material testing laboratory, temporary construction roads etc.
28 days prior to commencement of any Works the Contractor shall submit layout plans at adequate scale showing the temporary construction facilities of the Contractor to the Authority's Engineer and they shall include:

- the Contractor's camp, offices, parking space, workshop, warehouses and storage areas including explosive magazines
- water supply, electric power supply including illumination and communication system
- sewerage, sewage treatment and disposal
- construction roads

- concrete and material processing plant, cement and aggregate storage
- material testing laboratory
- temporary tunnel ventilation system
- survey plan
- security and safety arrangement plan, medical care services.

3.2 Contractor's Camp

The Contractor shall design, furnish, install, maintain and operate the Contractor's camp at the location and within the designated lines defined by the local Authorities or the Authority's Engineer. The Contractor's camp shall provide the housing, feeding and recreation of the Contractor's employees and those of his subcontractors. The Contractor's camp shall be designed for the maximum number of employees on the site.
All facilities shall be in compliance with the Indian Construction Workers Act 1996 on permanent and temporary housing of employees. Prior to any camp construction the Contractor's drawings and Specifications shall be approved by the Authority's Engineer. The Contractor shall provide additional housings for the Authority / Authority's Engineer staff.

3.3 Site Office, Stores

The Contractor shall design, furnish, install, maintain and operate all required offices, stores, warehouses and testing laboratories at the location and within the designated lines defined by the local Authorities or the Authority's Engineer.
The Contractor shall provide and maintain a fully equipped site office for the Authority's Engineer staff on each construction site.

3.4 Lighting & Ventilation during Construction

Lighting and ventilation during construction shall be in compliance with Clause 7.7 and 7.8 in this Specification.

3.5 Electrical Power Supply

3.5.1 General
The Contractor shall be responsible for obtaining an adequate electrical supply for all his Site operations during the whole construction period.

Installations shall comply with IEC 60204 Safety of machinery, electrical equipment of machines and IEC 60364 Electrical installations of buildings.

If so required by the Authority's Engineer, the Contractor shall make a copy of all certificates prepared upon completion of electrical installations and prepared for all required periodic checks available.

The Contractor shall appoint a competent person to be solely responsible for ensuring the safety of all temporary electrical equipment on site.

The Contractor is to comply at all times with the Electricity at Work Regulations.

The Contractor shall furnish, install and keep operational throughout the duration of the Works standby generating facilities of such capacity as to be able to maintain minimum services such as illumination, ventilation, water supply, dewatering etc. necessary for the Project HighwayArea safety and security during a failure of the primary power source.

Oil filled transformers are not permitted in subsurface usage. Transformers shall be air-cooled and dry type.

Electrical heaters or radiators having exposed coils or elements shall not be permitted underground.

The lighting circuits shall be separated from the other sub-circuits.

The Contractor shall furnish, operate and maintain 100% standby diesel-driven generators or alternative source of power supply at each working portal. The generators or alternative supply shall be capable of operating the lighting system and the pumps required to flooding of the underground works besides operating all other systems so to allow the work function smoothly in event of main power system failure. The generators shall be tested by the Contractor weekly to ensure the full working capability.

Drawings showing the design of the electrical power distribution system within each area shall be submitted to the Authority's Engineer for approval at least 28 days prior to installation. This shall at least include a single line diagram for the distribution systems within each area, protection schemes for the systems and description of the operation concept. The installation of the electrical distribution systems shall not be started unless the Authority's Engineer has approved the submitted documents.

The client or representative of the client shall be allowed to access always all facilities of the construction site.

3.5.2 Earthing

All light fittings, electrical equipment and appliances shall be earthed electrically, and the Contractor's specialised personnel shall periodically check the effectiveness of such earthing. The earthing shall meet the requirements for plant and equipment given by Indian Standard 3043.

3.5.3 Cables

All exposed electrical cables installed within the tunnel shall comply with the following requirements:

- Flame retarding properties to IEEE 383,
- Toxicity level Acid evolution when burned 7%
- Flame propagation Oxygen index value 30% minimum
- Smoke density rating: 35% maximum

Supply cables at 3.3 kV or below shall be 3-core with the armouring used as the earth return in conditions where the cable is not subject to continues movement after installation or where the supply is to be a fixed point.

For supply to mobile or transportable equipment, where operation of the equipment subjects the cable to flexure, cables shall be sheathed in flame retardant LSFH.

3.6 Site Communication

The Contractor shall provide a suitable system for communication between the underground work site and workstations outside the tunnel, and maintain such system in working order at all times. An underground station (including telephone socket with bell and indicator) shall always be within 50 m of the point where major work is being carried out and at 200 m intervals along the driven tunnel.

3.7 Water Supply

The Contractor shall provide water that is adequate for year-round use in his camps as well as for general construction use.

The Contractor shall furnish, install, operate and maintain all necessary equipment including pumps, piping, fittings, valves, storage tanks and disinfection for the water supply and distribution systems.

Special measures during low temperature periods shall be taken such as heating or thermal insulation of pipes to avoid freezing of water.

3.8 Concrete and Material Processing Plant

At each construction site the Contractor shall install and erect all required materials processing plants of sufficient capacity to meet his planned peak requirements during construction. The plants shall be subject to approval by the Authority's Engineer. All control and measuring shall be regularly serviced and calibrated.

The following plants shall be installed but not limited to:

- concrete aggregates processing plant (crushing and screening);
- concrete plant (batching and mixing);
- grouting plant

3.9 Testing Laboratory

The Contractor shall install, equip and maintain an adequate field laboratory for the sampling and testing of materials such as concrete, earth or any other materials as specified herein.

The laboratory shall be adequately lit, supplied with sufficient electrical power, water and heating. Adequate space for testing devices and storage areas shall be provided.

The equipment to be supplied and the methods of testing shall be in accordance with the referenced Standards in these Specifications. The proposed type and number of items of laboratory equipment shall be presented to the Authority's Engineer and approved prior to purchase.

All facilities and services shall be available to the Authority's Engineer as required. All sampling and testing to be undertaken shall be subject to the supervision of the Authority's Engineer. The laboratory shall be run by

Contractor's personnel experienced in sampling and testing of materials, and be subject to quality control.

Specialised testing which may be required and which cannot be performed in the Contractor's laboratory due to lack of time or equipment shall be assigned by the Contractor to an independent organisation approved by the Authority's Engineer. The Contractor shall accept all test results and all instructions or restrictions stipulated by the Authority's Engineer based on such tests.

3.10 Removal

The Contractor's Camp shall be dismantled and removed subsequently to completion of the Works by the Contractor, unless otherwise specified or directed by the Authority's Engineer.

All temporary installations must be completely removed after finalization of the relevant works. Rubbish, waste, debris and material must be removed.

Any disturbed area that will not be taken over for permanent use shall be restored at the completion of the Works to the original appearance as far as possible.

4 WORKING ENVIRONMENT

4.1 Health, Safety and Welfare

The Contractor shall adopt safe systems of work which minimise the risk to health and safety. All persons working on the site shall be competent to carry out their tasks and duties safely and in a manner that will endanger neither their own health nor the health of others. Persons, who are employed on the site for the first time, shall be subject to appropriate pre-employment occupational health checks, instructed on the hazards inherent in the site, precautions to be taken, the form of construction, and emergency procedures and fire safety. Such instructions shall be given whenever there is a material change in the working arrangements. The Contractor shall maintain a record of all persons instructed and each person shall be required to sign such record confirming that instruction has been received. No person shall be permitted on site without being inducted as set out above. The Contractor shall prepare a written statement of Safe Systems of Working which shall be issued to all persons at site.

All parties shall comply with the requirements and recommendations of BS 6164, BS EN 815, BS EN 12336, BS EN 12110, BS EN 12111 and BS 7671.

The Contractor shall also comply with the requirements of the Employer's codes of practice for safe working and those of any authority or body where their services or property are affected by the works.

A person responsible for Safety shall be appointed by the Contractor and this person shall be conversant with corporate policy, management operational instructions, regulations, legislation and current best practice and how these relate to health, safety and welfare. Compliance with health and safety requirements is the responsibility of managers and individuals at each and every level.

The Contractor shall establish on site:

- Welfare and first aid facilities with appropriately trained personnel, both on the surface and underground, as required by the scale of the Works. Welfare facilities shall include toilet and washing facilities. Where water washing facilities cannot be provided, appropriate alternative means of hand cleaning shall be provided. Barrier creams etc. for skin protection shall also be provided.

- Occupational health facilities on the surface, staffed by appropriate occupational health professionals as required by the nature and scale of the Works.

- Equipment for the rescue and evacuation of persons underground with persons instructed in its use.

- All necessary equipment, safety barriers, notices and the like for the protection of persons.

- Procedures to ensure that all plant and equipment underground is fitted with on-board fixed fire-extinguishing equipment covering fluid tanks, motors or engine compartments and tyres along with the use of reduced flammability (HFDU) hydraulic fluid.

- Comprehensive fire detection and fire fighting facilities.

- Sufficient chemical or compressed oxygen self-rescuer sets for all persons underground in accordance with HSE guidance.

- A competent safety officer shall be appointed by the Contractor who shall be conversant with the hazards associated with the form of construction to be undertaken and who shall be responsible for ensuring compliance with all management directives, rules and regulations concerning occupational health and safety.

- Subject to any legal requirement or requirement of the Employer and the size and nature of the Works, the Contractor may appoint a visiting competent safety officer under item above. He shall visit the site at the start of operations and for changes in methods of working, but in any event his visits shall not be at greater intervals than one month.

4.2 Noise & Vibration

4.2.1 General

The Contractor shall minimise occupational exposure to noise and vibration, the amount of noise emitted to the environment and the environmental vibration levels generated by his work activity.

The Contractor shall select and utilise methods of working and items of plant and control in his Works so as to minimise noise and vibration levels, including occupational noise and vibration exposure of the workforce, and not to exceed maximum permitted noise and vibration levels specified in the Contract or defined by local Authorities.

The adherence to any vibration levels specified in the Contract does not relieve the

Contractor of his obligations with respect to structural or other property damage.

4.2.2 Temporary Fencing and Barriers

Where required the Contractor shall erect and maintain throughout the construction period temporary fencing of appropriate height taking account of the need for this fencing to act as a noise barrier around all working areas. The fencing shall be dismantled and re-erected as the progress of the Works requires.

The line of the fencing shall be uniform and the exterior face of the fencing shall be treated with a durable finish. Where required, in order to prevent reflection of noise, the Contractor shall line the inside of fencing with sound-absorbent material with accepted acoustic absorption properties. The material shall be fire and water resistant.

Local fencing barriers or shelters shall be erected as necessary to shield particular activities, such as those involving the use of pneumatic or hydraulic techniques, and all stationary plant.

4.2.3 Plant & Equipment

The Contractor shall select and use plant, equipment and working practices which minimise occupational exposure to noise and vibration and minimise emissions of noise and vibration to the environment.

All plant shall be properly maintained and relevant service records completed. All plant shall be provided with effective silencers and vibration-dampening devices, and shall be operated according to the manufacturer's recommendations in such a manner as to avoid causing any excessive noise emission or vibration. The noise

emitted by an item of plant shall not exceed the relevant values quoted in the Contract or defined by local Authorities.

4.2.4 Noise & Vibration Monitoring

Where monitoring is required the Contractor shall provide, calibrate, operate according to the manufacturer's recommendations appropriate equipment for monitoring construction noise and vibration throughout the construction period.

The Contractor shall arrange for adequate standby equipment.

The Contractor shall notify the Authority's Engineer immediately whenever the specified noise or vibration limit has been exceeded, and agree measures to avoid repetition.

Any items of plant causing excessive noise or vibration levels shall be removed from the site and substituted by alternative compliant equipment.

The Authority's Engineer may instruct the Contractor to devise and use an alternative process if a construction method is causing unnecessary disturbance.

4.3 Access & Egress

The Contractor shall make all arrangements and assume full responsibility for transportation to the Site of all construction plant, materials and supplies needed for the proper execution of the Works.

Where designated access routes are indicated in the Contract, the Contractor shall use no other without the agreement of the Authority's Engineer.

4.3.1 Maintenance of Routes

All public and private highways and roads which are being used by the Contractor's, Subcontractors' or Suppliers' vehicles for the construction of the Works shall be kept clean and free of dirt and mud arising from the Works. The Contractor, unless otherwise provided for in the Contract, shall provide, maintain and use as necessary suitable equipment including mechanical road sweepers, throughout the course of the Works where and as agreed with the highway authority.

The Contractor shall provide, maintain and use mechanical wheel washers and high-pressure hosing facilities at work sites and at such additional locations as required under the Contract.

The Contractor shall be responsible for all maintenance in all respects of all site roads.

Any area of public highway which is closed because of the Works shall not be reopened until appropriate safety and traffic management measures have been completed and until the Authority's Engineer confirms that it is in a suitable condition for use by the public.

The Contractor shall protect the public from the Works by secure fencing and gates and shall control access through the gates as required under the Contract.

4.3.2 Access for Others

The Contractor shall at all times meet the full requirements for access for fire, ambulance and other emergency services and maintain liaison with them in that respect.
The Contractor shall at all times maintain access for the authorised representatives of utility providers and allow emergency operations to be carried out on any utility or service facilities within the Site.

The Contractor shall not use public or private rights of way for depositing or storing plant or materials. The Contractor shall maintain those parts of the public or private rights of way not temporarily occupied by the Works in a clean, passable and safe condition at all times.

The Contractor shall execute the Works in such a manner that safe pedestrian access, including disabled person access, to all properties is maintained at all times.

Unless otherwise provided in the Contract, methods of construction and programming of the Works shall be such that vehicular access to properties affected by the Works is not restricted.

4.3.3 Traffic Safety and Management

Where work is carried out on or adjacent to a trafficked highway the Contractor shall ensure that personnel shall, at all times, wear high-visibility fluorescent garments which shall comply with BS EN 471.

All proposals, details, execution, maintenance, removal and necessary reinstatement associated with traffic safety and management and temporary decking and other temporary structures on, or subways beneath, the highway shall be subject to the approval of the appropriate authorities. The Contractor shall supply all information required, for consultation with the appropriate authorities including the local authority, police and other authorities with jurisdiction or interest.

The Contractor shall agree a traffic management plan with the Employer's

Representative based on consultation and agreement with highway authorities. This shall show the scheme of traffic safety and management measures including the provision of safety zones and traffic signing. The plan shall include the requirements of emergency services for access into and through the site.

Fenced storage areas, gantries, loading bays, skips and other temporary structures on the public highway shall be provided and maintained to the conditions of a licence issued by the local authority.

All traffic safety and management measures necessitated by the Works shall be fully operational before the Contractor commences any work which affects the public highway.

The Contractor shall devise and put into effect traffic management procedures, including appropriate speed limits, within the site including on haul roads and temporary access roads, which are to an equivalent standard to those for a public highway unless directed otherwise by the Authority's Engineer.

4.3.4 Signing, Signalling & Lighting

The Contractor shall provide suitable entry and exit signs, at the points of access to and from the site, for vehicles and plant engaged on the Works. As far as possible, vehicles and plant shall enter and exit the site in a forwards direction.

Unless otherwise specified, the Contractor shall make all necessary arrangements including notices to relevant authorities for the provision, erection, maintenance, repositioning, covering and uncovering and final removal of all traffic signs as the progress of the Works requires.

The Contractor shall devise and put into operation traffic management arrangements to separate pedestrian and vehicular traffic. Pedestrian access shall be clearly signed and provided with barriers of adequate strength.

The temporary traffic Contractor shall be responsible for the design, provision and maintenance of all signals and associated equipment unless otherwise given in the Contract.

Where required during the execution of the Works, the Contractor shall provide and maintain temporary lighting for the highways. Temporary lighting shall provide the same level of illumination as that of the existing street lighting, which it replaces. Temporary lighting shall be provided and approved prior to the removal of any

existing street lighting.

4.3.5 Survey & Reinstatement

Prior to commencing the Works the Contractor shall carry out a condition survey of all roads and footways adjacent to the site. The survey record shall be available to the Contractor.

Unless stated otherwise, the Contractor shall reinstate all roads and footways affected by the Works to the extent, lines and levels that existed prior to the commencement of the Works and to standards that are at least equivalent to those that existed prior to the commencement of the Works.

Unless stated otherwise, the Contractor shall reinstate all surface water drainage systems (including but not restricted to gullies, channels, catchpits, piperuns, manholes and covers and the like) affected by the Works. The Standard of reinstatement shall be at least equivalent to that existing prior to the Contract commencing.

4.3.6 Access within Works

The Contractor shall provide safe access in and about the site and underground workings. All shafts shall have a ladder access in addition to any mechanical means.
The Contractor shall provide a safe designated pedestrian access in the tunnel and throughout the site area at all times. This shall have a firm, level, slip-resistant and continuous surface and shall be suitable for use in emergencies when lighting may be unavailable.

The Contractor shall segregate pedestrian and vehicular access routes.

The Contractor shall maintain a clear means of egress from each tunnel face at all times. Such means of egress through or past equipment, trains and similar obstructions shall meet the minimum dimensions in BS EN 12336.

The Contractor shall establish, maintain and operate a system whereby the presence of personnel underground is recorded, together with their location where appropriate.

4.4 Disposal of Spoil & Water

The Contractor shall prepare 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 will be reviewed by the Authority's Engineer and accepted or approved as required by the Contract.

4.4.1 Solid Waste Disposal

The Contractor shall remove all excavated material, spoil, surplus materials and rubbish from whatever source on site and shall, except where otherwise specified in the Contract, make his own arrangements for their disposal and provide all the necessary facilities to achieve this. The Contractor shall also comply with any legal or local authority requirements applying to the handling and disposal of any contaminated spoil.

The Contractor shall set up a system to control and monitor the transport of spoil from site to the tip site, in accordance with the current legislation and requirements of the local Authorities. The system shall be agreed with the Authority's Engineer and will provide evidence that each load has been deposited at a licensed tip site.

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

The Contractor shall comply with all statutes and statutory instruments relating to spoil disposal.

4.4.2 Liquid Waste Disposal

Before discharging any surplus water, the Contractor shall obtain the prior approval of the owner of the sewer or water-course and of the Environment Agency.

The Contractor shall ensure that the condition of any discharged water complies with permitted limits. The parameters to be monitored include pH values, temperature and suspended solids.

5 DEWATERING ARRANGEMENT

5.1 General

The Contractor shall design, furnish, maintain and remove temporary works for protecting the Works under construction against flood flows in rivers and creeks, and design, furnish, operate, maintain and dismantle the temporary dewatering facilities required to remove water from construction activities and from natural surface flow or groundwater seepage from working areas on the surface as well as in the tunnel.

The Contractor's working methods and systems shall be designed to control ground and surface water to permit the construction of shafts, tunnels, breakouts and portal structures.

Where dewatering operations are used they shall be kept to the minimum necessary for the execution of the Works. If, at any time, during construction, the inflow of water increases more than the installed pumping capacity, the Contractor shall be required to install additional pumping facilities and perform additional sealing as required by the Authority's Engineer. The dewatering system shall include a system for identifying ingress of soil material during the dewatering operation.

In planning temporary pumping systems, the Contractor shall take due consideration of water quality, pressure, quantity and variations in water levels.

Settlement ponds and other measures shall be provided so as to ensure that potentially contaminated or polluted matter from the execution of the Works is nowhere released into creeks, rivers or the ground.

The Contractor will be held responsible for all damage caused by his dewatering procedures or the lack of such, and he shall reinstate or repair disturbed ground or structures to their original condition or as otherwise approved.

Plant shall be delivered to site and maintained in good working order. Plant and pipe work shall be fitted with appropriate valves, controls and gauges. Each dewatering well shall be capable of individual adjustment and being shut down and isolated from the rest of the system. Appropriate standby equipment and spares shall be maintained on site at all time.

5.2 Construction Site

The Contractor shall perform all works necessary to drain the surface construction sites of rain, groundwater and service water. The work shall include, but not be limited to the following:

- design and construction of drainage, ditches, pits, pump sumps and settlement ponds with oil separators
- design, furnish, operate and maintain dewatering equipment and conduits
- relocation of dewatering facilities required for the performance of other works
- diversion of creeks where required by construction of any permanent or temporary structure, including spoil and stockpile areas
- all auxiliary work required for the safe and continuous dewatering of the surface construction sites

The Contractor shall perform all work necessary to collect and drain construction water and infiltrating groundwater, convey it to main conduits and convey it out from tunnel work to discharge points. The work shall include, but not be limited to, the following:

- design and construct pits, trenches and drainage measures along the tunnel invert
- design, furnish, operate and maintain dewatering equipment (including pumps and power supply) and conduits
- relocate dewatering facilities as required for the unhindered performance of the tunnel work
- design, construct and operate settlement ponds, with oil separators, at the portals or elsewhere, with discharge into creeks and rivers, as approved
- all auxiliary-work required for the safe and continuous dewatering of the underground working areas

The Contractor shall design and install complete facilities for the drainage of the temporary and permanent portal areas and the muck disposal areas.

Drainage ditches shall be excavated along the top of excavated slopes and on the berms. Such ditches shall be kept well back from the excavation edges. In loose materials the ditches shall be lined with concrete or with rock paving set in mortar immediately after completion of excavation. The ditches shall be regularly cleaned out of accumulated silt and other matter so that water may flow freely at all times.

Rivers, creeks and intermittent streams in the vicinity of temporary or permanent works shall be diverted into culverts of lined ditches. Erosion must be prevented. Sediment laden water must be diverted through settling ponds or basins according to the environmental regulations.

5.3 Tunnel

The Contractor shall perform all necessary works to collect and drain construction and ground water in all tunnel drifts at all headings. The longitudinal inclination of the Zojila Tunnel is continuous upward from west to east portal. Due to this, all tunnel drifts heading towards western portal must be excavated with falling gradient. All required drainage measures including collection and pumping of any ground water in these downward inclined tunnel drifts must be included in the given prices. The water shall be drained out of the tunnel with minimum impact on ground stability and construction works. This includes, but not limited to:

- pits, trenches and drainage along the tunnel floor
- dewatering equipment including pumps
- pipes along tunnel side wall
- collecting local inflows directly from tunnel perimeter before and after installation of primary support
- collect inflowing water with dimpled sheets along the tunnel perimeter
- settlement ponds or basins with oil separators before discharge into rivers

Mountain water due to tunnel construction shall be collected and drained. Excavation areas shall be drained of all construction water and ground water. Water appearing at the face shall be drained to the longitudinal drainage system as soon as possible.

Dewatering arrangement has to be considered for falling and rising gradient of the excavation, a softening and damaging of the bench shall be avoided. The water drainage length shall be kept at a minimum. In case of falling gradient temporary pump sumps must be max 5m behind the excavation face (top heading, bench, temporary and permanent invert).

The Contractor shall provide adequate pumping capacity where required, including a sufficient number of standby pumping units and standby power, to handle all water entering any portion of the tunnel works. These units shall be connected to the power supply and dewatering systems in such a way that proper and uninterrupted drainage will be ensured throughout the construction period.

Heavy mountain water may occur and therefore additional drainage system to the longitudinal drainage system may be required. In such zones systematic drainage drillings ahead of the tunnel face may be required and ordered by the Employer's Representative.

If required, drainage drillings (placement, direction and length according to local conditions) shall be constructed with no delay. Instrumentation, for measuring the pore pressure, may be required by the Authority's Engineer.

In tunnel sections with ground material sensitive to water (softening or swelling ground condition) particular care has to be taken concerning water drainage. The inflowing water shall be collected as soon as possible and conveyed in pipes not to allow contact to the tunnel floor. Construction water must be reduced to a minimum and collected and pumped immediately into pipes.

Water entering a working face from another part of the tunnel must be deviated not to affect construction works such as bench/invert excavation or concreting.

Unless otherwise specified, all water emanating from the tunnel excavation shall be discharged into settlement ponds, designed so as to meet the requirements of the prevailing Indian regulations. The outflow from each settlement pond shall be arranged in a way to prevent any oil from leaving the pond irrespective of the volume of water entering the pond.

Dimpled sheet membrane shall be of HDPE with a sheet thickness of 1.0 mm. The drainage capacity shall be 10 l/s/m. The compressive strength shall be 150 kN/m².

Strip drains shall consist of dimpled sheet membrane as defined above, wrapped in a nonwoven het bonded geotextile. The geotextile shall comply with Clause 12.2.

5.4 Measurement and Monitoring

The Contractor shall install, operate, maintain and relocate the necessary devices for flow measurements. These measuring devices shall be checked and approved by the Authority's Engineer before usage.

Gauging stations shall be installed and measurement of the total discharge shall be made as follows:

- Heading Zone: Measurement shall be performed during excavation and supporting work at a point not less than 50 m and not more than 100 m behind the heading face. Transfer of the measuring station in drill and blast advances shall be done in 100 m steps or as approved by the Authority's Engineer.
- Rear Zone: Flow measurements at the portal or at the outlet of installed pump lines shall be performed during the entire excavation and supporting work.

Measurement of water flow shall be performed once a day jointly by the Authority's Engineer and the Contractor or as otherwise agreed upon.

All pumping rates must be recorded and the Contractor shall keep full and detailed records of all monitoring carried out. Copies of such records shall be available to theAuthority's Engineer.

The Contractor shall monitor all springs and wells which may be influenced by the lowering of the ground and mountain water table due to the tunnel construction. The zero readings must be done prior to any excavation.

5.5 Final Tunnel Dewatering Arrangement

5.5.1 Ground Water

A minimum gradient of 0.5% of the drainage pipes shall be provided in each tunnel cross section. If not otherwise specified by the detailed design drawings or the Authority's Engineer, the following ground water drainage pipes with the given diameters shall be installed at the lines given in the detailed design drawings.

- Side wall drainage: $\Phi \geq 250$ mm
- Sub-base drainage: $\Phi \geq 150$ mm
- Ground water collecting pipe: $\Phi \geq 400$ mm

Perforated pipes shall be made of slotted Polypropylene (PP) or polyvinyl chloride (PVC) or any other equivalent material in agreement with the Authority's Engineer. The upper section of the pipe shall be longitudinal corrugated and slotted, withthe bottom section closed. The width of slots shall not exceed 1.0 mm. The total area of the slots for water intake shall exceed 50 cm2 per metre length of pipe. The bedding shall consist of dry lean concrete in compliance with Clause 10.2. The pipe shall be embedded in no-fines concrete in compliance with Clause 10.3.

5.5.2 Carriageway Water

The carriageway water shall be collected and drained in a separate drainage system. The collection shall be continuous by a slot channel or punctual with a minimum interval of 65 m. Slot channels shall be made of water impermeable concrete with plastic fibre reinforcement.

The slot channel diameter shall be minimum 250 mm. A minimum longitudinal gradient of 0.5% shall be provided.

6 OPEN EXCAVATION

6.1 General

In these Specifications the following works are covered:

- surface excavation in soil or rock (Cut) for the temporary and permanent tunnel portals, the tunnel portal structures, control building, muck dump areas, ditches, drains,
- surface fill (Fill) with soil and rock material for the platform of the tunnel portal structures and buildings, muck dump areas or roads,
- erosion protection of embankment slopes with gabions, mattresses, rip-rap,

etc.

- sub surface drainage
- backfill of structures
- water proofing of structures before refill

The existing ground surface area below which open excavation is required shall be cleared of trees, brushes, shrubs, embedded logs, fallen timber and surface litter and shall be grubbed of vegetation, roots and stumps. Cleared and grubbed material shall be disposed of in the designated spoil disposal areas.

No unexcavated material is permitted inside the design lines of the excavation.

14 days prior to commencement of any surface excavation the Contractor shall submit all detailed drawings and/or descriptions of his proposed excavation methods, sequences and equipment to the Authority's Engineer for approval.

28 days prior to dumping of any spoil, the Contractor shall submit all detailed drawings and/or descriptions of his proposed method for laying, compacting and protection against erosion of the muck dump material including information of dumping sequences and equipment. The muck dump areas shall be within the areas so designated by the Local Authorities or the Authority's Engineer and in compliance with Clause 4.4.1.

At least 28 days prior to placing of any fill material, the Contractor shall submit detailed drawing and/or descriptions of the construction procedure, mixing, treatment and compaction procedures, topsoiling, slope stabilisation and surface erosion protection, and other completion works for approval, for construction of embankments. All data of working methods, equipment and provisions for the stability of the construction as well as temporary and permanent drainage of these areas shall be included. Details of volumes, material types, heights and grades shall be provided.

The Contractor shall forward information of the progress of surface excavation including information on excavated volumes, ground type, ground support installed, water inflows and difficulties encountered to the Authority's Engineer at an interval in agreement with the Authority's Engineer.

6.2 Standards

Open excavation works shall be in compliance with the following Standards and Guidelines unless otherwise defined in these Specifications.

- Specification for Road and Bridge Works (Fourth Revision) August 2001 reprinted in April 2005 issued by MoSRT&H and published by IRC.
- IS 2720: Methods of test for soils — applicable parts
- IS 4532: Method of test for stabilized soils
- ASTM D3282: Classification of soils and soil-aggregates mixtures for highway construction purposes
- Eurocode 7: Geotechnical design

6.3 Cut

The excavation requirements and limits shown on the drawings have been established on the basis of the results of subsurface exploration by the Designer. The Authority's Engineer will examine the conditions exposed at the actual excavated surfaces and, if the conditions are deemed unacceptable for the intended purpose, will relocate the excavation design lines locally outside of the excavation design lines shown on the Drawings.

If, in the opinion of the Authority's Engineer, the necessity for excavation outside of the excavation design lines has been caused by negligence on the part of the Contractor or by ineffective executed excavating or blasting operations by the Contractor, the volume of additional excavation shall be backfilled with concrete or other material as required by the Authority's Engineer. Such additional excavation and backfilling shall be done at no additional cost to the Employer.

Unclassified material and rock excavated outside of the excavation design lines for the Contractor's own purposes shall be replaced with concrete or other material as required by the Authority's Engineer. Such additional excavation and backfilling shall be done at no additional cost to the Employer.

All initial support measures as given in the detailed design drawings or directed by the Authority's Engineer e.g. sprayed concrete, pre-stressed anchors, wire mesh etc. shall be in compliance with Clause 9 of this Specification.

The Contractor shall draw his own conclusions from site inspection, from the logs of rock cores, test pits, test trenches, test tunnels, test chambers and surface exposures and from other site investigation data made available to the Contractor, as to the excavation method that will be best suited for the satisfactory removal of materials to be excavated and as to the behaviour of unclassified material and rock in situ, during and after excavation.

Excavation shall include all items of work, equipment, facilities and material with respect to the proper excavation as specified, including mucking, dumping and transport of excavated materials in stockpile or disposal areas approved by the Local Authorities.

The Contractor shall apply, as approved by the Authority's Engineer, excavating, drilling and blasting techniques, which will produce a smooth final profile, i.e. smooth blasting resulting in minimum over break as well as - minimum detrimental effect beyond the design lines for excavation in compliance with Clause 7.3.3. Explosives and detonating systems shall be used by the Contractor to produce a smooth final excavated surface.

The Contractor shall adopt excavation procedures such that the stability of surfaces in open excavations is not impaired. The Contractor shall be responsible for the stability and safety of all excavations until final acceptance of the Works and shall install such instrumentation in the excavations, in addition to the instrumentation required by the Authority's Engineer, that the Contractor considers necessary to measure deformation and to establish that unstable conditions do not develop. The Contractor shall execute all remedial work required in excavations to ensure that the excavated surfaces are maintained in a sound and stable condition. The

Contractor shall submit to the Authority's Engineer all readings taken the instruments he installs not more than 1 working day after taking the readings.

During excavation, and at any time during the Work, all material which is unsafe or appears to endanger persons, the Works or the property of others, shall be immediately scaled and removed from the excavations. The fact that such scaling and removal may enlarge the excavation beyond the excavation paylines shall not relieve the Contractor from the necessity of doing such scaling and removal of such materials. If it is not possible to remove loose rock by normal barring and wedging, then rock support, shotcrete or chain link mesh or any combinations of each, shall be applied to secure and prevent the loose rock from falling or becoming unstable.

Notwithstanding the provisions specified herein, the Authority's Engineer may require the Contractor to take such action as the Authority's Engineer deems necessary to assure the safety of the excavations and the Contractor shall immediately comply with such requirements. Nothing in these Specifications shall be construed to relieve the Contractor from the sole responsibility for safety.

If drilling and blasting operations is required, these shall be carried out in such way that they do not interfere with the work of others nor cause any damage to adjacent structures.

Snow and ice shall be removed when necessary to ensure the safe and effective

performance of the Work.

If slides occur in excavated slopes, all materials affected shall be excavated and removed to the designated spoil disposal areas. The slopes shall then be further excavated to a safe, stable and neat condition or to the lines, slopes, dimensions and elevations required by the Authority's Engineer. If, in the opinion of the Authority's Engineer, any slide was caused by negligence on the part of the Contractor, all remedial work shall be done at no additional cost to the Employer.

The Contractor's excavation operations and schedule shall allow for interruption while the geological conditions exposed at the excavated rock surfaces are mapped and assessed by the Authority's Engineer. Local areas shall be cleaned off where required by the Authority's Engineer to expose a fresh undisturbed surface. Such interruption and assistance shall be at no additional cost to the Employer.

Construction traffic shall only be routed over suitably protected parts of the excavated surfaces.

6.4 Excavation Classification

Surface excavation shall be classified according to the excavation method as:

- Loose excavation
- Rock excavation

Loose excavation means all excavation which may be performed without continuous and systematic drilling and blasting. Clearing and grabbing of trees, shrubs and plants, stockpiling of topsoil layer, digging, ripping and occasional blasting may be required.

Rock excavation means excavation which requires continuous and systematic drilling and blasting for loosening, including measures for smooth blasting methods. The Contractor shall solely adapt blasting hole diameters, distance, charging and detonating delay of holes to form a smooth, sound surface along the excavation design lines. The distance between blasting holes shall not exceed 10 times of the blasting hole diameter.

6.5 Excavation Material Disposal

The disposal of excavation material shall be in accordance to Clause 4.4.1 of this Specification. Excavation material suitable to be utilised in the Works shall be stockpiled separately from materials to be disposed. The use of excavation material in the Works shall be in agreement with the Authority's Engineer. Suitable materials shall, wherever possible, be transported directly from the required

excavation to the various designated final locations. Excavated materials, not suitable for or in excess of the construction requirements, shall be disposed of in spoil areas designated by the Local Authorities or the Authority's Engineer. Unless otherwise provided for, spoil areas shall be built up in layers, with a maximum layer thickness of 0.6 m, and evenly compacted by the traffic of the construction equipment, aimed at minimizing future differential settlement. Final sloping and shaping of surfaces shall be as indicated on the Drawings. Other details of the work such as stabilisation and drainage measures are shown on the Drawings.

All activity by the Contractor at spoils areas shall be confined to the limits designated by the Local Authorities or the Authority's Engineer. The limits shall be clearly marked and, where directed barricaded to prevent traffic in areas outside the limits.

6.6 Fill and Embankment

The Contractor shall construct all compacted earthfill or rockfill embankment as shown on the Drawings or as otherwise directed by the Authority's Engineer.

This work shall include such work as selection of suitable material, transporting, spreading, adjusting moisture content, compacting to specified minimum dry density and completion in all respects, all in accordance with this Specification.

The embankment shall extend to the design lines as given in the drawings.

All permanent and long term temporary slopes shall generally be stabilised and erosion protected by planting of vegetation and greens similar to the typical local vegetation of the area. Additional measures such as bolts, anchors, shotcrete for cut slopes or gabions, rip-rap, geo-textile for embankment slopes must be applied as designed or ordered by the Authority's Engineer.

The Contractor shall construct all sub-surface drainage measures in cuts or embankments as shown on the Drawings or as otherwise directed by the Authority's Engineer. This work shall include such work as excavation, selection of suitable material, transporting, placing, and completion in all respects, all in accordance with this Specification. The material beneath the road sub-base shall have CBR values. The testing procedure shall be in accordance to AASHTO T193 and fulfil the requirements shown in the detailed design drawings and Indian Standards.

Trees, shrubs, grass, humus/topsoil shall be removed from the existing ground surface and stockpiled for later reinstatement if required by the Authority's Engineer prior to any placing of embankment.

The prepared surface shall be benched in vertical and horizontal cuts to provide a shear key with the embankment material.

The material of the embankment shall be placed and compacted layers with a thickness not exceeding 300 mm loose before compaction.

The moisture content of the material to be compacted shall be as wet or just wetter than optimum moisture content determined by laboratory testing.

All embankment material shall be compacted to a dry density not less than 95 per cent of the maximum laboratory dry density in accordance with IS 2720, Part 8.

6.7 Back Fill

Backfill shall be placed to the specified type of the lines, grades and dimensions in the locations shown on the detailed design drawings by the Contractor or directed by the Authority's Engineer.

All material proposed by the Contractor to be used as backfill shall be approved by the Authority's Engineer prior to any placing of backfill material. The material to be used as backfill shall be as far as possible obtained from required excavation for Underground Excavation Works.

Backfill material shall be homogeneous without layers, pockets and lenses and may not consist of any organic component. Each load of material shall be distributed well and operation of equipment shall be restricted in the area near permanent structures to avoid any kind of damage. The Authority's Engineer may reject full loads of backfill material that contain unacceptable percentage of organic component.

Backfilling may not be done before reaching full load capacity of adjacent structures and only after approval of Authority's Engineer. The placing of the backfill shall be done simultaneously and with similar method, procedure and material at the different sides of a structure to avoid differential earth pressure. The work may not be done at low temperatures and frozen backfill material is not permitted.

Back fill material shall consist of well graded granular material containing 35% or less by weight passing a 0.075 mm sieve, as specified in ASTM D3282 and with a maximum particle size of 300mm.

Back fill material shall be placed and compacted layers with a thickness not exceeding 300 mm loose before compaction and shall be compacted to a dry density not less than 95 per cent of the maximum laboratory dry density in

accordance with IS 2720, Part 8.

The moisture content of the material to be compacted shall be as wet or just wetter than optimum moisture content determined by laboratory testing.

Backfill material shall be tested every 300 m^3 or 600 m^2 or 1 test per shift, whichever is less, or as directed by the Authority's Engineer. Proctor test procedures shall be done in random backfill and impervious backfill; whereas the relative density testing of IS: 2720 shall be done for free-draining backfill.

6.8 Gabions

The foundation for each gabion and mattress shall be prepared by the Contractor to the satisfaction of the Engineer. Irregularities in the foundation shall be excavated or tightly filled with gravel to produce a surface which has no protrusions or cavities in excess of 100 mm and the surface shall be covered with a geotextile fabric. Gabions and mattresses shall consist of double twisted woven mesh gabions with coated, polymer sheathed wires or equivalent in agreement with the Authority's Engineer. The construction working procedures of gabions and mattresses shall be in compliance with the manufacturer's recommendations and instructions.

6.9 Rip-Rap Layers

Rip-rap layers shall be furnished and placed by the Contractor on permanent embankments as erosion protection layer as shown on the detailed design drawings of as directed by the Authority's Engineer.

Prior to any placing of rip-rap layers the source of the material shall be approved by the Authority's Engineer. Rip-rap material shall consist of hard, dense and durable rock. Material from Underground Excavation Works may be used.

The minimum rock size shall not be less than 500 mm and shall not be greater than that which can be encompassed in the specified layer thickness.

Rip-rap layers shall not be placed on earth, gravel or weathered rock foundation when not agreed with the Authority's Engineer. When the underground is not suitable for bedding of rip-rap layers, the rip-rap shall be placed on a 300 mm thick continuous layer of gravel, sand or rock fragments in agreement with the Authority's Engineer.

6.10 Water Proofing Membrane

The water proofing membrane shall cover all backfilled structures from water and

moister and is similar to the tunnel water proofing membrane as specified in 12.5.

7 UNDERGROUND EXCAVATION

7.1 General

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

The geological/geotechnical information presented in the tender documents represents the state of knowledge of the geological/geotechnical conditions along the tunnel alignment based on available information at this stage.

Tunnel works are to be executed prefably based on the New Austrian Tunnelling Method, hereafter referred to as NATM, with observance of all principles related to the application of this method.

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

The excavation material shall be classified in compliance with Clause 6.4 of this Specification. Different and adequate excavation methods shall be considered for rock excavation and loose excavation by the Contractor.

A detailed description, defined by the Contractor, of all excavation methods including equipment, location of headings, benches and pilot tunnels, drilling and blasting, controlled perimeter blasting, ripping, mucking, loading, hauling, temporary support systems, scaling, ventilation, lighting, pumping, safety measures, schedules, excavation cycles, simultaneous working of faces and sequence of operations he plans to follow in each excavation area to complete the work shall be included in the offer or submitted to the Authority's Engineer prior to commencement for review. Additionally details concerning installation of pumping, ventilation and lighting systems shall be forwarded to the Authority's Engineer for review. The Authority's Engineer shall be provided with all submissions in sufficient time ahead of the construction works or at such dates as mutually agreed upon. No excavation shall be started in any excavation area until permission has been received in writing from the Authority's Engineer.

The approval given by the Authority's Engineer to the Contractor's methods and equipment does not relieve the Contractor of his full responsibility for proper and safe execution of tunnel excavations, or of liability for injuries to persons or fatal accidents, or any obligations under this Contract.

Manufacturer's certificates of compliance shall be submitted certifying that the

materials and equipment proposed to be used meet Specification requirements.

During excavation, and at any time during the work, all ground material which is unsafe or appears to endanger persons, the Works or the property of others, shall be immediately scaled and removed from the excavations. The fact that such scaling and removal may enlarge the excavation beyond the line of excavation shall not relieve the Contractor from the necessity of doing such scaling and removal of such materials. If it is not possible to remove loose rock by normal barring and wedging, then rock support, shotcrete or steel mesh or any combinations of each, shall be applied to secure and prevent the loose rock from falling or becoming unstable.

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.

Drilling and blasting operations shall be carried out in such way that they do not interfere with the work of Others nor cause any damage to adjacent structures.

The Contractor's excavation operations and schedule shall allow for interruption while the geological conditions exposed at the excavated rock surfaces are mapped and assessed by the Authority’s Engineer. Local areas shall be cleaned off where required by the Authority’s Engineer to expose a fresh undisturbed surface. Such interruption and assistance shall be at no additional cost to the Employer.

The excavation invert shall not be damaged due to construction works. Hence 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 Authority’s 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.

Additional excavation, not shown on the drawings, but the Contractor considers being required for his own purpose such as cross passages, mucking pits, turning cavern or spaces for site installation may only be carried out in agreement with theAuthority’s Engineer. Such excavations are done at no additional cost for the Employer and shall be backfilled to the excavation line.

7.2 Overbreak

The overbreak-line is defined with 30 cm for tunnel sections with drill and blast excavation and 20 cm for tunnel sections with excavation by excavator of road header. Overbreak shall be secured with determined measures in agreement with the Authority's Engineer and according to the local conditions. Loose rock mass shall be removed. Any voids formed during the excavation process by overbreak and temporary works shall be backfilled completely with grout, concrete, sprayed concrete or other approved durable material.

Accepted geological overbreak in tunnel excavation is defined as a local overbreak which occurs while the following four conditions are simultaneously fulfilled:

- overbreak extends beyond the "overbreak"-line;
- the overbreak occurs above the tunnel invert;
- the Authority's Engineer is immediately notified and given the opportunity for inspection, while both the cause and the extent of the overbreak are clearly visible; and
- appropriate working methods were used and adequate rock reinforcement and support was installed in due time, and properly applied by the Contractor.

The Contractor shall survey and plot cross sections at sufficient intervals to allow for a reasonably accurate estimate of the volume of overbreak which he claims to be due to geological conditions.

Voids created by overbreak extending beyond the "overbreak"-line in tunnel excavations shall, as directed, be backfilled up to the "overbreak"-line as required by the Authority's Engineer.

In the event of excessive geological overbreak, support shall be installed immediately as required to stabilize the ground. The Authority's Engineer shall be informed immediately of such conditions. Remedial works shall be in agreement with the Authority's Engineer. The design of the remedial works shall be done by the Contractor and approved by the Authority's Engineer. Remedial works shall be executed before further advance of the face unless otherwise directed by the Authority's Engineer.

The void formed by the geological overbreak shall be measured in-situ. Individual voids of less than 1 m3 shall be discarded for measurement purposes. The materials required to complete the repair shall be quantified and approved by the Employer's Representative and certified for payment.

7.3 Tunnel Excavation

7.3.1 General

Tunnel excavation in any kind of ground shall be performed in accordance with modern blasting and excavating practice, using methods and techniques that will reduce overbreak to a minimum outside of the line of excavation (payline), and which will preserve, in the soundest possible condition, the structural integrity of the rock beyond the line of excavation.

Excavations shall not be advanced until the pattern ground support for the previous round has been installed and the profile of the previous round has been checked and all rock remaining inside the line of excavation has been removed. The Authority's Engineer may stop the work for removal of undercuts at any time if undercutting is observed.

Tunnel excavation shall not be started until the exposed rock faces in its portal excavation have been stabilized with rock support and shotcrete and drainage measures have been installed as given in the drawings.

The Contractor shall maintain accurate records of all blasting and excavating operations and at the end of each shift he shall provide the Authority's Engineer with two copies of the records, together with such additional data as the Authority's Engineer may request. The forms shall bear the signatures of the Contractor's and the Authority's Engineer certifying that records are accurate and complete and include but not limited to the following:

- length of tunnel excavated and theoretical volume of solid material excavated
- quantity of any rock support installation
- occurred rock falls, zones of instability and logs of pilot holes
- water inflow at the head and rate of discharge at the tunnel portal
- unusual occurrences and all delays with reasons for these.

Holes drilled in swelling ground shall be conducted without water.

7.3.2 Geotechnical Design

The procedure of ground characterisation during construction sequence is based on the Austrian "Guideline for the Geotechnical Design of Underground Structures

with Conventional Excavation" by the Austrian Society for Geomechanics.

Rock mass classes are determined based on the rock at the excavation face of the tunnel before the commencement of the respective excavation sequence.

7.3.2.1 General

A continuous updating of the geotechnical model and an adjustment of excavation and support to the actual ground conditions during construction is required.

The rock mass characterisation shall be determined according to the following steps, which are summarized and presented in Figure 1.

- Step 1: Determination of the encountered Ground Type (GT) and prediction of ground characteristics
- Step 2: Assessment of system behaviour in excavation area
- Step 3: Determination of excavation and support measures and prediction of System Behaviour in supported section
- Step 4: Verification of system behaviour

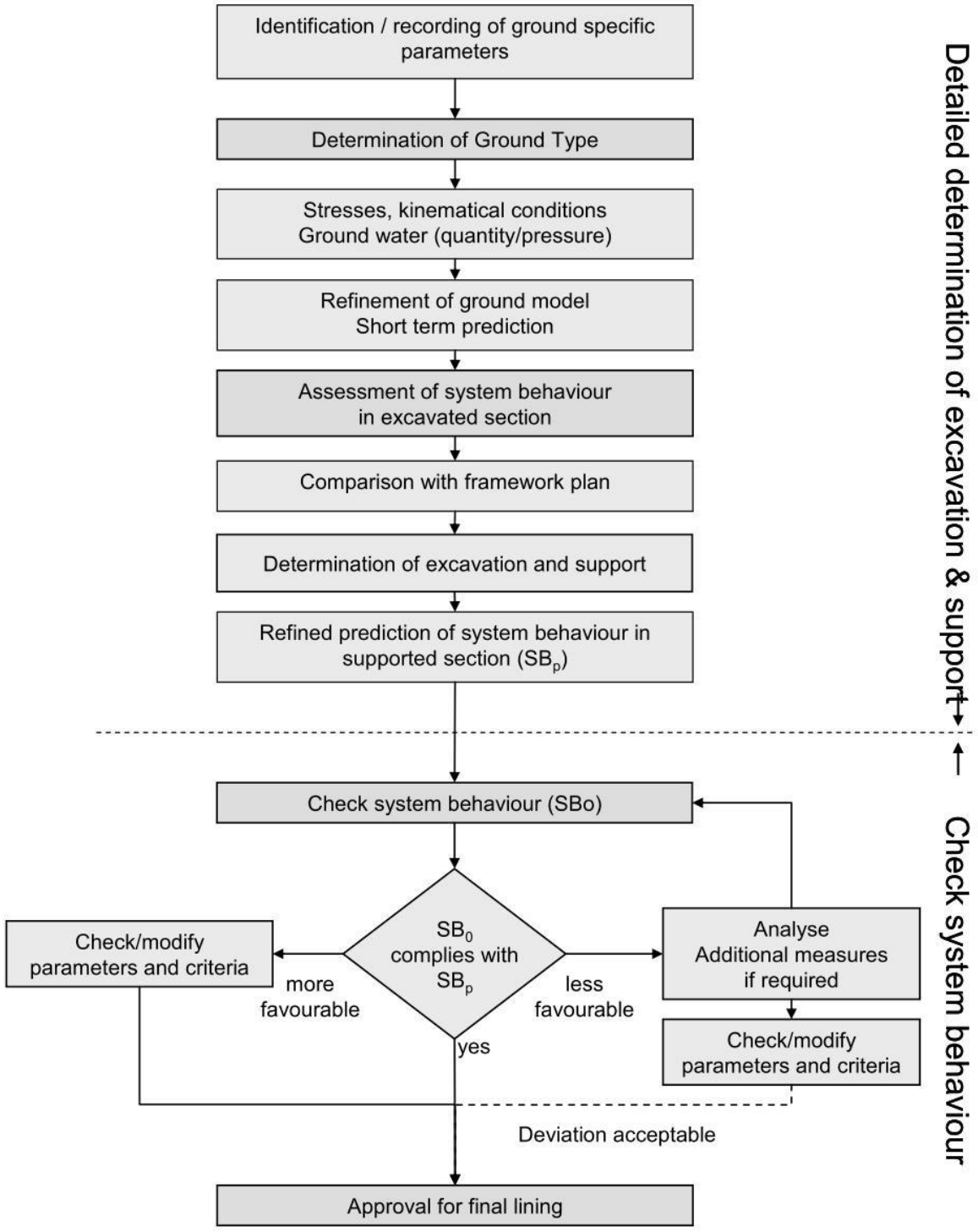

Figure 1: Basic procedure of determination of construction measures and check of system behaviour during construction (SBp = predicted system behaviour, SB0 = observed system behaviour) from Austrian "Guideline for the Geotechnical Design of Underground Structures with

Conventional Excavation" by the Austrian Society for Geomechanics

Step 1: The geological conditions during construction shall be monitored as defined in Section 7.3.4 to collect and record the relevant parameters specified in the design. Based on the geological conditions the Ground Type (GT) shall be determined. Additional observations, like indications of overstressing, deformation and failure mechanisms as well as results from probing ahead and the evaluation of the geotechnical monitoring shall be used to update the ground model and predict the conditions ahead of the face.

Step 2: Based on the predicted ground conditions the system behaviour in the section ahead shall be assessed under consideration of the influencing factors, and compared to the framework plan. Particular attention has to be paid on potential failure modes.

Step 3: To determine the appropriate excavation class and support category the criteria laid out in the framework plan have to be followed. Consequently, it has to be checked if the actual ground conditions (Ground Type, system behaviour) comply with the prediction. The additional data obtained during construction form the basis for the determination of the applied excavation and support methods.

The system behaviour has to be predicted for the next excavation section, considering ground conditions and the chosen construction measures. This process is to be done during the daily review meeting as per Clause 8.4. Records of this meeting shall be kept and signed of all attended parties in compliance with Clause 8.4.

Step 4: The system behaviour shall be monitored (visually and by measurements) in compliance with Clause 8 of this Specification and the criteria defined in the geotechnical safety management plan. When differences between the observed and predicted behaviour occur, the parameters and criteria used during excavation for the determination of the Ground Type and the excavation and support have to be reviewed. When the displacements or support utilization are higher than predicted, a detailed investigation into the reasons for the different system behaviour has to be conducted, and if required mitigation measures (like increase of support) ordered. In case the system behaviour is more favourable than expected, the reasons have to be analysed as well and the used parameters modified, if appropriate. This allows for a continuous improvement and refinement of the method for assignment of excavation and support methods.

7.3.2.2 Determination of Actual Ground Type

Key parameters shall be defined in agreement with the Authority's Engineer for the identification of each Ground Type, considering that those can be recorded during

construction. If directed by the Authority's Engineer, additional parameters shall be monitored, which the Authority's Engineer deems necessary for determination of the system behaviour.

Each of the key parameters shall be categorized. Whenever feasible, numerical values shall be used preferably than descriptive data, like spacing, joint opening, strength, etc. Due to practical reasons some of the required parameters can only be described qualitatively.

Using predefined criteria the parameters are weighted and combined, allowing the appropriate Ground Types to be identified. A correlation matrix shall be used.

Data collection on site shall be concentrated on collecting relevant geological and geotechnical data and on observing and recording the ground structure. The collected data are recorded in prepared forms. With the criteria defined during the design the Ground Type is determined. In heterogeneous ground conditions, the ground shall be divided into several sections, and the appropriate key parameters shall be collected for each section separately.

The geological and geotechnical data collected and evaluated on site are the basis for the extrapolation and prediction of the ground conditions. The geological work is not limited to recording the face conditions, but also shall involve prediction of the conditions in the volume of rock that controls the ground response.

7.3.2.3 Assessment of System Behaviour in the Excavation Area

In addition to the parameters required to determine the Ground Type(s), influencing factors, like ground water conditions, ground structure, estimated stress situation and kinematical conditions as well as observations of the system behaviour in the excavation area shall be recorded by the Contractor.

The reaction of the ground to the excavation and support are observed by the Contractor using an appropriate monitoring system in compliance with Clause 8 of this Specification.

The predicted ground structure in combination with the on-site observations and monitoring results shall be used for prediction of the ground behaviour for the sections to be excavated subsequently.

7.3.2.4 Determination of Excavation and Support and Prediction of System Behaviour

For the final determination of the excavation and support method, it must be checked if the ground conditions and system behaviour observed on site conform to the design assumptions. When the observed conditions conform to the predicted

ones, stipulations in the framework plan have to be followed when determining the construction measures. In case of a deviation exceeding the specified tolerance in the framework plan, the designer has to be informed to allow for an adaptation of the prediction, based on new findings. The designer shall agree with the required additional measures in due time and update the framework plan accordingly.

The final decisions on the applied construction measures are based on the design and additional information gained during construction and shall be done during the daily review meeting as per Clause 8.4 of this Specification. The goal is a safe and economical construction. The decisions have to be coherently explained and documented, for example in an appendix to the required excavation and support sheet (RESS) in compliance with Clause 8.6 of this Specification.

The prediction of the system behaviour shall contain the following but is not limited to:

- Expected magnitude and orientation of the tunnel displacements, and the surface (if applicable), including the displacements spatial and time dependent development
- Expected utilization factor of the support

7.3.2.5 Check of System Behaviour

The actual system behaviour in the supported area and in the final stage shall be compared to the predicted system behaviour, and checked, whether the behaviour is within the specified limits of the warning criteria. Additional measurements or evaluations may be required on direction by the Authority's Engineer to determine for example the utilization of the lining.

Deviations between the expected and the observed behaviours have to be analysed and documented by the Contractor and discussed with the Employer's

Representative in the daily review meeting as per Clause 8.4.

The reasons for the deviation in behaviour have to be analysed. In case the assumptions regarding the influencing factors are inappropriate, the parameters have to be modified. The modifications have to be supported by appropriate data and analyses and documented in an updated framework plan.

In case the ground quality is better than predicted, the geotechnical model has to be revised. In case of a significant deviation, the criteria for the determination of excavation and support have to be modified.

In case the ground quality is worse than predicted and warning levels exceeded, contingency measures according to the safety management plan have to be

implemented, and excavation and support shall be adjusted accordingly. This can be done for example by additional bolting, installation of a temporary invert, etc. In some cases the installation of a stronger support in the following rounds may be sufficient to achieve the target. All additional support measures are defined in the daily review meeting and presented in the RESS in agreement with the Employer's Representative.

In case of significant deviations, the geotechnical model has to be revised and the criteria for the determination of excavation and support have to be modified. This generally requires that the framework plan is updated.

7.3.2.6 Updating of Design

Due to limited information available during design, a number of assumptions and simplified models have to be used to arrive at a design, which is the basis for the framework plan and the tender documents.

A continuously update of the geotechnical design with the increasing level of information shall be done. This applies to the determination of the Ground Types, the assignment and calibration of key parameters and criteria as well as for the determination of the system behaviour. The refinement of parameter categories, the introduction of additional criteria, etc. help in improving the geotechnical model.

The tunnel engineer on site has to report to the designer in case of significant deviations of the actual geological/geotechnical situation or system behaviour from the predicted ones, as outlined in the framework plan. A detailed report, containing all relevant information and coordinated with the site geologist and the Authority's Engineer and the Contractor, has to be prepared and submitted. After consideration of the facts the designer has to update the framework plan. This has to be documented in a supplement to the geotechnical report.

7.3.3 Blasting

7.3.3.1 General

Not less than 40 days prior to commencement of rock excavation in each area, the Contractor shall submit, for review by the Authority's Engineer, details of the drilling and blasting methods which he intends to use in that area. If, at any time in a specific area, a plan which has been previously adopted does not produce conditions at the excavated rock face that conform to the requirements of these Specifications, the Contractor shall submit a revised plan to the Authority's Engineer before continuing excavation in adjacent areas.

The Contractor shall develop controlled blasting techniques, which will satisfy the

excavation requirements specified herein. In each different type of rock conditions the Contractor's initial blasts shall be performed as trials, and the burden, drill hole pattern and depth, explosive type and quantity, blasting sequence and drill delay pattern shall be modified to achieve the requirements specified herein.

Blasting means have to follow the licensing requirements and orders as well as the manufacturer's instructions. Blasting operations shall be carried out only under the direction of an experienced operator. The Contractor shall appoint one competent person to be responsible for the security of explosives.

Blasting shall be carried out carefully so as to avoid loosening or shattering rock beyond the required line of excavation, and loose or shattered rock (where it does not contribute to stability of the excavation) shall be removed by scaling down or other means before personnel will be permitted to restart operations after blasting.

Notices of blasting operations shall be posted on site. Before each firing, the Contractor shall give audible warning, clear the area and shall take positive measures to prevent personnel from entering the danger area. The Contractor shall monitor the results of blasting closely and, where it is proper to do so, shall propose changes to his blasting operation for the agreement of the Authority's Engineer. Under no circumstances shall any holes be charged until completion of all drilling operations at the face.

After each blasting operation the tunnel drive shall be sufficiently ventilated to remove any nitrous gases and the atmospheric conditions shall be constantly checked prior to personnel accessing the excavated face in compliance with Clause 7.7.

No person shall be allowed to approach the face and no face operation shall commence until the Contractor's authorised person in charge of the operation has given permission after blasting round.

As soon as practicable after blasting and without undue delay the Contractor shall erect such support as may be necessary to safeguard the excavation and personnel.

The shot-firer must keep a record of the number of shots fired, their time of firing, type and weights of explosives used and the type and number of detonators used, together with a record of the post-blast situation for each and every location. A copy of the record shall be available to the Authority's Engineer at the end of every shift on which shots are fired.

7.3.3.2 Controlled perimeter blasting

Controlled perimeter blasting techniques shall be used to produce rock faces

conforming to the required excavation lines, slopes, elevations and dimensions shown on the drawings with a minimum of disturbance to the rock at, or outside of, the excavation paylines.

Drill holes for controlled perimeter blasting shall not be less than 42 millimetres in diameter and shall be a single row of closely spaced holes drilled to a maximum depth of one round length along the excavation paylines and a spacing of 0.4 to 0.6 m depending on the ground condition. The spacing of the perimeter holes may be modified on the basis of results obtained and in agreement with the Authority's Engineer.

All blast holes within a distance of 5 meters normal to the excavation paylines shall be less than 75 millimetres in diameter and shall be loaded in a manner and detonated in a sequence to ensure that a minimum of damage will result to the face when the main charge is fired.

7.3.3.3 Explosives

The Contractor shall use explosives only in circumstances where it is safe to do so having due regard to the safety of persons, third-party property and the safety of the Works. Explosives shall not be used without the agreement of the Authority's Engineer.

The Contractor shall obtain all necessary licences and consents and shall provide secure storage facilities for all explosives and equipment in accordance with Indian or International Standards Code of practice for the safe use of explosives in the construction industry and the requirements of the local Authorities and the Authority's Engineer.

Explosives shall be handled and used only by the Contractor's duly authorised personnel. The names and qualifications of such personnel shall be submitted to the Authority's Engineer in writing in advance of any possible use of explosives.

At an early stage, in advance of the proposed use of explosives, the Contractor shall notify the Authority's Engineer, third parties, statutory authorities and services which have an interest in or are likely to be affected by blasting operations, of the general nature of the operation. The Contractor shall subsequently give a minimum of 14 days notice to the Authority's Engineer and others described above of the proposed use of explosives. With this notification the Contractor shall submit to the Authority's Engineer a detailed method statement on all aspects of the proposed use of explosives, including the treatment of misfires.

The Contractor shall comply with the following documents in respect of the use of explosives:

- Indian Explosives Act 1884
- Indian Explosive Rules 1983
- The Manufacture and Storage of Explosives Regulations 2005
- BS 5607:1998 Code of practice for the safe use of explosives in the construction industry
- Control of Explosives Regulations 1991
- Carriage of Explosives by Road. Road Traffic (Carriage of Explosives) Regulations 1996
- PD CLC/TR 50426:2004 Assessment of inadvertent initiation of bridge wire electro-explosive devices by radio- frequency radiation. Guide Quarries (Explosives) Regulations 1988, as far as it is relevant to tunnel works.

7.3.3.4 Blasting Vibrations

For structures in the proximity of blasting, the peak particle velocity shall be measured at the locations immediately adjacent to the structure nearest to the face being blasted or any other location where it is necessary to limit vibration.

Vibration monitoring proposals shall be submitted to the Authority's Engineer for his agreement.

The measurement of peak particle velocity shall be obtained from instruments capable of measuring along three orthogonal axes, one of them shall be aligned parallel to the centre line of the excavation and another shall be vertical. The Contractor has to provide supports for the measuring instrument if so required by the manufacturer's instructions. The measurements of the particle velocities shall be the responsibility of the Contractor. Copies of the readings in an agreed form shall be supplied to the Authority's Engineer. Prior to the commencement of blasting in any location, the Contractor shall demonstrate by the use of test firings, or by other means, that neither the peak particle velocities given in the particular Standards and Specifications will be exceeded.

The maximum allowable blasting vibrations shall be defined by the Contractor for every influenced structure with reference to the applicable Standards and Specifications for the relevant structure. The allowable blasting vibrations shall be approved by the Authority's Engineer prior to any blasting operations.

7.3.4 Geological mapping

Geological mapping shall be performed by the Contractor's qualified geologist to provide a documentation of rock and rock mass condition encountered during excavation. Additionally all exposed rock surfaces of the open and underground excavations shall be washed down by the Contractor for inspection and geological mapping by the Authority's Engineer if he deems to do so. Exposed rock surfaces at the required excavation paylines shall be mapped after preparation but before shotcrete application. Tunnel and other underground faces shall be mapped just before the start of drilling. The Contractor shall allow in his construction procedure and schedule for the geological mapping of each tunnel face not less than 30 minutes.

The geological mapping shall include but not limited to the following information:

- excavation face
- tunnel meter
- geological unit
- intact rock:
  - rock type and lithology description
  - weathering and alteration degree
  - uniaxial and unconfined compressive strength (from point load tests)
- rock mass:
  - jointing degree
  - geometry, orientation (strike and sip) and properties of discontinuities
  - face condition (homogeneous or heterogeneous)
  - water inflow
  - overbreaks (separated in geological and non-geological)
  - ground response
  - suspected pervious zone
- the GSI value and the corresponding excavation class
- groundwater appearance

The Contractor shall provide lights, ladders, platforms and free access and shall assist the Authority's Engineer to carry out inspection and geological mapping.

In case of sudden and unexpected changes of the geological conditions the Authority's Engineer shall be informed immediately by the Contractor.

7.3.5 Exploratory Drillings

Long exploratory drillings with full core recovery shall be carried out when deemed necessary and required by the Authority's Engineer. Based on the geological mapping and the exploratory drillings the Authority's Engineer may require rock mechanic laboratory tests.

7.4 Shaft Excavation

7.4.1 General

Prior to excavation, the shaft area shall be thoroughly checked for existing pipes, cables or structures and the appropriate measures taken in agreement with the Authority's Engineer.

7.4.2 Safety

At all times shafts shall be provided with safe primary and secondary means of access and egress. Should heavy plant and heavy loads have to be located in close proximity to any shaft, the Contractor shall take into account the effects of these loads as well as any ground loads when designing the shaft.

The Contractor shall guard against distortion of shaft lining during construction and the possibility of shaft settlement or uplift at an intermediate stage of construction.

7.4.3 Temporary Shafts

Full details of temporary shafts required by the Contractor's working methods shall be submitted to the Authority's Engineer for his agreement. Such shafts shall be adequately sized for all operations required for the execution of the Works. Backfill for temporary working shafts shall comprise material agreed by the Authority's Engineer.

Where the Contractor wishes to recover temporary shaft linings the structure shall be removed in safe stages as backfilling proceeds, taking care to maintain the safety and structural integrity of the remaining lining. No part of Temporary Works shall be left in the ground within 2 m of the designed final surface level.

7.4.4 Construction

Shaft sinking shall be carried out by a method suitable for all the particular circumstances of the site including ground parameters, groundwater, depth and final purpose.

Where work is done by underpinning, only that ground which may be safely excavated for the installation of one ring or one unit of support shall be carried out. Until that depth is properly secured by permanent or temporary shaft lining, no further excavation shall take place. In the case of pre-formed rings, securing shall include grouting.

Where work is done by a caisson operation, a cutting edge shall be fitted to the leading ring. The Contractor's details for bolting caisson rings shall avoid working at height where practicable. The cutting edge shall be maintained at an even level all round during shaft sinking.

Jacking arrangements or kentledge shall be adequate for the work. The Contractor's arrangements shall ensure the stability of any kentledge. A lubrication space shall be maintained completely filled with the lubricating material around the full shaft periphery during sinking. On completion of sinking the lubricating material shall be displaced with grout.

Concrete walls installed by slurry trench or secant piling techniques shall comply with best practice. The Contractor's proposals shall be submitted to the Employer's Representative for his agreement.

Where low-pressure compressed air is used to assist shaft construction, air decks and locks shall be designed by the Contractor to give adequate margins of safety against the air pressures to be used in the shaft. The Contractor's proposals shall be submitted to the Authority's Engineer for his agreement.

Excavation in rock shall generally be carried out by methods outlined in Section 7. Where explosives are used, full-width shaft covers and blasting mats shall be installed during blasting. Blasting shall be carried out in compliance with Clause 7.3.3.

Full details of Temporary Works required by the Contractor's method of working for the construction of tunnel or pipe jack eyes in the shaft lining shall be submitted to the Authority's Engineer for his agreement.

Shaft bases shall be concreted as shown on the drawings. In the case of Temporary Works shafts the Contractor shall submit his proposals for the shaft base structure taking account of ground and groundwater forces and sealing the shaft against

water entry. Water pressure shall not be allowed to build up under shaft bases until the shaft has sufficient resistance to prevent flotation. The construction sequence shown on the drawings shall be followed unless agreed with the Authority's Engineer.

Shafts shall be sunk to a maximum divergence of 1:300 from the design centre line at any depth.

7.5 Control Survey

The Contractor shall be entirely responsible for the accuracy of the control survey and the plotting and periodic checking thereafter. Location and positioning of all survey control stations, reference pillars, bench marks etc. must be presented in coordinates and in a map (scale 1:1000) and approved by the Authority's Engineer before the start of any works.

The Contractor shall install all necessary above ground survey stations and reference points well in advance of the commencement of excavation works so as to allow the Authority's Engineer sufficient time to check the initial control survey and subsequent setting out for the alignment and levels of the respective tunnels.

Survey stations, centre lines, bench marks and grade lines shall be clearly marked in paint on the tunnel walls, chainages at 10 metre intervals or as otherwise agreed by the Authority's Engineer. The Contractor shall appoint and employ the necessary qualified and experienced staff to carry out the required survey and setting out. The Contractor shall provide all necessary instruments, equipment, record books, level books measuring devices etc. required for survey and setting out. The Authority's Engineer shall have use of any of the survey equipment required for the checking of survey work and setting out throughout the period of the Contract. Chainmen and transport shall be provided by the Contractor for checking purposes at the request of the Authority's Engineer.

All additional work found to be necessary because of negligence in/or incorrect setting out, shall be carried out immediately by the Contractor as directed by theAuthority's Engineer at no additional costs.

7.6 Excavation Cross Section Check

7.6.1 General

Tunnels and shafts shall be constructed to the centre lines as defined herein and subsequently agreed on site with the Authority's Engineer. Average deviation of the tunnel centreline from the design centreline, along a 100 m length of any tunnel section, shall not exceed 30 mm. If deviations in tunnels excavated exceed the

specified tolerance, the Contractor shall be required to adapt his working methods so that the specified tolerances are achieved.

Immediately after excavation and before support installation the cross section of the actual round has to be checked to avoid unexcavated ground reaching into the excavation area as per excavation and support category. The check must be done with proper instrumentation, either with free positioned theodolite or with temporarily installed monitoring device for profile check.

When all ground material inside the excavation area is removed the support installation shall start earliest. In case of partial excavation the similar procedure shall be executed for each partial excavation area. For checking the primary lining cross sections refer to 9.12.

7.6.2 Definitions

The theoretical excavation line means the line of excavation within no unexcavated ground material shall remain at any time. If due to additional displacements of the ground unexcavated material extends into the line of excavation, the Authority's Engineer may order to excavate this material at no additional costs.

The practical excavation line shall compensate for radial displacements and construction tolerances according to the actual ground conditions and Support Categories and shall consider allowances for deformation and practical constructability. The values defined in the Bill of Quantities and on related drawings are paying item values. These documents are developed based on the theoretical line of excavation. The displacements must be predicted during detailed design and construction works. Practical excavation line may be adjusted by Contractor to suit actual deformations and excavation techniques used as experience is gained during excavation. Adjustments shall be approved by the Authority's Engineer.

All additional quantities due to tolerances and displacements must be included in the item prices which are based on theoretical line of excavation.

In the following the basic geometrical conditions for the definition of line of excavation are given.

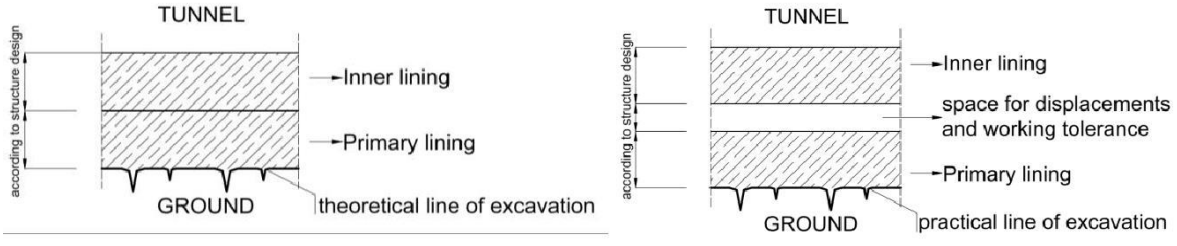

Figure 2 Schematic sketch of the geometrical condition for the definition of the line of excavation

7.7 Temporary Ventilation System

7.7.1 General

Pits, shaft tunnels and headings shall at all times be kept ventilated to maintain an atmosphere fit for respiration and free from oxygen deficiency, potentially explosive or noxious gases and dust, whether present naturally or otherwise. Ventilation shall also be used to maintain a safe working temperature.

Underground works shall be ventilated in accordance with all applicable regulations. Details of the proposed ventilation system shall be submitted to the Authority's Engineer, for review, not less than 40 days prior to the start of commencement.

Where more than one pollutant is present any adverse interaction between them shall be identified and mitigated.

All diesel engines used in the underground works shall be provided with means, which shall be maintained in efficient order, of cooling exhaust gases and reducing the concentration of toxic gases to acceptable levels, filtering particulates and preventing emission of flames or sparks.

In underground workings and in confined spaces the air breathed by persons shall contain not less than 19% of oxygen by volume, and shall not contain concentration of gases, vapours or dust greater than is safe for the health or workmen, having regard to the effects of time, temperature, humidity and the combined effects contaminants. Smoking is forbidden in tunnels, headings, pits or shafts and all confined spaces.

In rock excavation all drill holes shall be wet drilled unless otherwise specified in this Specification in compliance with special ground condition.

7.7.2 Ventilation

The Contractor shall agree ventilation proposals with the Authority's Engineer. Agreement shall not relieve the Contractor of his obligations under the Contract.

Proposals shall include but not be limited to the types of fan employed, sitting arrangements where appropriate, the power supply and the fan performance data, together with duct characteristics.

In forcing systems, fans shall normally be placed on the surface. The inlet to any surface forcing fan shall have unobstructed access to fresh air. It shall not be in the vicinity of a storage site for oil, chemical or diesel drums. The fan shall also be

sited so that it cannot draw in internal combustion engine fumes or gas from charging batteries.

Blasting fumes shall be discharged from the underground works into a filter system or diverted adequately to ensure that concentrations of noxious or other harmful gases or dust are kept to the minimum limit as stated in the applicable laws/ Standards or the limits specified in the contract of lower.

If booster fans are to be employed by in-line staging, they shall be of an approved flameproof (FLP) construction and a monitoring system shall be installed so that the status and condition of such fans can be monitored at all times.

Provision shall be made for the fan to be run continuously whether persons are within the underground works or not. After tunnel break-through the ventilating system shall be kept in operation in order to maintain the fresh air-volume requirements stated hereinafter.

If a ventilation system ceases to function for any reason and for a period exceeding 30 minutes, all work in areas being ventilated by that ventilation system shall immediately cease and all workers shall immediately leave the areas.

Where a fan has been stopped and restarted, the condition of the air shall be tested before personnel enter the tunnel. If only forcing surface-mounted fans are employed, the ventilation system should be restarted and run continuously ensuring that any plugs of oxygen-deficient, flammable or noxious mixtures of gas are flushed out. Care should be taken that workmen do not encounter any plugs of these gases on re-entry to the tunnel. The Contractor should take into account that air residence time in long drivages can be several hours and that layered gases of different densities are difficult to disperse, especially where the gradient of the tunnel changes.

All equipment and ventilation duct shall be maintained in sound working order at all times. Any damage to ventilation duct shall be repaired within 12 hours of the damage. The outlet of the duct shall be kept as close to the face as is practicable, designed to avoid turbulence and creation of dust and not more than 10 m away. Where dust is being produced by the tunnelling system, exhaust ventilation shall be used to extract such dust from the working area. Tunnelling shall not continue more than 10 m from the shaft or pit unless positive ventilation has been established.

The fresh air supply for underground works shall not be less than two cubic meters per minute at the face for each man underground and four cubic meters per minute per kW power for all diesel units operating underground. These fresh air volumes shall be cumulative and the Contractor shall allow, in his design calculations, for the maximum number of persons and diesel powered equipment deployed in the

Works at any one time. Any estimated losses, e.g. due to the leaks in the ducts, shall be considered. The fresh air supply shall also be adequate to produce a linear velocity of 0.3 meters per second throughout the underground works.

Testing devices shall be provided for measuring carbon monoxide, methane, oxides of nitrogen and aldehydes in underground works during the operation of internal combustion engines. Readings of carbon monoxide content shall be taken by the Contractor at least once during each shift. Readings of oxides of nitrogen content and of aldehydes content shall be taken frequently to ensure safety of the workers. A record of all taken readings shall be kept by the Contractor and submitted to the Authority's Engineer daily.

Ventilation ducts shall be firmly fixed to the vaults in such position that a minimum clearance of 20 cm remains between the duct and the extremities of vehicular traffic employed in the Underground Works.

7.7.3 Monitoring

Atmospheric monitoring equipment shall be positioned at each working face and also within 20 m of the tunnel entrance when the tunnel has advanced 250 m or more. Monitors shall also be provided every 500 m along the tunnel. Monitoring equipment shall be capable of continuously monitoring the levels of potentially explosive gases, toxic gases and radioactive gases as appropriate and the oxygen content. The equipment shall give both visual and audible warning of the presence of potentially explosive, radioactive or toxic gases and where the oxygen content falls below safe working levels defined in Table 2. An immediate and effective means of communicating warnings to the surface shall be installed. The atmospheric monitoring system shall be a fixed system supplemented by portable monitoring equipment as necessary, except in small tunnels where the use of portable equipment only shall be permitted at the discretion of the Authority's Engineer.

Table 2: Admissible maximum concentrations of pollution gasses in underground works

Pollution gas	Max. concentration
H2S	10 ppm
SO2	2 ppm
CO	50 ppm
NO2	5 ppm
CO2	5000 ppm
CH4	1000 ppm
Silica dust	8 mg/m³

Each working shaft and the full length of all tunnels shall be monitored continuously for the presence of explosive or noxious gases or lack of oxygen. Records shall be kept of monitoring results. If concentrations of noxious gases or other inflammable gases exceed the permissible limits stated in Table 2, BS 6164 or HSE guidance document EH40, or oxygen content below the level set out in BS 6164, all operations shall be interrupted immediately and personnel shall be removed to a safe area. All sources of ignition shall be extinguished or removed. All equipment with the exception of ventilation equipment shall be shut down.

When any explosive gas concentration of 1.25% is present, all persons other than those essential for safety shall be withdrawn from all parts of the tunnel. The use of explosives and locomotives shall be prohibited and all electrical equipment not intrinsically safe shall be disconnected. All persons shall be withdrawn when the explosive gas concentration exceeds 2.0%.

The required measures will be mutually determined and agreed to by the Authority's Engineer and the Contractor. If required by the Authority's Engineer, the Contractor shall consult the services of an independent consultant experienced in gaseous tunnelling. Re-entry and resuming of the Work shall be prohibited until the Authority's Engineer has authorised re-entry.

If the ventilation system is for any reason not in operation for a period greater than 2 hours, a start-up procedure shall be invoked. This requires that the shaft and tunnel shall not be re-entered until one complete air change in the tunnel has taken place and the tunnel atmosphere is shown, by monitoring, to be safe.

Persons re-entering after shutdown must carry instruments to detect the presence of dangerous gases and the sufficiency of oxygen, and these must be used continuously during re-entry.

7.7.4 Checking & Inspection

During each shift, the following checks shall be made:

- The fan or fans shall be checked for heat, unusual noise and vibration. The results shall be reported and remedial action shall be taken if required.
- The ventilation ducting shall be checked for damage and the joints checked for integrity. The results shall be reported and remedial action shall be taken if required.
- The atmospheric monitoring system shall be checked at both local and remote stations and the results shall be recorded.

The air flow quantities shall be checked at both the face and 20 m from the shaft bottom on a weekly basis. These figures shall be recorded and compared with the

calculated flows. Any shortfall shall be made good.

The ventilation records shall be maintained and be made available for inspection by the Authority's Engineer.

7.7.5 Control of Dust Silica and Noxious Gases

To reduce the amount of dust, only wet drilling will be allowed and during mucking, muck piles shall be kept constantly damp by sprinkling with water. The use of high pressure water jets for this purpose is not permitted.

Air Samples for this purpose shall be taken within 10 days of commencing underground excavation, at 30 days intervals thereafter and within 20 days following major changes in tunnel excavation operation or whenever required by the Authority's Engineer. Samples shall be taken from actual working areas. The sampling and testing shall be performed by a qualified person or laboratory to be proposed by the Contractor and approved by the Authority's Engineer. A copy of the test results shall be submitted to the Authority's Engineer within 2 weeks of the sampling date.

In general, the concentration of fine dust (diameter less than 0.005 mm) may not exceed the value of 8.0 mg/cum of air and in relation to the silicon dioxide SiO2 content in the rock this value is lowered in compliance with Table 3.

Table 3: Maximum admissible fine dust concentration with respect of SiO2 content in the rock

per cent per weight	mg/m³ air
1-15%	8.0
15-20%	6.0
20-30%	4.0
30-60%	2.0
60-80%	1.5
80-100%	1.3

The Contractor shall take necessary measures and install appropriate equipment in agreement with the Authority's Engineer if the concentration of fine dust exceeds the limits stated in Table 3.

Use of internal combustion engines, other than approved mobile diesel powered equipment will not be permitted in underground construction Sites.

7.8 Lighting

Floodlighting on the site surface shall be adequate for the safe operation of the site. It shall be shrouded where necessary to ensure the light is directed to areas within the site, and to avoid nuisance.

Lighting in the tunnel shall extend the full length and not be less than that required for safe working and access. Lamps shall be located with an interval of 25 m.

An alternative source of power and emergency lighting system shall be provided to allow emergency securing operations and evacuation safely in the event of a primary power failure as specified in Clause 3.5.1. An adequate number of hand lamps shall be located at key points underground.
The Contractor shall also provide suitable movable lamps to illuminate any area in Underground Works including areas for instrumentation and where the Engineer may wish to carry out inspection and rock mechanics tests or instrumentation.

Lighting illumination by flame is strictly not permitted in the underground Works.

8 MONITORING

8.1 General

The Contractor shall submit to the Authority's Engineer for agreement a detailed method statement for instrumentation and monitoring, including instrumentation layout, trigger, design and allowable values and the procedures for evaluating the monitored data.

The Contractor shall appoint within his site team an experienced Monitoring Engineer who shall lead the Contractor's monitoring team. The Monitoring Engineer shall present the results of the previous day's monitoring in the daily monitoring meeting as per 8.4 with the Authority's Engineer where they shall be presented to the Authority's Engineer by the Monitoring Engineer.

The frequency of such review meeting may be increased if requested by the Authority's Engineer. The Contractor's Site Manager shall attend monitoring review meetings if requested by the Authority's Engineer. The accuracy and precision of the required measurement will depend on the purpose of the monitoring.

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.

Instrumentation and monitoring for the tunnel and appurtenant structures shall be carried out with the following instruments but not limited to:

- theodolites and reflectors
- tape extensometer and convergence pins
- borehole extensometers (multiple-point)
- strain gauges
- load cells
- radial pressure cells
- tangential pressure cells
- temperature gauges

All instrumentation operating on electrical, mechanical or hydraulic systems shall be accompanied by individual test certificates, and shall be tested in the presence of the Authority's Engineer prior to installation, unless specifically stated otherwise.

The installation of instruments may interfere with the overall construction progress. The Contractor shall make provision for such interferences in his construction schedule. He will not be entitled to any compensation or extension of the Time for Completion by reason of any such delays, including repair and replacement of damaged instruments if the damage is due to construction procedure of Contractor.

No material shall be installed prior to the Authority's Engineer's approval. However, approval by the Authority's Engineer of the Contractor's proposals and drawings or data shall not relieve the Contractor from his sole responsibility to meet all the requirements.

8.2 Ground Movement Monitoring

Unless otherwise provided in the Contract, the Contractor shall monitor the effects of tunnel construction at the surface, including all ground movements and the effects on all structures, including the Works. Where specifically requested, the subsurface effects, including movements of the water table, shall also be monitored.

Monitoring shall be referenced to stable survey stations located outside the zone of influence of the Works and not subject to ground movement. Such benchmarks and coordinated stations shall be established and agreed with the Authority's Engineer before any ground is excavated and before any ground treatment or dewatering takes place. They shall be checked at intervals during the duration of the Works.

The Contractor shall observe, record and analyse the readings to establish trends in movement and reconcile movements measured with those predicted. He shall

provide a copy of all recorded results to the Authority's Engineer. He shall make available results to the Authority's Engineer in accordance with an agreed programme. However, movements greater than predicted shall be reported to the Authority's Engineer immediately.

Prior to construction Works commencing, a defect survey shall be carried out of all structures within the zone of influence and a schedule of defects shall be prepared. This schedule shall be agreed by the Contractor and the owner of the structure, or his representative, prior to the start of construction. Existing pipelines, tunnels and services shall be regarded as structures.

During the execution of the Works, defects which have been scheduled shall be inspected and monitored as necessary. Defects which arise during the course of the Works shall be recorded. The Contractor shall keep records of such inspections and a copy shall be available to the Authority's Engineer.

Monitoring of settlement, scheduled defects and defects arising during the course of the Works shall continue at agreed intervals for a period of at least 6 months after completion.

8.3 Tunnel Excavation Monitoring

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 and total advance.

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 Authority's Engineer on a daily basis unless another interval has been agreed.

3-dimensional deformations of the tunnel lining shall be monitored by means of optical methods. The points to be observed are marked by targets or reflectors mounted on standard convergency bolts.

Where the Contractor considers that any corrective action he may take will exceed the tolerances in the Contract, he shall so inform the Authority's Engineer and obtains his agreement. Measurements shall be carried out with a free-stationed high precision electronic theodolite as laid down in Clause 8.9.2 with integrated coaxial EDM device. The flow of data shall be fully automatic. The software shall allow determination of displacements in an absolute coordinate system with an accuracy of min ± 1.0 mm.

The Contractor shall determine the elevation of tunnel crown or any other point as directed by the Authority's Engineer during tunnel excavation to monitor vertical settlements and bottom heaves and to be able to interpret and figure the absolute amount of displacements together with convergency readings out. Pins or bolts shall comply with Clause 8.9.1. The method of performing the level measurements shall be such as to ensure an accuracy of ±1 mm.

Necessary conclusions shall be drawn from the geotechnical measurements, from their magnitude, alterations and tendencies about stability of the primary lining and surrounding rock, performance of the initial support applied and utilization of the supporting elements. The locations and spacing between geotechnical measurement sections depends on geological conditions, frequency of geological alterations, rock mechanical behaviour, length of tunnels, primary stress conditions and size of tunnels. The location of designed measurement sections shall be modified during tunnelling according to the local geological conditions and the experience gained during tunnel driving and as required and approved by the Authority's Engineer.

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. The Clause 7.3.4 applies accordingly. The Contractor shall keep copies of all recent face records at the workface for the information of supervisory personnel.

All significant groundwater ingress shall be recorded and monitored.

All atmospheric testing shall be recorded and monitoring for all gases carried out in compliance with Clause 7.7.3.

8.4 Daily Review Meeting

The monitoring instrumentation shall be read on a regular basis – as per drawings and monitoring plan – and the results shall be made available for a daily review meeting (DRM) attended by the senior members of the Contractor's and the Authority's Engineer's staff. Input into the meeting shall also include current geotechnical investigations, face logs and any recent non-conformance reports relating to the tunnel construction.

This DRM shall be held daily during the excavation of the tunnels at the site unless otherwise agreed by the Contractor and the Authority's Engineer.

The minimum team attending the meeting shall include the following persons:

- MonitoringEngineer's Representative
- Authority's Representative

- Contractor's Representative
- Authority's Engineer

At the meeting the Contractor shall present the current results of all monitoring equipment of the tunnels and adjacent structures respectively together with trends in these results and comparison with the deformations predicted by the calculations. Additionally the Contractor shall present the installed support measures and results from the geological mapping including information as defined in Clause 7.3.4.

The purpose of the daily review meeting is to assess the behaviour of the ground in order to:

- confirm the design assumptions
- confirm that the construction methods are appropriate for the ground conditions
- provide early warning of potentially unpredicted behaviour
- determine the likely cause of adverse behaviour
- confirm the safety of the applied construction method

The outcome of the meeting shall be a report, the Required Excavation and Support Sheet (RESS) as per Clause 8.6, agreed by the Contractor and the Authoroty's Engineer, which states that tunnelling may continue as proposed, or gives the requirements for modifications to the tunnelling (e.g. support measures, shorter advances, smaller headings etc.).

The Contractor shall keep minuted records of the monitoring meetings. The minutes of the construction monitoring meetings shall be signed by the attendees. Monitoring results shall be attached to the minutes and recorded on site. 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.

8.5 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 as follows:

- in-tunnel convergence monitoring (SCL)
- ground movement monitoring

- monitoring of adjacent and overlying structures
- geological mapping

The KPI values specified in the design documentation shall be used to indicate whether t there is cause for concern during tunnel construction or no. 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 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.
- A comprehensive review of the trends for monitoring data specific to the area of concern shall be carried out by the Contractor and the Authority's Engineer.
- The Contractor shall assess the extent to which the deformations comply with the SCL serviceability and extreme limit conditions.
- Together with the Authority's Engineer, the Contractor shall decide whether changes in the SCL excavation 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.
- The Contractor and Authority's 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.
- 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.

8.6 Required Excavation and Support Sheet (RESS)

Based on the design and the evaluation of the results of monitoring, a RESS will be issued as the outcome of the Daily Review Meeting (DRM) as per Clause 8.4. In the absence of any approved 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, who is responsible for the tunnelling works, the designer and the Authority's Engineer on site. Unless all the three signatures are obtained, the proposals indicated on the RESS shall not be implemented.

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

- the tunnel section (chainages) to which the RESS is applicable
- the support to be installed
- the excavation sequence
- the method of working related to ground support including staging of application of sprayed-concrete layers and lapping of reinforcement
- monitoring to be installed in the tunnel section in question
- measures to be taken during stoppage of works
- other instructions relevant to the tunnel section in question
- reference to relevant design drawings
- ground conditioning

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 for every advance per round of the tunnel excavation.

If, for any reason, the approved design method of working is changed, then this will be reviewed prior to the DRM and, subject to acceptance by the Authority's Engineer, a new RESS will be issued.

8.7 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 approval to the Authority's 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:

- changing ground conditions
- excessive movement of the linings
- excessive ground movement

- excessive settlement of the existing structures
- unplanned stoppages
- mechanical excavation plant failure
- insufficient labour resources
- failure of services to underground works (air, light, power, etc.)
- incidents within underground works
- delay in supply of sprayed concrete (SCL)

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.

8.8 Instrumentation

8.8.1 General

The supply of all labour, supervisors, plant, Contractor's Equipment and materials and the execution of all work necessary to supply, assemble, check, calibrate, drill, install, backfill, embed, test and protect instrumentation in the tunnel and appurtenant structures or elsewhere as specified on the drawings and as specified herein, shall be provided by the Contractor.

During the period of the Contract, the Contractor shall ensure that his construction operations do not interfere with, or damage any of the existing instrumentation, shown on the drawings, or the instrumentation to be installed by the Contractor and by others. The Contractor will be penalized, as specified herein if any of the existing instruments or instruments that have been installed by others or by the Contractor, are damaged by his construction equipment. In addition to the penalty, the Contractor, within the days required by the Authority's Engineer, shall supply and install a replacement instrument adjacent to each instrument that was damaged by his construction equipment, at no additional cost to the Employer.

Not less than 120 days prior to the required installation date of each instrument,

which is shown on the Contractor's work schedule, the Authority's Engineer will either confirm that the instrument to be supplied is to conform to the requirements of the Specifications or he will issue information on the number, type, model number, manufacturer, supplier, location and other details of the instrument or instruments that are to be supplied and installed.

The Contractor's request for approval to supply and install alternative instruments shall provide sufficient information on each alternative instrument for thAuthority's Engineer to compare it with the specified instrument. The information shall be submitted to the Authority's Engineer not less than 90 days prior to the first installation of that instrument.

Not less than 60 days prior to the start of instrument installation, the Contractor shall submit to the Authority's Engineer a detailed description of all instrumentation, cabling and accessories including any ancillary measuring equipment, details of his checking, testing, calibrating, installing and monitoring procedures for each of the instruments.

Not less than 30 days prior to installation, each instrument shall be checked, tested and calibrated according to the instrument manufacturer's instructions and as specified herein to ensure that the instruments are in good working order and properly calibrated. A report on each such checking, testing and calibration of each instrument shall be submitted to the Authority's Engineer not more than seven days after the checking, testing and calibration of that instrument.

Each instrument shall have a certificate from the manufacturer stating that the instrument was inspected before leaving the factory and presenting details of the instrument calibration. A copy of the certificate for each instrument shall be submitted to the Authority's Engineer not more than three days after the delivery of the instrument to the site.

A manual shall be provided with each type of instrument.

The Contractor shall supply all components, accessories and electrical leads for the instruments from the sensor to the observation house or station including materials, equipment and tools required to install, calibrate and protect the instruments as specified herein and as shown on the drawings. All instruments and their accessories shall be new and have been successfully performed in similar projects. Instruments shall be assembled, tested and calibrated by the manufacturer before delivery to the site. The instruments and accessories shall be stored at the site by the Contractor under the condition conforming to the manufacturer's requirements.

Instruments shall be handled, stored and installed with care so as to avoid damage. If during handling, storing and installation instruments are damaged, the Contractor

shall replace and reinstall the instruments within 30 days as specified herein, as shown on the drawings or as required by the Authority's Engineer and at no additional cost to the Employer.

All instruments and equipment used and required for the geotechnical measurements shall be made available to the Authority's Engineer throughout the construction period.

8.8.2 Installation Comments

Instruments shall be installed as specified herein and in accordance with manufacturer's instructions at the locations and to the lines, slopes, dimensions and elevations shown on the drawings or directed by the Authority's Engineer. No instrument shall be installed until the Authority's Engineer has approved the testing and calibration. Instruments and instrument leads shall not be backfilled or embedded in concrete until the Authority's Engineer has inspected the installation and has given his approval.

All work in connection with the calibration and installation of instrumentation shall only be done in the presence of the Authority's Engineer. Calibrating, adjusting, assembling, installing and maintenance work in connection with the installation of instrumentation shall be undertaken by personnel who have been employed full time during the last five years installing geotechnical and other instruments on major civil works projects. Instrument installation shall be supervised by a graduated geotechnical Authority's Engineer who has specialized in the installation and monitoring of instruments in soil, rock, fill, concrete and metals.

The instrumentation supervisor and all other Contractor's personnel working on instrument installation shall be subject to the approval of the Authority's Engineer and shall be replaced for cause if required by the Authority's Engineer. Unless otherwise required by the Authority's Engineer, the calibration of each instrument shall be checked and, if necessary, adjusted at the site and the instrument shall be installed by the Contractor, all in the presence of a representative of the manufacturer.

During construction of the Works, the Authority's Engineer will survey the installed locations of instruments. The Authority's Engineer will take an initial set of readings of all instruments immediately after the Contractor has completed their installation. The placement of concrete and backfill material over the instruments or instrument leads shall not be started until these readings have been taken. To ensure that the instruments are being installed as specified and to make a permanent record of the soil and rock properties, the Authority's Engineer will take samples of soil and rock from drill holes and will perform in situ tests whenever he considers them necessary. The Contractor shall allow time in his construction schedule to enable

such samples to be taken and such tests to be made.

All instruments and connections shall be protected from damage and displacement during the progress of the work. Instruments embedded in concrete shall be visibly and clearly marked. At all times, the Contractor shall ensure that adequate lighting is available, whether by natural or artificial means, to ensure proper execution of the work. No traffic or equipment other than placing and compacting equipment required for concrete placement shall be allowed to pass close to any instrument or connection installed in the concrete or rock until they are covered by at least 1.5 meters of concrete. Protection cages, markers and barricades shall be provided by the Contractor where required by the Authority's Engineer.

Cables and tubes shall be installed in the maximum lengths practicable. Splicing and coupling shall be performed in accordance with the manufacturer's recommendations. Calibration readings shall be taken prior to and immediately alter splicing. Open ends of all incomplete lines of tubing and casing shall be kept plugged or sealed and the Contractor shall at all times during installation keep the insides of casings and tubes free from foreign matter. Cables and tubes shall be protected from mechanical damage.

The instrumentation shall be put in operation at the earliest practicable period during construction in order to obtain information pertaining to the support design performance of the tunnel.

The Contractor shall protect all instruments and connections from damage and displacement during the progress of the Works. If damage or displacement of the instruments or connections occurs during the progress of the Works, they shall be repaired or replaced immediately by the Contractor and new baseline readings shall be taken before any further construction work proceeds.

The Contractor shall be fully responsible for the maintenance and repair of all instrumentation for the duration of the Contract period.

The geotechnical instrumentation and monitoring program may always be subject to alterations and modifications if required by the actual geological or geotechnical conditions or the Authority's Engineer.

8.8.3 Quality Assurance

The Contractor shall prove that the system of monitoring instruments and measurement devices are suited to the particular purpose and fulfil the requirements and specifications. All instruments shall be factory calibrated and shall have multiple zero reading features. The Contractor shall carry out an agreed program of functional tests.

Not more than 15 days after the installation of each instrument, the Contractor shall submit type and model of instrument, location coordinates and elevation, date and time of installation, weather, temperature, rainfall and wind conditions, construction activities in the vicinity during installation, drilling records, core log, groundwater observations, a description of any unusual observations during drilling, installation records, method, materials, any unusual observations during installation, a plan and sections to scale showing the structure in which the instrument has been installed, instrument location, the exact location of the leads, location of all connections in the leads, the materials used in its installation, colour photographs of the installation including close-ups of the instrument before embedment and adjustments made and testing data taken during installation.

The Contractor shall cooperate with the Authority's Engineer to permit continuous observations and recording of the data to be obtained by the Authority's Engineer from existing instruments previously installed and those installed by the Contractor and by others. The Contractor shall allow in his construction planning for the instrument readings to be completed by the Authority's Engineer within a reasonable time. During the time that the instruments are being read no construction equipment shall be operated within 50 meters of the instrument.

The Contractor, after consultation with the Authority's Engineer, shall program his work and make all necessary arrangements to allow the reading of instruments as soon as possible after their installation. Such arrangements shall include, where necessary, the provision of temporary read out points.

During construction, the Contractor shall read the instruments according to the data requirement of the ground behaviour as specified in this section or as directed by the Authority's Engineer. The data collected from instrumentation should be immediately provided to the Authority's Engineer for his use and he should have access to all the data records through the construction period.

During the service life of equipment, calibrations of readout units are required.

Calibrations of any embedded components provided with in-place calibration check features shall also be required. Instrument calibrations shall be performed by qualified personnel responsible for data collection. The intervals for calibration shall follow the manufacturer's recommendations or be carried out as requested by the Authority's Engineer.

Parts of the instrumentation which are not embedded in the rock, fill or other protective material, shall be adequately protected against mechanical (e.g. site vehicles) and environmental damage. Protective covers or housings shall be used to prevent damage of the instruments.

The installed measuring instrumentation as well as the required space for measuring must be kept free and accessible for the entire duration of construction works. Defective or damaged measuring devices shall be replaced at the earliest opportunity to enable the recording of measurements to continue.

The Contractor shall arrange and maintain all the equipment throughout the construction period which is required for the installation and the monitoring of the measuring sections.

8.8.4 Installation and Reading Frequency

Two measuring cross sections, main measuring sections and subsidiary measuring sections, are defined. The distance between measuring sections with respect to the support category shall be in accordance to Table 4.

Table 4: Distance between measuring sections

Support Category	Main measuring section	Subsidiary measuring section
A	-	25 m
B	100 m	25 m
C	60 m	15 m
D	35 m	10 m
E	25 m	7.5 m
F	25 m	7.5 m
G	20 m	5 m

The number of instruments as specified in 8.9 installed in each measuring section shall be in compliance with Table 5, with respect to the support category and type of measuring section.

Table 5: Instrumentation per measuring point with respect to the support category

Instrument	Main measuring section		Subsidiary measuring section	
	Support Category A-C	Support Category D-E	Support Category A-C	Support Category D-E
Reflectors	5	9	5	9
Extensometers	2	4	-	-
Anchor load cell	2	2	-	-
Tangential pressure cells	5	5	-	-
Radial pressure Cells	5	5	-	-

The Authority's Engineer will take the initial readings on each instrument which will consist of not less than five separate readings at intervals of 15 minutes. The further reading frequency of each instrument shall be in accordance to Table 6 unless otherwise specified herein or directed by the Authority's Engineer.

Table 6: General reading frequencies with respect to time after installation

Distance to excavation (top heading, bench or invert)	Reading frequency
0-50 m	every 24 hours
50-100 m	every 48 hours
100-250 m	once per week
More than 250 m	once per month

Reading intervals shall be agreed with the Authority's Engineer and shall be dependent on the position of the excavation face, activities in the vicinity and actual deformation behaviour. However, the Contractor shall increase the reading frequency whenever directed by the Authority's Engineer.

In the event of any change of trend or where other circumstances may be anticipated, for example influence due to the construction of other structures or nearby junctions, openings or intersections, the frequency of readings shall be increased.

Readings shall continue to be taken until the rate of change in the reading has diminished sufficiently to allow a lower frequency to be adopted with the confidence that the safety of the works is not in doubt and such that the amount of data retrieved allows trends with time to be clearly identified and evaluated. Decrease of any reading frequency shall be in agreement with the Authority's Engineer. At any time the Authority's Engineer may require an increase of reading frequency. The readings of instruments shall not be ended without the approval of the Authority's Engineer.

When the bench is approaching the instrumentation section, which was installed during top heading, the reading frequencies shall be increased again. When the parallel tunnel tube approaches the station of an instrumentation section installed in the first tunnel tube, readings shall be activated again and reading frequencies increased respectively.

At sections where increasing rates of deformation occur, readings shall be taken frequently (at least once per day) until the rate of deformation decreases with time. Readings shall be taken by the same personnel. If the person needs to be replaced, a series of duplicate readings shall be carried out by the out-going person and the replacement.

The Contractor shall ensure that all activities carried out during the execution of the monitoring programme comply with his Health and Safety Management Plan.

8.8.5 Reading Information and Presentation

Measurement results shall be both tabulated and presented to the Authority's Engineer in graphical form. The graphical data submission shall be presented as follows:

- development of measuring results versus time related to the progress of the excavation headings
- development of measuring results versus distance of the measuring sections from the excavation face

The Contractor shall use a software package to allow a direct data flow from the optical displacement measurements and to be in compliance with the following Specifications:

- free stationing of the theodolite and calculation of standard deviation in all three coordinate directions
- automatic target identification and recognition of new zero readings
- calculation of 3D-coordinates and displacements of any desired point and its radial distance to the theoretical profile
- correction of errors based on physical effects
- transformation of coordinates after control measurements
- measurement results shall be tabulated and presented in graphs

When recording instrumentation readings, all site conditions that may affect the results shall be recorded including but not limited to the following:

- progress of excavation and other works
- time elapsed between particular construction activities
- taking of first readings
- temperature and humidity
- date and time of reading
- measuring instrument and / or read out unit reference

8.9 Requirements of Instruments

8.9.1 Bolts and Pins

Bolts or pins shall consist of ribbed bars protected against corrosion with a minimum length of 250 mm. Prior to installation of bolts and pins the type shall be approved by the Authority's Engineer. The pins shall be securely attached to the exposed rock or shotcrete surface. After installation the convergency pins shall be protected by a protective cap.

In case of opto-electronical measurements the bolts shall be provided with a plastic cap with a predetermined breaking point serving as an adapter for the mounting of a reflector with marked centre point.

8.9.2 Theodolites and Reflectors for Convergence Measurement

Convergence measurement shall be performed in underground excavation works to determine the absolute horizontal and vertical displacements of measuring points placed around the excavation perimeter.

The measuring points shall consist of plastic reflectors of an approved manufacturer by the Authority's Engineer and mounted on a treaded bar grouted into predrilled holes.

The absolute position of the reflectors shall be measured in 3-dimensional space by opto-electronical theodolite equipped with coaxial electronic distance measuring facility and data logging. The equipment shall be such as to ensure an accuracy of 3 seconds for directions and an accuracy of ± 0.1 mm for distances.

The reflectors shall be installed directly behind the face within the heading and bench zones, as appropriate, immediately after the installation of supports. Installation frequencies and numbers of reflectors per measuring cross section shall be in compliance with Table 4, Table 5 and Table 6 or as directed by the Authority's Engineer. The reflectors shall be designed for high precision measurements with two axes of rotation and to be observable from both sides. The reflectors may be replaced by a positive centred prism, if required, with the same standard as the reflector above and in agreement with the Authority's Engineer.

The recorded data shall be available and submitted to the Authority's Engineer on a daily basis and discussed as per Clause 8.4.

8.9.3 Tape Extensometers

Convergence measurements shall be supplemented by direct measurement of convergence using tape extensometer units. Arrays consisting of three bolts or pins shall be installed at a spacing of 100 m or as directed by the Authority's Engineer. At each cross section a pin or bolt shall be installed in the crown of the tunnel with the two remaining pins or bolts to be installed in the side walls to enable convergence in three directions.

The tape extensometer unit shall comprise of a steel tape, fixed to the reference pins and tensioned with a constant force. An integrated dial gauge shall allow a sufficient accurate measurement.

8.9.4 Borehole Extensometers

Rod extensometers shall be installed in boreholes drilled in tunnel in upward, horizontal and downward directions. The rods shall consist of fibre glass or

stainless steel fitted with groutable anchors with grout tubes, packers, protective tubes and caps and shall be of the multipoint point type with not less than four down hole anchors installed at different elevations in the bore hole, a rod connected to each anchor and a reference head, where measurements are made. The furthest anchor may be 25 m from the excavation perimeter. So the Contractor shall allow and provide drilling equipment for such a length and for the borehole diameter required for four anchors in one hole in compliance with the manufacturer's recommendations and requirements.

Reference heads shall be of the electric version fitted with displacement transducers to allow remote read out or the use of data loggers. Displacement transducers shall be of the vibrating wire or potentiometer type.

Multipoint extensometers may have a cumulated rod length of up to 50 m and shall comply with the following Specifications:

- Measuring range: 150 mm
- Accuracy: ±0.01 mm
- Resolution: 0.1 %

8.9.5 Strain Gauges

8.9.5.1 General

Strain gauges shall be required to record the tensile and/or compressive strain in concrete and shotcrete linings and in steel ribs and shall be of the vibrating wire type. Strain gauges shall be used to measure strain in the tunnel lining which will be used to monitor the performance of the lining in the long term. Strain gauges to measure strain in steel ribs are used to monitor the performance of the steel rib support.

Strain gauges shall be supplied by an approved manufacturer by the Employer's

Representative and shall permit a remote readout and data storage using an appropriate data recorder.

8.9.5.2 Concrete Strain Gauges

Concrete strain gauges shall be of the embedment type and shall be orientated in the tangential and radial direction before the placing of the concrete for the final tunnel lining or the application of sprayed concrete for the primary lining.

Concrete strain gauges shall be installed in the final tunnel lining as directed by the Authority's Engineer.

Concrete strain gauges shall comply with the following Specifications:

- Measuring range: 3000 micro strain, set mid-range
- Operating temperature: -50°C to 100°C

8.9.5.3 Steel Rib Strain Gauges

Strain gauges for steel ribs shall be of the surface mount type and shall be installed parallel to the axis of the steel set and located on the centre line of the web of the steel set. Strain gauges shall be installed on steel ribs as directed by the Authority's Engineer.

Steel rib gauges shall comply with the following Specifications:

- Measuring range: 3000 micro strain, set mid-range
- Operating temperature: -50°C to 100°C
- Resolution: 1 micro strain
- Accuracy: ±0.1% FS

8.9.5.4 Load Cells for Rock Bolts and Rock Anchors

Load cells are required to measure and monitor loads within rock bolts and rock anchors. The capacities of the load cells shall be 300 and 600 kN and they shall be suitable for the specified rock bolts and rock anchors. The cells shall be installed as directed by the Authority's Engineer.

Load Cells shall comply with the following Specifications:

- Load capacity: 150% of FS
- Accuracy: ±0.5% FS
- Resolution: 0.1% of FS

8.9.5.5 Pressure Cells

Hydraulic pressure cells shall be used for measurement of stress distribution in tunnel lining and sprayed concrete. Hydraulic pressure cells shall consist of a flat jack, which is placed at the rock surface or in the sprayed concrete, so that increasing stress can act on the flat jack. The pressure cells shall be installed as directed by the Authority's Engineer. The change of pressure shall be measured and the radial and tangential loads determined.

8.9.5.6 Temperature Gauges

Temperature gauges are required to monitor the temperatures in concrete structures as directed by the Authority's Engineer. These gauges are in addition to those the

Contractor may need to control the placement temperature of the concrete in compliance with Clause 10.1.4.

The temperature gauges shall comply with the following Specifications:

- Minimum range: -10°C to +80°C
- Accuracy: ±0.2°C
- Resolution: 0.1°C

8.9.6 Cables

Special cables suitable for use in concrete shall be used and shall be subject to the approval of the Authority's Engineer. All cabled instruments shall be supplied complete with the required length of cable. Splicing of cables on site shall be avoided wherever possible. No splicing of cables on site may be performed without the approval of the Authority's Engineer. Switchboxes shall be mounted in recesses in concrete structures, in instrument housings or at temporary read out points. Switchboxes shall be weather- and dustproof and all metal parts shall be of stainless material.

8.9.7 Portable Readout Units

The Contractor shall supply sets of portable readout units suitable for readout of all sensors used in the work.

The readout unit shall be capable of storing of up to 2000 readings with sensor identification number, date and time of record. The portable readout units shall comply with the Specifications defined in Table 7.

Table 7: Requirements on portable readout units

Parameter	Specification
Range	450 – 600 Hz
Resolution	0.01% FS
Accuracy	± 0.02% of Hz reading
Temperature measurement	-20° - 120°C
Temperature accuracy	± 1°C
Memory capacity	min 2000 readings

8.9.8 Instrument Housing

The Contractor shall construct instrument housings as required. Instrument housings shall be of steel cabinet construction with a painted mild steel lockable security door.

8.10 Probing Ahead

Where required the Contractor shall be responsible for probing ahead of the tunnel face in order to prove or investigate the ground. The selection of plant for probing shall be agreed with the Authority's Engineer and shall take the probable nature of the ground ahead and its water-bearing capacity into account. Probing shall be carried out in such way to allow modification of the excavation and support according to the encountered ground conditions. The number of probes, the diameter of drilling, their positions in the face and angles with respect to the tunnel drive shall be governed by the actual ground conditions and the machinery in use. The maximum probed distance ahead of the face shall be governed by the ground conditions and the degree of uncertainty with distance.

The diameter of probe holes shall be not less than 38 mm. The used flush shall be suitable for the type of ground conditions anticipated and the machinery in use.

An accurate and systematic record of probe hole positions (positions in the face and angles with respect to tunnel drives), drill penetration rate, drill parameters (percussion, torque, thrust), flush (colour, percentage return), drilling sounds (loud, quiet, intermittent), water strikes and interpretation of the nature of the ground ahead shall be noted at the time the holes are bored and a copy provided to the Authority's Engineer.

Full facilities shall be provided for the Authority's Engineer to inspect probing work in progress.

9 PRIMARY SUPPORT MEASURES

9.1 General

Generally the primary support measures are installed immediately after the performed blasting round and a break of work prior to support construction is not permitted. The type and amount of tunnel support is directly related to the Rock Classification as established. The initial support associated with the established rock classification system is shown on the Employer's design drawings. The Contractor may design his own tunnel support. However, as a consequence of variations from the anticipated rock conditions the support systems as shown on the Contractor's design drawings for each Excavation Class may require modifications and adjustment during construction as directed by the Authority's Engineer.

The Contractor shall ensure that support elements will be installed or applied in such a manner and sequence as to prevent disintegration and loosening of the rock mass surrounding the excavated tunnel. Comprehensive records, containing all particulars of the tunnel support actually installed and its performance in the course of the works, shall be prepared and maintained by the Contractor and made

available to the Authority's Engineer on a daily basis. These records shall include type, quantity and location of installed support elements, the clearance profile after installation of support, deviations from the designed support systems, observations of excessive deformations, shotcrete cracking, etc. Observations of excessive deformations, shotcrete cracking, etc. shall be reported immediately to the Authority's Engineer.

The Contractor shall keep a record of the chainage of each face position and shall keep this record updated as the face progresses. This record shall be available for consultation at any time at a convenient location close to the relevant face. The Contractor shall record the results of all tests performed on the rock bolts prior to, during and after their installation, and submit these documents to the Authority's Engineer.

The records as defined above in this Technical Specification will be submitted daily to the Authority's Engineer for review and approval. The Contractor has to check the rock mass support measures by on-going visual inspection. Surfaces of water sensitive rock mass shall be sealed immediately with adequate measures.

The Contractor shall apply shotcrete on rock masses which tend to local overbreak immediately.

Structural support consisting of wood is only permitted temporarily. It is not permitted to leave wooden support in the shotcrete or concrete layer.

Damaged rock mass support system due to re-profiling shall be reconstructed subsequently (see also 9.12).

The Contractor has to provide an adequate amount of rock mass support systems and required equipment on the site; hence no delays of excavation shall occur. Prior to the beginning of excavation the required rock supports shall be provided by the Contractor on the site.

Blasting round lengths, time schedules, construction sequences, quantity and location of installed support elements shall be constructed as per drawings. Deviations from the designed support systems shall be reported immediately to the Authority's Engineer and shall be approved.

The Contractor shall in case of emergency be obliged to undertake independently such support measures as he deems necessary without the prior consent of the Authority's Engineer. In such cases the Contractor shall inform the Authority's Engineer immediately.

Rock mass support is defined as follows:

- Primary support: is defined as the support which is installed systematically within the heading, bench and invert zone in order to ensure the short term integrity of the underground excavation and safety of personnel during excavation. The installation of primary support is an essential element of the excavation cycle.

- Final lining: is defined as support which is installed subsequent to the primary and supplementary support and which does not form part of the normal excavation cycle. It serves as the permanent lining of the tunnel and shall be a cast in situ concrete lining , plain or reinforced according to structural requirements.

The final lining may be installed in any section of the tunnel, with the Authority's Engineer's approval, at any time after convergence measurements show that movement in the rock in the immediate vicinity has stabilised.

9.2 Rock Bolts, Anchors

9.2.1 General

Unless otherwise defined herein, rock bolts shall comply with the following Indian Standards or their equivalent International Standards:

- IS: 1786 Specifications for high strength deformed-steelbars and wires for concrete reinforcement

- IS: 2062 Steel for general structural purposes

Rock bolts are untensioned steel bars threaded at one end and provided with a face plate, shim plates and a conical seated washer and nut or split or deformed steel tubes. Steel bars shall be grade 500 N/mm², deformed type 2 bars complying with BS 4449. Threaded parts of bars, nuts and seatings shall comply with the requirements of BS 4190. Face plates shall be of a dish shape in steel to the appropriate standard and shall have a hemispherical seating with centralised slot to suit dimensions of the rock dowels. Where required, the bar and components shall have corrosion protection and the threaded end shall be sealed by an end cap.

Rock bolts shall be installed according to the length, direction, placement and number as per approved design drawings for each relevant Excavation Class unless otherwise determined by the Authority's Engineer. Rock bolt length, direction, placement and number shall be adjusted to the Ground Type.

Comprehensive records about details of the installation of rock bolts during

drivage, such as reference number, grout consistency, drilling depth, length, inclination and type of rock bolts, deviations from the theoretical position, type and time of grouting, time of tightening, special observations, details of tests carried out, geological ground condition, etc. shall be kept for each rock bolt and round by the Contractor and countersigned by the Employer's supervisory personnel. Copies of these records should be submitted to the Authority's Engineer.

The trademark of rock bolts and anchors to be installed shall be approved by the Authority's Engineer. A quality assessment is required, unless common anchor steel and anchor plates were used. The Contractor's construction execution shall comply with the manufacturer's specifications and recommendations regarding drilling, installing, testing and maintenance of rock bolts.

The characteristic bearing capacity of the anchor plate and the connection between the anchor and anchor plate shall be equal to the characteristic bearing capacity (Ptk according to BS EN 1537) of the anchor steel.

The diameter of the drillings and the drilling technique shall be adjusted to the anchor type and Ground Type. Holes for the installation of bolts shall be drilled straight and with an accuracy of ±10°.

The drilling hole shall be flushed and cleaned with compressed air or water immediately prior to the installation of the bolt. The used technique shall be adjusted on the Ground Type (e.g. bore holes drilled in swelling ground no water flushing is permitted).

The water pressure during drilling may have an inadequate impact on the surrounding ground (e.g. decrease of mechanical strength properties) due to this the water pressure may be reduced or dry drilling may be conducted as directed by the Authority's Engineer.

Unless instructed otherwise, rock bolts shall be installed and tensioned prior to the excavation of the next bench or round excavation. The tension force shall be determined by the Authority's Engineer after completion of the initial testing program.

The Contractor shall provide torque wrenches of a type acceptable to Authority's Engineer. All impact and torque wrenches shall be calibrated once every month.

The grouted hole shall be completely filled with grout. This shall be done by filling the drilled hole from the bottom of the hole and withdrawing the grout slowly, always maintaining the hose embedded in the grout. A regular surface shall be provided to seat the face plate by trimming rock surfaces or forming pads of quick-setting mortar. Where mortar pads are required they shall be of adequate thickness

and extend beyond the face plate by 25 mm all round at that thickness before being chamfered at 45°. Care shall be taken to ensure that the mortar does not interfere with the installed bolt.

9.2.2 Bearing Plates

Rock bolts shall have face plates which shall be of a dish shape in steel to the appropriate standard and shall have a hemispherical seating with centralised slot to suit the dimensions of the rock bolts.

Bearing plates shall be flat or dished steel plate of minimum dimensions of 150 x 150 x 10 mm conforming to IS: 2062, or as otherwise recommended by the manufacturer and approved by the Authority's Engineer. Bevelled or hemispherical washers shall be used and nuts shall be heavy hexagonal type. For rock bolts that are permanently exposed, the bearing plates shall be coated before installation with an anti-corrosion protective coating compound. Any defects in the coating shall be adequately recoated after installation. The outer ends of the rock bolts, nuts and washers shall also be coated with anti-corrosion compound after installation and tensioning. The remaining portions of all rock bolts shall be clean and free of all deleterious materials.

Anchor plates, directed by the Authority's Engineer to be checked, shall be held free until the check for the section is completed.

9.2.3 Grouted Bolts

9.2.3.1 Specifications

Grouted rock bolts (SN-bolts) shall consist of deformed reinforcing steel bars with a corrugated surface and one end shall be fitted with a suitable thread which is to receive an anchor plate and a fixing nut.

High quality cement shall be used for the grouting. The anchor shall reach 40 % of the characteristic bearing capacity (=Ptk according to BS EN 1537) after 6 hours and 100 % of the characteristic bearing capacity after 12 hours.

Bolts shall have a minimum load capacity as defined in the design drawings. The load capacity shall also apply to the thread, nut, anchor plate and coupling, if any.

Washers and nuts shall allow the secure transfer from the anchor force to the anchor plate.

Where required, the bar and components shall have corrosion protection and the threaded end shall be sealed by an end cap.

9.2.3.2 Installation

Boreholes for all rock bolts shall be drilled to the depths as required by the lengths of rock bolts specified for the respective Excavation Class and at diameters which ensure best workability for grouting, coupling and installation. The minimum diameter of the boreholes shall be 10 mm larger than the diameter of the installed rock bolts/couplings. Holes shall be drilled to produce straight holes of the required length and with an accuracy of ±10°.

The boreholes shall be cleaned out by flushing with compressed air or with clean water to remove all drill cuttings, sludge and debris prior to fixing the rock bolt. The amount of water-flushing shall be kept to an absolute minimum. The installation of rock bolts shall follow the drilling and preparation of the borehole within 3 hours.

Prior to the installation of the rock bolt, the entire borehole shall be filled with cement mortar by inserting the grout hose to the full depth of the hole and withdrawing as the grout is pumped in. The nozzle shall be kept buried in the grout as the pipe is withdrawn so that air is displaced as the hole is filled. The grouting shall start at the bottom of the hole. For grouting of vertical anchors, the consistence of the mortar shall be chosen that no mortar leakage from the hole is appearing.

The bolts are inserted in the drilling hole after filling with cement grout and therefore fully bonded with the surrounding rock. The outer end shall be fitted with a suitable thread to receive an anchor plate, a washer and a fixing nut to allow the secure transfer of the anchor force to the anchor plate. The anchor plate is fixed on the bearing surface within 2 rounds behind the face or at least 6 hours with the anchor nut to achieve an approximate force of 20 kN. This force shall be applied by a cali-brated torque wrench.

In case of confined working space and/or great length of rock bolts, coupling shall be permitted. The number of coupled parts shall be kept to a minimum. However, the load capacity of such coupled rock bolts shall not be less than that of a standard integral rock bolt. Special attention shall be paid to the grouting procedure in order to ensure full embedment of the bolt by grout.

9.2.4 Frictional Bolts

9.2.4.1 Specifications

Frictional bolts (e.g. Swellex or similar) are mechanically folded steel tubes with immediate bearing capacity after installation in the pre-drilled borehole as high

water pressure (~300 bar) inflate the tube and adapt its shape to the irregularities of the borehole (split set bolt, expandable bolt or similar).

Steel anchor plates with a minimum size of 150x150 mm (thickness as required) allow the transfer of the anchor force at the anchor head to the shotcrete or rock surface. The frictional bolts shall have a minimum breaking load of 200 kN or higher as defined in the design drawings.

9.2.4.2 Installation

Boreholes for the rock bolts shall be drilled to the depths as required. The boreholes shall be cleaned of all drill cuttings, sludge and debris.

The installation of rock bolts shall be done not later than two hours after drilling of the borehole.

For inflation of bolts, equipment as recommended by the manufacturer of the bolts shall be used. After applying the water pressure, the water shall be drained into the excavation.

9.2.5 Self-Drilling Bolts

Self-drilling bolts are a combined system of a rock bolt with typical diameters lagrer than 32 mm outer diameter and a drill rod.

The system enables the installation of rock bolts in case of collapsing boreholes. Grouting of the bolt is conducted through the internal grouting canal.

The installation of self-drilling bolts shall be in accordance to the manufacturer's instructions and requirements.

9.2.6 Pre-stressed Anchors

Borehole drilling, grouting, installation, tensioning and testing procedures of pre-stressed ground anchors shall be in accordance with BS EN 1537.

Pre-stressed anchors shall be transported, stored and installed in compliance with the manufacturer's recommendations.

The boreholes shall be drilled in such way that the borehole is in the defined location given in the drawings within a tolerance of 75 mm and the bore hole axis is inclined within a tolerance of 2°. The maximum tolerance of the bore hole is 1/30 of the anchor length unless otherwise accepted by the Authority's Engineer.
Aberration from the defined tolerances shall be submitted immediately to the

Authority's Engineer.

The drilling method shall be in agreement with the Authority's Engineer.

The installation of buckled tendons due to transportation, storage etc. is not permitted. Boreholes shall be of sound condition prior to installation of tendons. Borehole drilling, installation of tendon and grouting shall generally be done in one working day.

Grouting pressure and volumes shall be recorded and made available to the Authority's Engineer at any time for review.

The tensioning of the tendons shall commence minimal 7 days after grouting of the fixed anchor length unless otherwise specified by the Authority's Engineer.

Pre-stressed anchors shall be tensioned to the specified level as per detailed design or as directed by the Authority's Engineer. Pre-stressing equipment shall be calibrated not longer than 6 month prior to any pre-stressing of anchors. The protocol of calibration shall be available at the site.

Records of tensioning sequences of each anchor with information of identification of anchor, time, personal, achieved pre-stressing force and distance shall be kept at site and submitted to the Authority's Engineer for review.

Testing of pre-stressed anchors shall be in compliance with Clause 9.11.1 and the requirements of the Authority's Engineer. Number of anchors to be tested shall be in compliance with BS EN 1537 or as directed by the Authority's Engineer.

9.2.7 Grout

Grout constituents shall comply with Clause 9.10.4 and Clause 10.1.3 of this Specification.

Cementitious grouting material shall be injected starting from the furthest point of the drilled hole so that the dowel is completely encased in grout. Grout shall not be used after a period equivalent to its initial setting time. Where cement grout is used, a set of six cubes of cement grout shall be taken when each series of rock dowels is in progress. Sampling, preparation, curing and testing shall be in accordance with BS EN 196. Half the cubes shall be tested at 1 day and the remainder at 28 days. The average compressive strength determined from any group of cubes shall exceed the specified characteristic strength by:

- 1 N/mm² for cement grout tested at 1 day
- 3 N/mm² for cement grout tested at 28 days.

9.3 Shotcrete

Shotcrete shall be mixed, charged, applied, cured and tested according to given Specifications which are based on "Specification for tunnelling" by British Tunnelling Society. Additionally to these Specifications and where these specifications do not cover any aspect the "Guideline for Sprayed Concrete", Austrian Society for Concrete- and Construction Technology, 2005, Austria. enclosed shall be applied.

9.3.1 General

70 days prior to any shotcrete application the Contractor shall submit detailed description of shotcrete to the Authority's Engineer for review and approval such as:

- number and type of equipment used for mixing, batching and applying shotcrete
- Manufacturer's certificates detailing any proposed admixture, inter alia, accelerator admixture and the Contractor's proposals for the use of such admixtures
- mix design

The Contractor shall, 42 days prior to commencement of the actual work of spraying concrete or as otherwise approved, submit results of preconstruction tests of sprayed concrete with the actual materials, inclusive of admixtures, mixed in the proportions proposed for the Works for approval.

The Contractor shall make available testing, production and application records daily to the Authority's Engineer when concrete is applied. The application records shall contain information on when, where and how much sprayed concrete was applied in each operation.

The sprayed concrete shall comply with the BS EN 14487-1 Sprayed concrete, except as noted otherwise below.

The requirements listed below generally refer to high-quality temporary or permanent sprayed concrete.

This Specification is primarily for the use of wet-mix sprayed concrete but in certain circumstances dry-mix sprayed concrete may be suitable.

Sprayed concrete shall be applied by either the wet or dry process as appropriate to the circumstances. All aspects of the application of sprayed concrete shall be subject to the agreement of the Authority's Engineer. Particular emphasis shall be

placed on the provision of adequate ventilation.

The compressive strength of shotcrete in-situ (taken from the tunnel lining or from panels sprayed in the tunnel) shall develop progressively to a final strength according to the minimum requirements specified below. Uniaxial compressive strength tests shall be done in accordance with the provisions stipulated in Clause 9.11.3. The strength development due to suitability tests must exceed the specified in-situ strength by a factor of 1/0.85 (=1.18)

The sprayed concrete mix design shall, unless otherwise stated, comply with the characteristic strengths specified by the detailed design for early-age and long-term loading.

The 28-day-strength (cube) of shotcrete shall be minimum 30 N/mm². The strength development of shotcrete shall be such to meet 2 N/mm2 after 9 hours, 5 N/mm2 after 24 and 17.5 N/mm2 after 7 days.

9.3.2 Mixing

The Contractor shall develop a sprayed concrete mix and a plan for its production and application. Constituent materials shall comply with those listed within this Section.

The mix for shotcrete shall be designed by laboratory tests and field trials as indicated in Clause 9.11.3 of this Specification to meet the requirements for strength development and final strength.

Batching and mixing shall be carried out by equipment capable of properly mixing materials in sufficient quantity to maintain the continuous application of sprayed concrete and to the accuracy defined in BS EN 14487-2.

All measuring equipment shall be maintained in a clean serviceable condition and shall be zeroed daily and calibrated once in a month.

If required according to the support category additional fibres shall be at a stage in the mixing suitable for the sprayed concreting equipment. Fibres shall be added and mixed in a manner to avoid clumping and bending of fibres. Any fibre clumps in the mix shall be diverted and removed by means of a screen placed over the sprayed concrete hopper. Fibres shall be uniformly distributed throughout the mortar matrix without isolated concentrations.

9.3.2.1 Aggregates

Aggregates for sprayed concrete shall comply with BS EN 12620 and the Section 10.1.3.1 of this Specification.

The aggregates shall be clean, strong, durable, suitably graded and shall not contain detrimental amounts of dust, mud, clay or organic impurities.

The aggregate shall be checked for chemical reactions, such as alkali-aggregate reaction, with latent hydraulic binders and admixtures, especially accelerators.

The grading and moisture content of the individual fractions of the aggregate shall be checked and recorded daily.

The total chloride content shall not exceed 0.35 %.

The coarse aggregates shall not contain a large quantity of long stone pieces

The maximum size of the aggregates shall not exceed 16 mm for the dry-mix process and 12 mm for the wet-mix process unless otherwise agreed with the Authority's Engineer. The grading shall lie within the grading range in ompliance with the Austrian Guideline on Sprayed Concrete given in Table 8 below.

Table 8: Range of the grain size distribution for grain sizes 0/8 and 8/11

Maximum grain size	passing the screen
[mm]	in [m%]
11	95-100
8	85-95
4	65-75
2	45-55
1	30-40
0,5	18-25
0,25	8-12
0,063	2-6

Frozen aggregates shall not be used. Minimum temperature of the aggregates shall be 5° Celsius.

During rainy and cold weather periods the aggregates shall be stored under cover for at least 48 hours before being used, in order to reduce the water content.

9.3.2.2 Admixtures

Admixtures may be used in sprayed concrete. Admixtures shall be compatible with each other and the mix. Details of the mix design and technical data demonstrating compliance with BS EN 206-1 and BS 8500 shall be submitted to the Authority's Engineer for approval.

Accelerating admixtures shall be compatible with the cement used. The compatibility shall be tested in the laboratory and in field trials to achieve the required properties for setting and strength development as specified in Clause 9.11.3 of this Specification.

Admixtures shall be free of chlorides such that the percentage of chlorides shall not exceed 0.1% by weight.

The required characteristic values and consistency of delivery to the site shall be agreed in writing with the manufacturer of each admixture before commencement of concrete spraying. Storage conditions and usage of admixtures shall comply with the manufacturer's recommendations.

Written confirmation of the stability of admixtures with the mix water shall be provided prior to commencement of site trials.

The content of SO3 shall not exceed 4.8% by weight of total binder content.

Only liquid alkali-free accelerators (pH value between 3.0 and 8.0 and having alkali content less than 1% by weight Na2O equivalent) shall be used unless pre-bagged dry mix is used where powdered accelerator has already been mixed in. Only the minimum quantity of accelerator necessary shall be permitted in normal concrete spraying operations. At no stage in the strength development should the strength of the accelerated mix drop below 0.7 times the strength of the unaccelerated concrete mix. The dosage rate to be used is evaluated following the suitability tests carried out in compliance with the characteristic compressive strength requirements of Clause 9.11.3 of this Specification. Compliance with this Clause shall be demonstrated by site trials. Any addition to this dosage rate shall not exceed 1% of the cement content of the mix design by weight. The dosage rate may be reduced if required for down hand and vertical spraying positions. Automatically device shall be used to add the accelerating admixture. Actual dosage shall be decided by laboratory tests. At least one set of tests shall be performed each month.

Testing of accelerators and the base mix with respect to acceleration of setting, early strength and decrease of strength at a later age (28 days), shall take place in due time before commencement of concrete spraying.

Setting time of the Portland cement and accelerator shall be determined in accordance with BS EN 196-1 and 196-3. The results should be:

- initial set <3 min
- final set <10 min

Additives for the improvement of performance, workability etc. may be added with the approval of the Authority's Engineer.

Additives intended to be used shall be included in the tests as described in Clause 9.11.3 of this Specification.

Accelerating admixtures shall be used to meet the requirements for setting and strength development of shotcrete applied in-situ.

Laboratory testing of the selected type(s) of accelerator shall be carried out at dosages as recommended by the manufacturer, to establish the variability of the above properties with dosage. Accelerators showing excessive variability with dosage will not be permitted.

Accelerators delivered to site shall be tested at least once every two months for their reaction with the Portland cement used, with particular reference to the setting behaviour and strength decrease after 28 days. The stability of accelerators during storage shall be visually inspected at similar intervals. Storage times and working temperature ranges shall be in accordance with the manufacturer's recommendations. The manufacturer's safety instructions shall be observed.

Plasticisers and retarders complying with BS EN 934-2 may be used to reduce the quantity of the mixing water and to improve the pumpability of the concrete. The effects and optimum dosages of plasticisers and retarders shall be determined by site trials.

The influence of the plasticisers and retarders within the concrete mix shall be checked regularly for setting time, water reduction and development of strength. These values shall be compared with the results from the pre-commencement trials.

Compatibility of plasticisers and retarders with Portland cements, latent hydraulic binders and accelerators shall be verified by observation and site trials.

Hydration control admixtures may be used to control the hydration of the mix as appropriate to expedite construction of the Works. The effects and optimum dosages of hydration control admixtures shall be determined by site trials.

Compatibility of hydration control admixtures with Portland cements, latent

hydraulic binders and accelerators shall be verified by observation and site trials. Hydration control admixtures shall be used in accordance with the manufacturer's instructions.

Dosing of admixtures by hand shall not be permitted.

9.3.2.3 Cement & Additions

Portland cement shall conform to the requirements of BS EN 197-1 or National Standards and must be suitable for sprayed concrete application.

The cement content shall be designed to meet the strength requirements of shotcrete applied in the field.

As a minimum, Portland cement shall be CEM I, strength class 42.5; class N and R are both appropriate.

The Portland cement fineness shall not be less than 350 m2/kg and C3A content not less than 5%.

The minimum Portland cement content shall be 360 kg/m3. The minimum total binder content shall be 400 kg/m3.

In order to determine a suitable dosage rate of accelerating admixtures, suitability tests shall be carried out

Table 9: Maximum level of additions (in percentage of binder)

Cementitous Material	Maximum Addition
Silica fume (solids)	15% of Portland cement
Pulverised fuel ash	30% of Portland cement
GGBS	30% of Portland cement

Pulverised fuel ash and ground granulated blast furnace slag shall conform to BS EN 450-1 and BS EN 15167 respectively and may also be included in the mix provided.

Silica fume shall be in the form of water slurry and shall comply with BS EN 13263-1.

Silica fume (microsilica) shall comply with the following requirements:

- The content of SiO2 by weight of dry mass shall be not less than 85%.
- The silica fume shall not contain more than 0.4% elemental silica (by weight of dry mass) or any deleterious materials such as quartz, rust and/or cellulose fibres.
- The specific surface area shall not be less than 15000 m²/kg.
- The carbon content shall not exceed 2% and the total alkali content as Na 2 O equivalent shall not exceed 2%.
- SO3 content (by weight of dry mass) shall be less than 2%.
- pH value shall be between 5.5 and 1.0.
- The viscosity shall be 20 seconds with a 4 mm viscosity cup in accordance with British Board of Agreement Certificate 85/1568 and the relative density shall be between 1.3 and 1.4.
- The activity index shall be at least 100% after 28 days.

Testing to establish compliance with items above shall be carried out on a monthly basis.

Silica fume shall be regularly agitated by circulation pumps prior to use.

The compatibility of silica fume and liquid admixtures shall be established by carrying out appropriate accelerated testing procedures agreed with the Authority's Engineer.

The optimum content of silica fume shall be determined during site trials.

9.3.2.4 Water

Water shall comply with the Clause 10.1.3.5 in this Specification.

For the dry-mix shotcrete, the water content shall be controlled by the nozzleman to suit the conditions of the shotcreting surface and location of application. An indication that the water/cement ratio is in the correct range will be, that the

shotcrete will seem to have a slightly shining appearance immediately following application.

For the wet-mix shotcrete, field trials shall be carried out to determine and establish the suitable water/cement ratio.

Due to aggressive mountain water, admixtures shall be defined in agreement with Authority's Engineer.

The water/cement ratio range for permanent sprayed concrete shall be not more than 0.50.

9.3.3 Application

9.3.3.1 General

Details of all equipment to be used shall be made available to the Authority's Engineer prior to commencement of site trials. The sprayed concrete nozzle and ancillary equipment shall be of an adequate capacity for the volumes to be applied.

The equipment selected and approved by the Authority's Engineer will be capable of maintaining the ratio of concrete and accelerator as selected from the trials and approved by the Authority's Engineer. The actual ratio of accelerator to selected concrete shall be identified at the nozzle, and take into account the filling efficiency of the equipment and the efficiency of the accelerator dosage equipment to overcome the air and concrete pressure at the nozzle while spraying at typical outputs and air flows.

Equipment shall be thoroughly cleaned at least once per shift. The spray nozzle shall be checked for wear and where necessary replaced. Transport pipes consisting of hoses and pipes shall be designed to convey the concrete efficiently and without leakage or blockage. The transport pipes shall have uniform diameter appropriate to the mix characteristics determined by site trials and be free of any dents or kinks between the sprayed concrete machine and the nozzle.

Working area for sprayed concreting shall be well illuminated and ventilated. Dust pollution shall be minimised by choice of appropriate equipment and by means of additional ventilation, water sprays and by maintaining equipment in good order. Protective clothing and dust masks shall be provided for and used by all persons present during spraying.

The equipment shall allow for air and water in any combination to be available for preparation of surfaces and/or cleaning of finished work.

The Contractor shall enable the Authority's Engineer access to the sprayed concrete Works at all times, and shall allow the Authority's Engineer access to inspect the excavated ground surface prior to spraying if requested.

9.3.3.2 Proficiency of Nozzlemen

Nozzlemen shall hold relevant certificates of competence issued by the Contractor or written evidence of previous satisfactory work indicating compliance with EFNARC Nozzleman Certification Scheme, ACI 506R-03 (USA) or similar National Standards to the approval of the Authority's Engineer. Each crew shall demonstrate acceptable proficiency in the application of sprayed concrete to trial areas before being employed on the Works to the agreement of the Authority's Engineer.

Subject to the Authority's Engineer's agreement, tests for proficiency may be combined with trial mix tests.

Tests for proficiency shall use the equipment selected for use in the Works where practicable.

9.3.3.3 Applying

Rock or previously applied shotcrete surfaces to be shotcreted shall be carefully cleaned of all loose material, scale and other contaminations. It may be necessary to use compressed air and a water jet.

Where groundwater flow could interfere with the application of sprayed concrete or cause reduction in the quality of sprayed concrete. The Contractor shall take all action necessary to control groundwater. Such action shall include the channelling of water by means of pipes and chases.

In order to prevent the build-up of water pressure behind fresh sprayed concrete, apparent water shall be drained through the concrete, either with appropriate drainage holes or by other approved methods, e.g. by installing a perforated drainpipe or drainage channel covered with filter fabric and extending as approved from the leakage area to the drainage system. Such drains must be secured to the rock surface.

Drainage holes shall be drilled in the sprayed concrete lining where the build-up of water pressure may occur, and where drainage was not installed prior to the placement of sprayed concrete. The diameter and spacing of such holes shall be as directed by the Authority's Engineer.

The optimum distance between nozzle and surface of application is 1.0 to 1.3 meter. The nozzle shall be positioned at right angles to the surface of application. Two nozzles shall be used at least for regular tunnel heading.

The sprayed concrete shall emerge from the nozzle in a steady uninterrupted flow. Should the flow become intermittent for any cause, the nozzleman shall direct it away from the work until it becomes constant again.

For vertical and near-vertical surfaces application shall commence at the bottom and the leading edge of the work shall be maintained at a slope. Downward spraying shall be avoided where possible. The nozzle may be inclined sufficiently to ensure reinforcement is properly embedded.

The projected shotcrete thickness ds shall be equal to the summation of thicknesses of each shotcrete layer. The Contractor shall determine the thickness of the shotcrete layers. The maximum shotcrete layer thickness is 20 cm, thicker layers shall be constructed with sub-sequences. Subsequent layer(s) must not be applied before the previous layer has developed sufficient strength to support the additional layer(s). These additional layers shall be completed within a period not exceeding three days.

Steel ribs, roof ties, wire mesh and other reinforcement shall be embedded in shotcrete as shown on the tunnel design drawings. The minimum cover of wire mesh and re-bars applied at the inner side of a shotcrete lining shall be 4.0 cm. Voids behind reinforcement and steel ribs must be avoided.

The shotcrete lining shall be constructed in a way that all bolts and anchors are fully covered with shotcrete of the primary lining. The surface of the primary lining must be smooth enough for the application of the water proofing system according to the specification of the water proofing system.

If more than one layer of reinforcement is installed, the second layer shall not be positioned before the first one is embedded and covered completely with shotcrete.

No rebound shall be shotcreted to avoid structural weaknesses in the lining. Rebound shall be removed immediately after finishing of each shotcrete application. The rebound shall be removed, in particular at horizontal shotcrete connections due to separate excavation sequences and at all construction joints, if necessary by pneumatic hammers, prior to further application of shotcrete.

All joints in the sprayed concrete lining shall be as specified in the Design.

The surface to receive sprayed concrete shall be damp but shall not exhibit free water.

The temperature of the mix before placing shall not be below 5°C and shall not exceed 35°C unless special provisions are made. Spraying shall not be undertaken when ambient temperature is below 5°C unless special measures can be taken to provide protection against frost until the sprayed concrete has developed a compressive strength of at least 5 MPa.

The surface of the shotcrete lining can follow the rounded surface of the rock mass including corners and edges. The minimum thickness of the shotcrete lining as given in the design drawings must be reached in every point of the lining.

Cracks in the shotcrete induced by shear failure shall be removed and a clean connecting face shall be constructed prior to further shotcreting.

The base mix concrete may be used up to 2 hours after the addition of water to the cement provided that the sprayed concrete can be applied satisfactorily. Any unused material after this time shall be discarded. This period may be extended by the use of hydration control admixtures, subject to the approval of the Employer's Representative.

9.4 Reinforcement – Wire Mesh

9.4.1 General

The reinforcement for primary support measures shall be in compliance with Clause 10.4 of this Specification.

Cutting of reinforcement for better placing due to edges is permitted; hence additional reinforcement in these sections is required.

Welded wire mesh fabric shall be installed in surface excavations in conjunction with sprayed concrete, as shown on the drawings, or as directed by the Authority's Engineer. Chain link fabric may be used for surface applications if previously approved by the Authority's Engineer.

9.4.2 Specification

Welded wire mesh fabric shall conform to the requirements of IS: 4948 and shall have a mesh size of 150 x 150 x 6 mm as shown on the drawings, or as required by the Authority's Engineer.

The diameter of additional steel bars shall be limited to 14 mm according to Austrian Guideline "Sprayed Concrete". The characteristic yield strength of the welded wire mesh shall be 500 N/mm².

9.4.3 Installation

Welded wire fabrics shall be installed in such way so that it follows as close as possible the irregularities of the excavation surface or previous layers of shotcrete. It shall be firmly fixed to prevent vibration and change of position during spraying of shotcrete. The use of wooden pegs or pins for attaching the wire mesh to the rock surface shall not be permitted. Welded wire fabrics shall be installed in the longest practical length. The overlap for welded wire fabrics applied in the shotcrete lining shall be at least twice the pitch distance in circumferential direction. In longitudinal direction, the overlap shall be at least one pitch distance for the first layer of fabric and at least twice the pitch distance for the second layer of fabric.

A minimum concrete cover at the tunnel side of 4.0 cm of all wire mesh layers shall be provided.

9.5 Lattice Girder

9.5.1 General

Steel arches or lattice girders shall be installed to maintain the designed shape of the opening and if necessary, provide an immediate support at the working face over the length of the last excavation completed. The lattice girder mainly functions as reinforcement. If necessary, the installation of steel arches or lattice girders shall also prevent ground loss and shall improve load distribution.

For the application of support arches and lattice girders the following shall be taken into account:

- axial stress and bending moment in the steel arch ribs induced by the ground loads
- lateral stability and bracing of steel arches or lattice girders
- method of installing the steel arches or lattice girders
- method of blocking and spacing of blocking points
- bearing capacity of the ground at the toe of the arch ribs
- the stand-up time of the unsupported part of the excavation
- the groundwater regime and permeability of the ground

9.5.2 Specification

Lattice girders shall consist of three primary bars, connected by stiffening elements to the manufacturer's design or as shown on the drawings. They shall be designed so as to:

- facilitate sprayed concrete penetration into and behind the girder, thereby

minimising the creation of projection shadows and/or voids
- provide good-quality bonding between the steel and sprayed concrete, to form a composite structure acting as a continuous reinforced concrete lining
- make allowance for the specified tolerances including convergence

Stiffening Elements: A minimum of 5% of the total moment of inertia shall be provided by the stiffening elements. This percentage is calculated as an average along the repeatable lengths of the lattice girder. To ensure stability against buckling, the maximum spacing between the stiffening elements shall be less than three times the cross-sectional height of the girder.

Dimensions and tolerances: The lattice girders shall be fabricated to meet minimum clearances and tolerances shown under consideration of accuracy of placement during construction, manufacturing tolerances and of lining deflection following installation. Prior to installation, each girder shall be inspected as specified below and all measurements taken shall be recorded along with any comments. Any changes in the inspection frequency must be authorised by the Authority's Engineer following a review of previous inspection results.

Each girder inspection shall check the following criteria:
- That the girder is fully identified with the girder type and the unique traceability reference.
- That the girder links and sinusoidals are in the correct positions and are adequately welded.
- That the reinforcement and plate types and sizes are as specified on the drawings.

When inspecting weld quality, the following criteria shall be used:
- The reinforcement shall be free from undercut in excess of 1 mm.
- The weld metal deposition shall be even and blend smoothly with the bars.
- The weld metal shall be free from cracks and porosity.

The chord length shall be checked by measuring the distance from the outer edge of the connection plate to the corresponding point on the connection plate at the other end of the girder. The measurement shall be taken to the nearest millimetre.

The chord height shall be checked by placing a tight cord across the centreline of the girder between the outer edges of the end plates then measuring the height from the chord to the inside edge of the lower main bar. The measurement shall be taken to the nearest millimetre. Where the girder consists of a double radius the chord lines shall be taken along the outer edge of the connection plates to the point at which the radius changes.

Lattice girders shall also comply with the following tolerances:

- The erected lattice girders shall not deviate from the design shape and position by more than -0 mm and +50 mm.
- Lattice girders shall be fabricated to include an allowance for 10 mm of convergence.

Fabrication: Each of the primary bars of the lattice girder segment shall be composed of only one piece of high-yield steel (minimum grade 500 N/mm² characteristic yielding strength). Secondary bars are either plain round profile or deformed high yield steel (minimum grade 500 N/mm² characteristic yielding strength).

The connection elements at the end of the girder segments shall be constructed of flat or angle steel to BS EN 10025:2004, grade S275JR. Connections between lattice girder segments shall be bolted as shown on the drawings. Welded connections between segments shall not be permitted. Nuts and bolts supplied are to be grade 8.8 or higher. The connections shall transfer the maximum tension load of the steel bars.

All welding shall be carried out in accordance with BS EN 1011-1:2009.

9.5.3 Installation

The single steel bar is situated at the outer side of the profile. The lattice girder is usually separated in five elements. Three elements form the top heading arch and two elements are placed as bench segments. The arch elements are connected with screwed head plates which are welded onto the main steel bars. The connection has to transfer the (tension) forces in the steel arch bars. The lattice girders have to be embedded entirely in shotcrete.

A minimum 50 mm thick sprayed concrete layer must be in place before the installation of the lattice girders. Under no circumstance lattice girders shall be installed under unsupported ground.

Lattice girder segments shall be secured by use of steel wedges, concrete spacers, mortar sacks and/or other appropriate means to maintain position during application of sprayed concrete. The means of support shall be subject to the approval of the Authority's Engineer. No wood blocking shall be used.

Lattice girders shall be firmly fixed in their final position against the excavation prior to application of sprayed concrete. Lattice girders shall be sufficiently clear of the excavation and final internal profile of the structure to accommodate the required sprayed concrete cover.

Lattice girder segments shall have butt plates and the method of installation shall ensure tight connection of all elements.

Immediately prior to concreting, casting or spraying, the lattice girder shall be rendered clean and free from deleterious matter.

9.6 Steel Ribs

9.6.1 General

Steel ribs provide an immediate support of the excavation after installation and shall subsequently act as reinforcement and load distributing members for the shotcrete lining. Steel ribs are required as support for forepoling elements, which are installed in advance of the excavation. During the entire construction period, they will contribute as load bearing members within the shotcrete lining.

The steel ribs shall be manufactured to meet the geometrical requirements for the excavation geometries for each Excavation Class including the relevant tolerances.

Prior to the beginning of the work the complete fabrication details, installation procedures and layout, details of joints, rib connections, rib spacers, geometry etc. and certificates of compliance of the materials shall be submitted to the Employer's Representative for approval.

9.6.2 Specification

The fabrication and installation of structural steel support shall conform to the latest edition of the following Indian Standards or, where not covered by these Standards, to the equivalent International Standards:

- IS: 800 Code of practice for general construction in steel
- IS: 816 Code of practice for use of metal arc welding for general construction in mild steel
- IS: 2062 Steel for general structural purposes

Rib splices shall be welded or connected with bolted plates. Splices shall not reduce the section moment of resistance. Where possible all connections shall be welded and all field connections shall be bolted.

Arches, base plates, ties and connections shall be formed from steel with the characteristic in accordance to reinforced concrete standards. Arches shall be rolled to suit the dimensional requirements of the Contract. Welding shall conform with BS EN 1011-1. Holes for ties, struts and any bolted connections shall be drilled. No

burning will be allowed whether for temporary Works items or permanent elements.

Threaded tie rods and struts shall be of adequate length to suit arch centres and allow 25 mm projection each end beyond the nut.

Where arches are to be provided as part of the Contractor's obligation for support the Contractor shall provide dimensional details of the arches, calculations regarding imposed loads and design and such other information that the Authority's Engineer may reasonably request.

Galvanised arches, where required, shall be treated in accordance with BS EN ISO 1461. All components, including the rods, fish plates, nuts and bolts, shall be galvanised.

9.6.3 Installation

The length of the single segments of the arch is defined by the contractor. Prior to installation the arches shall be clean and free from oil or other deleterious material.

The number of joints in the arch shall be varied to suit the Contractor's method of working subject to the Authority's Engineer's agreement. Steel ribs shall be erected to the lines and levels as indicated on the approved detail design drawings. The exact excavation levels may however be determined by the Contractor to match best his equipment and construction method subject to the approval of the Authority's Engineer. Hardwood footblocks and wedges shall be used to bring the steel ribs to the required line and level. Any timber used in the installation and setting of the steel ribs shall not be permanently remaining in sections where shotcrete or concrete is to be applied. Tie bars shall be provided to connect the rib to the adjacent steel rib and fix it securely in place.

Steel arch ribs and full circle ribs shall be firmly fixed in their final positions against the excavation. Arch bases shall be provided with integral base plates of size to suit the bearing capacity of the ground and shall bear on rock or concrete of adequate strength. If required, the base plates of the ribs shall be anchored to the rock by rock bolts. Arches and ribs shall be sufficiently clear of the excavation and the final internal profile of the structure to accommodate any required concrete cover.

Placing of the steel ribs shall be perpendicular to the tunnel axis. The bearing capacity of the steel ribs shall not be endangered by the joints of the steel segments.

Immediately after placing of the steel support, the ribs shall be interconnected and braced by means of steel tie rods in order to prevent any displacement and to

maintain spacing. Immediately prior to concreting, casting or spraying, the arches, ties and struts shall be rendered clean and free from deleterious matter.

Steel ribs shall be embedded in shotcrete, in order to get contact between rock and steel rib by a solid shotcrete packing which shall have a minimum cover to steel of 40 mm. In the case of overbreak, the bulk of the void space may be filled with cast in place concrete or sprayed concrete, as approved. In the case of TH - profiles, the trough of the steel profiles shall be oriented towards the tunnel in order to enable load transfer and to avoid cavities behind the steel profile.

In sections with a ductile tunnel lining, the steel arches are cut in the area of the gaps in the shotcrete lining. To allow shortening of the steel ribs, they are connected with U-profiles, which allow lateral sliding. In these sections head plates are only used for the connection of the bench arch segments.

The Contractor shall survey and record the chainage of all steel ribs installed inorder to facilitate any subsequent drilling operations.

Structural steel supports shall be maintained in position after installation. Any steel support installed improperly or damaged shall be adjusted, repaired or replaced by the Contractor without delay, as directed by the Authority's Engineer.

9.7 Forepoling

9.7.1 General

To support the excavation roof (tunnel crown) forepoling elements are installed if required at the upper part of the tunnel excavation face. Forepoling shall be applied in rock and soil conditions which tend to produce overbreak, collapses or material inflows immediately following excavation. Forepoling shall be applied locally or systematically, as the circumstances require for the safety of the works and for preventing overbreak. The installation of forepoling always requires the erection of steel ribs. They shall be driven from the supporting frame in a slightly upwardly inclined direction at the crown of the heading and should penetrate at least half a set beyond the next excavation cycle.

Forepoling shall be applied as shown on the approved detail design drawings by the Contractor or as instructed by the Tunnel Designer's Representative and/or the Authority's Engineer.

Forepoling shall be properly supported by the steel rib and the shotcrete above the steel rib. Therefore, the shotcreting of the gap between steel rib and the shotcreted sealed rock surface along the area of forepoling shall be completed after the installation of forepoling.

Spacing between consecutive forepoling pipes or bars around the crown of the excavation profile shall not exceed the maximum distance specified on the approved design drawings, and shall be reduced if the actually prevailing geological conditions at the tunnel face require to do so.

Great care shall be taken to prevent the disturbance of face boards and supports in general during the forepoling cycle.

9.7.2 Spiles

Where spiling is employed to provide support for advancing the excavation, spiles shall be driven into the ground or placed in pre-drilled and grouted holes as specified on the drawings or by the Authority's Engineer.

9.7.2.1 Specifications

Spiling is to be done with deformed reinforcing steel bars with a corrugated surface and a nominal diameter of 32 mm or tubes with similar steel cross section according to the design drawings. Deformed reinforcing steel bars shall be of a characteristic yield strength class of at min 500 N/mm².

The length of the spiles is as given on the drawings based on the support category or directed by the Authority's Engineer. The embedded length of the steel pipes shall be minimum 1 m longer than the instructed round length of the subsequently excavation step.

Pre-drilled and self-drilled spiles shall be grouted. If grout is to be used for spile installation, it shall be commensurate with the ground conditions and angle of spile inclination. If grout is used, Specification and methods should comply with those given in Clause 9.10.4 and 10.1.3 respectively.

The accuracy of spile installation shall be better than ±5° away from the alignment specified.

The number, location, overlap and angle of spiles shall be commensurate with the ground conditions and methodology specified on the Contract drawings or by the Authority's Engineer.

9.7.2.2 Installation

Spiling with deformed reinforcing steel bars: The spiles are inserted in drill holes with a larger diameter which are filled with grout prior to spile installation. The spiles have a distance of approx. 30 cm. They are installed outside (onto) the steel

arch and outside the excavation profile as close as possible to the theoretical line of excavation after the installation of the first layer of shotcrete. After their installation the area of the steel arch and the spiles have to be shotcreted before excavating the next round.

Spiling with steel pipes: Based on the weakness of the ground two methods of installation are commonly used. In rock the pipes are grouted in drill holes with a larger diameter. The grout is pumped into the drill hole through the steel pipe until it flows out from the annulus between rock mass and pipe. In weak ground pipes with a welded tip are pushed into a drill hole of a diameter slightly less than the outer diameter of the pipe. This leads to a tight contact and a fast interconnection of the pipes and the surrounding rock mass. The pipes are not grouted. Both types of spiles have a distance of approx. 30 cm. They are installed outside the excavation profile as described before.

Spiles shall be installed in such manner that a tensile bond is formed between the spile, the ground ahead of the proposed excavation and the sprayed concrete lining. Typically this may involve grouting the spile into the hole for pre-drilled and self-drilling spiles or hammering the spile in.

Care shall be taken during installation of spiles to ensure minimum disturbance of the ground due to the installation process.

Probing shall be carried out in conjunction with spiling in order that fully embedded spiles are installed prior to the required location.

9.7.3 Pipe Umbrella

9.7.3.1 Specifications

Pipe umbrella shall be of steel pipes with a smooth surface and a diameter of 114 mm and a minimum wall thickness of 6.5 mm. The pipes shall have a length of 12 m with an overlap of minimum 4 m. The steel pipes shall have a solid steel shell (not punched). The characteristic yield strength of the pipes shall be 240 N/mm².

9.7.3.2 Installation

The pipes are placed outside the excavation profile as close as possible to the theoretical line of excavation. The inclination of the pipes is approx. 5° and their distance is 30-50 cm according to the ground condition. The pipes are inserted in drill holes with a larger diameter and grouted subsequently to be fully bonded with the surrounding ground.

9.8 Driven steel lagging

9.8.1 General

Steel Lagging (sheet piles) shall be employed mainly in weak ground with low cohesion with the purpose of preventing a collapse of material during and immediately after excavation. The use of lagging will always require the erection of steel ribs.

9.8.2 Specifications

Steel lagging sheets with a thickness of 4 to 6 mm shall be used.

Lengths shall be in accordance with the round length of excavation and the support requirements beyond the face as defined by the drawings or directed by the Authority's Engineer.

Voids and gaps behind the lagging sheets shall be either filled with shotcrete or by contact grouting with a suitable cement mortar.

9.8.3 Installation

Lagging sheets shall be driven at distances shown on the approved detail design drawings. They shall be driven in advance of excavation of the respective round to a depth extending a minimum length of 0.5 metres beyond the face of the subsequently round length into the ground.

9.9 Yielding Elements

9.9.1 Specification

Large deformations occurring during tunnel excavation in rock with unfavourable characteristics shall be managed with yielding elements.

The primary tunnel lining shall be divided into segments by means of longitudinal gaps. To make better use of the lining capacity, yielding elements (LSC – Lining Stress Controller or equivalent) consisting of multiple steel pipes in a concentric assembly with a total length of app. 510 mm are installed in the deformation gaps in the circumferential direction.

The yielding elements shall be used to achieve controlled ductility of the tunnel lining in order to prevent overstressing. To allow a smooth initial load development, special provisions have to be foreseen (predetermined breaking points at the ends of the load tube). In order to optimize the bearing capacity of the shotcrete lining, a multi-stage system may be used in agreement with the

Authority's Engineer, where the bearing capacity of the element unit is increased stepwise.

It shall be possible to adjust the bearing load of the yielding elements to the actual ground conditions (e.g. variation of steel cylinders of LSC).

9.9.2 Installation

Installation shall be done prior to any shotcreting. The elements shall be fixed to the wire mesh or to steel ribs. The elements shall be protected to ensure functionality after primary lining installation prior to shotcreting.

The elements shall have proper contact to the shotcrete lining to transfer the lining forces.

9.10 Grouting

Grouting operation is defined as follows:

- contact or cavity grouting, at pressures up to 300 kPa, to fill voids between final concrete lining and primary sprayed concrete lining, or between the primary lining and rock
- consolidation grouting or strata grouting, at pressures up to 6 MPa, of the rock surrounding the excavated space, which shall commence after completion of contact grouting, where applied
- consolidation grouting or strata grouting in the heading zone, at pressures up to 6 MPa, in zones of sheared and disturbed material or of high water inflow
- final grouting of temporary drainage holes

9.10.1 General

The Contractor shall prepare a detailed grouting Specification to suit best the actual conditions encountered. This grouting specification shall be submitted to the

Authority's Engineer for approval unless otherwise agreed or directed by the Authority's Engineer. The Tunnel Designer's Representative shall specify the maximum pressures to be used for grout injection at each location. The pressures specified are subject to approval by the Authority's Engineer.

Records of all details of grouting works such as location, inclination, diameter of boreholes, drilling time, equipment used, results of water pressure tests, mix, quantity, pressure of grouting, development and special events during grouting operation etc. shall be kept by the Contractor, countersigned on site by the Employer's supervising personnel and submitted to the Authority's Engineer.

Where necessary due to the nature of the ground conditions or where adverse water conditions are anticipated, the requirements for the use of special grouts shall be stated in the Contract.

Special grouts supplied by proprietary manufacturers may be used subject to agreement with the Authority's Engineer.

Preconstruction grout trials shall be undertaken to demonstrate that the required setting times and strength gains will achieved. Details of the trials and results shall be submitted to the Authority's Engineer.

Quality control of grout mortar shall be in compliance with Clause 9.11.2 of this Specification.

As directed by the Authority's Engineer, water pressure tests shall be carried out.

9.10.2 Drilling

Grout holes shall be drilled either with percussion type or rotary type drilling equipment, depending on Ground Type.

The diameter at the bottom of the grout holes shall not be less than 35 mm. For percussion drill holes the diameter of the drilling bit shall be at least 8 mm larger than the diameter of the couplings used for the drill rods.

Only water shall be used for flushing during drilling unless directed otherwise by the Authority's Engineer. All holes shall be thoroughly cleaned immediately after drilling using water and/or air under pressure. After washing, downward holes shall be kept plugged until the commencement of grouting operation.

9.10.3 Mixing

All grout mixes shall be prepared using high speed, high shearing action mixers to produce a grout of uniform consistency.

General-purpose cement grout shall be mixed in accordance with the proportions given in Table 10. The water content shall be kept to the minimum required to ensure a smooth, fluid mix.

Table 10: Mix proportions for cement grout

Class	Proportion by mass		
	Cement	Sand	Pulverised Fuel Ash (PFA)
G1	1	-	-
G2	1	3	-
G3	1	10	-
G4	1	-	10
G5	1	-	4
G6	1	-	0,5

When, prior to pumping, mixed grout is to be stored for short periods, purpose made agitator tanks shall be used. Grout shall be used within 1 hour of mixing.

When clay or bentonite additives are used, separate mixing tanks shall be provided for mixing and agitation.

Grouts containing polymer additives shall only be mixed in a colloidal-type mixer.

Water meters shall be provided for accurate measurement of water used for mixing. Pressure gauges, safety valves, by-pass valves etc. shall be provided where required on mixers, agitators, pumps and injection hoses.

Special grouts from proprietary manufacturers shall be mixed and used in accordance with the manufacturers' instructions.

9.10.4 Materials

The following types of grout mixes may be used:

- neat cement grout, possibly with admixture

- cement-sand grout, possibly with admixture
- cement (with silica fume) grout with or without sand
- micro-cement grout
- chemical grouts (polyurethane or epoxy)

General the constituents of the grout (cement, water, sand and admixtures) shall comply with the requirements given in Clause 10.1.3 unless specified otherwise hereinafter.

9.10.4.1 Cement

Cement for grouting purposes shall in general be rapid Portland type in accordance to ENV 197.

Micro-cement for grout shall be milled from pure Portland cement clinker and shall have a minimum blaine specific area of 900 m2/kg with 95% of all particles < 10 and with a maximum particle size of30

9.10.4.2 Sand

If sand is required in the grout mix design, it shall comply to the following gradation (Table 11).

Table 11: Sand gradation used for grout mix

Sieve size in mm	Percentage passing by weight
2.00	100
1.00	90 – 100
0.50	50 – 80
0.25	18 – 48
0.125	7 – 25
0.063	0 – 3

9.10.4.3 Additives

Silica fume for grout shall be micro fine powder with an average particle size less than 0.5 um.

Pulverised fuel ash (PFA) shall not be used as a constituent of grouts which contain sulphate-resisting cement.

9.10.4.4 Admixtures

Only admixtures tested prior to the start of grouting work and approved by the Authority's Engineer may be used. The approval and Manufacturer's certificates or guarantees will not be accepted as relieving the Contractor of his responsibility for the suitability of any admixture.

If admixtures or chemicals are proposed for use in grout, the Contractor shall transmit all relevant manufactures certificates (including toxicity, health, safety and environmental certification) to the Authority's Engineer for review prior to any grouting measures.

Details of accelerating and retarding agents for proposed inclusion within the grout mix shall be submitted to the Authority's 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.

9.10.5 Grouting

All hoses and piping should be of a small diameter to ensure a high velocity flow without segregation.

Grouting operation shall be performed without major interruptions. In case of an interruption before completion of grouting (plant breakdown), the hole shall be washed with clean water.

Grouting in the tunnel shall be performed in a manner that pressures are equally distributed and do not overstress the initial tunnel lining.

In case of any grout communicating between holes, grouting shall be done simultaneously or holes where grout issues shall be plugged.

Grouting is completed, when the required pressure can be kept constant over a period of 10 minutes.

9.10.5.1 Cavity Grouting of In-situ Lining

The Contractor shall grout all cavities, voids and spaces remaining unfilled outside the in-situ concrete lining. Grouting of a section of lining will not be allowed until that section has achieved its design strength.

Procedures for cavity grouting of in-situ lining to tunnels and shafts constructed with a waterproof membrane shall be subject to agreement with the Authority's Engineer.

Grout for cavity grouting shall be in compliance with this Specification, except where otherwise agreed by the Authority's Engineer, who may direct that large voids be filled with other materials. The grout consistency shall be sufficiently fluid, but not more as, to ensure that the grout flows freely under low (<100 kN/m²) pressure into all parts of the space to be filled via grout pipes or grout holes provided for the purpose.

The injection points shall be provided and used for cavity grouting at an average of at least one per 2.5 linear metres of tunnel and more frequently in any areas of excessive overbreak. Vent pipes shall be provided extending to the highest points of cavities. The injection points for cavity grouting in arched roofs shall be located within 500 mm of the crown unless otherwise agreed by the Authority's Engineer.

The Contractor's proposals for the installation of grout pipes shall be submitted to the Authority's Engineer for agreement. Grout pipes and grout holes for cavity grouting shall be at least 40 mm internal diameter.

Grouting shall be carried out by equipment similar to that used for segmental tunnel grouting. Grouting pressures shall be such as not to damage the Works or any other property.

Grout pipes shall not remain within 25 mm of a finished concrete internal surface, and when no longer required all injection holes in concrete linings shall be filled with dry pack mortar to within 25 mm of the finished concrete surface and finally made good.

Control grouting, to verify that voids have been completely filled with grout, shall be carried out where directed by the Authority's Engineer.

9.10.5.2 Consolidation or strata grouting

Consolidation grouting of the rock shall be carried out in sections of the Tunnel structures as shown on the drawings or as directed. Additionally, consolidation grouting may be required during the excavation works, in order to consolidate the

heading face or seal off inflow of groundwater.

Strata grouting shall start with neat cement grout. Depending on the grout consumption the water/cement ratio may be reduced subsequently. In case of large grout consumption, injections shall be continued with cement mortar grout. Final injections shall be done with neat cement grout again.

Grouting of a hole will be considered as complete when the rate of grout consumption at the maximum grouting pressure is less than an amount set by the Authority's Engineer, or otherwise directed.

Upon completion of grouting, the packer shall remain in the hole and the pressure maintained until the grout has attained its initial set.

9.11 Testing

9.11.1 Rock Bolts

The required bearing capacity of rock bolts is to be ensured by pull out test procedures, in agreement with the Authority's Engineer. The pull out tests shall be conducted with a hydraulic press, in appearance of the Authority's Engineer. The test results shall be recorded and forwarded to the Authority's Engineer for review.

The equipment for pull out test procedures shall be provided and maintained by the Contractor during the whole construction phase.

9.11.1.1 Suitability Test

A detailed suitability test program elaborated by the Contractor set up on basis of BS EN 1537 shall be approved by the Authority's Engineer prior to all testing work. Deviations from the European Standard shall be approved by the Authority's Engineer.

Suitability tests in different ground types and with all types of bolts shall be conducted prior to the commencement of tunnelling. The tests shall be performed in similar geological ground conditions as expected during tunnel excavation. The location of the bolts to be tested shall be selected by the Authority's Engineer.

A minimum of five bolts of each type shall be tested. Depending on the testing procedure and the test results the Authority's Engineer may require further bolts to be tested. Adequate testing equipment shall be provided to record bolt elongation, movement of the bolts and tension forces.

The bolts shall be installed in the designed manner and the external anchor resistance (Ra according to BS EN 1537) shall be determined. The anchor shall be stressed to the external anchor resistance Ra or to the proof load Pp. The proof load Pp is defined to 0,8 Ptk (= characteristic bearing capacity according to BS EN 1537).

For each type of rock bolt information of type, testing equipment, location and installation records, applied testing loads and records of deformation shall be forwarded to the Authority's Engineer. For failed pull-out tests, the evaluation and interpretation of test results as specified in BS EN 1537 and proposed action shall be submitted to the Authority's Engineer. Based on the suitability tests and considering the economical respects the Constructor shall define the rock bolt types in agreement with the Authority's Engineer.

With specific order of the Authority's Engineer rock bolts with a smaller proof load Pp (according to BS EN 1537), due to smaller shaft friction may be installed. The characteristic anchor resistance Rak of the rock bolt is therefore determined with the factor Ra (according to BS EN 1537) based on the suitability tests. Further quality testing is based on the characteristic anchor resistance Rak.

9.11.1.2 Quality tests during tunnel excavation

The Authority's Engineer will select 5 % of all rock bolts, which shall be tested. The test quantity can be reduced to 3 % of all rock bolts, in case of on-going positive test results and in agreement with the Authority's Engineer. TheAuthority's Engineer may order additional quality tests in case of a high failure rate of the rock bolts with no additional costs for the Employer. The quality tests shall be conducted in attendance of the Authority's Engineer and only with hydraulic presses. The test results shall be documented and forwarded to the Authority's Engineer for review.

The pre-stressing of rock bolts, chosen by the Authority's Engineer, shall be tested with adequate torque wrench. The bearing capacity of rock bolts shall be ensured by pull out tests. The testing stress is 80 % of the critical strength (= characteristic bearing capacity Ptk according to BS EN 1537) of the bolt system.

Bolts which fail the tests or which are pulled out shall be replaced. For each failure, the Authority's Engineer shall require further bolts to be tested in the vicinity.

9.11.2 Grout Mortar

Prior to acceptance tests of rock bolts, tests with available cements and sands shall be carried out to determine an appropriate mix design to achieve the specified strength and a proper workability in association with the grouting equipment used.

Additives may be used to improve workability. The influence of the additive on the strength development shall be followed by tests. The grout mortar shall be tested on cubes 5 x 5 x 5 cm. The cubes shall be cured in water. Five numbers of cubes shall be prepared for each compressive strength test. The resultant strength is the average evaluated from the three remaining values after elimination of the highest and the lowest value.

During construction, cube sample shall be taken weekly at each five bolts drivage from the grouting hose at the nozzle. Preparation and evaluation shall follow the procedure as described above.

9.11.3 Shotcrete

The testing procedure and quantity of tests shall be in accordance to "Guideline for Sprayed Concrete", Austrian Society for Concrete- and Construction Technology, 2005, Austria.

An Authority's Engineer shall be on site at all times to check the consistency of materials and workmanship with the design intent, and to ensure that ground and groundwater conditions are in accordance with design assumptions. The Contractor shall establish a procedure to respond effectively to changes in ground and groundwater conditions from the design assumptions.

The Contractor shall establish and maintain the instrumentation and monitoring required by the design. The Contractor shall establish a procedure that will enable prompt and regular review and effective response to the results from the instrumentation and monitoring. The shotcrete lining designer shall be included in the monitoring review procedure.

9.11.3.1 Strength

The compressive strength of sprayed concrete after 28 days shall be in accordance with BS EN 206-1, with minimum concrete strength class C25/30. According to BS EN 13791 a reduction factor of 0.85 can be applied for cores from in-situ concrete. The early-strength development shall conform to Table 12, unless otherwise specified in the detailed design.

Table 12: Sprayed concrete early strength development for a C25/30 mix,

Age	Uniaxial compressive strength (cube), MPa
1 h	0.5
3 h	1.0
9 h	2.0
12 h	2.5
24 h	5.0
28 d	30.0

The concrete shall not show any decrease in strength with time.

9.11.3.2 Field suitability tests – preconstruction tests

Prior to first application of shotcrete mixture in the tunnel the field suitability tests under construction conditions using concrete components intended for executing the construction job shall be performed and approved by the Authority's Engineer. Field suitability tests determine the early and final strength of the intended shotcrete mixture. If the conditions or the mixture of the shotcrete vary to the tested ones, the field suitability test has to be repeated.

The equipment proposed for the application of concrete in the Works shall be used for the trial. The trial will establish whether the selected equipment is capable of efficiently mixing concrete, accelerator and air at the nozzle, and is capable of positioning the nozzle at a suitable distance and orientation to the surface geometry of the structure to which the concrete is to be applied.

For each mix design a trial mix shall be sprayed into test panels (3 Nos. per trial mix). Different dosages of the accelerating admixture shall be tested following the recommendation of the accelerator manufacturer.

If a particular quality of finish is required other than as sprayed, the trials will evaluate the methods and tools to be used to achieve the required finish and the Authority's Engineer will approve the method and quality of finish achieved.

The compressive strength development up to 1.2 N/mm2 shall be determined indirectly by the Penetrometer using a plunger of 3 mm diameter according to Clause 12.3.1.

The compressive strength development in the range between 2 and 16 N/mm2 shall be determined using the bolt-driving method according to Clause 12.3.2.

The compressive strength above 10 N/mm2 shall be determined by crushing of cylindrical shotcrete specimens. After spraying, the test panels shall be covered and not be moved for 18 hours after spraying. Cores for strength testing shall be obtained from the panels between 18 hours and 1 day. The cores for determination of final strength shall be stored in water until 3 days before testing. The specimens shall have a diameter of 100 mm and be cut to a height of 100 mm. The average value of five test results shall exceed the strength specified in Clause 9.3.1 by 5 N/mm2.

If required by the Authority's Engineer, the trial shall include the construction of the proposed joints including layer joints and advance joints.

Should any mix fail to produce satisfactory sprayed concrete, the Contractor shall repeat the construction of test panels and test the same mix, plant and labour or make such adjustments as he considers as necessary.

9.11.3.3 Quality control tests

The performance requirements shall be set by the Designer.

The strength class of the shotcrete shall be ensured by the quality tests. If the strength class of the tested shotcrete is smaller than the required one, adequate measures shall be performed to secure the shotcrete strength. The Authority's Engineer shall, in the event of repeated failure in Quality Control, require the Contractor to adjust the mix to achieve the required strength. A new quality test shall be performed if differences in the mixture of the shotcrete will be taken.

In sections where the strength class can't be ensured, the thickness of the shotcrete layer may be increased, by order from the Authority's Engineer, based on following equation:

$$d_1 = \left(\frac{F}{M} - 1\right) \cdot d$$

F is the required compression strength in N/mm², M is the measured compression strength in N/mm², d is the required theoretical shotcrete thickness in cm and d1 is the additional required shotcrete thickness in cm.

The Contractor shall keep a record, in a form to be agreed with the Authority's Engineer, of all tests on sprayed concrete, which shall be kept on site identifying the tests with the section of work to which they relate.

The testing procedure and quantity of tests is according to the Austrian Guideline "Sprayed Concrete". A summarize is given by following clauses.

Site-specific calibration is required for the strength tests of young sprayed concrete as per BS EN 14488-2. Every 500 m³ of shotcrete delivered to the site, the early strength of shotcrete up to 30 minutes and at 1 day shall be tested. The test results shall comply with the requirements for early strength given in Clause 9.3. Every 500 m³ of shotcrete delivered to the site, the in-situ final strength of shotcrete shall be tested. The specimens shall be prepared by means of core drilling at random places from the tunnel lining after 1 to 3 days but as close as possible to 24 hours after placing. The specimens shall have a diameter of 100 mm and be cut to a

height of 100 mm and water stored until 3 days before testing. The average 28 days strength of five cores shall exceed the strength specified in Clause 9.3

Where the nominal required sprayed concrete thickness is less than 100 mm, the cores for the compressive strength testing shall be taken from areas where the actual thickness is greater than 100 mm. Alternatively additional sprayed concrete thicknesses shall be applied in selected areas agreed by the Authority's Engineer for subsequent coring of test specimens.

All required drillings for the testing procedure shall be filled with concrete subsequent.

9.11.3.4 Measures on strength failures

Failure of 1 day compressive strength tests: 1) Inform the Tunnel Designer's Representative and the Authority's Engineer, 2) Immediate examination of tunnel lining in suspect area, 3) Immediate examination of elements concerned in making, transporting and placing of shotcrete, 4) Assess the results of the geotechnical monitoring program to determine any correlation between non-conformance and tunnel deformation behaviour, 5) Prepare to take further tests at three days, 6) Take further compression tests as soon as possible, 7) The Contractor may propose measures for strengthening of the area for approval of the Authority's Engineer.

Failure of final strength: 1) Inform the Tunnel Designer's Representative and the Authority's Engineer, 2) Further cores shall be taken from the tunnel lining in the vicinity of the failed specimen to establish the area of non-conformance, 3) Assess the results of the geotechnical monitoring program to determine any correlation between non-conformance and tunnel deformation behaviour, 4) The Contractor shall propose measures - if any - for strengthening of the area for the approval of the Authority's Engineer

9.11.3.5 Thickness of shotcrete

Measures to establish the total thickness of shotcrete shall be set up by the Contractor and approved by the Authority's Engineer. These may include visual guides installed prior to shotcreting or holes drilled after completion of shotcreting.

All required drillings for the testing procedure shall be filled with concrete subsequently.

The thickness of shotcrete is defined as a minimum thickness, consequently the shotcrete shall not be less than nominal design thickness at any place. 5 independent tests shall be done per every 500 m^3 of applied shotcrete per construction element (e.g. tunnel lining, shaft lining, slope support…).

9.12 Cross Section Check of Primary Lining

9.12.1 Tolerances

No reduction of the theoretical thickness of the inner concrete lining is permitted unless it is approved by the Authority's Engineer. To achieve this requirement, no support elements such as shotcrete, anchor heads, steel ribs etc. may protrude into the theoretical inner concrete lining, as shown on the drawings.

The primary lining must be constructed outside the inner lining and inside the overbreak-line at any point.

In the area of the invert and the foundation beams no rock parts or rock peaks may protrude into the theoretical excavation line.

For tunnel sections with no concreted invert arch the Contractor shall excavate the bottom level of the invert with an accuracy of +0 to -100 mm related to the theoretical excavation line of the invert.

If the bottom excavation level, after the clearing of all detritus material, is more than 100 mm below the designed theoretical excavation line, the Contractor shall backfill such areas up to the designed, theoretical level by means of sub-base material or as directed and approved by the Authority's Engineer.

For tunnel sections with a concrete invert arch no reduction of the designed, theoretical thickness of the concrete structure is permitted. Over excavation must be compensated with structural concrete for the invert arch as specified or as directed by the Authority's Engineer. The inside face of the invert arch may deviate not more than +/- 50 mm in elevation from the theoretical cross section.

9.12.2 Profile Control

The final geometry of the primary lining shall be checked solely and systematically by the Contractor in order to accommodate the designed nominal thickness of the inner concrete lining. After incremental displacements are smaller than the permitted displacement velocity and prior to the water sealing construction, the Contractor shall measure the excavated profile by electronic means, or another method approved by the Authority's Engineer.

Provision is made for the final concrete lining to be cast using a rail mounted shutter running on footing beams constructed to the designed longitudinal alignment levels and cross falls at each side of the tunnel.

It is the Contractor's responsibility to ensure that the minimum clearance for the

final lining, as shown on the drawings, is provided. In order to establish deviations from the theoretical profile the Contractor shall provide a gantry furnished with a template set to show the minimum profile required to give the nominal thickness of the final concrete lining. The gantry shall be designed to move along the rail tracks to be used for the movement of the tunnel shutter and is to provide access for the marking out of the areas of the initial lining which protrude into the minimum clearance zone.

The Contractor shall submit full details of the design of the gantry with its template for the approval of the Authority's Engineer. On approval the Employer's

Representative will issue instructions with regard to the systematic checking of the geometry of the template during profiling operations.

The Contractor may prefer to use advance surveying techniques and data processing to establish the final clearance profile. The Contractor shall define a method of marling out areas of deviation from the theoretical profile to be approved by the Authority's Engineer.

The clearance checking of the primary lining shall not commence until the rate of convergence at any of the adjacent monitoring stations is more than 2 mm per month.

Any deviations from the theoretical clearance profile shall be made good, either by providing extra shotcrete or inner lining concrete in the case of excess clearance, or by re-profiling any parts of the tunnel support protruding into the clearance profile. Contractor is responsible for these Works without any extra payments. The remedial Works shall be in agreement with the Authority's Engineer. No re-profiling shall be carried out without approval by the Authority's Engineer. If the thickness of the re-profiling layer is more than 1/3 of the primary lining thickness or if an area is larger than 5 m^2 detailed procedures including structural stability proof shall be elaborated and shall be reported in a written document to the Authority's Engineer prior to commencement for approval. The Structural safety of the tunnel shall not be endangered due to re-profiling and is secured by geotechnical measurements prior, in between and afterwards. Measurement equipment in the re-profiling area shall be replaced in adequate vicinity.

Records shall be kept for each stage the remedial measures executed.

The final clearance profile shall be recorded at intervals in longitudinal direction and points along the periphery of the tunnel as proposed by the Contractor in agreement with the Authority's Engineer.

The final checking of the clearance profile after completion of re-profiling and

surface shall be done in presence of the Authority's Engineer.

10 CONCRETE WORK

10.1 Concrete

Concrete shall be mixed, charged, applied, cured and tested according to given Specifications which are based on "Specification for tunnelling" by BTS and the Indian Standards. For the tunnel inner lining and where these Specifications do not cover all aspect the "Guideline for Inner Shell Concrete", Austrian Society for Concrete- and Construction Technology, 2006, Austria shall be applied.

10.1.1 General

All structural elements must be designed for fire load if required according to the above mentioned standards and guidelines.

The final lining cross section geometry shall be checked and the tolerances shall be in accordance with these Specifications.

If squeezing ground conditions are observed during primary lining construction, stress gauges and pressure cells shall be installed in the final lining to monitor the actual stress-strain condition of the final lining. Minimum three stress gauges and pressure cells shall be installed in cross sections where squeezing ground conditions are encountered or as directed by the Authority's Engineer. Records shall be kept available at site and submitted to the Authority's Engineer for review.

Concrete and concrete constituents and all materials and operations relating to concrete shall meet the requirements of the Indian Standards Code of Practice for Plain and Reinforced Concrete IS 456 unless otherwise specified herein and as required by the Authority's Engineer.

Where concrete is to be placed in aggressive ground, appropriate ground investigation shall be undertaken to identify the nature of the chemical composition of groundwater and ground.

The grade and properties of the concrete used in each part of the work shall be as stated on the drawings or in the Specification.

No material shall be added to ready-mixed concrete at the site unless approved by the Authority's Engineer. Full responsibility shall be taken for ensuring that any materials added to ready-mixed concrete on site not causes the concrete to fail the quality control testing requirements of this Specification. Items made from such concrete which fail the quality control testing shall be rectified.

Concrete is not permitted to contact to aluminium during mixing, conveying and placing.

10.1.2 Concrete Requirements

Concrete mixed by the Contractor or any other Sub-Contractor shall comply with the exposition classes and strength classes as defined in the approved detailed design drawings and BS EN 206-1.

The maximum chloride content of concrete shall be in accordance with IS 456.

Chloride content class for concrete containing steel reinforcement shall be Cl 0.20 (maximum Cl content by mass of cement 0.20%) and for concrete containing pre-stressed steel reinforcement Cl 0.10 (maximum Cl content by mass of cement 0.10%), unless otherwise directed by the Authority's Engineer.

Consistence of concrete mix, other than concrete mix used for tunnel lining, shall be in compliance with IS: 456.

10.1.3 Concrete Composition

10.1.3.1 Aggregates

Aggregates shall be supplied only from sources approved by the Authority's Engineer. The Contractor shall demonstrate compliance with laboratory tests that shall be made at regular intervals to confirm the suitability of aggregate.

Approval of a source shall not be constructed as constituting acceptance of all materials from that source.

The quality of all aggregates used in the work, including processing such as washing, classifying, screening, rescreening crushing and blending, necessary to meet the required Specifications, shall all be subjected to acceptance of the Authority's Engineer.

Aggregate shall be free from earth, clay, loam and soft, clayey, shaley or decomposed stone, organic matter and other impurities and shall be hard and dense.

Aggregates shall not contain any other matter likely to affect the long-term durability of the concrete. Reference is to be made to the BRE Digest 330 for guidance in reducing the risk of deleterious alkali–silica reaction to the absolute minimum.

Mineral aggregates shall comply with IS: 383 and BS EN 12620 respectively.

Tests shall be carried out in accordance with International Standards, as appropriate, and the results shall comply with the limits given therein, or as otherwise specified. Testing will be carried out to BS EN 932, BS EN 933, BS EN 1097 and BS EN 1744 as appropriate.

If necessary, fine aggregate shall be washed to remove excess fines.

Coarse aggregate shall be washed at the aggregate source. However, further washing at the batch plant may be required if the aggregate is found to be unacceptable to the Authority's Engineer.

Coarse aggregate shall be tested for drying shrinkage characteristics in accordance with BS EN 1367-4. The drying shrinkage shall not exceed 0.075%. Coarse aggregate delivered to the batching plant shall have an uniform and stable moisture content. The acid-soluble sulphate (SO3) level shall not exceed the values specified in BS EN 12620. The alkali reactivity of aggregates in combination with the proposed cement shall be tested in accordance with IS 383 and IS 2386.

The maximum permitted level of equivalent acid-soluble chloride ions (Cl–) for any single constituent or combination of the constituents of the concrete in the hardened mix shall not exceed the limits given in BS EN 206-1.

The total estimated sulphate content (SO3) shall comply with the limits given in BS EN 206-1. The water-soluble chloride ion content of the sand and coarse aggregate, combined in the proportions intended for a particular mix, shall not exceed the values given in IS 23 86; Methods of test for aggregates for concrete.

Hardness and abrasion characteristics of the aggregate will comply with BS EN 12620.

Water absorption shall not exceed the permitted value in BS EN 12620.

Where specific thermal characteristics of the mix are required, the aggregate will be appropriately selected and tested in accordance with BS EN 1367.

Each size of aggregate shall be stored separately in drained concrete-based bins or on stages to prevent intermixing and the inclusion of foreign materials. The size of aggregates shall be in accordance with IS 456 such as to establish the required properties of the concrete best. The grading of aggregates shall conform to IS:383.

10.1.3.2 Cement

The Contractor shall submit cement and cementitious material manufacturers' certificates in accordance with the relevant Standard. Details of all cements and cementitious materials shall be supplied including any alternative sources that might be used. The Contractor shall show that the quantity and quality required can be attained and maintained throughout the construction period. Any cement type proposed for usage in the Works shall be approved by the Authority's Engineer.

Cement shall comply with the requirements as per:

- IS 269 Ordinary Portland Cement, 33 Grade
- IS 8041 Rapid Hardening Portland Cement
- IS 8112 Ordinary Portland Cement, 43 Grade
- IS 12269 Ordinary Portland Cement, 53 Grade
- IS 12330 Ordinary Portland Cement, 33 Grade

Requirements to be met by cement (heat build-up, water segregation, fineness, C3A content, cement temperature) shall comply with BS EN 197.

Where Sulphate resistance is required, the selected cement will be appropriate to the required Design Chemical (DC) class.

Where specified or appropriate to use, blast furnace cements, Portland slag cements and blended ground granulated blast furnace slag (ggbs) cements will comply with the blending proportions specified in BS 8500-2.

Where specified or appropriate to use, Portland limestone cements and blended limestone cements will comply with the blending proportions specified in BS 8500-2.

Cementitious materials shall have a reactive alkali content not exceeding a value of 0.6% by mass and/or the total mass of reactive alkali in the mix shall be calculated and controlled to satisfy the requirements of BS 8500-2 and the British Research Establishment (BRE) Digest 330. Certification will be supplied by the producer to demonstrate compliance with BRE Digest 330.

Cementitious materials shall be supplied in bulk, unless such cementitious materials are to be used for mortar finishing, patching or grouting. Bulk cementitious materials shall be delivered to the Site in bulk carriers which shall be clean and dry prior to loading. All carriers for bulk or bagged cement shall be equipped with watertight closures for all openings. Immediately upon delivering to the site, cementitious materials shall be stored in dry, watertight, ventilated structures.

Cements which have exceeded the manufacturer's designated shelf life will not be

used and appropriate measures shall be taken for its safe disposal or return to the manufacturer.

10.1.3.3 Admixtures

No admixtures shall be permitted without written acceptance of the Authority's Engineer.

All admixtures shall be obtained from the same manufacturer to ensure compatibility between the admixtures. Technical details including data of all admixtures proposed to be used shall be forwarded to the Authority's Engineer for review. The Contractor shall carry out tests and trial mixes to determine that the admixtures are compatible with the other mix ingredients.

Unless otherwise specified by the Authority's Engineer, all admixtures shall be of a liquid type.

Handling and storing of admixtures shall be in accordance with the manufacturer's recommendations. Admixtures shall be stored in weatherproof buildings at a temperature not higher than 35 degree Celsius. Mechanical agitators shall be used for those admixture solutions required by the admixture manufacturer to be agitated prior to and during use.

Admixtures shall be in compliance with IS: 9103.

Water-reducing admixtures in liquid form shall comply with BS EN 206 and BS EN 934.

Admixtures shall not be mixed together prior to introduction to the mix.

The use of set-retarding and water-reducing admixtures shall be in agreement with the Authority's Engineer, unless otherwise specified in the Contract. Admixtures not covered by International Standards shall not be used.

Concrete containing fly ash shall not be air entrained, unless the Contractor supplies proof (from tests on trial mixes or previous production) that the amount of air entrained can be controlled within specified limits and that the compressive strength of the concrete will be satisfactory.

10.1.3.4 Additions

General suitability as a Type II addition is established for the following:

- fly ash conforming to BS EN 450-1

- silica fume conforming to BS EN 13263-1
- ggbs conforming to BS EN 15167-1
- metakaolin with an appropriate agreement certificate

General suitability as a Type I addition is established for the following:

- filler aggregate conforming to BS EN 12620 or BS EN 13055-1
- pigments conforming to BS EN 12878

10.1.3.5 Water

Water for concrete mixing and curing shall be clean and free from injurious amounts of oil, silt, salt, organic matter, acid, alkali, sediment or other deleterious substances and shall conform IS 456-1978 and BS EN 206 respectively.

Recycled water may be used provided controls are in place to demonstrate compliance with BS EN 206.

The Contractor shall supply, install, operate and maintain a system for water supply for concrete, mortar, shotcrete and grout manufacture. Not less than 40 days prior to the start of concrete production, shotcrete placement, or grout injection whichever occurs first, the Contractor shall submit to the Authority's Engineer details of the method by which the Contractor proposes to ensure a clean and adequate supply of water.

Alternative water storage facilities shall be provided to ensure that concreting, shotcreting and grouting operations will not be hindered by a temporary breakdown in the main water supply system.

The permissible limits for solids when tested in compliance with lS 3025 shall be as given in Table 13.

Table 13: Limits of deleterious material in water for concrete mixing

Deleterious material	**Max. permissible limit**
organic	200 mg/lit
inorganic	3000 mg/l
sulphates (SO4)	500 mg/lit
chloride (Cl)	500 mg/lit
suspended matter	2000 mg/lit

The pH value of the water shall not be less than 6.

10.1.3.6 Fibres

Fibres are generally accepted for use in concrete conforming to BS EN 206-1 and BS 8500 if the fibre conforms to BS EN 14889, an European Technical Approval.

Fibre-reinforced concrete will be trialled and tested to ensure it meets the designers' requirements before inclusion in the works. Historical data of the same fibre and dosage will be accepted in place of trials provided the data are deemed appropriate.

10.1.4 Temperature

Every effort shall be made to maintain the temperature of concrete during manufacture, placement and curing as per IS 7861 (Part I & II) unless otherwise specified herein.

The concrete temperature at the time of placing shall not exceed 27°C nor be less than 5°C. Fresh concrete temperatures of 13°C to 18°C are most favourable. Concrete and concrete constituents may be heated to reach the preferable concrete temperature. Heating of concrete or concrete constituents shall under no circumstances increase the concrete temperature above 27°C.

Aggregates shall be heated uniformly and carefully; all frozen lumps, ice and snow shall be eliminated before entering the concrete mix; average aggregate temperature shall not exceed 60 °C and maximum spot temperature shall be below 100 °C. Frozen aggregates shall not be used.

Mixing water shall not be heated exceeding 60°C.

To avoid surface cracking caused by heat generated during setting of concrete, the temperature difference between a measuring point at the surface and a measuring point in the centre of a concrete body, or 1000 mm inside the surface if the body is more than 2 m thick, shall be less than 20°C, if not otherwise approved by the Authority's Engineer. The location of the measuring point at the surface plane shall be defined as 10 mm inside the surface on a perpendicular projection of the structure member's centre point to the surface plane.

Temperature difference across construction joints shall be less than 15 °C at the time of concrete placement.

The maximum temperature during setting of concrete shall not exceed 40 °C except it is approved by the Authority's Engineer.

10.1.5 Mix Design

The selection design and quality control of mixes shall be carried out by the

Contractor or on his behalf by the manufacturer.

The Contractor shall design concrete mixes for each class of concrete. The concrete mixes shall be designed to produce a workable plastic mixture with the lowest slump that will suit the specified condition at the time of placement and will produce concrete of uniform consistency that conforms to the requirements specified for the various parts of the works.

In order to minimize thermal cracking, the cement content of all classes of concrete shall be the minimum necessary to produce the specified strength, permeability, freeze-thaw resistance and temperature rise requirements.

10.1.6 Mixing and Batching

10.1.6.1 General

The Contractor shall provide at the site, modern and dependable, automatically or semi-automatically controlled batching and mixing plant or plants, in an "as new" condition, capable of supplying concrete in accordance with the Specifications and at a continuous rate adequate to meet the requirements of his schedule for concrete placement. Each plant shall have not less than two concrete mixers, each with a separate power and drive system with a standby generator and other equipment to ensure a continuous supply of concrete during concrete placement operations.

10.1.6.2 Batching

The Contractor shall provide, operate and maintain all necessary equipment and plant required to determine accurately and to control the amount of each separate ingredient entering the concrete mix. The actual amount of fine aggregate, each size of coarse aggregate, cement, fly ash, admixtures, ice and water entering each batch of concrete shall be determined by automatic weighing of each ingredient separately and not cumulatively. All constituents shall be weighed or metered in compliance with the limits prescribed in BS EN 206.

Proportioning of concrete mixes shall be in accordance with IS 456-1978 and IS 4925.

Admixtures shall only be introduced using purpose-made equipment accurately calibrated. Where such equipment is unavailable, and where agreed with the Authority’s Engineer, alternative dosing methods to the manufacturer’s recommendations may be adopted.

Water shall not be added to concrete after it has left the mixer unless controlled, recorded and agreed with the Authority’s Engineer.

Where fibre reinforcement is added to the concrete mix, this shall only be introduced using purpose-made equipment.

All necessary measures shall be taken to prevent charging the batching plant with frozen aggregates. Aggregates in bins at the batching plant shall be kept above zero degrees Celsius at all times. Heating and cooling equipment shall be provided with sufficient capacity to heat or cool the water and aggregates to a uniform temperature so that the concrete will meet the placement temperature requirements.

Free access for testing and inspection of the cementitious materials shall be provided. The batchers shall be arranged that the loading cycle cannot start again as long as materials remain in the batchers.

A thermometer shall be installed in the cement day bin such that the operator can see readily the temperature of the cement at the time of batching.

The plant shall be equipped with a batching recorder which shall print the mass or volume for each material in each batch, identify the concrete mix being batched, the size of each batch in cubic meters, and the time and date of batching. The records shall be submitted to the Authority's Engineer at the end of each shift and shall become the property of the Authority's Engineer.

The accuracy of the measuring and weighing equipment shall be maintained so that the indicated mass does not vary by more than 0.6 per cent from the true mass throughout the range of use.

The measuring and weighing equipment shall be capable of being operated to control the delivery of materials so that the combined inaccuracies in feeding and measuring do not exceed the limits in Table 14.

The Contractor shall provide standard certified test weights and any other auxiliary equipment required for checking the operating performance of each measuring and weighing device. Unless otherwise required by the Authority's Engineer, check tests of equipment used for measuring water, cement and the admixtures shall be made at intervals not exceeding one month. Check tests of measuring and weighing equipment used for measuring fine and coarse aggregate shall be made at intervals not exceeding two months. The tests shall be made in the presence of the Authority's Engineer and the Contractor shall make such adjustments, repairs or replacements as the Authority's Engineer may deem necessary to secure satisfactory performance before further use of the measuring or weighing equipment will be allowed.

All aspects of the batching and mixing operation including quantities of aggregates, cement, fly ash, admixtures and water shall be automatically recorded.

Table 14: Batching tolerances

cement	2,0 % per weight
fine aggregates	3,0 % per weight
coarse aggregates	3,0 % per weight
admixtures	2,0 % per weight
water	1,5 % per weight

10.1.6.3 Mixing

The mixing plant shall combine fine aggregates, each size of coarse aggregates, cement, fly ash, admixtures, ice and water into a uniform mass and shall discharge the mixture without segregation.

The batching and mixing plant shall have capacity of batching and mixing concrete at a rate in excess of the Contractor's peak placing requirements. A standby mixer with a capacity of not less than 40% of the peak placing requirements shall be available at all times for use during critical concreting operations.

A mixer timer with an automatic lock which will not release the discharging mechanism until the completion of a pre-set mixing time shall be provided on all mixers.

Separation of coarse aggregate from the mortar shall be avoided by arranging the discharge mechanism so that the concrete will fall vertically into the receiving container or hopper.

Mixers shall be examined by the Contractor at regular intervals to ensure that wear on the blades and liners does not allow dead spots or agglomerations of mortar around the sides of the mixer. Mixers shall be cleaned of any hardened materials which have built up on the insides. Should a mixer at any time produce unsatisfactory results, in the opinion of the Authority’s Engineer, its use shall be discontinued until it is repaired or replaced.

Mixer performance tests shall be performed on all mixers, as soon as the equipment is in operating condition at the start of the Work, at least once every 30 days during the course of the Work and at any time the Authority’s Engineer suspects any type

of operating difficulties with the machinery. At the end of the mixing period prescribed by the Authority's Engineer for the test, two samples of concrete shall be taken.

When necessary mixing times shall be increased until the required uniformity and consistency of the concrete is adequate. Mixers shall not be used if they produce unsatisfactory concrete.

10.1.7 Conveying

Concrete shall be conveyed from the mixer to the place of final deposit without segregation, contamination, loss of ingredients, loss of entrained air, loss of slump or damage from exposure. Trucks, buckets, belt conveyors, pumps, chutes and drop pipes may be used for conveying concrete and shall be of such size, design and condition as to ensure a continuous and even supply of concrete at the point of delivery. Alternative methods will be required to prove their success in conveying concrete rapidly, without segregation and the loss of materials. All conveying equipment shall be supported independently of the forms.

Concrete conveying equipment shall be checked by means of site trials prior to general use for its ability to deliver uniform concrete as per Clause 10.1.11.1. Slump tests shall be made on samples of concrete taken from the first and last one-tenth of a batch of mixed concrete. If these slumps differ by more than 25 mm, the equipment shall not be approved for use until the condition causing the inconsistency is corrected. Concrete conveying equipment used shall be examined daily for accumulations of hardened concrete or mortar, or for wear of the blades. Where necessary, the uniformity test may be repeated.

The time elapsed between completion of the mixing of the concrete at the plant and its discharge at the forms shall not exceed 45 minutes for concrete agitated while in transit and 30 minutes for non-agitated concrete. These basic limits apply in the case of non-set-retarded concrete. For set-retarded concrete the limits may be increased. Open conveyances shall be covered against the weather when required by the Authority's Engineer.

Dispatch tickets or a record direct from the batching plant recorder shall be furnished to the Authority's Engineer with each batch of concrete recording the serial number of ticket, date, batch number, truck number, amount and class of concrete, location of placement, and time of mixing. At the end of each day or shift, the Contractor shall supply the Authority's Engineer with a written report concerning the quantity of each class of concrete and the number of batches produced.

Equipment to be used to convey the concrete shall not contain hardened concrete or

foreign materials.

In general, the use of chutes to convey concrete will not be permitted, except that chutes less than 3 m in total length may be used with acceptance of the Employer's Representative. The delivery end of the chute shall be as close as possible to the point of deposit. The chute shall be thoroughly flushed with fresh clean water before and after each run, the water used for this purpose being discharged outside the form.

Concrete in the walls and arches of tunnel linings shall be placed by a displacement type pump or by other approved methods by the Authority's Engineer. The equipment used in placing the concrete, and the method of its operations, shall be in a way to permit introduction of the concrete into its final location without high-velocity discharge and resultant segregation.

Concrete pumps shall have a variable speed control and shall be capable of pumping concrete containing 20 mm aggregate through delivery lines not less than 75 mm diameter and for a distance required for placement within the works to meet requirements of this Specification.

10.1.8 Placing

10.1.8.1 General

The Contractor shall develop a detailed plan of concrete lifts for each structure which shall show the location of all construction joints and all concrete lifts in the structure and shall take reinforcing steel bars, embedded parts and water stops into account. The submission shall include calculations supported by laboratory and full scale test data showing how the temperature control requirements will be achieved. The plan for each structure, which shall include detailed drawings, shall be submitted to the Authority's Engineer not less than 80 days prior to the start of concrete placement in that structure and not less than 20 days prior to the submission of reinforcing steel bar placement drawings, bar bending schedules and bar lists for that structure. The Authority's Engineer shall have the right to require the Contractor to move the location of any construction joint if the location proposed by the Contractor will have an adverse effect on the design and performance of the structure.

The construction joints shown on the drawings shall not be moved unless the Contractor can satisfy the Authority's Engineer that there is justification for the relocation and that there will be no adverse effect on the performance of the structure.

After the Contractor's plan for construction joints and concrete lifts has been

approved by the Authority's Engineer no additional joints shall be incorporated into the Works unless approved by the Authority's Engineer.

Details of proposed additional joints shall be submitted to the Authority's Engineer not less than 60 days prior to concrete placement at the location of the proposed additional joints.

Concrete shall not be placed in any part of the Works until the foundations, previously placed concrete, formwork, reinforcing steel bars, embedded parts and waterstops in that area have been inspected by the Authority's Engineer and permission has been given by the Authority's Engineer for concrete placing to proceed. Concrete shall be placed only in the presence of the Authority's Engineer.

All surfaces to be in contact with the in-situ concrete lining shall be thoroughly cleaned and scaled of all loose or defective material.

The surfaces of waterproofing membranes shall be thoroughly cleaned to remove any loose and foreign materials. They shall be cleaned by washing with a stream of air and water, but care shall be taken not to displace the membrane or its fixing and seals.

Concrete shall not be placed in still or running water and shall not be subjected to the action of running water until the concrete has set.

All formwork shall be true to form, securely made and supported, and joints shall be sealed to prevent the loss of cement from the mix. Where required, grout pipes shall be incorporated for pressure relief and subsequent grouting.

Concreting shall not commence until the formwork has been inspected and agreed with the Authority's Engineer.

The build-up of water pressure behind uncured linings shall be prevented. Concrete shall be placed continuously in each length of formwork. Concrete shall be protected from rain during placement.

The time between batching and complete discharge shall be less than 90 minutes and shall be such that the concrete can be placed and consolidated without the addition of extra water. The time between batching and complete discharge shall be reduced to a maximum of 60 minutes when the air temperature exceeds 25 degrees Celsius.

In order to reduce bleeding, slump shall not be higher than necessary to achieve proper placement and consolidation.

The depth of concrete placed in each lift shall be as shown on the Contractor's drawings. All concrete shall be deposited in approximately horizontal layers 50 centimetres in thickness at such a rate that the formation of cold joints will be prevented. Each new lift of concrete shall be placed on the oldest exposed lift.

Hardened or stiff concrete shall not accumulate on reinforcing steel or formwork. Partially hardened concrete shall not be re-tempered with or without additional aggregate, cement or water.

Once concrete placing has started it shall be carried on as a continuous operation until the placing of the lift is completed. The rate of placing shall be such that each successive layer can be vibrated and bonded into the previous layer.

When concrete is placed on an inclined surface, the placing operation shall begin at the lower end of the slope and shall progress upward.

The sequence of work within the tunnels or shafts shall be arranged as that no damage occurs to permanent linings. The proposed sequences and methods of operations shall be agreed with the Authority's Engineer.

Before any concrete is placed for tunnel linings the Contractor shall demonstrate to the Authority's Engineer that his concrete mix, equipment and working methods are capable of producing fully compacted concrete to the required surface finish. If required by the Authority's Engineer, this shall take the form of a trial length.

10.1.8.2 Preparation

Immediately after the removal of blasted rock, excavated rock surfaces against which concrete will be placed shall be scaled and cleaned to remove unclassified material, loose, broken and detached rock fragments and unsound, slaked, deteriorated and closely fractured rock which remain in the excavated surface of the rock. Where required by the Authority's Engineer, scaling and cleaning shall be followed by dental excavation to remove the unclassified material remaining in open and debris filled joints, cracks, fissures, seams, crevices, faults, shear zones and other relatively narrow openings. The purpose of scaling, cleaning and dental excavation is to produce a sound, intact, tightly anchored rock surface.

Scaling, cleaning and dental excavation will require the use of manual labour, with hand held pneumatic tools, shovels, bars, trowels, compressed air jets, high pressure water jets, brooms, brushes and other hand held tools. High pressure water jets shall not be used.

Foundation surface of the rock, concrete and shotcrete shall be protected against weathering and the deleterious effects of frost action, rain, groundwater seepage

and construction equipment until concrete placement commences.

Shotcrete in underground works shall be cut back so that no shotcrete protrudes inside the concrete payline (see 7.6 and 9.12).

Rock, shotcrete and concrete surfaces against which concrete is to be placed shall be kept continuously damp for a period of not less than 24 hours immediately prior to concrete placement.

Surfaces of reinforcing bars, forms and embedded parts shall be cleaned of all dried mortar, grout, oil and all other coatings except epoxy coating and galvanizing.

Immediately before concrete is placed, forms shall be inspected to ensure that the forms are accurately placed to the specified tolerances and are sufficiently rigid and braced to prevent movement during concrete placement and that all reinforcing bars are in the correct position and secured against movement during the placing operation. Chemicals shall not be used to remove ice or hardened concrete from the forms.

In hot weather or concreting on surfaces which are highly water absorbent, the surfaces against which concrete is to be placed, including reinforcement and formwork, shall be lightly sprayed with water to prevent excessive absorption of water from the fresh concrete. Pre-wetted surfaces shall be free from excessive water before concreting.

10.1.8.3 Placing

The concrete shall not be placed until the rate of convergence at any of the adjacent monitoring stations is less than 4 mm per month, unless otherwise approved by the Authority's Engineer.

Concrete shall be placed while still sufficiently plastic for adequate compaction and shall be carefully worked around all reinforcement and embedded fixture and corners of the formwork. Concrete shall be inspected at the point of placing.

There shall be no vertical drop greater than 1.5 m except where equipment such as tremie pipes and chutes satisfactory to the Authority's Engineer to use to confine and control the falling concrete. Horizontally movement of concrete exceeding 1.0 m by the use of vibrators is not permitted.

Concrete shall be placed as close as possible to its final position, in continuous near level layers not exceeding 500 mm. Each layer shall be compacted before succeeding layers are placed. The depositing of large quantities of concrete at any one point and running or working it along the forms will not be allowed.

Placing equipment shall be operated by experienced operators only. In general, the concrete placing shall continue uninterrupted until the structure is filled over the entire length of the formwork. In the event of equipment breakdown or if for any other unavoidable reason placing is interrupted, the Contractor shall thoroughly compact 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 water jet before the concrete achieves a primary set, to provide an irregular clean surface free from laitance. Prior to restarting concreting, the surface shall be wetted. The work shall be carried out in a way that a sound dense homogeneous structural element is produced.

The concrete which forms the openings to caverns and niches or other recesses shall be placed concurrently with the concrete in the parent tunnel at the same cross section.

Concrete shall not be subjected to disturbance between 4 hours and 24 hours after placing.

10.1.8.4 Consolidation

As concrete is being placed, it shall be compacted thoroughly and uniformly by means of vibrators, supplemented by hand spading, ramming, and tamping to produce dense, homogeneous concrete, that is at its maximum density, that is in complete contact with forms, that is effectively bonded to the reinforcing steel bars and the embedded parts and that has smooth formed surfaces, free of air pockets and blemishes.

Concrete shall be consolidated with the aid of approved immersion type mechanical vibrators complying with IS 2505. Immersion vibrators shall be a minimum of 40 mm in diameter and shall be capable of transmitting vibration to the concrete at frequencies in excess of 150Hz or 4000 rpm and shall visibly affect the concrete at a radius of 300 mm.

At least one vibrator in working order shall be held in reserve for emergency use.

Concrete vibrators shall not be used for moving concrete. Vibrators shall be operated as nearly as practicable in a vertical position. The vibrating head shall be allowed to penetrate under its own weight until it can re-vibrate the top 5 centimetres of the underlying concrete layer. The vibrator 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. Vibrators shall be inserted at uniform spacing over the entire area of placement. The distance between insertions shall be approximately 1.5 times the radius of action of the vibrator. Vibrators shall

be held stationary until the concrete is consolidated and then withdrawn slowly. The concrete ingredients shall not be allowed to segregate and no laitance shall be allowed to appear on the surface. Vibrators shall not come in contact with nor disturb embedded parts, waterstops, reinforcing steel bars and formwork.

Particular care shall be taken with the compaction of concrete surrounding water bars to avoid honeycombing and to prevent the displacement of the water bar. Care shall also be taken to avoid displacement of pre-fixed pipes, block-outs, thermocouples and the like.

Where placing concrete for tunnel linings, formwork vibrators shall be used for compacting concrete in the tunnel arch above the highest openings in the formwork. They shall be operated at intervals of not more than 1.2 m behind the advancing slope of the concrete in the shoulders and crown of the arch. The location and operation of the vibrators shall be carefully coordinated with the withdrawal of the discharge line so as to avoid settlement and flow of the concrete from the filled crown.

10.1.8.5 Finishing

The surface of formed and unformed concrete shall be within the specified allowable deviations from the lines, slopes, elevations and dimensions shown on the drawings and shall be smooth and uniform in texture and free from streaks, discoloration and surface irregularities to the extent specified herein.

Any damage to finished concrete resulting from the action of removing from work or any other cause shall be repaired to the satisfaction of the Authority's Engineer.

Formed Surfaces:

Table 15: Formed concrete finishes

F1	No specific requirement
F2	The irregularities in the finish shall be no greater than those obtained from the use of wrought thickness square-edged boards arranged in a uniform pattern. Fins shall be removed and imperfections shall be made good.
F3	The resulting finish shall be smooth and of uniform texture and appearance. The formwork lining shall leave no stain on the concrete and shall be so joined and fixed to its backing that it imparts no blemishes. It shall be of the same type and obtained from only one source throughout any one structure. The Contractor shall make good any imperfections in

the finish. Internal ties and embedded metal parts shall not be used

All formwork joints for F2 and F3 finish shall form a regular pattern.

Unformed Surfaces:

Table 16: Unformed concrete finishes

U1: Screened finish	The concrete shall be levelled and screeded. No further work shall be applied to the surface unless it is a first stage for a wood float or steel trowel finish.
U2: Wood float	A pre-screeded finish shall be floated with light finish pressure using a wooden float to eliminate surface irregularities.
U3: Steel trowel finish	A steel trowelled finish shall be first wood-floated and then trowelled under firm pressure with a steel float to produce a dense, smooth, uniform surface. The final surface shall be free from trowel marks.

When required by the Authority's Engineer and before commencing concreting the Contractor shall prepare a trial panel to demonstrate that the required surface finish can be achieved by the equipment and methods proposed. The panel shall be filled with the proposed concrete compacted by the method to be used in the work. When agreed with the Authority's Engineer the trial panel shall be retained and will form the benchmark against which all Works concrete shall be prepared.

Where the concrete surface is to receive waterproofing it shall be in accordance with the waterproofing system manufacturer's recommendations.

Permanently exposed concrete surfaces shall be protected from rust marks and all kinds of stains.

After removal of the formwork no treatment, other than that approved for curing, shall be applied to the concrete until its surfaces have been inspected by the Authority's Engineer.

Where any surface fails to comply with the Specification in respect of finish, dimensional tolerance, or in any other way, the Contractor shall rectify the work as

agreed with the Authority's Engineer.

The Contractor shall be responsible for preventing any damage to the finished concrete surfaces, and shall adopt any necessary protective measures to prevent subsequent staining from any cause.

10.1.8.6 Curing

The concrete shall be protected from damage due to load overstress, heavy shocks, excessive vibrations and the effects of rain and running water particularly during the curing period.

Curing and protection of concrete in cold weather shall be carried out in compliance with IS 7861 Part.

All concrete should be allowed to cure by methods which will ensure the production of concrete of the specified quality. Curing materials and methods shall be compatible with any subsequent waterproofing.

In general, concrete shall not be placed when the temperature at the location of the Work is below, or likely to fall below, 5°C before the section of work can be completed except in emergencies.

Concrete shall be continuously moist cured from the time that the concrete has hardened sufficiently to prevent damage to the surface finish and shall be continued for not less than 14 days for concrete not containing fly ash and 21 days for concrete containing fly ash or until fresh concrete has been placed on or against the concrete surface or until a membrane curing compound has been applied. All material and equipment required for adequate curing and protection shall be on hand before concrete placement begins.

Concrete shall be protected from exposure to rain for 12 hours, from exposure to the sun for 72 hours and from exposure to flowing water for 14 days. For concrete surface temperature below 5°C, the duration of curing shall be extended for the number of days the temperature has been below 5°C. Concrete shall be moist cured by maintaining the surfaces continuously wet for the duration of the specified curing period. During the curing period concrete shall not be intermittently wetted and allowed to dry. Curing water temperature shall not exceed 25 grade Celsius or above the expected minimum ambient temperature of the curing period.

At least 14 days prior to the use of curing compound, full details of the proposed compound shall be submitted to the Authority's Engineer for review. Such details shall be accompanied by test certificates to show that the compound will give satisfactory results for the proposed application.

Curing compound shall be wax-based compounds and shall be approved by the Authority's Engineer. The compound shall be applied in strict accordance with the manufacturer's Specification and shall be applied as soon as the surface water has disappeared.

Curing compounds shall be delivered to the Site in suitably labelled containers to enable identification of the batch number and date of manufacture.

Curing compounds shall comply with the requirements of ASTM C309.

For each curing compound proposed for use in the Works, the Contractor shall obtain a Certificate of Compliance from the supplier, supported by test certificates from a laboratory with appropriate registration, certifying that the curing compound complies with this Specification.

The curing compound shall be applied by a pressurised sprayer to give a uniform cover. The sprayer shall incorporate a device for continuous agitation and mixing of the compound in its container during spraying.

The curing compound shall be applied using a fine spray at a rate of 0.2 litres/m² and per coat or otherwise directed by the Authority's Engineer. The application rate shall be checked by calculating the amount of curing compound falling on felt mats, each approximately 0.25 m2 in area, placed on the concrete surface.

Two coats shall be applied at the full rate. The curing compound shall be applied to unformed surfaces immediately after completion of all finishing operations, and to formed surfaces within half an hour of the removal of formwork from the section.

10.1.9 Joints

Joints in concrete are either movement (deflection, expansion or contraction) joints or construction joints. All construction joints shall comply with IS 11817.

Joints shall be formed on horizontal or vertical planes except for joints in tunnel linings which shall be formed on radial planes.

Joints in horizontal planes, which intersect with exposed surfaces making an angle of 45° or more with the horizontal, shall be truly horizontal. Joints in horizontal planes, which intersect with exposed surfaces making an angle of less than 45° with the horizontal, shall be formed to provide at least 75 mm of surface normal to the slope of the surface.

Construction joints shall be positioned only where agreed with the

Authority's Engineer. The Contractor's proposal on constructions joints shall be given on lift drawings submitted to the Authority's Engineer for review.

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.

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 to a depth of not less than 3 mm 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.

At horizontal construction joints on exposed surfaces forms shall be constructed with strips to produce a straight joint at the exposed surface, unless otherwise directed.

Movement joints shall be constructed as shown on the drawings. The Contractor shall provide the various joint components and install these in accordance with the drawings and the manufacturer's recommendations, or as directed or approved by the Authority's Engineer.

Any material used for expansion joint filler shall be approved by the Authority's Engineer.

Sealing compound is applied as surface sealant for movement joints or other boundaries of construction elements. The compound shall be polyurethane-rubber type or other type approved by the Authority's Engineer. 56 days prior of any sealing compound is applied, the Contractor shall submit a sample of the proposed sealing compound together with the manufacturer's technical data and the details of the recommended method of application for approval.

10.1.10 Water Stops

Water stops shall be installed as shown on the drawings or as directed by the Authority's Engineer.

Detailed information on all water stops, their properties, installation and standard support, shall be submitted to the Authority's Engineer for approval. Only approved

water stops shall be used in the Works and the manufacturer's regulations and instructions shall be followed.

All joints of sealing strips shall be welded by the appropriate device to the tensile strength at least 80% of the initial material.

Prior to any concrete work the water stops shall be placed as given in the drawings and adequate measures shall be made to prevent a dislocation of water stop due to concreting works.

Thermoplastic sunken sealing strips for construction joints shall be in compliance with DIN 18541.

10.1.11 Quality Check & Tolerances

The Contractor shall keep logs on all his concrete activities, i.e. production, placing, supervision and production control, inspection and testing. These logs shall be available to the Authority's Engineer for examination at any time.

The Contractor shall supervise and inspect the concrete works so as to fulfil the provisions of this Specification. This applies to the inspection of materials and products, of concreting execution, of false work and form-work, of reinforcement, of concreting operations and of pre-cast concrete elements.

The Authority's Engineer may at any time, unless critical concrete work is done, inspect and test any Contractor's equipment intended for batching, mixing, transporting, placing and testing concrete.

10.1.11.1 Trial Mix Testing

In conjunction with the design of concrete mixes, the Contractor shall complete a laboratory trial mix program for each class of concrete. The trial mix program will be used to confirm to the satisfaction of the Authority's Engineer, that the proposed concrete mix designs will produce concrete having the properties required by the Specification with minimum cement content.

Unless otherwise agreed with the Authority's Engineer, field trial mixes shall be prepared under full-scale site conditions at least 35 days before the commencement of concreting and tested in accordance with IS 10262, BS EN 12350 and BS EN 12390.

For each concrete plant proposed by the Contractor the field trial mixes shall be tested separately.

The field trial mixes shall be tested to determine compliance under statistical evaluation where required by BS EN 206. An acceptable value for the limits of the required properties shall be established during the trials which shall thereafter be used to monitor the Quality Control of the mixes and set the standard of compliance.

In the event quality control tests indicate that concrete below the specified standards is being produced, the Authority's Engineer may order such adjustment of mix design, additional quality control, or other measures as it may deem necessary to raise quality to specified standards.

If, at any time during the Work, the Contractor proposes to change or modify the source, type or quality of any concrete material or materials for the selected concrete mix designs, the laboratory testing program shall be repeated for each class of concrete affected by the proposed change.

Detailed test results on the concrete mix designs with changed or modified materials shall be submitted to the Authority's Engineer not more than three days after the completion of each test.

The 28 day compressive strength test results and details of the changes or modifications to the concrete mix designs proposed by the Contractor shall be provided to the Authority's Engineer before the changed or modified concrete mix designs are used to produce concrete for the works.

The following minimum values of samples shall be taken for trial mix testing:

- nine compression test cylinders (3 for each of 3, 7 and 28 days)
- six shrinkage test prisms
- three test cubes (200 mm) or slabs (200 mm x 200 mm x 120 mm) for water permeability testing according to DIN 1048 Part 5
- one specimen for sulphate and chloride testing

10.1.11.2 Conformity Control of Concrete

In the event the specified strength criteria are not met, the Authority's Engineer may, if he deems it necessary, require that the unacceptable concrete be cut out and replaced.

The conformity control of strength parameters required shall be demonstrated in accordance with BS EN 206-1. Specimens tested to demonstrate compliance will be cubes, cylinders or prisms appropriate to the testing standards and BS EN 206-1.

Test samples shall be made, cured, stored, transported and tested according to BS

EN 12350 and BS EN 12390. Spot samples will not be used to evaluate strength parameters. Concrete cube test results will be acceptable if statistical analysis of the results meets the requirements of BS EN 206-1.

Concrete shall be tested for durability properties by means of absorption and capillary suction (sorptivity) tests (RCPT) where appropriate. An appropriate test method will be agreed by all parties before testing is undertaken.

Compaction factor, slump, Vebe, flow table or other workability tests shall be carried out as required during concreting of permanent works to control workability at the batching plant and at the site of the pour. The degree of workability shall be as specified or as determined during the trial mixes. Permitted tolerances shall be in accordance with BS EN 206. Samples tested will be either spot samples or composite samples taken in accordance with BS EN 12350-1 and the appropriate tolerances for compliance will be applied in each case.

Where inspection reveals non-conformity, appropriate measures shall be taken in accordance to EN206-1 and in agreement with the Authority's Engineer.

10.1.11.3 Production Control of Concrete

All concrete shall be subject to production control by the Contractor in accordance to EN 206. All data of production control shall be recorded by the Contractor and made available to the Authority's Engineer at any time.

10.1.11.4 Tolerances

Surface finishes shall generally conform to the types and tolerances indicated in Table 17 unless otherwise specified herein, as shown on the drawings or as required by the Authority's Engineer.

The Contractor shall carry out a cover meter survey over all reinforced concrete surfaces within 24 hours of removal of formwork. The cover survey shall be undertaken on a 500 mm grid over the whole structure. Access for the Authority's Engineer to verify cover meter surveys shall be provided.

The deviation of the inner face of the concrete lining according to the theoretical cross section may in general not exceed 50 mm to the inner side. At the lower side wall (walkway level/cable duct) the deviation of the inner face is limited to the inner side in order to maintain minimum dimensions of the cable ducts. Pre-cast concrete cover plates for the cable ducts shall be fabricated based on the as-built survey results. No tolerance will be permitted inside of the specified clearance profile for vehicles or pedestrians.

In any case and for all specified deviations permitted, the specified theoretical thickness for the inner concrete lining as well as the specified clearance profile for the roadway and the walkways shall be maintained.

Niches, recesses and similar structures are to be constructed with a tolerance of +/- 50 mm related to the designed stationing.

Pre-cast elements and other structural elements are to be constructed and placed with a tolerance of +/-15 mm, related to the theoretical tunnel cross section.

Table 17: Types and tolerances for finishing of concrete surfaces

Type of finishing	General areas of application and method of forming	Tolerances in mm
F1	Formed surfaces of construction joints and other surfaces which will not be permanently exposed, including surface upon or against which backfill or concrete is to be placed. Minor blemishes caused by entrapped air or water will be accepted. In general the surface will require no treatment after form removal, other than repair of defective concrete and specified curing, or treatment as specified for construction joints.	+10
F2	All permanently exposed formed surfaces for which type F3 finish is not specified. For which sheating or lining shall be placed so that joint marks on the concrete surface will be in general alignment, both horizontally and vertically, and conform to a standard pattern. Immediately on the removal of forms, all unsightly ridges or fines shall be removed, all holes left by removal of ends of form rods shall be neatly filled with mortar and surfaces treated to meet the required tolerances by tooling and rubbing. In general, not more than 50 air voids of 5-15 mm diameter per m' will be accepted. Air voids exceeding 15 mm in diameter shall be repaired. When filling holes and repairing defective areas of permanently exposed surfaces, effort shall be made to match the colour of the concrete. The use of release agents which may permanently stain or discolour the finished surface will not be permitted.	+5 -5
F3	Formed surfaces which will be exposed to flowing water.	+3 -3

	These surfaces shall be hard, smooth and dense, free from offsets, pits, voids, air holes and irregularities and shall be chipped, ground and thoroughly cleaned as necessary to conform to the required tolerances.	
U1	Unformed, screeded surface which will be covered by fill materials, static water or concrete. Type U1 finish shall be used as the first stage. Types U2 and U3 as finishes. Finishing shall consist of sufficient levelling and screeded to produce an even, uniform surface meeting the required tolerance.	+10 -10
U2	Unformed surfaces not permanently concealed by fill or concrete or not required to receive Type U3 finish. Floating by means of hand or power driven equipment shall be started as soon as the screeded surfaces has stiffened sufficiently, and shall be the minimum necessary to produce a surfaces that is free from screed marks and that is uniform in texture. If type U3 finish is to be applied floating shall be continued until a small amount of mortar without excess water is brought to the surfaces so as to permit effective trawling.	+5 -5
U3	Unformed, screeded surfaces which will be exposed to flowing water. This finish shall be applied by steel trawling after the concrete has hardened enough to prevent excess of fine materials and water from blemishes, ripples and trowel marks. After the surface has nearly hardened, it shall be trowelled once more until the surface is hard and glossy in appearance.	+3 -3

10.1.12 Repair of Damage

All irregularities on concrete surfaces shall be repaired to produce smooth, uniform surfaces that conform to the tolerances specified herein for the finishes shown on the drawings.

The Contractor shall notify the Authority's Engineer not less than 24 hours prior to the start of any concrete repairs.

Surface irregularities shall not be repaired until they have been inspected by the Authority's Engineer. The Authority's Engineer will inspect the surface

irregularities and determine whether the surface irregularities shall be repaired by cutting out the concrete to a depth of 75 millimetres beyond the reinforcing bars and filling the cavity with cement mortar or concrete, or whether the concrete shall be cut out to a shallower depth and the cavity filled or patched with cement mortar or saran latex dry pack mortar or epoxy sand mortar, or an alternative mortar approved by the Authority's Engineer. The Authority's Engineer will also determine the extent to which concrete shall be cut out, the shape of the resulting cavity, the material that is to be used for the repairs and whether the filling shall be secured with keys, dovetails or anchors. Reinforcing steel bars shall not be cut.

Should the concrete exhibit any form of cracking at 28 days, in excess of 0.l5mm width, it shall be brought to the attention of the Authority's Engineer. The Authority's Engineer may, at his discretion and based on the particular crack location, require that the crack be repaired. Where so instructed, the concrete shall be repaired using an epoxy injection system or other approved method of permanent crack repair. Repairs using an epoxy injection system shall not be performed for at least 56 days from the original date of concrete placement.

Repairs shall be performed only in the presence or on direction of the Authority's Engineer.

The Contractor shall repair all leakage spots in concrete joints or elsewhere in agreement with the Authority's Engineer.

10.2 Lean Concrete

The strength class C12/15 shall be applied for wet lean concrete. With the following constituents:

- Cement shall be in accordance with Clause 11.4.2.1
- Water/cement ratio shall be in accordance with Clause 11.4.2.2
- Aggregates shall be in accordance with Clause

Consistence shall comply with Clause 11.4.3.1.

Wet lean concrete shall be spread uniformly, without segregation and without varying degrees of pre-compaction. The concrete shall be struck off to a level so that the surcharge is sufficient to ensure that after compaction the surface is at the required level.

The spread wet lean concrete shall be compacted using internal or external vibration, or a combination of both to meet the required density.

At transverse and longitudinal construction joints between two separately constructed slabs, the previously laid slab end or edge shall present a vertical face before construction of subsequent slabs.

Longitudinal joints in wet lean concrete shall be staggered by at least 300 mm from the position of longitudinal joints in any superimposed concrete slab, and by 1m for transverse joints.

Curing of wet lean concrete shall comply BS EN 12390-2 as appropriate.

The density shall be determined as in Clause 11.4.3.3 and sampling shall be as specified therein.

The surface of the wet lean concrete after compaction and finishing and before overlaying shall be free from ridges, loose material, pot holes, ruts or other defects. The surface of wet-laid concrete bases shall be roughened before the application of any curing compound by brushing with a wire brush or stiff broom.

Trial concrete mixes shall conform with BS 8500-2 for designed concretes for strength class C12/15 and above, unless recent data relating entirely to the proposed concrete, satisfies the requirements of the Specification.

At least 10 days before the start of the main wet lean concrete works a trial length of at least 400 m² for mechanised construction and 30 m² for hand-guided methods shall be constructed. The trial length shall be laid to assess the suitability of the proposed material, plant, equipment and construction methods to meet the requirements of the Specification. The main construction in the Permanent Works shall not start unless the trial length complies with the Specification. If any trial length does not conform to the Specification another trial length shall be constructed. Trial lengths not complying shall be removed unless they can be rectified to comply with the Specification.

After satisfactory completion of the trial, the material, plant, equipment and construction methods shall not be changed unless the Contractor lays a further trial length to assess the suitability of the proposed changes or agrees the changes with the Authority's Engineers.

10.3 No-Fines Concrete

No-fines porous concrete shall be used for the surround of ground water drainage pipes in tunnels at locations indicated on the drawings.

No-fines porous concrete shall be composed of ordinary Portland Cement and 37.5 mm single size aggregate complying with Clause 10.1.3.1.

The ratio of aggregate to cement shall be 8:1 by volume or 10:1 by mass.

The concrete shall be mixed by machine or by hand to a uniform colour and consistency before placing. The quantity of water used shall not exceed that required to coat all of the aggregate particles without forming excess grout.

No-fines concrete shall be compacted by hand.

10.4 Reinforcement

10.4.1 General

The items of work falling within the scope of work under this section shall be in accordance with the Indian and European Standards Specification (Latest edition) given under:

- IS:280-1978: Specifications for mild steel wire for General Engineering purposes
- IS:432-1966/82: Specifications for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement
- IS:432 (Part I): Mild steel and medium tensile bars
- IS:432 (Part II): Hard drawn steel wire
- IS:456-1978: Code of practice for plain and reinforced concrete
- IS:814-1974: Specifications for covered electrodes for metal arc welding of structural steel
- IS:814 (Part I): For welding products other than sheets
- IS:814 (Part II): For welding sheets
- IS:1139-1966: Hot rolled mild steel medium tensile steel and high yield strength deformed bar for concrete reinforcement
- IS:1786-1979: Specifications for cold worked steel high yield strength deformed bars for concrete reinforcement
- IS:2502-1963: Code for practice for bending and fixing of bar for concrete reinforcement
- IS:5525-1979: Recommendations for detailing of reinforcement in reinforced concrete constructions
- IS:9417-1979: Recommendations for welding cold-worked bars for reinforcement concrete constructions
- BS EN 10080: Steel for the reinforcement of concrete. Weldable reinforcing steel. General
- BS 4449: Steel for the reinforcement of concrete – Weldable reinforcing steel – Bar, coil and decoiled product
- BS 4482: Steel wire for the reinforcement of concrete products. Specification

- BS 4483: Steel fabric for the reinforcement of concrete

The Contractor may adjust the position of lap joints to fit in with available stock lengths, or construction joints, subject to the Authority's Engineer's agreement to the altered positions. The Contractor shall amend the bending schedules, as necessary, to allow for such alterations.

Reinforcement shall be obtained from a Certificated Authority for Reinforcing Steels Quality Assurance approved supplier and the Contractor shall provide copies of the manufacturer's certificates of test results relating to the steel reinforcement to be supplied.

Reinforcing steel bars and welded steel wire fabric may be stored outside in an approved manner provided that they do not rust and are placed on sleepers which will prevent the steel from coming into contact with the ground and a protection against contact with aggressive elements is provided.

Reinforcing steel bars shall be free from dirt, oil, flaky rust, loose mill scale and any other coating that would destroy or reduce the bond with the concrete.

Tying wire shall be 1.6 mm diameter soft annealed mild steel, and when fixed shall not Project Highwayinto the concrete cover.

Where the Contract so requires, the Contractor shall produce bending schedules.

10.4.2 Placing and fastening

Placing and fastening of reinforcement shall comply with IS 456 unless specified otherwise herein.

All reinforcement shall be accurately placed, securely fixed and adequately maintained in the positions shown on the drawings. The reinforcement shall be fixed so that the cover specified on the drawings is achieved, subject to the tolerances specified therein.

Reinforcing steel bars shall be installed as shown on the drawings and shall be solidly attached to the formwork. Reinforcing steel bars shall be tied together with wire ties to form a rigid grid which shall be supported in its required position, on chairs and with spacers and hangers. The wire ties shall be used in a staggered pattern at a spacing not exceeding 60 centimetres. Reinforcing steel bars shall be accurately placed within the specified tolerances and shall be secure against displacement during concrete placement.

Reinforcement shall not be re-bent on site unless agreed with the Authority's

Engineer.

The minimum clear distance between parallel reinforcing steel bars shall be the nominal diameter of the reinforcing steel bars or 1.25 times the maximum size of the coarse aggregate, whichever is the greater, provided that the minimum clear distance between parallel reinforcing steel bars in beams shall not be less than 30 millimetres and in columns shall not be less than 50 millimetres.

Spacer blocks shall be of comparable strength, durability and appearance to the surrounding concrete and shall be factory produced. Site-produced concrete or mortar cover blocks shall not be used.

Spacers and chairs shall ensure that the reinforcement is correctly positioned, be as small as possible consistent with their purpose, and designed so that they will not overturn or be displaced when the concrete is placed. Wire cast in the block for the purpose of tying it to the reinforcement shall be as specified below.

Prior to placing reinforcement on rock or gravel foundation, the foundation shall be covered with at least 50 mm thick layer of concrete or other approved cover.

Tying wires shall be 1.6 mm soft annealed iron wire unless drawings require the use of stainless steel tying wire. Where stainless steel tying wire is required it shall be 1.2 mm diameter stainless steel wire throughout the structure.

Projecting ends of ties or clips shall not encroach into the concrete cover.

Overlap between adjacent sheets of welded wire fabric shall be a minimum of 2 squares.

Concreting shall not commence until the reinforcement has been inspected in accordance with the Inspection and Test Plan.

10.4.3 Splicing

Joints or splices in reinforcing bars shall generally be made at the positions shown on the drawings, but the contractor would be permitted to make joints or splices at positions other than those shown on the drawings, providing that such positions are approved by the Authority's Engineer-in-Charge and that joints and splices in adjacent bars are staggered if directed by the Authority's Engineer-in-Charge. Approval of such additional splices will generally be restricted to splices not closer than 8 m in horizontal bars or 4 m in vertical bars measured between mid-points of laps. The number of splices shall be kept to a minimum.
If the Contractor proposes to use mechanical couplings for reinforcing bars, he shall submit samples of the proposed coupling to the Authority's Engineer for approval

not less than 60 days prior to their proposed use.

10.5 Formwork

10.5.1 General

Material and workmanship shall comply with IS 456 and IS 14687.

The supply of all labour, supervisors, Contractor's equipment and materials and the execution of all work necessary to design, supply, fabricate, erect, treat, support, brace, use, remove and dispose of formwork for retaining and forming concrete structures as specified herein and as shown on the drawings shall be provided by the Contractor.

Not less than 60 days prior to the start of fabrication of formwork and falsework for each structure or part of a structure, the Contractor shall submit to the Authority's Engineer design calculations and erection drawings showing the formwork and falsework for that structure or part of the structure. The general method and system proposed shall be submitted in detailed drawings of the formwork to the Authority's Engineer for agreement.

The erection drawings shall indicate the method and schedule of construction, member sizes and type, grade and quality of materials, the arrangement of joints, splices, liners and locations of temporary openings and embedded parts. Details of mechanical equipment that will operate or be supported on the falsework, shall be submitted with the erection drawings. Design assumptions, loads and allowable stresses shall be indicated on the erection drawings.

All formwork shall be dimensioned, constructed and securely braced as to prevent displacement.

All joints in the formwork and between the formwork and previous work shall be sufficiently tight to prevent loss of liquid from the concrete.

Formers for all chases, grooves, recesses, etc. shall be securely fixed as part of the formwork. No part of the concrete shall be cut away for any such item, or for any other reason, without the Authority's Engineer's agreement.

The face of the formwork shall be clean and applied with non-staining release agent. The agent shall not touch reinforcement, or items to be embedded, and shall not be allowed to collect in the bottom of the formwork, or flow onto previously placed concrete.

Before any concrete is placed, the Contractor shall examine and clean out the

formwork and ensure that the specified reinforcement cover is attained.

Where cyclical casting, e.g. in-situ concrete tunnel lining, striking times may be agreed with the Authority's Engineer following criteria determined from trial lengths.

10.5.2 Material Requirements

The surface of steel plate formwork and steel faced lumber formwork shall be smooth and free from dents, buckles and other surface irregularities. The sheathing for steel formwork shall be steel plate not less than three millimetres thick. All bolts and rivet heads shall be countersunk. Means shall be provided to ensure a snug fit of steel plate sheathing and steel faced sheathing against previously hardened concrete so as to provide smooth joints.

Lumber used for formwork shall be free from warp, loose knots and decay and shall be sawn straight and dressed smooth.

Plywood shall be non-warping and non-wrinkling and shall be manufactured with waterproof glue. Only plywood sheets with identical length and width shall be used.

Fillers for repairing and reconditioning formwork shall be subject to approval by the Authority's Engineer. All filler material shall be sanded flush and sealed with an approved sealer to prevent adhesion to the concrete.

10.5.3 Tunnel Formwork

Formwork for tunnel lining shall be constructed in such lengths that each concrete placement can be completed without cold joints.

Concrete pads, pedestals and other means to support tunnel formwork shall be subject to approval by the Authority's Engineer on the basis of the effects of such supports on the structural properties of the tunnel section and on the finish of the lining.

Formwork for tunnel lining above the invert shall be provided with rows of openings along each side. The bottom row shall be located with the centreline of the openings above the longitudinal construction joint at the invert. Successive rows shall be located on two meters centres above the next lower row. The rows of openings shall be staggered. Openings shall permit access for inspection and vibration of concrete being placed behind the formwork. Each row of openings shall be provided with a platform for access to the openings. Openings shall be located at a minimum spacing of 2.5 meters along the tunnel centreline and up the tunnel walls. Openings shall be not smaller than 45 by 60 centimetres, with the

long dimension parallel to the centreline of the tunnel.

10.5.4 Execution

10.5.4.1 Preparation

Formwork shall be constructed in strict accordance with the erection drawings after they have been reviewed by the Authority's Engineer and shall produce concrete conforming to the lines, slopes, elevations and dimensions and with the surface finishes shown on the drawings. Joints between formwork sections shall be sufficiently tight to prevent loss of mortar from concrete. Formwork shall be securely tied and anchored to maintain shape and position and to avoid warping and bulging.

Formwork for curved surfaces shall be constructed so as to conform accurately to the required curvatures of the surfaces within the allowable tolerances specified.

Formwork joints shall fit together without gaps greater than two millimetres at any point. The joint marks on the concrete surface in the water passages shall follow in general the line of water flow. Forms shall be placed so that the joint marks on concrete surfaces will be in alignment both horizontally and vertically and the joint marks between surfaces shall be smooth.

10.5.4.2 Installation

Formwork shall be braced to maintain its position and shape. Formwork and falsework shall be arranged for ease of dismantling and stripping to ensure that its removal will not damage the concrete. Formwork blocking and supports to be left permanently in the concrete shall be fabricated of steel.

The interior surfaces of formwork shall be covered with colourless mineral form oil or other bond breaking compound approved by the Authority's Engineer. The bond breaking compound shall be applied before reinforcing steel bars are placed. Form oil or bond breaking compounds shall not come in contact with reinforcing steel bars or with concrete surfaces on which additional concrete, epoxy mortar or any bonded coating is to be placed.

10.5.4.3 Tolerances

Formwork and falsework shall be constructed, located, supported and braced in such a manner that the finished surfaces of concrete structures are within the allowable construction tolerances as defined in Clause 10.1.11.4 of this Specification.

10.5.4.4 Concrete Placement

Temporary openings shall be provided in the formwork at any place where necessary to facilitate concrete placement, insertion of vibrators, cleaning and inspection. The temporary openings shall be closed with removable panels that are flush with the formwork surface on the inside. Immediately before concrete is placed, formwork shall be inspected to ensure that it is accurately placed, rigid, tight, clean and free from foreign matter.

Inspection of formwork by the Authority's Engineer and approval to proceed with concrete placement shall not relieve the Contractor of his responsibility for safety and accuracy of the Work. Any repairs of concrete due to faulty or inaccurate formwork shall be done by the Contractor at no additional cost to the Employer.

10.5.4.5 Quality Control

The alignment and position of formwork shall be checked frequently during concrete placement. Any misalignment shall be corrected by wedging and shoring.

Formwork and falsework may be reused, provided that the material is undamaged and the surface in contact with concrete is cleaned and is capable of producing the required surface finish. Timber and plywood formwork shall not be repaired with metal patches.

10.5.4.6 Removal

Formwork shall be removed in such a manner as to prevent concrete spalling and to produce sharp and clean joints.

Formwork shall be eased, struck or removed in such a manner that the structure is not distorted, damaged or overloaded.

Except where otherwise agreed with the Authority's Engineer, formwork shall not be eased or struck until:

- the concrete has attained sufficient strength to support itself in the position cast without deformation or
- a minimum period in line with Section 6 of ENV 13670-1
- vertical forms and formwork for tunnel crown lining may be removed when the concrete has attained a compressive strength of min 6 MPa, deduced from the strength development of comparable test specimens cured under similar conditions
- 10 hours after concrete placing unless measures are taken to prevent excessive cooling and drying. These measures shall be agreed with the

Authority's Engineer

10.5.5 Design and Installation Criteria

Formwork and falsework shall be designed to withstand, safely and without distortion, all loads that will be applied before, during and after concrete placement. The design loads shall include wind, concrete, equipment and personnel. Formwork shall be designed to permit the concrete to be deposited as nearly as practicable directly in its final position and shall have access facilities that will allow inspection, checking and clean-up of the surface of the preceding concrete placement and inspection and vibration of the concrete.

11 PAVEMENT

11.1 General

The Contractor shall furnish all materials, equipment and labour necessary for permanent roadwork as shown on the drawings or as directed. The design for the permanent roadwork will be provided by the Employer.

The Contractor shall design and furnish all materials, equipment and labour necessary for construction roads or tracks to other work sites, to spoil areas, to installation areas and to camps to the extent that he considers necessary for his activities. These roads shall be constructed at the minimum standard necessary for the Contractor to safely execute the Works. The layout and design for all temporary roadwork shall be provided by the Contractor and approved by the Employer before the work commences.

The Contractor shall place compacted and treated, if necessary, selected backfill, either from required excavations or approved borrow areas, to completed structures as shown on the drawings or as directed. The Clause 6.7 for backfill material shall be applied accordingly.

All permanent road work, materials, workmanship, quality, construction tolerances, testing and etc. shall be carried out in accordance with the "Specifications for Road and Bridge Works" by Ministry of Road Transport and Highways (MoRTH 2000), unless otherwise specified in the drawings or as directed by the Authority's Engineer. This requirement applies to both the road outside the tunnel or portal buildings/structures as well as that inside these. The main Clauses of the "Specifications for Road and Bridge Works" (MoRTH 2000) which shall be applied are summarized in this Specification.

11.1.1 Tolerances

The design levels of pavement courses shall be calculated from the vertical profile, crossfalls and the pavement course thicknesses as described in relevant drawings. The level of any point on the constructed surface of the pavement courses shall be the design level subject to the appropriate tolerances stated in Table 18.

Table 18: Tolerances in surface levels of pavement courses

Pavement course	Tolerances
General Adjacent to a surface water channel1	± 6 mm + 0-10 mm
Base under concrete pavement surface slabs laid full thickness in one operation by machines with surface compaction	± 10 mm
Unbound sub-base layer	+ 10-30 mm

1: Where a surface water channel is laid before the adjacent road pavement layer the top of that layer, measured from the top of the adjacent edge of the surface water channel, shall be to the given tolerances.

Notwithstanding the tolerances permitted in surface levels of pavement courses, the cumulative tolerance shall not result in a reduction in thickness of the pavement, excluding the sub-base and filter layer, by more than 15 mm neither from the specified thickness nor a reduction in the thickness of the bituminous surface course by more than 5 mm from that specified.

For checking compliance with this Clause, measurements of the surface levels of all courses shall be taken on a grid pattern in agreement with the Authority's Engineer.

The longitudinal regularity of the surfaces of surface courses, binder courses and concrete slabs shall be such that the number of surface irregularities is within the relevant limits stated in Table 19.

An irregularity is a variation of not less than 4 mm or not less 7 mm of the profile of the road surface as measured by the rolling straight-edge set at 4 mm or 7 mm as appropriate or equivalent apparatus capable of measuring irregularities within the same magnitudes over a 3 m length. No irregularity exceeding 10 mm shall be permitted.

Prior to checking any final road surface it shall be cleaned of loose or extraneous materials. These operations shall be carried out without damaging the surface of the pavement as soon as possible and within 3 days of construction of the pavement.

Compliance with Table 19 shall be checked by the rolling straight-edge along any line or lines parallel to the edge of pavement on sections of 300 m at regular intervals in agreement with the Authority's Engineer, whether or not it is constructed in shorter lengths. Sections shorter than 300 m forming part of a longer pavement shall be assessed using the number of irregularities for a 300 m length pro - rata to the nearest whole number.

Pavements shall be measured transversely for irregularities at regular intervals in agreement with the Authority's Engineer, by a 3 m long straight-edge placed at right angles to the centre line of the road. The maximum allowable difference between the pavement surface and the straight-edge shall be 3 mm.

A 3 metres long straight-edge shall be used to check longitudinal surface regularity for all lengths of base layers under concrete pavement slabs laid full thickness in one operation by machine with surface compaction.

The maximum allowable difference between the surface and the underside of the straight-edge, when placed parallel with or at right angles to the centre line of the road, shall be:

- 3 mm for pavement surfaces
- 10 mm for bases under concrete pavements

Table 19: Maximum permitted number of surface irregularities

	Surfaces of each lane of carriageway, each hard strip and each hard shoulder for each irregularity limit				Surfaces of lay-bys, service areas for each irregularity limit			
Irregularity limits	4 mm		7 mm		4 mm		7 mm	
Length [m]	300	75	300	75	300	75	300	75
Number of irregularities	40	18	4	2	60	27	6	3

11.1.2 Rectification

Where any pavement area does not comply with the Specification for regularity, surface tolerance, thickness, macrotexture depth, material properties or compaction, the full extent of the area which does not comply with the Specification shall be made good and the surface of the pavement course shall be rectified in the manner described below:

- Unbound base layer: The top 75 mm shall be scarified, reshaped with material added or removed as necessary, and re-compacted. The area treated shall be not less than 30 m long and 2 m wide or such area as necessary to obtain compliance with the Specification.

- Bituminous bases: With coated macadam or asphalt bases, the full depth of the top layer as laid shall be removed and replaced with fresh material laid and compacted in accordance with the Specification. Any area so treated shall be at least 5 m long and the full width of the paving laid in one operation. Alternatively for low areas in bituminous bases, the Contractor may make up the level with additional binder course material.

- Concrete slabs: Concrete slabs shall be rectified by planing, grinding or bump cutting. Large depressions, which cannot be dealt in this way, shall be rectified by cutting out the surface and replacing by a thin bonded surface repair. Where the slab cannot be rectified as above, the full depth of slab shall be removed and replaced with a slab constructed in compliance with these Specifications. Remedial works involving the placing of fresh concrete shall be completed in sufficient time for the concrete strength which have to be developed as specified before that section of pavement is opened to traffic.

11.2 Unbound Sub-Base Layer

11.2.1 General

This work shall consist of laying and compacting well-graded material on prepared sub-grade in accordance with the requirements of these Specifications. The material shall be laid in one or more layers as sub-base as necessary according to lines, grades and cross sections shown on the drawings or as directed by the Authority's Engineer.

The sieve size distribution shall be in compliance with Table 20 as per MoRTH (2000).

Table 20: Grading for unbound sub-base layer

Designation	Per cent per weight passing
75.0 mm	-
53.0 mm	100
26.5 mm	70-100
9.5 mm	50-80
4.75 mm	40-65
2.36 mm	30-50
0.425 mm	15-25
0.075 mm	3-10

The unbound mixture shall satisfy the minimum CBR value of 25 when it is compacted and finished.

When directed by the Authority's Engineer, this shall be verified by performing CBR tests in the laboratory as required on specimens remoulded at field dry density and moisture content and any other tests for the "quality" of materials, as may be necessary and required by the Authority's Engineer.

11.2.2 Laying

Unbound mixtures in a frozen condition shall not be incorporated in the Works but may be used, if acceptable, when thawed. Unbound mixtures shall not be laid on any surface which is frozen or covered with ice.

The unbound mixtures of grading specified herein (Table 20) shall be placed and spread on the prepared surface evenly. Unbound mixtures shall be spread using a paving machine or a suitable spreader box and operated with a mechanism which levels off the material to an even depth.

Material up to 225 mm compacted thickness shall be spread in one layer so that after compaction the total thickness is as specified. Material of compacted thickness greater than 225 mm shall be laid in two or more layers and the minimum compacted thickness of any such layer shall be 110 mm. Where the layers of unbound mixtures are of unequal thickness, the lowest layer shall be the thickest layer.

Moisture content of the loose material shall be checked in accordance with IS:2720 (Part 2) and suitably adjusted by sprinkling water uniformly and at controlled quantities to variable widths of surface or other means approved by the Authority's Engineer so that, at the time of compaction, it is from 1 per cent above to 2 per cent below the optimum moisture content corresponding to IS:2720 (Part 8). While adding water, due allowance shall be made for evaporation losses.

11.2.3 Compaction

Compaction shall be completed as soon as possible after the mixture has been spread and in accordance with the requirements for the individual mixtures.

Compaction of unbound mixtures shall be carried out by a method the Contractor demonstrates at site trials that compacted density achieved is at least 98 % of the maximum dry density for the material determined as per IS:2720 (Part 8).

The surface of any layer of material shall on completion of compaction and immediately before overlaying, be well closed, free from movement under construction plant and from ridges, cracks, loose material, pot holes, ruts or other defects. All loose, segregated or otherwise defective areas shall be removed to the

full thickness of the layer, and new material shall be laid and compacted.

11.2.4 Site traffic

Construction plant and other traffic used on pavements under construction shall be suitable in relation to the material, condition and thickness of the courses it traverses so that damage is not caused to the subgrade or the pavement courses which are already constructed. The wheels or tracks of plant moving over the various pavement courses shall be kept free from deleterious materials.

Final excavation levels (formation level) for pavement construction shall be protected against any wear or deterioration of rock properties following site traffic by backfilling with rock material excavated in the tunnel or similar to a minimum thickness of 0.5 metres.

Ponding water and traffic through ponding water shall not be allowed.

Any deteriorated material shall be removed and replaced prior to pavement works as directed by the Authority's Engineer.

The backfill material used for protection purposes shall not be removed until immediately prior to pavement construction works.

No site traffic shall be allowed to run on unprotected invert structures, temporary or final, concrete or shotcrete. Structures as such shall be protected against destruction by backfilling with suitable excavation material from the tunnel or similar with a minimum thickness of 0.5 metres. Backfilling material shall not contain boulders larger than 150 mm diameter.

11.3 Bituminous Base Layer

11.3.1 General

Natural, recycled unbound and manufactured (artificial) aggregates shall be clean, hard and durable and shall comply with BS EN 13043.

Irrespective of source, coarse aggregates for bituminous mixtures shall be considered suitable if:

- the resistance to fragmentation category of the coarse aggregate as defined in clause 4.2.2 of BS EN 13043 shall be LA30 or better for natural aggregates and LA50 or better for blast furnace slag or

- crushed rock aggregate has a Los Angeles Value greater than 30 but less than

35, where evidence can be presented to the Authority's Engineer of previous satisfactory use of the source in asphalt.

Natural and manufactured (artificial) aggregates recovered from a previous use in an unbound form shall comply with the requirements of this Clause.

The freezing and thawing (soundness) category, as defined in BS EN 13043, clause 4.2.9.2, shall be MS25 unless otherwise specified herein. The water absorption value of the coarse aggregate shall be determined in accordance with BS EN 13043, clause 4.2.9.1. If the water absorption value of the coarse aggregate is greater than WA242, the soundness test shall be carried out on the material delivered to site. The requirements for water absorption do not apply to blastfurnace slag aggregate.

Before work commences, the Contractor shall submit a method statement to the

Authority's Engineer that includes:

- Laying and compaction procedures for each layer – including paving speed and paved width; size, type and number of rollers; and number of roller passes.

- The joint formation procedures for each layer – including the location of longitudinal and transverse joints; and the method(s) of treating upstanding edges.

11.3.2 Placing

In order to exclude moisture from interfaces and ensure full interlayer bonding, the surface of all bituminous material shall be kept clean and uncontaminated. If any surface becomes contaminated, it shall be made good by cleaning and if this proves impracticable, by rectification.

Prior to placing bituminous material on any new or existing bound substrate, a bond coat or tack coat shall be applied in accordance with Clauses 920 or 942, as appropriate.

Hot bituminous mixtures shall be transported in accordance with the requirements of BS 594987 and shall remain covered whilst awaiting tipping.

Wherever practicable, hot bituminous mixtures shall be spread, levelled and tamped by a self-propelled paving machine. The rate of delivery of material to the paver shall be regulated to enable the paver to operate continuously.

Hand placing of hot bituminous mixtures shall be restricted to the following

circumstances:

- For laying regulating courses of irregular shape and varying thickness.
- In confined spaces where it is impracticable for a paver to operate.
- For footways.
- At the approaches to expansion joints at bridges, viaducts or other structures.
- For laying mastic asphalt.

The method of laying shall be such that the finished mat is free from dragging, tearing and segregation of the material.

Dense base course asphalt concrete (formerly macadam) recipe mixtures shall be asphalt concrete conforming to BS EN 13108-1.

Bituminous mixtures shall not be laid on layers with a surface temperature beneath 5°C.

The surface tolerances shall be in compliance with Clause 11.1.1.

11.4 Concrete Pavement

11.4.1 General

The work shall consist of construction of unreinforced, dowel jointed, plain cement concrete pavement in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross sections shown on the drawings. The work shall include furnishing of all plant and equipment, materials and labour and performing all operations in connection with the Work, as approved by the Authority's Engineer.

Concrete in rigid or rigid composite pavements shall be of the class C32/40 XF4 and shall confirm to the Clauses of Chapter 10 unless given otherwise below.

Prior to commencement of any concrete works the base layer shall be checked of adequate bearing capacity and elevation the tolerances are given in Clause 11.1.1. The check has to be in appropriate time prior to commencement hence measures shall be taken contemporary and no time delay may occur.

If the thickness of the base layer is not in the range of the tolerances the base layer shall be corrected. If this is not possible, the base layer shall be fully replaced.

The base layer shall be clean and free of deleterious material.

The concrete slab shall be laid in two layers. The surface layer shall be laid monolithically with the lower layer. The surface layer shall be not less than 50 mm thick.

11.4.2 Concrete Composition

The concrete composition shall comply with Clause 10.1.3 unless given otherwise below.

11.4.2.1 Cement

The cement content shall be in accordance to Table 21 and means any of the following materials or combinations below:

- Portland cement CEM I, BS EN 197-1
- Portland slag cement CEM II/A-S and CEM II/B-S, BS EN 197-1
- Blastfurnace cement CEMIII/A, CEM III/B BS EN 197-1
- Portland-fly ash cement CEM II/A-V, CEM II/B-V BS EN 197-1
- Pozzolanic cement CEMIV/A BS EN 197-1
- Portland cement CEM I BS EN 197-1with ground granulated blastfurnace slag (ggbs) for use with Portland cement CEM I
- Portland cement BS EN 197-1
- CEM I with pulverised-fuel ash (pfa) for use as a cementitious component in structural concrete BS EN 197-1

Table 21: Minimum cement or combination contents with 40 mm maximum aggregates

Min. Portland cement CEM I, BS EN 197-1 in [kg/m³]	320
Min. other cements or combinations permitted	340
Maximum proportion of ggbs in [%]	25
Max./min. proportion of pfa in [%]	25/15
Min. CEM I content in [kg/m²] for combinations with pfa and ggbs	255

For 20 mm maximum size aggregate 20 kg/m3 cement content per cubic meter fully compacted concrete shall be added, and for < 20mm maximum size 40 kg/m³ cement content shall be added

If the concrete layer shall be laid in two layers, the cement of the surface layer shall

be limited to Class 42.5N/42.5R Portland cement CEM I in accordance to BS EN 197-1. The minimum cement content of the concrete shall be 375 kg/m³.

The cement content shall not exceed 425 kg/m³.

11.4.2.2 Water

Water from a water company supply may be used without testing. Water from other sources may be used if it conforms to BS EN 1008. The water content shall be the minimum required to provide the specified consistence for full compaction of the concrete to the required density, as determined by trial concrete mixes or other means. The maximum free water/cement ratio shall be 0.45 for strength classes C32/40 and C25/30 and 0.60 for strength classes C16/20 and C12/15.

If the concrete layer shall be laid in two layers, the free water/cement ratio of the surface layer shall be max. 0.40 for strength classes C32/40 and C25/30.

11.4.2.3 Admixtures

Concrete for pavement slab shall incorporate an air-entraining admixture complying with BS EN 934-2 in at least the top 50 mm of surface slabs.

Plasticisers or water reducing admixtures shall comply with BS EN 934-2. Admixtures containing calcium chloride shall not be used.

11.4.2.4 Aggregates

Aggregates for all pavement concrete, including wet lean, shall comply with IS:383 and BS EN 12620 respectively.

The aggregates shall be free from chert, flint, chalcedony or other silica in a form that can react with the alkalies in the cement. In addition, the total chlorides content expressed as chloride ion content shall not exceed 0.06 per cent by weight and the total sulphate content expressed as sulphuric anhydride (S03) shall not exceed 0.25 per cent by weight.

No aggregate which has water absorption more than 2 per cent shall be used in the concrete mix.

If the concrete layer shall be laid in two layers, the surface layer shall comply with following requirements:

- For 6.3/10 mm coarse aggregate or 4/8 mm coarse aggregate the amount of aggregate retained on the 10 mm sieve and 8 mm sieve respectively shall not

exceed 3% by mass. The aggregate passing the 6.3 mm sieve and 4 mm sieve respectively shall not exceed 10% by mass.

- The fine aggregate grading shall comply with the 0/2 (FP) or 0/1 (FP) grading in BS EN 12620 except that not less than 99% of the mass of the material shall pass the 2 mm sieve.

- The coarse aggregate shall comprise at least 60% by mass of the oven dry constituents of the concrete.

- The polished stone value (PSV) and the aggregate abrasion value (AAV) of

  the coarse aggregate determined in accordance with BS EN 1097-8 shall be PSV50 and AAV15. The Category of flakiness index of the aggregate is FI15.

  The resistance to fragmentation of the coarse aggregate shall be of class LA20. The resistance to freezing and thawing shall be of class F1 for the coarse and fine aggregates.

11.4.3 Concrete Requirements

11.4.3.1 Consistence (Workability)

The consistence shall be determined by the Degree of Compactibility (Compaction Index) test in accordance with BS EN 12350-4, or the Vebe test in accordance with BS EN 12350-3. Alternatively for concrete class C16/20 or below, consistence may be determined by the slump test in accordance with BS EN 12350-2. The sampling for all concrete classes shall be undertaken in accordance with BS EN 12350-1 and the rate of testing in accordance with Table 12 of BS EN 206-1. Consistence shall be carried out at the point of placing, in conjunction with tests for strength and any tests for air content. The consistence shall be maintained at the optimum within the limits specified in BS EN 206-1.

If any determination of consistence gives a result outside the tolerance, a further test shall be made immediately on the next available load of concrete. The average of the two consecutive results and the difference between them shall be calculated. If the average is not within the tolerance or the difference is greater than 0.1 for CI or 20 mm for slump or 6 seconds for Vebe, subsequent samples shall be taken from the delivery vehicles, which shall not be allowed to discharge into the Works until compliance with the Specification has been established.

11.4.3.2 Air content

The concrete shall meet the requirement for exposure class XF4 in BS EN 206-1. This shall be achieved by the use of an air-entraining agent. The minimum quantity of air in air-entrained concrete as a percentage of the volume of the concrete shall be as in Table 22.

Table 22: Minimum air content with respect to max. aggregate size

max. aggregate size in [mm]	min. air content in [%]
20	3.5
40	3

The air content shall be determined at the point of delivery to the paving plant by the pressure gauge method in accordance with BS EN 12350-7, at the rate of one determination per 300 m² of slab or at least 6 times per day, whichever is the greater, in conjunction with tests for consistence and strength. For areas less than 300 m² the rate shall be at least one determination to each 20 m length of slab or less constructed at any one time or at least 3 times per day. If the air content is outside the specified limits in BS EN 206-1, the Contractor shall remove the concrete from the Works.

The air-entraining agent shall be added at the mixer by an apparatus capable of dispensing the correct dose within the tolerance for admixtures given in Table 14, to ensure uniform distribution of the agent throughout the batch during mixing.

11.4.3.3 Density (Manual of Contract Documents for Highway Works)

The density of a saturated core cut from the full depth of the concrete pavement shall not be less than 95% of the average density of at least six fully compacted saturated moulded specimens made from the same concrete and tested at the same age.

The density of the concrete pavement shall be determined in accordance with BS EN 13877-2. The density of a saturated core cut from the full depth of the concrete pavement shall be determined in accordance with BS EN 12390-7. The determination of the saturated density of the fully compacted moulded specimens shall be in accordance with BS EN 12350-1, BS EN 12390-1 and BS EN 12390-2.

The core shall have an average diameter of at least four times the nominal maximum aggregate size, and in any case at least 100 mm diameter. Where

different concrete mixes are used in separate layers, the density of each layer shall be separately determined by splitting or cutting the cores between the layers.

If the density of any core is below the minimum required, the concrete across the whole width of the slab constructed at the time relating to that core shall be removed. In unreinforced concrete the whole slab length between joints shall be removed. For reinforced slabs, in order to determine the limit of the defective area of concrete which shall be removed, additional cores shall be taken at 5 m intervals on each side of any defective core until concrete of satisfactory density is found. Defective areas shall be made good with new material in accordance with the Specification.

In calculating the density, allowance shall be made for any steel in the cores.

Core holes shall be reinstated with compacted concrete with mix proportions of 1 part of Portland cement CEM I: 2 parts of sand: 2 parts of 10 mm single sized coarse aggregate by mass.

11.4.3.4 Pavement concrete strength

Sampling and testing for and compliance with the specified characteristic core strength of designed concretes shall be undertaken by compressive strength testing in accordance with BS EN 13877-2 on cores cut from the full depth of the slab. No correction for maturity shall be applied to the 7 day or 28 day strength.

Concrete cores of the appropriate size shall be taken, cured and tested in accordance with BS EN 12504-1 with the exception that the core shall be cured under water at 20°C ±2°C as soon as practically possible. The sampling rate shall be as designated in BS EN 13877-2 for Category 2, three cores shall be taken from areas of concrete of up to 3000 m² and one additional core for every further 1000 m² of concrete laid.

An exception to the above sampling rate is that in the trial slab at least six cores shall be taken, three to be tested at 7 days and three at 28 days.

The end preparation of the core shall be by grinding and the height/diameter (h/d) ratio of the tested specimen shall be between 1 and 2.

If during the construction of the trial length the average corrected core compressive strength, from the three cores, falls below the 7 day corrected core compressive strength given in Table 23, then either the cement content of the concrete shall be increased by 5% by mass, or a further trial slab shall be constructed using an improved compaction technique and/or an increased cement content. The increased cement content shall be maintained at least until the three corresponding 28-day core strength tests have been assessed. If the cement content is increased, the

concrete shall be adjusted to maintain the required consistence.

Table 23: 7 day corrected core compressive strength

Concrete Class	7 day corrected compressive strength for CEM I concrete in [N/mm²]	7 day corrected compressive strength for CEM I with pfa or ggbs concrete in [N/mm²]
C32/40	32	26.8
C25/30	25	20
C16/20	16.5	13
C12/15	12	10
C8/10	7.5	6.5
C6/8	5	4

Overlapping groups of four consecutive 28 day corrected core strengths shall be used for assessing the pavement for compliance with the criteria in Table A.1 of BS EN 13877-2. The pavement shall be accepted if the criteria in Table A.1 are satisfied for four results derived from strength tests on cores taken from the constructed pavement. Conformity control of the concrete will be the responsibility of Contractor.

11.4.3.5 Finished Surface Requirements

The finished surface of the pavement shall comply with the requirements of Clause 11.1.1. Where a pavement area does not comply with the Specification in any respect, the full extent of the surface which does not comply shall be rectified in accordance with Clause 11.1.2

After the final regulation of the surface of the slab and before the application of the curing membrane, the surface of concrete slabs to be used as running surfaces shall be brush-macrotextured in a direction at right angles to the longitudinal axis of the carriageway. The macrotexture shall be applied evenly across the slab in one direction by a brush not less than 450 mm wide. The macrotexture shall be uniform

both along and across the slab.

The macrotexture depth shall be determined by the volumetric patch technique as described in BS EN 13036-1. Tests shall be taken within 100 m of commencement of paving and thereafter at least once for each day's paving at the times after construction as given below and in the following manner: 10 individual measurements of the macrotexture depth shall be taken at least 2 m apart anywhere along a diagonal line across a lane width between points 50 m apart along the pavement. No measurement shall be taken within 300 mm of the longitudinal edges of a concrete slab constructed in one pass.

Macrotexture depths shall be as required in Table 24.

Where the required macrotexture depth is found to be deficient the Contractor shall make good the texture across the full lane width over lengths necessary to comply with the requirements of Table 24, by retexturing the hardened concrete surface as described in Clause 11.4.14.

Table 24: Required macrotexture depth and tolerances

Time of test		Required macrotexture depth in [mm]	
		Specified value	Tolerance
between 24 hours and 7 days after the construction of the slab or until the slab is first used by vehicle	an average of 10 measurements	1.0	±0.25
not later than 6 weeks before road is opened to public traffic	an average of 10 measurements	1.0	+0.25 -0.35

11.4.4 Transverse Joints

11.4.4.1 General

Transverse joints shall be provided in unreinforced and jointed reinforced concrete slabs and shall be contraction, expansion or warping joints at spacing of 25 times the plate thickness and with a maximum of 5.0 m, such that for unreinforced concrete slabs the length/width ratio shall be not greater than 1.5.

Joints in the surface slab and sub-base shall be staggered so that they are not coincident vertically and are at least 1 m apart.

Transverse joints shall be straight within the following tolerances along the intended line of the joint, which is the straight line transverse to the longitudinal axis of the carriageway.

- deviations of the filler board or bottom crack inducer from the intended line of the joint shall be not greater than ± 10 mm;
- the best fit straight line through the joint groove as constructed shall be not more than 25 mm from the intended line of the joint;
- deviations of the joint groove from the best fit straight line of the joint shall be not greater than 10 mm.

Transverse joints on each side of a longitudinal joint shall be in line with each other and of the same type and width.

Concrete pavement layers shall be isolated from fixed structures by expansion joints, or earthworks or a granular layer over the structure, or by bridge-type expansion joints, or by lengths of fully flexible pavement construction. End of pavement surface slabs shall have a transition bay leading into the fully flexible construction.

Transverse joints shall have a sealing groove which shall be sealed in compliance with Clause 11.4.10.

11.4.4.2 Contraction Joints

Contraction joints shall consist of:

- a sawn joint groove complying with Clause 11.4.8
- dowel bars complying with Clause 11.4.6,
- a sealing groove complying with Clause 11.4.10.

11.4.4.3 Expansion Joints

Expansion joints shall consist of:

- a joint filler board complying with Clause 11.4.9,
- dowel bars complying with Clause 11.4.6,
- a sealing groove complying with Clause 11.4.10.

The filler board shall be positioned vertically within the prefabricated joint assemblies along the line of the joint within the tolerances of Clause 11.4.4.1, and at such depth below the surface as will not impede the passage of the finishing beams on the paving machines. The joint filler board together with the sealing groove shall provide a complete separation of adjacent slabs and any spaces around dowel bars and between the sub-base and the filler board shall be packed with a suitable compressible material after fixing the joint assembly.

11.4.4.4 Warping Joints

Warping joints shall consist of:

- a sawn joint groove complying with Clause 11.4.8,
- tie bars complying with Clause 11.4.7,
- a sealing groove complying with Clause 11.4.10.

11.4.4.5 Construction joints

Construction joints made at the end of a working day in unreinforced concrete slabs and jointed reinforced concrete slabs shall be contraction joints. In the event of mechanical breakdown of the concreting machinery, or at the onset of adverse weather, emergency joints may be formed.

Emergency joints in unreinforced concrete slabs shall be contraction joints not less than 2.5 m from the preceding or succeeding joint position. The stop end formwork shall be sufficiently rigid to ensure that dowel bars and tie bars will be held in position in compliance with these Specifications.

11.4.5 Longitudinal Joints

11.4.5.1 General

Sawn or wet-formed longitudinal joints shall be provided in surface slabs between or at the centre of traffic lanes within the allowable positions as shown on the

drawings, so that bay widths are not greater than 4.2 m. Joints in the surface slab, base or sub-base shall be staggered so that they are not coincident vertically and are at least 300 mm apart.

Wet-formed longitudinal joints shall consist of:

- wet-formed joint grooves complying with Clause 11.4.8,
- a bottom crack inducer,
- tie bars complying with Clause 11.4.7.

Longitudinal joints shall be constructed within the following tolerances:

- deviations of the bottom crack inducer from the intended line of the joint, parallel to the axis of the road shall be not greater than ± 13 mm;
- the joint groove shall be located vertically above the bottom crack inducers within a horizontal tolerance of ± 25 mm;
- the best fit line along the constructed joint groove shall be not more than 25 mm from the intended line of the joint;
- deviations of the joint groove from the best fit line of the joint shall be not greater than 10 mm.

Sawn longitudinal joints shall consist of joint grooves complying with Clause 11.4.8

11.4.5.2 Longitudinal Construction Joints

Longitudinal construction joints between separate slabs shall have tie bars as in Clause 11.4.7 with a joint groove as in Clause 11.4.8.

11.4.6 Dowel Bars

Dowel bars shall be Grade B500 steel conforming to BS EN 13877-3 and shall be free from oil, dirt, loose rust and scale. They shall be straight, free of burrs and other irregularities and the sliding ends sawn or cropped cleanly with no protrusions outside the normal diameter of the bar. For expansion joints, dowel bars shall be 25 mm diameter at 300 mm spacing and 600 mm long for slabs up to 239 mm thick and 32 mm diameter for thicker slabs. For contraction joints, dowels shall be 20 mm diameter at 300 mm spacing and 400 mm long for slabs up to 239 mm thick,

and 25 mm diameter at 300 mm spacing and 600 mm long for thicker slabs.

Dowel bars shall be supported on cradles in prefabricated joint assemblies positioned prior to construction of the slab. For contraction joints, as an alternative to prefabricated assemblies, dowel bars may be mechanically inserted with vibration into the concrete by a method which ensures full recompaction of the concrete around the dowel bars and the surface finished by a diagonal finishing beam, or a longitudinal oscillating float travelling across the slab.

Dowel bars shall be positioned at mid-depth from the surface level of the slab ± 20 mm and centred equally about intended lines of the joint within a tolerance of ± 25 mm. They shall be aligned parallel to the finished surface of the slab to the centre line of the carriageway and to each other within the following tolerances:

- for bars supported on cradles prior to construction of the slab and for inserted bars in two layer construction prior to placing the top layer:
    - all bars in a joint shall be within ± 3 mm per 300 mm length of bar;
    - two thirds of the bars shall be within ± 2 mm per 300 mm length of bar;
    - no bar shall differ in alignment from an adjoining bar by more than 3 mm per 300 mm length of bar in either the horizontal or vertical plane;
- for all bars, after construction of the slab:
    - twice the tolerances for alignment as above
    - equally positioned about the intended line of the joint within a tolerance of 25 mm.

Dowel bars shall be covered by a flexible polymeric corrosion resistant coating. The coating shall be smooth and free of indentations. During coating, the bar shall be supported at each end. Minimum thickness shall be 0.3 mm. The coating shall also be able to withstand 250 hours immersion in a salt fog cabinet complying with BS EN ISO 7253, without showing any visible crazing or corrosion of the protected bar. The coated bar shall comply with the following pull out test:

Four bars shall be taken at random from stock and shall be coated as required in this Clause without any special preparation. The dowel bars which have been coated shall be cast centrally into concrete specimens 150 x 150 x 450 mm, made of the same concrete mix proportions to be used in the pavement, but with a maximum aggregate size of 20 mm and cured in accordance with BS EN 12390-2. At 7 days a tensile load shall be applied to achieve a movement of the bar of at least 0.25 mm.

The average bond stress to achieve this movement shall be not greater than 0.14 N/mm².

For expansion joints, a 100 mm long closely fitting cap consisting of waterproofed cardboard or an approved synthetic material like PVC or GI pipe shall be placed over the sheathed end of each dowel bar. An expansion space at least equal in length to the thickness of the joint filler board shall be formed between the end of the cap and the end of the dowel bar by using compressible sponge. To block the entry of cement slurry between dowel and cap it may be taped.

11.4.7 Tie Bars

Tie bars in longitudinal joints shall be deformed steel bars of strength 415 N/m².

Tie bars for use across joints shall have corrosion protection in the form of a flexible polymeric corrosion resistant coating, bonded centrally onto 150 mm of the previously cleaned centre section of the bars. Where tie bars are to be cranked for construction joints and later straightened, the coating shall be shown to be capable of being straightened through 90 degrees without cracking.

Tie bars in warping joints and wet-formed longitudinal joints shall be made up into rigid assemblies with adequate supports and fixings to remain firmly in position during the construction of the slab. Alternatively, tie bars at longitudinal joints may be mechanically inserted by vibration from above using a method which ensures recompaction of the concrete around the tie bars.

Tie bars in warping joints shall be positioned from the top surface of the slab within +20, -10 mm of the mid depth of the slab. Tie bars shall be positioned and remain within the middle third of the slab depth, approximately parallel to the surface and approximately perpendicular to the line of the joint, with the centre of each bar on the intended line of the joints within a tolerance of ± 50 mm, and with a minimum cover of 30 mm below any top crack inducer of joint groove for slabs 200 mm thick or more, or 20 mm for slabs up to 200 mm thick.

11.4.8 Joint Grooves

Transverse contraction or warping joint grooves shall be sawn in the hardened concrete.

Transverse joint grooves which are initially constructed less than the full width of the slab shall be completed by sawing through to the edge of the slab and across longitudinal joints as soon as any forms have been removed and before an induced crack develops at the joint.

Sawn transverse and longitudinal joint grooves: Sawing shall be undertaken as soon as possible after the concrete has hardened sufficiently to enable a sharp edged groove to be produced without disrupting the concrete and before random cracks develop in the slab. The grooves shall be between 1/4 and 1/3 of the specified depth of the slab and of any convenient width not less than 3 mm. The sealing groove may be sawn to the required width later. Expansion joint sealing grooves shall be sealed as soon as practical after sawing.

Wet formed longitudinal joint grooves: When slabs are constructed in more than one lane width in one operation, a joint groove shall be formed by inserting a groove former ahead of the finishing beams from dispenser. The concrete so displaced shall be recompacted by a vibrating compactor or similar device, at least 300 mm wide operating symmetrically along the line of the joint. After finishing the concrete, the groove forming strip shall be in the correct position and alignment, within 10° of the vertical, and to sufficient depth below the surface to allow for the passage of the finishing beam within the range 0-3 mm below the finished level of the slab. Groove forming strips in wet-formed longitudinal joint grooves shall be left in place.

Construction joint grooves in surface slabs: The grooves shall be formed by fixing a groove-former or strip or cork seal along the top edge of the slab already constructed, before concreting the adjacent slab. Where the edge of the concrete is damaged, it shall be ground or made good before fixing the groove forming strip. Alternatively the subsequent slab may be placed adjacent to the first and a sealing groove sawn later in the hardened concrete to the minimum of 1/4 to 1/3 of the specified slab depth or to the manufacturer's instructions if greater, and to sufficient width to eliminate minor spalling of the joint arris, up to a maximum of 25 mm for longitudinal joints and 40 mm for transverse joints. The joint shall be sealed in compliance with Clause 11.4.10.

11.4.9 Joint Filler Board

Joint filler board for expansion joints and manhole and gully slab joints shall be 25 mm thick unless otherwise shown in the drawings, within a tolerance of ± 1.5 mm. It shall be a self-expanding cork seal or a firm compressible material or a bonded combination of compressible and rigid materials of sufficient rigidity to resist deformation during the passage of the concrete paving plant.

11.4.10 Sealing of Joint Groover

Sealing shall be carried out continuously along the full length of joint in any one rip, except for remedial areas. When hot or cold applied sealants are used the sealant shall be applied within the minimum and maximum drying times of the primer recommended by the manufacturer. Priming and sealing with applied

sealants shall not be carried out when the naturally occurring temperature in the joint groove to be sealed is below 10°C except between 8°C and 10°C it may be carried out when the temperature is rising.

11.4.11 Inspection of Dowel Bars

Compliance with tolerances for the position and alignment of dowel bars as per Clause 11.4.6 at contraction and expansion joints shall be checked

When the slab has been constructed, the position and alignment of dowel bars and any filler board shall be measured after exposing them carefully across the whole width of the slab. When the joint is an expansion joint, the top of the filler board shall first be exposed sufficiently in the plastic concrete to permit measurement of any lateral or vertical displacement of the board. During the course of normal working these measurements shall be carried out at a rate of one joint per 1500 m length of slab or one per 5 days whichever occurs the sooner. For small areas the rate shall be one joint for up to each 100 joints.

If the position or alignment of the bars in a single joint in the slab is unsatisfactory, then the next two joints shall be inspected. If only the one joint of the three is defective, the rate of checking shall be increased to one joint per day until compliance is being achieved. In the event of non-compliance in two or more successive joints, the Contractor shall revert to the construction of trial lengths and make any necessary alterations to the concrete mix, paving plant or methods until the dowel bar position and alignment is satisfactory.

After the dowel bars have been examined, the remainder of the concrete shall be removed 500 mm on each side of the line of the joint, and reinstated to the requirements of the Specification. Alternatively, if the dowels are examined in the penultimate joint of a day's work, that joint shall be made a construction joint for the next day's work and the remainder of the concrete in the last slab may be discarded.

11.4.12 Curing

Immediately after the surface treatment described in Clause 1026, the surface and exposed edges of surface slabs shall be cured for a minimum period of 7 days, by the application of an approved resin based aluminised curing compound, or polythene sheeting or an approved sprayed plastic film which hardens into a peelable plastic sheet and which shall be removed before road marking and opening to traffic.

Resin based aluminised curing compound shall contain sufficient flake aluminium in finely divided dispersion to produce a complete coverage of the sprayed surface

with a metallic finish. The compound shall become stable and impervious to evaporation of water from the concrete surface within 60 minutes

The curing compound shall not react chemically with the concrete to be cured and shall not crack, peel or disintegrate within three weeks after application.

Prior to application, the contents of any containers shall be thoroughly agitated. The curing compound shall be mechanically applied using a fine spray on to the surface at a rate of at least 0.22 l/m². For the sides of slip-formed slabs or when the side forms are removed within 24 hours and for small areas where mechanical application cannot be used, the compound shall be sprayed by hand lance at a rate of at least 0.27 l/m². The rate of spread shall be checked during construction of each trial length and for each 1000 m² of treated slab.

11.4.12.1 Exposed Aggregate Concrete Surface

In order to obtain a suitable exposed aggregate surface the main requirement shall be the removal of the surface mortar from the top of the slab to produce an exposed aggregate finish. This objective may be achieved by the application of suitable cement set retarder which is sprayed on the surface of the fresh concrete immediately after it has been levelled and finished. Retarded mortar shall be removed by wet or dry brushing generally not sooner than when the surface concrete has reached a maturity of 16 hours at 20°C or after a suitable interval determined by trial.

The finished surface of the pavement concrete after application of retarder shall be protected against precipitation, moisture loss, contamination and dispersal of the retarder by air movements. This protection shall be applied immediately after the application of the retarder.

Where waterproof sheeting is used, it shall be laid onto the surface of the concrete immediately after the retarder has been sprayed. It shall be retained in position until immediately prior to exposing of the aggregate.

The protection system shall not adversely affect either the finish, the line or the level of the concrete surface or the even distribution of the retarder in any way. Where sheeting is used, any air bubbling or blistering shall be prevented.

Brushing equipment shall be used to expose the concrete surface aggregate. Where the brushing equipment runs on the slab, the concrete shall have gained sufficient strength to avoid any damage to the concrete.
Removal of the protection system shall take place as brushing proceeds. If waterproof sheeting is used as protection system, it shall be maintained in position until immediately in advance of the brushing operation.

The Contractor shall complete the process of exposing the aggregate before the retarder becomes ineffective. Failure to do so shall entail the remedial measures.

Sufficient brushing capability shall always be maintained on site to complete the exposure of the aggregate before the retarder becomes ineffective. An adequate back-up brushing facility shall be available on the site at all times for use in case of a breakdown of the brushing equipment.

Brushing shall be used to produce an even macrotexture on the surface of the slab and shall be carried out in the longitudinal direction of the concrete slab.

The wheels of any brushing equipment which may run on the slab shall be fitted with tyres with a shallow tread pattern and a low inflation pressure and be sufficiently wide to avoid damage to the concrete.

Within one hour of completing exposure of the aggregate the surface shall be dampened with water. A curing compound shall be applied to the entire exposed aggregate surface of the slab. In wet weather the curing compound shall be applied as soon as practicable after the rain stops. The surface may, alternatively, be covered by hessian provided it is maintained in a wet condition at all times during the curing period of the concrete.

During brushing, initial interim spot check measurements of the surface macrotexture depth shall be made as soon as it is considered that the required texture depth has been reached. This shall continue until the specified macrotexture depth has been achieved.

In the event that it is not possible to achieve the specified minimum macrotexture depth by further exposure, the Contractor shall treat the surface in accordance with Clause 11.4.14 to achieve the specified macrotexture depth. This treatment shall not be applied until the concrete has reached an age of 28 days.

Failure to achieve a satisfactory minimum macrotexture depth by mechanical means shall result in removal of the full thickness of the slab to the extent required to permit reconstruction of the slab in accordance with the Specification. Where the maximum macrotexture depth is exceeded suitable remedial measures shall be employed

11.4.13 Trial Tests

The Contractor shall demonstrate the constituent materials, concrete proportions, plant, equipment and methods of construction that are proposed for concrete paving, by first constructing a trial length of slab, at least 150 m but not more than

300 m long for mechanised construction, and at least 30 m long for hand guided methods. The concrete proportions decided by trial concrete mixes may be adjusted during the trial but shall not be changed once the trial length has been satisfactorily completed unless the Contractor lays a further trial area to assess the suitability of the proposed changes.

The trial length shall be constructed in two parts over a period comprising at least part of two separate working days, with a minimum of 75 m constructed each day when mechanised paving plant is used and a minimum of 15 m on each day for hand guided methods. The trial length shall be constructed at a similar rate to that which is proposed for the main construction in the Permanent Works.

Preliminary trial panels shall be constructed off-line incorporating a top surface of exposed aggregate concrete similar to that specified for the permanent Works. These panels shall be 20 m long and not less than 100 mm deep and the maximum intended paving width. They shall be used to enable the Contractor to determine the required application rate of the retarder and the amount of brushing required to achieve the specified macrotexture depth.

The trial panels may alternatively be constructed on-site, but in this case, they may only form part of the permanent Works if they meet all the requirements of the Specification, otherwise they shall be removed after they have served their purpose.

The surface macrotexture depth shall be determined by volumetric patch technique at approximately 2 m spacings along a diagonal line across each trial panel, and shall follow the procedure described in BS EN 13036-1.

The average value of each set of 10 individual measurements shall be taken as the resulting macrotexture depth which shall be assessed against the Specification.

At least two transverse joints and one longitudinal joint of each type that are proposed for unreinforced concrete slabs and jointed reinforced concrete slabs in the main construction in the Permanent Works shall be constructed and assessed in the trial length. If in the trial length expansion joints are not demonstrated, the first 2 expansion joints and at least the first 150 m of longitudinal construction joint for mechanised paving, or 30 m for hand guided method of construction laid in the main construction in the Permanent Works, shall be considered the trial length for these joints.

The trial length shall comply for strength and density with the Specification in all respects, with the following additions and exceptions:

- In checking for compliance with Table 18 the levels shall be taken at intervals of not more than 2.5 m along any line or lines parallel to the

longitudinal centre line of the trial length.

- The maximum number of permitted irregularities of pavement surfaces shall comply with the requirements of Table 18 for 300 m lengths. Shorter trial lengths shall be assessed pro-rata based on values for a 300 m length.

- At least 3 cores of minimum diameter 100 mm shall be taken from the slab at joints to check the lateral and vertical location of joint grooves and bottom crack inducers.

- Alignment of dowel bars shall be inspected as described in Clause 11.4.11 in any two consecutive transverse joints. If the position or alignment of the dowel bars at one of these joints does not comply with Clause 11.4.6, but if that joint remains the only one that does not comply after the next 3 consecutive joints of the same type have been inspected, then the method of placing dowels shall be deemed to be satisfactory. In order to check sufficient joints for dowel bar alignment without extending the trial length unduly, the Contractor may construct joints at more frequent joint intervals than the normal spacing required.

- If there are deficiencies in the first expansion joint that is constructed as a trial, the next expansion joint shall be a trial joint. Should this also be deficient, further trial expansion joints shall be made as part of a trial length. Deficient expansion joints shall not form part of the Permanent Works.

- Compliance with Clause 11.4.7 for the position and alignment of tie bars shall be checked by drilling additional cores from the slab unless they can be determined from cores taken for density assessment.

The Contractor shall not proceed with normal working unless the trial length complies with the Specification and any earlier defective trial lengths have been removed, unless they can be remedied to comply with the Specification.

After satisfactory completion of the trial length, the constituent materials, concrete proportions, plant, equipment and construction methods shall not thereafter be changed, except for normal adjustments and maintenance of plant, unless the Contractor lays a further trial length as described in this Clause to demonstrate that the changes will not adversely affect the Permanent Works or in agreement of the changes with the Authority's Engineer.

11.4.14 Texturing of Hardened Concrete

Worn, rain damaged or inadequately textured surface slabs shall be macrotextured by sawing grooves in the hardened concrete surface at right angles to the

longitudinal axis of the pavement with machines using diamond or other abrasive cutting discs.

Grooves shall be irregularly spaced and shall be not less than 2 mm and not more than 5 mm wide. The sequence of distances between groove centres in mm shall be: 40, 45, 35, 45, 35, 50, 30, 55, 35, 30, 50, 30, 45, 50, 30, 55, 50, 40, 35, 45, 50, 40, 55, 30, 40, 55, 35, 55. A tolerance of ± 3 mm shall be allowed on each of the spacings. The minimum width of grooving head shall be 500 mm and a head not providing a complete sequence of spacings shall use the number of spacings appropriate to its width commencing at the start of the sequence.

Groove depths shall be measured using a tyre tread depth gauge and measurements shall be taken as follows:

- At 10 locations at least 2 m apart along a diagonal line across a lane width between points 50 m apart longitudinally. No measurement shall be taken within 300 mm of the longitudinal edge of a slab. Where a grooved area is less than 50 m in length the locations where measurements are taken shall be as proportional to the requirements for 50 m.

- At each of the 10 locations the depth of 10 adjacent grooves shall be measured.

- The average of each set of 10 measurements shall be not less than 3 mm nor greater than 7 mm.

Slurry from the sawing process shall be prevented from flowing into joints, drains or into lanes being used by traffic, and all resultant debris from the grooving shall be removed.

11.4.15 Weather Conditions

Road pavement materials in a frozen condition shall not be incorporated in the Works but may be used, if acceptable, when thawed.

Road pavement materials shall not be laid on any surface which is frozen or covered with ice.

The temperature of concrete in any pavement layer shall not be less than 5ºC at the point of delivery. These materials shall not be laid when the air temperature falls below 3ºC and laying shall not be resumed until the rising air temperature reach 3ºC unless all surfaces of the concrete slabs are protected by thermal insulation blankets laid immediately after placing and finishing the concrete. The insulation shall be placed before the temperature of the concrete surface has dropped below 2ºC and

shall be retained for a minimum of 3 days or until the concrete is assessed to have reached 50% of the specified characteristic compressive strength provided the air temperature is above 0ºC and rising at that time. Thermal insulation blankets shall be closed cell polyethylene foam sheets, minimum 10 mm thick with a 'U' value of 4 watts/mC (or K value of 0.04 watts/m Kelvin) or suitable material with an equivalent or lower thermal conductivity. They shall be sufficiently robust and capable of being held in place against variations in wind and weather conditions for the necessary curing time.

11.4.16 Construction Traffic

Construction plant and traffic used on pavements under construction shall be suitable in relation to the material, condition and thickness of the courses it traverses so that damage is not caused to the subgrade or the pavement courses already constructed. The wheels or tracks of plant moving over the various pavement courses shall be kept free from deleterious materials.

Concrete slabs may be used by traffic when the cube compressive strength is assessed to have reached 25 N/mm². In the absence of test data establishing compliance, no vehicle with an axle loading greater than 2 tonnes shall run on concrete slabs within a period of 14 days after placing the concrete. Vehicles with rubber tyres with an axle loading less than 2 tonnes, or wheels or tracks of concreting plant, shall not use any part of a newly constructed pavement within 7 days. The above periods before traffic may run on the pavement shall be increased if the 7 day cube strength is below that what is required in the Specification. These periods shall be extended by one day for each night on which the temperature of the layer falls to 0ºC or below.

12 WATER PROOFING SYSTEM

12.1 General

Sheet waterproofing membrane systems for the tunnel shall comprise of a geotextile fleece fixed to the primary lining substrate in combination with a sheet waterproofing membrane fastened to this; see Section 12.6 for details of installation.

Waterproofing shall be applied to crown and sidewalls above footing or invert arch level. The waterproofing membrane shall always be located between shotcrete support and final concrete lining. As the underground structures referred to be not immersed below a distinct groundwater table no membrane waterproofing will be provided for tunnel inverts.

The design life of the water proofing membrane shall be minimum 100 years.

Where the waterproofing system is to be divided into sectors, the waterstops should be formed of material that can be welded to the sheet waterproofing membrane.

Additional drainage capacity shall be provided in case of water inflows in agreement with the Authority's Engineer by studded drainage membrane made from thermoplastic material (dimpled sheet) attached prior to installation of the geotextile fleece or equivalent drainage layer approved by the Authority's Engineer.

Waterproof membranes shall not be stored in direct sunlight prior to use. Waterproof membranes shall be protected from damage at all times especially during installation of reinforcement. The water proofing membrane shall have a signal layer to indicate damages due to handling and installation of reinforcement. The integrity of the signal layer shall be checked prior to concreting of final lining.

Fire protection measures during construction of water proofing system are required as but not limited to the following.

- The amount of membrane stored in the tunnel shall not exceed two working day's production to minimise the fire load stored underground.

- The installation length of the water proofing system in advance of the final lining shall not exceed 300 m, unless special measures are considered in agreement with the Authority's Engineer.

12.2 Geotextile Fleece

The purpose of the geotextile fleece is to protect the sheet membrane against mechanical puncture and to provide a drainage path for any ground water along the rock side of water proofing system around the tunnel structure.

The geotextile fleece and the membrane shall be combined in accordance to the hydraulic requirements to drain the encountered water inflows. The geotextile fleece only provides low long term drainage capacity. If the hydraulic capacity of the geotextile fleece is not sufficient an additional drainage layer shall be installed.

The geotextile, used in combination with dimpled sheet as strip drain is to protect the dimpled sheet and allows the inflow of ground water into the dimpled sheet drainage area.

The geotextile fleece shall be a non-woven fleece and shall provide a minimum weight of 500 g/m² in tunnel vault and 900 g/m² in tunnel invert if required and in c&c tunnels, in accordance to the Specification set forth in Fehler! Verweisquelle

konnte nicht gefunden werden..

Table 25 Requirements of geotextile fleece

Description	Standard	Requirement	
		500 g/m²	900 g/m²
Mass per unit area	BS EN ISO 9864	≥ 500 g/m²	≥ 900 g/m²
Nominal weight	BS EN ISO 9864	≥ 556 g/m²	≥ 1000 g/m²
DSC analysis	BS EN ISO 11357-1 & -3	Tolerance of melting temperature ≤±10%	
Thickness under normal pressure	BS EN ISO 9863-1	Within the tolerances of the manufacture r	
2 kPa			
200 kPa		≥1.7 mm	≥3.4 mm
Tensile strength in longitudinal and transversal direction to the direction of production	BS EN ISO 10319	≥30 kN/m	≥50 kN/m
Elongation at break in longitudinal and transversal direction to the direction of production	BS EN ISO 10319	Within the tolerances of the manufacture r	
Elongation at maximum tensile force	BS EN ISO 10319	≥50%	
Static puncture	BS EN ISO 12236	≥3kN	≥7kN
Cone drop test	BS EN ISO 13433	≤13mm	≤7mm
Behaviour during oxidation	BS EN ISO 13438	design life of minimum 25 years in compliance with	

		BS EN 13256
Behaviour in basic environment (pH≥9)	BS EN 14030 and BS EN ISO 10319	Decrease of tensile strength and elongation at break during design life of 25 years: ≤20%
Behaviour during fire	BS EN ISO 11925-2 and BS EN 13501-1	Class E
Permeability in flow direction with 200 kPa	BS EN ISO 12958	≥7l/(m*h)
Protection	BS EN 14574	≤0.1 mm

The geotextile is to provide adequate protection from chemical aggression caused in the curing processes of concrete.

Water transmissivity of the geotextile fleece should be designed to suit expected volume of water ingress.

12.3 Fixing Element

The geotextile is fixed onto the substrate with non-projecting disks. The disks are secured through the geotextile and into the substrate with shot-fired nails.

The disks should be made of a compound that allows the sheet waterproofing membrane to be fully welded to the surface.

In order to prevent stresses being transferred from the secondary lining to the sheet waterproofing membrane, the resistance to failure in shear of the nails and disks must be less than the shear resistance of the sheet membrane itself.

All accessories and compounds of fixing elements, flashing, reinforcement for expansion joints, sealing flanges etc. shall be in accordance to the recommendations of the membrane's manufacturer and compatible with the waterproofing system.

12.4 Layer with higher drainage capacity

If the hydraulic capacity of the geotextile fleece for water drainage is not sufficient

due to significant water inflows an additional drainage layer shall be installed.

The layer shall have minimum drainage capacity of 360 l/(m*h) with applied pressure of 200 kPa and hydraulic gradient of 1.

Drainage elements with higher drainage capacity shall be in compliance with requirements laid down in Table 4.

Table 26 Requirements of drainage elements

Description	Standard	Requirement
Mass per unit area	BS EN ISO 9864	within the tolerances of the manufacturer
Tensile strength	BS EN ISO 10319	≥ 10 kN/m
Thickness under normal pressure:	BS EN ISO 963-1 (Method A)	2 kPa: within the tolerances of the manufacturer 200 kPa:≥4 mm and ≤12 mm
Drainage capacity, hydraulic gradient 1, with thickness under normal pressure of 200 kPa (see above)	BS EN ISO 12958	≥360 l/(m*h) and 10-4 m²/s respectively
Behaviour during fire	BS EN ISO 11925-2 and BS EN 13501-1	Class E

12.5 Waterproof Membrane

The waterproof membrane shall consist of a continuous impermeable heat-welded sheet of one of the following materials:

- soft polyvinyl chloride (PVC) unreinforced

- flexible polyolefin (FPO/TPO) unreinforced

The membrane as supplied shall be of such dimensions and shape as will result in the minimum of on-site seam welds.

The installation of recycled membranes and/or membranes including DEHP (DOP) plasticizer is not permitted.

Unless otherwise stated in the Contract, the membrane shall conform to performance requirements and have properties shown in Table 27.

Table 27: Performance requirements of sheet waterproof membranes

Description	Standard	PVC-P	TPO
Identification	BS EN 13491	manufacturer, type, material, thickness, date of manufacture, CE marking including CE document	
Thickness including signal layer	BS EN 1849-2	min 2.0 mm for seepage water and min 3.0 mm for pressurized water	
Thickness of signal layer	BS EN 1849-2	≤ 0.2 mm	
Density	BS EN ISO 1183-1	tolerance ≤±0.005 g/cm³	tolerance ≤±0.02 g/cm³
Appearance	BS EN 1850-2	free from blisters, crack, external capsule and voids	
Straightness	BS EN 1848-2	≤ 50 mm	
Flatness	BS EN 1848-2	≤ 10 mm	
DSC analysis	BS EN ISO 11357-1 & -3	individual evaluation from diagram	
MFR Index (Melt Flow	BS EN ISO 1133	tolerance ≤±15	-

Index)	Method A	% of nominal value	
Tensile strength in longitudinal and transversal direction	BS EN ISO 527-1 & -3	≥15 MPa	≥12 MPa
Elongation at break	BS EN ISO 527-1 & -3	≥ 500 %	≥ 250 %
Youngs Modulus between 1 % and 2 % elongation in longitudinal and transversal direction	BS EN ISO 527-1 & -3	≤ 65 MPa	≤ 20 MPa
Static puncture	BS EN ISO 12236	≥2.8 kN	≥2.5 kN
Burst strength elongation multi- axial elongation test	BS EN 14151	≥50 % with Ø 1.0 m ≥80 % with Ø 0.4 m	≥50 % with Ø 1.0 m ≥80 % with Ø 0.4 m
Impact resistance (500 g), method A	BS EN 12691	nominal thickness 2.1 mm: fall height 750 mm nominal thickness 3.15 mm: fall height 1250 mm	
Long term compression strength	SIA-V 280 Test No. 14	impermeable during test duration of 48 h and 7 MPa	
Folding in cold environment	BS EN 495-5	no requirements	no cracks at -20°C
Behaviour during warming: Dimensional change	BS EN 1107-2	≤2% (1h/100°C)	≤2% (6h/80°C)

Appearance	BS EN 1850-2	no blistering	no blistering
Resistance under water pressure	BS EN 1928 method B	5 bars at 1 hour	
Thermal ageing (70 d with 80°C)	BS EN 1296 (BS EN 1850-2, BS EN 1849-2, BS EN ISO	no requirements	decrease of tensile strength ≤20% decrease of tensile
	527-1 & -3)		elongation at break ≤20%
Resistance to oxidation after 90 d with 85°C	BS EN 14575	decrease of tensile strength and elongation ≤20%	values shall be determined in agreement with Employer's Representative
Behaviour after storage in water with 50°C and 8 month	SIA-V 280 Test no 13	no requirements	Change of elongation at break ≤20%, change of mass ≤4%
Behaviour after storage in aqueous solutions (no 2), 90 days with 23°C Ca(OH)2(sat.); NaCl(10%)	BS EN 14415 (BS EN 1847, BS EN ISO 527-1 & -3)	decrease of tensile strength and elongation at break ≤25%	
Behaviour after storage in aqueous solutions (no 3) 90 days with 23°C, H2SO3 (5-6%)	BS EN 1847 (BS EN ISO 527-1 & -3)	decrease of tensile strength and elongation at break ≤20% no cracks at folding at -20°C	

Root resistance	DD CEN/TS 14416	No penetration	
Tear resistance	BS EN 12310-2	80 N/mm	
Water absorption	BS EN ISO 62	<4,0%	
Fire rating	BS EN ISO 11925-2 BS EN 13501-1	Class E	Class E
Smoke class	BS EN ISO 11925	E	
Welding	DVS 2225-5	accurate	
Peeling strength of welded seam	BS EN 12317-2	≥6 MPa	
Shear strength of welded seam	BS EN 12316-2	Failure shall appear outside welding seam	

Further guidance on test methods and requirements for mechanical properties and durability can be found in BS EN 13492:2004 (E): "Geosynthetic barriers – Characteristics required for use as a fluid barrier in the construction of tunnels and underground structures".

Where reinforced concrete is to be placed against the sheet 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. The signalling layer shall be of the same material as the waterproofing membrane.

An additional waterproofing strip with a width of 50 cm shall be placed around the vault in the area of construction joints between two final lining blocks.

12.6 Installation

The manufacturer's instructions for installation of felt backing and waterproofing membrane, including procedures for preparation, fixing, welding and splicing,

flashing shall be followed solely by the Contractor.

Prior to application of the geotextile fleece layer the primary lining shall be surveyed to confirm that it does not encroach into the designed extrados of the secondary lining. Any proposals to rectify areas of the primary lining shall be agreed with the Authority's Engineer.

The shotcrete lining shall be constructed in a way that all bolts and anchors are fully covered with shotcrete of the primary lining. The surface shall be prepared in accordance with the manufacturer's instructions. The surface shall be clean, smooth and free from any deleterious material. Except where indicated on the drawings, all

fixtures shall be removed from the primary lining prior to application of the geotextile fleece layer. All core holes shall be backfilled with mortar to be flush with the surface of the primary lining.

Shotcrete cover of minimum 50 mm to rock is required.

For sheet waterproof membranes, the profile of the substrate (tunnel surface) shall not have any irregularities that exceed a ratio of length to depth of 5:1 for PVC-P waterproofing membranes and 10:1 for flexible TPO waterproofing membranes. The minimum radius shall be 200 mm. Transitions and intersections of tunnel profiles such as niches and cross passages shall be rounded off with a minimum radius of 500 mm. The substrate surface shall be free from protrusions or sharp edges which may lead to membrane puncture. Crushed aggregates of a grain size greater than 8 mm shall not be used.

Groundwater penetrating through the primary tunnel lining shall be collected and drained by appropriate measures. This drainage shall be maintained throughout the membrane placing process, and shall be so arranged that excess water pressure behind the membrane cannot develop.

All shotcrete surface shall finally be smoothened with fine-graded shotcrete (rounded aggregates, grain size 0 - 8 mm), applied in a layer of 30 mm minimum thickness.

A layer of protective geotextile shall be attached to the substrate by suitable non-projecting fastenings installed directly through the geotextile fleece. When fixing the geotextile fleece overhead, sufficient fixings (minimum 2 to 4 elements per sqm) shall be installed to ensure the fleece is in close contact with the substrate and is self-supporting. The sheets shall overlap by at least 200 mm and jointed by point weld or equivalent method as approved by the Authority's Engineer.

When placing the sheet waterproof membrane, no other Works shall be carried out

in the vicinity which may cause personnel or equipment to come into contact with the sheet waterproof membrane before it has been protected. If it is likely that excessive dust may be generated in the vicinity of the Works (vehicle movements etc.), then dust suppression measures shall be put in place.

The sheet waterproof membrane shall be fixed to the tunnel structure by means of fastening devices which preserve the integrity of the sheet waterproof membrane. Sufficient fixings shall be installed to ensure the fleece is in close contact with the substrate and is self-supporting. No perforation of the membrane shall be allowed for installation purposes. The waterproofing membrane shall be laid with the signal layer towards the inside and with sufficient slack to prevent overstressing during concreting. All sheet waterproof membrane overlaps shall be welded in accordance with the membrane manufacturer's instructions.

Where waterproof membrane has been installed in the tunnel invert, it shall be protected from any damage as soon as possible after testing.

Radial joints between sheets of sheet waterproof membrane shall be welded using flat-faced fillet welds. Two lines of weld shall be used on each joint forming a double seam of at least 15 mm wide, with the minimum sheet waterproof membrane overlap 80 mm for manual welding and 100 mm for automatic welding.

All welding personnel shall have certificate in compliance with the qualification testing of welders as per BS EN 13067.

If protrusions through the membrane are required, they shall be fitted with collars to maintain the water tightness of the system.

Star or cross joints shall be avoided.

The length of material roll shall be procured to enable a complete extrados to be installed as a continuous length. Longitudinal joints shall be avoided.

The placing of inner lining concrete sequence and processes shall be such that they do not displace or damage the geotextile fleece or sheet waterproofing membrane.

12.7 Checking

12.7.1 Field Trials

Field trials shall be made to demonstrate the capability of the equipment, workmanship, materials and application methods under field conditions.

The testing programme shall be started sufficiently early prior to installing the

membrane to ensure that the required water-tightness can be achieved and allow repetition of the trials should the initial results prove unsatisfactory. All trials and acceptance tests shall be completed satisfactorily by the time installation commences.

Prior to construction, trials shall be carried out in order to establish the speed and temperature of joint welding required to achieve welds which are acceptable to the Authority's Engineer. If hand-welded joints are proposed at junctions, then this type of weld shall be pre-tested and agreed with the Authority's Engineer.

12.7.2 Construction Testing

On-going inspection of the waterproofing system shall be carried out and documented by the Contractor. The inspection documents shall be made forwarded to the Authority's Engineer for review and approval.

A visual inspection of the sheet waterproof membrane shall be carried out as specified in Table 28. Areas where the sheet waterproof membrane is damaged shall be marked up, repairs carried out and tested in accordance with the manufacturer's instructions.

All welded joints shall be tested in accordance with Table 28. Any joints that fail the test and require repair shall be marked with a permanent marker, at the time of the test.

Repairs and hand-welded joints shall be tested by hand-held vacuum chamber in accordance with Table 28.

Table 28: Construction testing for sheet waterproof membrane

Parameter	Test Method	Frequency	Pass Criteria
Coverage	Visual	A visual inspection to be carried out continuously while the membrane is applied	100% coverage
Double welded seam joints	DIN 16726	Every joint	Pressure drop not to be greater than 10% when a 2 bar (PVC-P) and 3 bar (TPE-O/TPO) pressure is

			applied for 10 minutes
Hand welding and repairs	ASTM D5641-94 (2006)	Every hand-weld and repair	Pressure drop not to be greater than 20% when a 0.3 bar pressure is applied for 10 minutes

A visual inspection of the fleece shall be carried out. Areas in which the substrate is still visible, or where the fleece is damaged, shall be marked up and an additional layer of fleece applied with a minimum lap of 200 mm around the area.

12.7.3 Failure Measures

Where tears, rips or defective joints in the geotextile fleece are noted, these shall be repaired with a minimum overlap of 200 mm.

Where tears, rips or defective joints in the sheet waterproof membrane are noted, these shall be repaired in accordance with manufacturer's recommendations. These shall be tested by hand-held vacuum chamber in accordance with Table 28.

Any sheet waterproof membrane not meeting specified requirements shall be removed and replaced including any associated water management measures or smoothing layer. The cause of the problem shall be rectified before placing any further sheet waterproof membrane.

ATTACHMENT-DII

ROAD TUNNELS-E&M, LIGHTING AND OTHER FIXED OPERATING EQUIPMENT (FOE)

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Annexure (ii) to Attachment DII of Schedule-D
Product Information Sheets

1 PURPOSE OF THIS DOCUMENT

The purpose of this document is to provide a detailed product independent functional specification for Fixed Operating Equipment (FOE) for the Zojila Tunnel in the Republic of India.

The detailed Project Highwayreport contains plans, schematic diagrams, product information sheets and a bill of quantities.

1.1 General Tunnel Data

This document is the basic Project Highwayspecification for the design, construction, operation and maintenance of the Zojila Tunnel in India.

The Zojila Tunnel is designed as a bidirectional road tunnel between Srinagar and Leh of approx. 14,150 km in length.

Parallel to the main traffic tunnel, there is a smaller egress tunnel serving as emergency escape way as well as for tunnel maintenance and rescue operation purposes.

Cross passages are situated between the main tunnel and the egress tunnel at 250 m intervals and emergency lay-bys are located at intervals of 750 m staggered on both sides of the carriageway. There are sidewalks on both sides of the carriageway. Emergency call niches and hydrant niches are situated at intervals of 125 m.

A general system solution for the tunnel is proposed and function descriptions are provided to guarantee adequate safety of the tunnel operation.

1.2 Terms and Abbreviations

The following are the main terms and abbreviations used in this document.

CCTV	Closed Circuit Television
ECC	Emergency Call Column
ECS	Emergency Call System
ECU	Emergency Call Unit
ESC	Energy Supply Company
FOE	Fixed Operating Equipment
GUI	Graphic User Interface
HGV	Heavy Goods Vehicle

HV High Voltage
IDF Incident Detection Function
kph Kilometres per hour
LED Light Emitting Diode
LV Low Voltage
MMI Man-Machine Interface
OMC Operation and Maintenance Centre
PLC Programmable Logic Controller
PTZ Pan, Tilt and Zoom camera
SCADA Supervisory Control and Data Acquisition
SCF Speed Control Function
TLE Traffic Logging Equipment
UPS Uninterruptible Power Supply
VDF Vehicle Detection Function
VIP VIDEO over Internet Protocol
VMS Variable Message Sign
VoIP VOICE over Internet Protocol

2 STANDARDS AND NORMS

This section describes the general standardisation environment and operational circumstances of the FOE to be installed.

2.1 Standards Organisations

Where applicable, the equipment should comply with the latest revision of the relevant standards from the following recognised organisations:

Table 1: References to sources of standards, guidelines and recommendations

Abbreviation	**Name**
CENELEC	European Committee for Electro-technical Standardization, Avenue Marnix 17, B- 1000 Brussels
DIN	Deutsches Institut für Normung e.V. Beuth Verlag GmbH, Burggrafenstrasse 6 D-10787, Berlin, Germany.
EN, ENV	European Committee for Standardisation, Central Secretariat, Rue de Stassart 36 B-1050, Brussels.
IRC	The Indian Road Congress, Jamnagar House, Shahjahan Road, New Delhi- 110011.
IS	Bureau of Indian Standards, Manak Bhavan, 9 Bahdur Shah Zafar Marg, New Delhi – 110002.

ISO	International Organization for Standardisation, rue de Varembé CP 56, CH- 1211 Genéve 20, Switzerland.
ÖNORM:	Austrian Standard Institute, Heinestraße 38, 1020 Vienna, Austria
RVS	Austrian Guidelines and Regulations for Road Construction, published by Austrian Association on Road, Rail and Transport (FSV), Karlsgasse 5, 1040 Vienna, Austria

In the event of any conflict between the standards of the above-mentioned bodies, the prescriptions of the most specific one, which must also be compliant with the Indian law, shall apply.

2.2 Operating Temperature

The equipment to be supplied shall be able to operate under the following environmental conditions:

Externally installed equipment (for example ECCs, TLE):

- Minimum temperature: -30°C
- Maximum temperature: +60°C
- Relative non-condensing humidity: up to 100%

Facility installed equipment (for example. computers, printers):

- Minimum temperature: 5°C
- Maximum temperature: +30°C
- Relative non-condensing humidity: up to 80%

Should the external equipment proposed be unable to function under these conditions or under conditions anticipated at the installation site, protection to regulate the equipment operating environment must be provided. For internal equipment, the facility design will ensure that the temperature and humidity be kept at acceptable levels, i.e. temperature > 5°C and humidity < 80%.

The temperature range specified is the ambient temperature that is defined as the temperature of the surrounding atmosphere as determined by an instrument shielded from direct or reflected rays of the sun.

2.3 Protection of FOE

The equipment to be supplied shall be installed in appropriate housings protecting against thermal, mechanical, etc. effects like direct rays of sun, dust, water, humidity, etc.

Cables shall be installed in appropriate ducting.
All protective structures shall be vermin-proof.

3 PROJECT HIGHWAYOVERVIEW

Open road and tunnel fixed operating equipment (FOE) is provided to enhance the safety of journeys for motorists and to assist the operator in providing a cost-effective, efficient operation and maintenance function.

The FOE systems are installed along the tunnel route and are located in positions that best serve the intended function of the equipment and equipment access requirements.

Tunnel safety facilities such as CCTV cameras, traffic lights, variable message signs, traffic loop detectors, emergency communications, alarm push buttons, fire detection systems, etc. shall be provided.

An adequate lighting system shall be provided. The light intensity of the entry and exit zones shall be adapted to the actual outside lighting level according to external conditions (day/night, regulation through measurement of luminous density).

A fire-extinguishing water pipe is installed at one roadway side providing a fresh water supply to the hydrants in case of an incident or for maintenance measures.

The egress tunnel shall also be equipped with lighting and safety facilities such as CCTV cameras, fire detection system, etc.

Tunnel service buildings are located close to both tunnel portals.

The corresponding civil engineering specifications relate to ducts and relevant structures for the protection of the communications cables and equipment, installation of roadside equipment and appropriate access provision for operation and maintenance.

3.1 Definition of Fixed Operating Equipment (FOE)

In the context of this document, FOE is equipment required to manage the day-to-day operations of the tunnel, including alerting the traffic control centre of the occurrence of incidents and/or events on the motorway such as:

- Traffic accidents
- Hazardous driving conditions
- Level of traffic flow

Tunnel and open road fixed operating equipment sub-systems:

- Ventilation
- Traffic Control
- Closed circuit television (CCTV)
- Emergency call system (ECS)
- Communication systems
- Fire safety system
- Lighting
- Tunnel control system (SCADA)

3.2 Operation and Maintenance Centres (OMC)

Two operation and maintenance centres (OMC) shall be constructed at the locations of West Portal and East Portal.

The OMCs shall, in addition to other maintenance activities, accommodate the central control and reporting centres for the fixed operating equipment.

Open road and tunnel control operations, maintenance, control and recording functions will be managed from both OMCs.

The main control centre will be located in the west portal OMC, and the sub control room will be located in the east portal OMC.

The operator administration and management functions shall be carried out at the OMCs, where the traffic control room is located. The traffic control room will coordinate all traffic management, maintenance, emergency response and other related activities for the tunnel.

The main data storage and reporting points for the open road and tunnel FOE shall be situated at each of these locations.

The main control centre will be manned on a 24-hour-a-day basis by appropriately trained staff.

The following equipment and installation, contained in the service buildings, has to be provided (list not complete):

- Control room
- Facilities for the electrical power supply (main electricity substation, HV switchroom, LV switchroom, UPS room, battery room, space for transformers)
- Diesel generator, fuel tanks
- Plant rooms for the tunnel maintenance and future requirements, stores;
- Staff room and toilet facilities (if building is manned)

4 FIXED OPERATING EQUIPMENT

The FOE contractor shall be required to manufacture, supply and install the open road and tunnel FOE in order to carry out the functional requirements of the system to the required performance criteria.

All components have to be provided, installed und put into operation.

4.1 General Costs

All costs for setting up the construction site and maintaining the site during the whole construction period shall be included in this chapter.

4.1.1 Setting Up the Construction Site

The site shall be set up at a place agreed with the client. Site huts or trolleys shall be provided.

The services include the following main tasks:

- Preparing the ground for the building site
- Setting up, changing and installing the site huts or trolleys
- Delivery of all machinery, tools, small appliances
- Connecting the site to electricity and water supply, telephone facilities, waste water, toilet facilities
- Setting up of storage facilities for materials to be stored
- Fencing of the site

The client or representative of the client shall be allowed to access always all facilities of the construction site.

4.1.1.1 Site Power Supply

The contractor shall be responsible for obtaining an adequate electrical supply for all his site operations during the whole construction period.

The contractor shall appoint a competent person to be solely responsible for ensuring the safety of all temporary electrical equipment on site.

The contractor is to comply at all times with the Electricity at Work Regulations.

The contractor shall furnish, install and keep operational throughout the duration of the works standby generating facilities of such capacity as to be able to maintain minimum services such as illumination, ventilation, water supply, dewatering etc. necessary for the Project Highwayarea safety and security during a failure of the primary power source.

Oil-filled transformers are not permitted in subsurface usage. Transformers shall be air-cooled and of dry type.

Electrical heaters or radiators having exposed coils or elements shall not be permitted underground.

The lighting circuits shall be separated from the other sub-circuits.

The contractor shall furnish, operate and maintain 100% standby diesel-driven generators or alternative source of power supply at each working portal.

The generators or alternative supply shall be capable of operating the lighting system and the pumps required for the flooding of the underground works besides operating all other systems so to allow for smooth function in event of main power system failure. The generators shall be tested by the contractor weekly to ensure the full working capability.

Drawings showing the design of the electrical power distribution system within each area shall be submitted to the Authority's Engineer for approval no later than 28 days prior to installation. This shall at least include a single line diagram for the distribution systems within each area, protection schemes for the systems and description of the operation concept. The installation of the electrical distribution systems shall not be started unless the Authority's Engineer has approved the submitted documents.

4.1.2 General Costs of Machinery, Man and Site

The following costs must be included in the calculation:

- Salary costs of employees and workers
- Travel expenses
- Costs of the construction site such as rent, heating, lighting, telephone, energy costs, maintenance of common rooms and toilets
- Costs of maintenance of the equipment and machinery

4.1.3 Clearing the Construction Site

The evacuation of the building site includes also restoring the initial state of the surrounding area and the removal of all temporary connections (electricity and water supply, telephone facilities, waste water, toilet facilities).

4.2 Power Supply System

The FOE contractor shall be required to design the power reticulation system for the tunnel, which shall include high voltage and low voltage distribution networks, transformers, power supply and cabling of all the technical systems, distribution boards and earthing system.

The detail for the design of equipment shall include for the equipment sizing, capacity, fault levels and operational requirements of the electrical equipment.

This includes equipment:

- To be supplied by others and interfaced to the FOE
- Electrical circuits to be supplied by the FOE Contractor

The installation of the protective earthing system and the connection of equipment to the earthing system shall form part of the works.

HV power transmission lines to both portals are not in the content of the tunnel power supply system.

For basic graphical description see drawing "ELEMENTARY DIAGRAM OF SAFETY INSTALLATIONS" and “POWER SUPPLY SCHEME”.

4.2.1 High Voltage Power Supply

The power supply of the tunnel shall be adapted to the given network conditions of the energy supply company (ESC, 33kV-High voltage grid).

The power supply shall be provided from two independent power sources at the east portal and west portal (two independent HV transmission lines).

In the two OMCs, the voltage shall be stepped down from 33 kV to 11kV.
Further supply in the tunnel shall be via an 11 kV high voltage cable.

The transformers to lower the voltage from 11kV to 690V or 400V shall be situated in the OMCs, in the ventilation caverns and special power supply niches. The transformers have to be oil-filled.

Electrical substations are located at an interval of approximately 750 m in separated niches (power supply niches) at each lay-by and in the ventilation caverns in the tunnel.

The following voltage systems shall be used:

- HV power supply: 3 AC / 50 Hz / 33kV
- HV power transmission: 3 AC / 50 Hz / 11kV

- Ventilation: 3 AC / 50 Hz / 690V
- LV energy distribution: 3 AC / 50 Hz / 400V

4.2.2 Energy Distribution (LV system)

The LV system shall be designed in such a way that LV switch rooms shall be located in the control centres, in the ventilation caverns and in the power supply niches.

The cabinets in the power supply niches shall be supplied by the HV/LV transformers on the portals or the ventilation cavern. The power supply cables shall be located in the tunnel tube under the tunnel sidewalks.

The hydrant niches shall be supplied from the opposite emergency call niches.

The contractor will supply and install the power distribution cable networks from the utility power distribution board to the equipment installation at the OMCs and energy consumers in the tunnel.

The switch rooms of power supply networks shall be executed as separate fire segregated spaces. Cable passages through walls (borders) of fire segregated spaces shall be tightened by appropriate fireproof packing.

All cables which are placed in the tunnel tube environment have to be characterized by enhanced fire resistance, by low invasiveness of fire products and by low flame propagation.

Earthing is designed as underlying ground electrodes imbedded in concrete layers of the tunnel foundation. The value of tunnel earthing resistance shall be less then 1 Ohm. All of the electrical equipment in the tunnel is connected to the tunnel earthing system.

4.2.3 Safety Power Supply

To ensure an uninterruptible power supply of individual equipment, diesel generators and an on-line UPS shall be installed.

The UPS units will be installed in the switch room of the OMCs and the tunnel ventilation caverns and these will be provided with their appropriate power distribution and systems.

The FOE contractor is required to specify the power requirements for the Uninterruptible Power Supply (UPS) system for the FOE.

The runtime of the UPS system must guarantee that the following plants can be supplied at least 1 hour of energy.

- Tunnel emergency lighting

- Emergency call system (ECS)
- CCTV monitoring
- Variable message signs (VMS)
- Traffic lights
- Overheight vehicle detection
- Traffic logging equipment
- Guidance system
- Tunnel radio system
- Internal telephone system
- Sound system
- Tunnel physical variables measurement system
- Escape route lighting
- Integrated tunnel control system (SCADA)

In case of an outage of normal power supply, the electrical appliances in the OMCs, in the ventilation caverns and in the tunnel shall be powered from diesel generators.

To avoid the unwanted overload of the generator, the appliances shall be started one by one.

4.2.3.1 Uninterruptible Power Supply (UPS):

The UPS system shall be designed so that the tunnel lighting and safety equipment can be supplied with electric power during a period of at least 1 hour. The start capacity of the batteries must be calculated so that a supply time of at least 1 hour 20 minutes is given. Within 10 years, a remaining supply time of at least 1 hour must be guaranteed.

4.2.3.2 Diesel Generator:

In case of an outage of normal power supply diesel generators shall supply the safety-related equipment (reduced capacity).

Each dynamic diesel driven UPS shall supply an output power of 450 kVA for these devices. The diesel generators shall be situated in the OMCs and in the ventilation caverns. The supply of the ventilation by the diesel generator is not provided.

The dynamic diesel UPS system for stationary use in buildings is comprised of two major components: diesel engine and generator.

The diesel generators must be designed to operate with diesel or fuel oil. The tank capacity must be designed for continuous operation of the generator for the period of 1 week. The first filling has to be supplied by the contractor.

4.3 Tunnel Ventilation System

The purpose of the ventilation system is to ensure the safety of all persons who travel through the tunnel from harmful levels of vehicle emissions. Pollution measurement sensors will be installed throughout the tunnel, which will measure the intensity of gases present. The pollution level will determine when to activate the tunnel ventilation system to force out the harmful gases.

4.3.1 Tunnel Ventilation

The ventilation systems in road tunnel include two operating modes. These are:

- Normal mode of operation: Ventilation maintains the air quality at acceptable levels. That means that the ventilation system must be able to remove the engine vehicle emissions and also to maintain the air temperature at reasonable values.

- Emergency mode of operation: Ventilation provides a safe route of escape for the trapped users, and also facilitates the task of the fire brigade by controlling the fire smoke.

Therefore, the tunnel ventilation system has to be taken into account when designing emergency protocols, and all the subsystems related to the air quality in tunnels (CO sensors, opacity meters, etc).

The threshold for CO concentration, and for the visibility loss shall be agreed upon with the client.

4.3.1.1 Position

For the normal mode, fans shall be installed in the ventilation buildings at both portals and in the three ventilation caverns in the tunnel. The existing tender design defines 2 fans (one for fresh air and the other for exhaust air) in each ventilation building and 4 fans (for two ventilation sections) in each ventilation cavern.

For the emergency mode, jet fans shall be installed. The pairs of jet fans shall be mounted in the tunnel in special jet fan niches at regular intervals. The existing tender design defines 11 pairs (totally 22 units) of jet fans.

A jet fan is provided for the ventilation of the egress tunnel at each portal. Additionally a small fan shall be installed at the entrance of each cross passage.

4.3.1.2 Function

The ventilation shall be monitored and controlled in the OMCs via the SCADA system.

When the ventilation system function works in the normal mode of operation, the fresh air shall be introduced through the inlet portal and it shall push the engine emissions along the tunnel length up to the outlet portal or the exhaust shafts where the emissions shall be vented.

The jet fans shall be fully reversible and may be activated from the tunnel control centre by means of the PLC in accordance with the functional protocols to be established.

Each fan and jet fan shall be connected to the SCADA system via a PLC. The SCADA system shall be programmed to identify each cable for all of the fans.

The SCADA system shall monitor the data received from all of the pollution measurement sensors. When the SCADA system detects values exceeding their defined limits, it shall then instruct the appropriate fan to switch on.

A data cable from the fan motor shall be wired back to the SCADA system via the PLC and this shall inform the SCADA system about the current status of the fan (for example motor run status, motor speed, etc.)

The fans can be switched on as required from the PLC to adjust the system performance to the particular necessities, i.e. light traffic hours, peak hours, emergency, etc.

4.3.1.3 Performance

In the event of a fire, the tunnel ventilation system shall be capable of controlling smoke and heated gasses in the main tunnel to allow the safe escape of people in the opposite direction or the egress tunnel.

4.3.1.4 Interfaces

The jet fan system shall be controlled by the PLC, which shall be connected to the SCADA system. This aims to remotely control the following signals:

- Forward start
- Reverse start

- Stop

4.3.2 Tunnel Physical Variables Measurement System

The operational ventilation of the tunnel tube shall be managed particularly in accordance with data acquired by continuous measurement of tunnel air quality conditions.

The tunnel physical variables measurement system shall comprise the following elements:

- Visibility measurement (dust particle)
- Carbon monoxide (CO) measurement
- Air velocity and flow direction measurement
- Air temperature measurement

On the basis of the data, the operation of ventilation system by standard traffic conditions is automatically controlled by the integrated tunnel control system. These data are especially important for main tunnel tube ventilation in case of a fire.

The visibility sensor shall work on an optical measuring principle. The sender emits light of a specific wavelength and the receiver determines, depending on the strength of the received light, the visibility conditions.

The CO sensor shall be an electrochemical three electrode sensor for the continuous real-time monitoring of CO in the ambient air.

The air velocity and flow direction measuring device shall consist of two ultrasonic transducers, which will be fixed to both tunnel walls and will be adjusted in an angle of 45° to the driving direction. The transducers shall work alternately as sender and receiver, thus being able to determine air velocity and flow direction.

For Basic Graphical Description see drawing "ELEMENTARY DIAGRAM OF SAFETY INSTALLATIONS".

4.3.2.1 Position

The sensor units shall be mounted on the tunnel wall each to other at equal distances. CO and dust particle sensors two times in each ventilation section and air velocity and flow direction sensors three times in each ventilation section.

4.3.2.2 Function

The visibility sensor shall consist of a transmitter/receiver unit and a reflector. The transmitter emits light, which is reflected by the reflector to the receiver, next to the transmitter. The system shall determine the visibility conditions inside the tunnel by the amount of light that reaches the receiver. The light shall pass through the air twice, increasing the accuracy.

The air velocity and flow direction sensor system shall consist of two ultrasonic transducers and one evaluation unit. The two transducers shall work alternately as transmitter and receiver, so both transit times (with the flow, against the flow) will be determined. The evaluation unit shall calculate the air velocity and flow direction from the difference between the two transit times.

The tunnel physical variables measurement system shall be connected to the PLC, which shall be controlled in the OMCs via the SCADA system.

The sensor measurement shall be powered by UPS.

The threshold for CO concentration and for the visibility loss shall be agreed upon with the client.

4.3.2.3 Housing and Fabrication

The tunnel physical variables measurement system shall be designed to operate under the following environmental parameters:

- Protection: IP 65
- Minimum temperature: -30°C
- Maximum temperature: +60°C
- Relative non-condensing humidity: up to 100%

4.4 Traffic Control

Traffic control is operated by the integrated tunnel control system (SCADA) on the basis of tunnel operator's interventions.

The Traffic Control System shall cover the following needs

- Traffic Lights
- Overheight Vehicle Detection

- Traffic Logging Equipment
- Variable Message Signs (VMS)
- Guidance System

For basic graphical description see drawing "ELEMENTARY DIAGRAM OF SAFETY INSTALLATIONS", “TYPICAL CROSS SECTION INSTALLATIONS”, “SCHEMATIC LAY-OUT OF TECHNICAL EQUIPMENT IN FRONT OF THE TUNNEL”; “SCHEMATIC LAY-OUT OF TECHNICAL EQUIPMENT IN THE INNER AREA OF THE TUNNEL” and Product Information Sheets.

4.4.1 Traffic Lights

ln case of emergency situations like a fire, a failure of power supply system, an accident, etc. the tunnel traffic shall be closed immediately.

Traffic lights are located in the area before and after the tunnel, at the tunnel portals and inside the tunnel next to the lay-bys.

Traffic lights apply LED technology; their brightness may be adjusted according to the time of the day and the weather conditions and they must be connected to UPS system.

In exceptional traffic situations the amber lights of the Traffic Lights shall also serve as flashing warning signals.

4.4.1.1 Position

Traffic lights in the tunnel shall be installed on the tunnel wall and in the area before and after the tunnel they are installed on outside entrance road gantrys.

4.4.1.2 Function

The traffic lights are controlled by their own monitoring module and report the actual status of the lights to SCADA.

The following conditions shall be possible:

- Off
- Yellow and yellow flashing
- Red
- Green

The operator in the OMC must be able to address the locations of the traffic lights, individually or in groups.

In the case of an incident (for example fire alarm) the traffic lights shall be automatically switched to red.

When a lay-by is occupied, the traffic lights next to the lay-by shall automatically be switched to flashing yellow.

4.4.1.3 Housing and Fabrication

Traffic light equipment shall operate under the following ambient climatic conditions:

- Minimum temperature: -30°C
- Maximum temperature: +60°C
- Relative non-condensing humidity: up to 100%

4.4.2 Overheight Vehicle Detection

The optical height gate subsystem shall be designed to give alarm when an over-height vehicle is moving towards the tunnel. Each side shall be covered with one infrared barrier or laser distance measurement device that is intended to monitor the height line of the lanes. If an overheight vehicle breaks the beam, the system gives an alarm and initiates further actions. The sensors must be mounted at the predefined height, where the overheight vehicles can be detected.

For each installation site a gantry shall be provided. The system shall be able to identify the lane where the overheight vehicle is moving (using a laser product). Based on this information the system shall give an alarm to the SCADA indicating the location and lane number ID as well as the time where and when the system detected the incident. The system shall not be sensitive to occasional false alarms due to the built-in software solution that continuously monitors the signal of the beam.

4.4.2.1 Position

The overheight gates shall be installed about 500m from the tunnel portals to detect overheight vehicles, to activate visual and audible warnings and to instruct drivers to take appropriate action.

4.4.2.2 Function

For optical height measurement, laser devices or infrared beam devices and a detection system (inductive loops) can be placed at the roadside. The measuring devices and an embedded industrial computer shall be placed on roadside gantries at the required height where detection takes place.

The computer shall analyze the violation information received and shall check if the alarm is real. False alarms shall be identified and disregarded (e.g. a bird breaks the beam). To identify false alarms a loop sensor shall be installed in the traffic lane under the gantry.

When a real alarm is detected the system shall forward an alarm signal to the SCADA indicating the location as well as the time where and when the system detected the incident. The traffic lights in the area in front of the tunnel will be automatically switched to red and further information will be displayed on the variable message signs. Subsystem is interfaced with the SCADA system to provide an automatic alarm and has direct connection with the next variable message sign.
The system shall work independently, locally or controlled remotely from the control centre. This system shall be connected to the closest controllers for communications with the control centre.

4.4.2.3 Housing and Fabrication

The overheight detection system shall be based on a market leader laser or infrared beam device, which is designed for outdoor measurement.

Outdoor equipment shall operate under the following ambient climatic conditions:

•	Minimum temperature:	-30°C	
•	Maximum temperature:	+60°C	

Relative non-condensing humidity: up to 100%.

2 Functional Requirements

Overheight detection:

The overheight detection shall monitor the traffic travelling towards the tunnel and shall detect any moving object/vehicle exceeding the nominal determined maximum permissible height above the surface of the road.

Warning function:

The overheight detection shall comprise a warning functionality that is activated when moving objects are exceeding the predetermined height passing the monitored points. This warning function shall activate the overheight alarm function.

False alarms:

The warning functionality shall not provide false alarms exceeding the integrity requirement of the overheight warning function. Automatic provisions to ensure this shall be provided.

Driver warning:

The overheight alarm function shall alert drivers of the overheight object/vehicle via message signs.

Traffic operator alarm:

The overheight alarm function shall always be reported to the traffic operator. The alarm shall be visual and audible, readily recognisable and easily discernible above the ambient noise.

CCTV camera alarm action:

The overheight alarm function shall be activated automatically and sens the traffic operator images from the nearest CCTV camera showing the overheight vehicle. The tunnel operator shall be able to monitor the movements of the offending vehicle, to ensure that it leaves the main lane correctly.

Tunnel entrance control alarm:

The overheight alarm function shall automatically activate an alarm to the tunnel portal entrance control function (portal traffic lights).

4.4.3 Traffic Logging Equipment

Traffic Logging Equipment (TLE) is located to provide valuable data on vehicles using the tunnel, moving at speeds between 20 kph and 200 kph.

Traffic logging equipment consists of controllers, sensors and cabling.

4.4.3.1 Position

Sensors shall be installed at both portals of the tunnel and in the area of all lay-bys to control traffic flow.

Loop sensors shall also be installed in all lay-bys to indicate whether a vehicle has stopped in the lay-by.

Controller units shall be installed in the power supply niches and the LV switchrooms of the ventilation caverns.

4.4.3.2 Installation

Loop sensor pairs and axle sensors shall be installed into the wearing surface in the traffic lanes.

The measurement of traffic volume, vehicle speed, vehicle substitute electrical length and other parameters call for the installation of two induction loops mounted one after another in the direction of the traffic flow together with an axle sensor.

The equipment shall be capable of determining and recording the length, speed, travelling direction, classification, following distance, axle count and spacing with time-stamps, under all anticipated environmental conditions, with respect to vehicles travelling at motorway speeds on the travelling lanes of each carriageway.

All vehicles larger than a motorcycle travelling within the lane must be detected by the installed road sensors.

Road sensors shall be connected to the controllers via copper interface cables.

Controllers shall interpret electrical data input from the sensors, and generate and process logical data from them.

Data and sensor cables shall be pulled into protective ducts.

4.4.3.3 Interface

Each station shall have a unique ID code used by the central control station for identification, control and data communication.

Communication between traffic logging sites and the central station shall be based on Ethernet-based IP communication.

TLE shall count and classify vehicles, report measurements to a central monitoring station; furthermore, it shall also be capable of standalone operation in case of communication breakdown.

Data shall then be stored in the controller, and upon reestablishment of communication, without affecting regular actual real-time data traffic, transmitted to the central computer.

TLE shall have an automatic restart capability, without manual intervention and with appropriate safeguards to avoid data loss.

The TLE systems shall be designed to allow for diagnostic testing from either the roadside units or the central control station.

4.4.3.4 Performance

The traffic counter devices shall provide a continuous count of the total number of vehicles per hour in each direction with an accuracy of + or – 4% over every 24-hour-period with a 95% confidence interval, without bias to under- or over-recording. They shall provide a continuous count with the accuracy defined in the following table of the total number of

vehicles per hour in each direction, classifying each vehicle into one of the following categories (using the EURO 6 classification definitions):

Class	Counting Accuracy
Class 1: Motorbike	Plus or minus 10%
Class 2: Cars/Vans	Plus or minus 3%
Class 3: Cars/Vans + Trailer	Plus or minus 10%
Class 4: Rigid HGV	Plus or minus 3%
Class 5: Articulated HGV	Plus or minus 3%
Class 6: Buses and Coaches	Plus or minus 5%

4.4.3.5 Housing and Fabrication

The units shall be installed in robust cabinets, which are resistant to environmental conditions and equipped with tamper protection and detection.

The TLE electronics and all other related electronic equipment shall be housed in the tunnel niches.

Control units shall control sensors of all traffic lanes at the given location, and shall also include the data storage and communication devices.

The cabinet shall be equipped with a security lock and a door opening switch, it shall generate a door opening signal at the central unit at the traffic control room.

Cabinets are only accessible with the corresponding access key.

Access keys shall be supplied in the form of one master key per sub-system scheme. All cut-outs and openings shall be vermin-proof.

4.4.3.6 Functional Requirements

VDF (Vehicle Detection Function) detectors shall be installed to measure vehicles real-time and collect vehicle data from all lanes.

Measurement points:

Locations on the motorway are defined according to the drawings.
Wrong-way drivers:

The VDF shall be able to detect wrong-way drivers (vehicles moving in the direction opposite to the regular traffic) throughout the tunnel.

Traffic database:

Vehicle data shall be communicated to and stored in a central traffic database. This collected data shall be sent to the control centre at the OMC.

Vehicle data delay:

Vehicle data shall be transmitted and processed in a timely manner without impairing the VDF reaction time significantly.

Integrity monitoring:

The system implementation of the VDF function shall perform continuous system monitoring of itself and associated equipment and interfaces.

Any malfunction shall be automatically identified and logged without any delay.

VDF traffic data:

The traffic database shall continuously record and retain traffic data from at least the past 60 days and provide the means to extract any selected subset of these data.

Lay-by occupancy detection:

When a lay-by is occupied, an alarm signal shall be forwarded to the SCADA and the traffic lights next to the lay-by shall automatically be switched to flashing yellow.

4.4.3.7 Operator Functions

The operator shall be able to continuously view a graphical presentation of near real time traffic conditions of the whole tunnel.

Wrong-way driver alarm:

It shall be possible for the operator to receive an audible and a visible wrong-way driver alarm detected by the VDF function.

4.4.4 Variable Message and Traffic Signs (VMS)

Variable message signs are located in the area before and after the tunnel and inside the tunnel. Variable message signs aid drivers on the motorway by providing them with traffic control and other information.

Variable message signs are devided into:

- Variable message signs (information signs)
- Variable traffic signs

Variable message signs provide textual messages in front of the tunnel and are intended to inform drivers about traffic situation of traffic participants ahead. The textual information shall be always shown in local language and in English. The textual information shall be complemented on the display by various traffic control symbols.

Variable traffic signs consist of an alphanumeric zone in full color display to show images (speed limits or no overtaking symbols).

The VMS subsystem shall be directly interfaced with the SCADA system.

VMS located in front of and inside the tunnel must be connected to UPS system.

4.4.4.1 Position

Variable message and traffic signs in the area before the tunnel are installed on the outside entrance road gantrys.

Variable traffic signs in the tunnel shall be installed on the tunnel wall and they are installed on a pole in the area after the tunnel.

4.4.4.2 Equipment

The control unit consists of a computer and a communication unit for storing sign pictures, to control the displays and communicate with the centre. The power supply of the control unit is shall be uninterruptible (UPS).

Potential malfunction is warned by an automatic alarm system. The communication module consists of a network connection of the control computer and a suitable branch of the nearest LAN switch. There is an IP-based network connection between the centre and the individual VMS units.

4.4.4.3 Installation

The VMS, which are installed on a pole, shall be protected by H2 type guard rails.

The H2 guard rail shall be connected to any potential guard rail existing or to be installed within 50 metres; otherwise, it shall be installed with a flare end.

4.4.4.4 Housing and Fabrication

VMS equipment shall operate under the following ambient climatic conditions:

- Minimum temperature: -30°C
- Maximum temperature: +60°C
- Relative non-condensing humidity: up to 100%

4.4.4.5 Specifications

The signboards shall be able to display the appropriate icons and text messages.

The signboards apply LED technology; brightness may be adjusted according to the time of the day and the weather conditions.

4.4.4.6 Central Unit

The central unit shall be located in the technical room at the OMCs.

The decision support system (SCADA) for VMS runs on the central computer, the input data is provided by the central traffic management system. This decision support system is partly automatic; in certain traffic and weather circumstances it shall alarm the operator and automatically send a display command to the particular VMS units.

Furthermore, it shall provide the operator with the option to set icon messages manually on particular signboards.

The user interface to be developed on the central computer shall allow for:

- All-time monitoring of the system with testing function
- Displaying all signal pictures actually set on any signboard
- Archiving and retrieving of all processes

4.4.4.7 General VMS Functions

VMS remote control:
All signs and signals shall be remotely controllable from the traffic operators panel, and it shall be possible to individually turn all signs and signals on and off within the specified response times.

ln the event of an exceptional traffic situation like a vehicle breakdown, etc. vehicle speed should be limited by using of speed limit variable message signs, which shall be complemented by two amber flashing warning lights.

Override control:

It shall be possible for the operator to manually override any automatic control of the signs.

Control responsibility:

All VMS in a road segment shall only be controlled from a single traffic operator panel at a time. The operator ID, operator panel road segment, date/time etc. shall be logged.

Light Intensity Control:

Each VMS sign and signal shall be able to automatically adjust its display intensity in order to provide optimum visual effect under changing light and visibility conditions.

VMS response time:

The time delay between the command that the operator has issued to set or change the setting of a VMS sign and the system has changed shall not exceed 3 seconds.

Status:

It shall be possible for the operator to view the real-time operational status of the VMS systems and all of its components. VMS and signals without control/command connection shall default to blank display.

Error handling:

If the control link between the central site and a sign is NHIDCLken, the sign shall automatically display a blank screen.

4.4.4.8 Speed Control Function (SCF)

Speed control:

The speed control function (SCF) shall be implemented through the use of SCF signs capable of posting variable speed limit in kph.

Properties:

Each of the SCF signs shall generally have the ability to assume the following visual properties: 30, 40, 50, 60, 70, 80, 90 and 100 kph.

Cancellation of speed limit:

SCF signs for cancellation of the speed limit shall be provided. The cancellation signs shall display the cancelled speed limit and only be operational when a speed limit is in effect.

Signal control:

The SCF signs shall be controllable by the operator based on current traffic conditions.

Blanking:

It has to be possible to completely blank the signs.

Safety functions:

The SCF shall not allow the operator to set the SCF sign in a configuration which is not permissible by the approved general traffic control scheme in accordance with the traffic management plan.

Predefined settings:

It shall be possible for the operator to define a minimum of 10 predefined settings involving all individual SCF signs settings and manually enforce these settings with a keystroke.

Error handling:

If the control link between the central site and a sign is NHIDCLken, the sign shall autonomously display a blank face.

4.4.5 Reflective Traffic Signs

Standing reflective traffic signs ("Overtaking Prohibited", "Switch Vehicle Lights On", "Video Control", Transmitted NHIDCLadcasting Station Frequency and Name and Tunnel Name Plate) shall be located at standard intervals on outside traffic sign poles.

See drawing "SCHEMATIC LAY-OUT OF TECHNICAL EQUIPMENT IN FRONT OF THE TUNNEL".

4.4.6 Guidance System

The edges of the sidewalks shall be equipped with self-illuminating light modules for optimal detection of the road course.

The guidance system applies LED technology and the brightness may be adjusted according to the time of the day and the weather conditions.

4.4.6.1 Position

The light modules on the sidewalk shall be equipped on both sides with LEDs. The colours of the LEDs are red and white. (Red LEDs on the left side and white LEDs on the right side.)

The light modules at the entrance shall be located at 15 m intervals.

The light modules in the interior of the tunnels shall be located at 25 m intervals. No light modules shall be located in the lay-bys.

4.4.6.2 Function

The light modules of the guidance system shall work normally in continuous operation.

In the case of an incident (for example, a fire alarm or an accident) the guidance system shall be automatically switched to flashing mode.

For services in the tunnel the operator in the OMC shall also be able to switch the guidance system to flashing mode.

4.4.6.3 Housing and Fabrication

The covers and mechanical parts of the light modules must be resistant against the aggressive tunnel environment and must be passable by a truck tire.

4.4.7 Escape Exit Labelling

The access to each cross passage shall be equipped with self-illuminating light modules.

The light modules apply LED technology and the colour of the LEDs is green.

4.4.7.1 Position

The light modules are situated on both sides of the access to the cross passages at heights of 50cm, 100cm and 150cm above the sidewalk.

4.4.7.2 Function

The light modules of the escape exit labelling shall work in continuous operation.

4.4.7.3 Housing and Fabrication

The covers and mechanical parts of the light modules must be resistant against the aggressive tunnel environment.

4.4.8 Escape Exit Running Light

The access to each cross passage shall be marked with an escape exit running light.

The running light consists of light- and flashing-modules with LED technology, the colour of the LEDs is green. The LEDs in the light modules are arranged in a sagittate form.

4.4.8.1 Position

The light modules are situated on both sides of the access to the cross passages at a height of 150cm above the sidewalk.

If the access is situated in a lay-by, the light modules shall be situated on both sides of the access along the entire lay-by.

If the access is situated in the inner area of tunnel, the light modules shall be situated on both sides of the access at 5 m intervals.

A flashing module shall be situated at the beginning of the running light.

4.4.8.2 Function

The escape exit running light is normally in the switched-off mode. ln the event of an emergency in the tunnel, the running lights shall be immediately switched-on.

4.4.8.3 Housing and Fabrication

The covers and mechanical parts of the light modules must be resistant against the aggressive tunnel environment.

4.5 CCTV Monitoring

The remote camera monitoring system constitutes a basic visual aid to operators located in the control centre in order to take the appropriate measures against incidents that may happen in the tunnel and in the area before and after the tunnel.

This system also allows for the recording of different situations for subsequent analysis to prevent future incidents and respond more efficiently.

The possibilities that a system with these characteristics offers are varied and of vital importance:

- To allow for traffic monitoring: The vision of the traffic in the accesses serves as support for the operators to verify the real state of the traffic, either by direct observation, or like means of verification of possible false information of other systems (automatic detection of incidents, etc.)

- To allow for monitoring of meteorological conditions: The view of the surrounding area serves as support for the operators to visually verify the climatic conditions of the area and their possible influence on the sefety of the drivers.

- To serve as support for the operators in operation conditions. In this sense, the direct view is the only possible way of verifying certain circumstances (correct operation of a part of the system, validation of phases in a determined protocol of performance such as closing of tracks, etc).

- To serve as support in the management of incidents. The video surveillance systems constitute one of the key elements in the control and pursuit of the

different phases that follow one another when an incident occurs: detection, verification, information, answer, on-site construction areas and clean up.

For basic graphical description see drawing "ELEMENTARY DIAGRAM OF SAFETY INSTALLATIONS", "TYPICAL CROSS SECTION INSTALLATIONS", "SCHEMATIC LAY-OUT OF TECHNICAL EQUIPMENT IN FRONT OF THE TUNNEL", "SCHEMATIC DIAGRAM OF THE VIDEO SURVEILLANCE SYSTEM", "OPERATORS WORKPLACES – MAIN CONTROL CENTRE" and Product Information Sheets.

4.5.1 CCTV-Cameras

4.5.1.1 Position

The surveillance cameras in the tunnel shall be installed on the tunnel wall and the cameras in the area before and after the tunnel are installed on a pole.

The fixed cameras in the main tunnel shall be installed on the tunnel wall at a height of about 5.0 m above the sidewalk. The distance between individual cameras shall be less than 200 m each to other, providing 100% coverage of the carriageways.

Further fixed cameras shall be situated at each cross passage in the main tunnel, with a view of the accesses.

The surveillance cameras (fixed cameras) into the egress tunnel shall be installed on the tunnel wall at a height of about 3.8 m above road level. The distance between individual cameras shall be about 250 m at each cross passage. Further fixed cameras shall be mounted in each cross passage itself.

PTZ cameras (pan, tilt, zoom) shall be situated in each lay-by and in the area before and after the tunnel, with a resulting image at the control centres of adequate size and resolution to enable the operator to correctly observe vehicles and people.

The number of cameras is estimated to be about 300 pieces.

The individual camera visual angle shall be right adjusted and shots shall not be disturbed by obstacles and by curvature of the tunnel tube.

Data and video image shall be transmitted through the communications lines. To achieve this, transceivers and media converter shall be employed.

4.5.1.2 Function

CCTV cameras shall be as follows:

- The cameras shall be equipped with colour CCD, and motorised zoom lens.

- Cameras shall automatically switch over to black and white under poor lighting conditions.
- The system equipment shall be able to control the PTZ movement of cameras individually.
- 24-hour automatic recording of video of all camera images.
- The recorded camera images can be searched at any time together with the possibility of printing the selected image.
- Images must be saved in digital form in the central storage system.
- Time display, single and multiple camera images with identification on a single monitor. The number of camera images displayed on the monitor and on the video walls shall be adjustable.
- The cameras shall be of tough, heavy-duty construction, with increased optical clarity.

4.5.1.3 Housing and Fabrication

- The video camera installations shall be easily accessible for maintenance purposes.
- The mounting and equipment housing shall be able to withstand adverse weather conditions and the video cameras shall be capable of working satisfactorily under worst-case weather conditions.
- Cameras shall have waterproof housing with a heater.
- Cameras and associated units shall be water-resistant and dust proof.
- All cables and connections to the lens should be weatherproof.
- The equipment cabinets must be located for easy access for maintenance purposes. They must also be weatherproof.

Outdoor equipment shall operate under the following ambient climatic conditions:

- Minimum temperature: -30°C
- Maximum temperature: +60°C
- Relative non-condensing humidity: up to 100%.

4.5.1.4 Interface

The connection between the camera and the camera connection unit (control enclosure) shall be a single cable that will carry power, video signals and the data to position the camera.

The outgoing coaxial cable from the camera shall be changed to an FO single mode cable in a pair of receiver-transmitter of video and data before being encoded by a MPEG4 encoder at the OMC.

The video signal from the control enclosure shall be sent to concentration points (multiplexer in power supply niches) using fibre optic cables.

4.5.2 Central Unit

4.5.2.1 Position

The central CCTV system shall be located in the main control centre. The main control room system shall consist of:

- The video switching centre
- The video recording system
- The incident detection function

The main control room shall house a video wall (8 Large Screen Displays), 36 Video monitors and manual control panel.

The sub control centre shall house a manual control panel and 4 video monitors.

4.5.2.2 Function

The video wall shall be configured to be capable of displaying multiple separate or individual camera outputs. Recorded images shall be stored on the digital recorder for at least 14 days. System shall be capable of archiving the recorded images to a hard disk drive or DVD.

The CCTV control system shall provide the following reporting functions.

- Multiple camera displays for live viewing or playback while recording
- High-speed searching (date, time and alarm)
- Playback by date, time, and camera

The main control centre and the sub control centre shall be connected via fibre optic cables.

4.5.2.3 Housing and Fabrication

Indoor cameras shall operate at the following ambient conditions:

- Temperature; +5°C to +30°C
- Relative humidity: up to 80%

4.5.3 CCTV Operator Functions

Viewing facility:

A viewing facility allowing the operator to simultaneously view the same camera images from at least two separate locations shall be supplied. This facility shall be installed in the control room and the emergency control room.

Selection of camera:

It shall be possible at any time for the operator on duty at any time to select a view from any CCTV camera to be displayed on any selected viewing facility.

CCTV response time:

The time, from when an operator has issued a command to view the images from a specific location, until these images are provided on the viewing facility, shall not exceed 2 seconds. The same response time shall apply when an automated system requests images from a certain camera to be shown.

Control delay:

The camera function shall be interactively, remotely controlled by the operator on the basis of the monitor view in such a way, that tuning can take place quickly and safely. For example delays shall not have detrimental effects on the control.

Images ID:

Images shall automatically be supplied with a camera ID, operator ID, location name/viewing direction, day, month, year, hour, minute and seconds, and this information shall be visible on the images. The operator shall be able to remove this information during viewing.

Automatic camera select function, inside the tunnel:

The CCTV function shall be automatically activated upon the occurrence of any of the following events in the tunnel and shall automatically record the images of the activated area from the two nearest CCTV cameras and show them at the viewing facility:

- Opening of any emergency door
- Operation of a fire alarm push button
- Operation of an emergency push button
- Removal of fire-fighting equipment
- Incident detected by Vehicle Detection Function (VDF) and Incident Detection Function (IDF)

This control function shall have certain priority functions related to the normal camera and image control.

The occurrence of any of the above events shall also activate a visual and audible alarm to the operator.

Automatic camera select function outside the tunnel:

The CCTV function shall be automatically activated by the occurrence of any of the following events outside the tunnel, accompanied by a visual and an audible alarm to the traffic operator, and automatically record the images of the activated area from the two nearest cameras and show them at the viewing facility:

- Alarm from the overheight vehicle detection function
- Operation of an emergency push button of an Emergency Call Column (ECC) on the tunnel approach ramps

4.5.4 Incident Detection Function (IDF)

Incident:

The IDF shall continuously and automatically detect any out-of-the-ordinary situation, i.e. vehicles on the hard shoulder, stopped vehicles or objects in lane and transverse or inverse moving objects (wrong-way drivers, persons, leaves, debris etc.) occurring in or near the tunnel, on the specified road segment and on the associated hard shoulder areas, and automatically alert the operators of such incidents.

4.5.4.1 Functional Requirements

Object definition:

An object to IDF identification is any object, which may cause dangerous situations involving personal injury or damage to property.

Incident detection:

The IDF shall be able to continuously identify the following conditions on the applicable segments:

- Any new objects on a hard shoulder. New is identified as an object that was not previously accepted by an operator
- Slow moving objects in lanes (V < 15 kph)
- Queues of objects in lanes (V< 5 kph)
- Stationary objects on lanes (V=0 kph min. time 3 seconds)
- Inverse moving direction of objects (Ghost drivers)
- Smoke or fog presence in the tunnel

Location data:

Such incidents shall be reported to the operator, including information of incident location and camera identification.

Reaction times:

Reaction times for the IDF shall be adjustable and decided on operational trials, but the IDF shall generally react within:

- 5 seconds for stopped objects and vehicles
- 30 seconds for queues and slow-moving vehicles
- 30 seconds for smoke or fog detection
- Less than 3 second for ghost drivers

Presentation of incidents:

The IDF shall automatically present the operators with real time CCTV images of the area of the incident when it is detected.

4.6 Emergency Call System (ECS)

The emergency call system shall consist of roadside units (emergency call columns ECC) installed on both portals (3 at each portal) and of tunnel units (132), providing two-way

communication between the ECCs and the central monitoring and control unit located at the operators workplaces in the traffic control rooms at the OMCs.

All components have to be provided, installed und put into operation.

For basic graphical description see drawing "ELEMENTARY DIAGRAM OF SAFETY INSTALLATIONS" and Product Information Sheets.

4.6.1 Emergency Call Column (ECC), Open Road Unit

The emergency call columns (ECC) shall provide hands-free communication activated by a single push button for ease and simplicity of operation by the road user. Clear operating instructions shall be affixed to the ECC housing by means of pictograms.

4.6.1.1 Position

ECCs are required at the beginning and end of the tunnel.

The ECC sites shall be suitable for use and access by disabled wheelchair users.

ECC sites shall be protected by road-side guard rails, which shall be opened for motorway users for proper access to the call column.

A hardstanding shall be provided around the ECC, which shall be provided by the construction contractor.

The call boxes shall be additionally equipped with shields to protect both the ECC and the user from snow clearing operations and materials stirred up by passing vehicles on the motorway.

The microphone and speaker of the ECC shall be placed on the call box side opposite to the carriageway in order to provide the user with more safety, and to provide clearer sound.

4.6.1.2 Function

The ECC shall provide full duplex voice communication between motorway users and the operator located at the premises of the motorway police station.
The ECC shall provide for clear, full duplex communication with effective suppression of background noise at the call box.

Each call box shall have a unique site identity code both visible for the motorway user and displayed on the central monitoring unit GUI.

The ECC unit shall be designed to provide the following functions:

- A motorist pushes the call button to initiate a call at the ECC.

- The motorist hears a ring tone if the call is successfully initiated. Otherwise an out of order tone/voice must be generated.

- A ring tone on the operator handset shall indicate that the call has been received.

- The call shall be received and indicated at the central monitoring and control unit (also referred to as central unit) by an audible tone and simultaneously on the graphical user interface (GUI) display, with the calling ECC icon changing its colour. Depending on the scale, a zoom-in on the location of the call is provided; the system shall zoom in on a zone where the call has been made.

- The connection shall be established once the operator lifts the telephone handset at the central unit. The operator can then converse with the caller.

- Simultaneous calls shall be displayed on the GUI by flashing icons of the new calling station. The operator can put the current call on hold by a simple mouse click on the GUI, or the current call can be terminated and the next call can be handled.

- Upon completion of the call, the operator disconnects the call and classifies the call in one of several options available on the GUI.

- The central unit shall allow the operator to transfer the call to a public switched telephone network line.

The ECCs shall be equipped with the following:

- Weatherproof speakers installed inside the call box, mechanically protected by the grating on the ECC housing. The user will hear the operator's voice from this speaker.

- A microphone installed inside the call box, mechanically protected by the grating on the ECC housing. The microphone shall be installed near the speaker to provide the user with comfort and support him talking at the same position, where the operator can be best heard.

- A push button installed in the close proximity of the microphone and speaker. The button shall be pushed once, and the call control and conversation will be carried on in a hands-free manner.

- Pictograms describing the usage of the ECC.

- The ECC shall house the call control and communication module. It shall handle the speaker, push button and microphone, and shall also manage communication with the central monitoring and control unit.

All ECCs equipment shall be connected to uninterruptible power supplies (tunnel-UPS).

4.6.1.3 Housing and Fabrication

- The ECCs shall be resistant to environmental conditions, robust, vandal proof and tamper protected.
- The colour of ECCs shall be maintained for the life of the equipment.
- The system shall be designed to provide for diagnostic interrogation with the remote ECC units.
- The housings are designed to provide for ease of access for physical maintenance procedures.
- The equipment housings are provided with secure fasteners and locks to prevent unauthorised access.
- The design of the system is modular enabling ease of access to carry out maintenance.

4.6.2 Emergency Call Unit (ECU), Tunnel Unit

The manufacturer of the tunnel ECU equipment is recommended to be the same as that of the open road ECCs.

Emergency call niches also contain adjacent ECU energy socket outlets for service purposes and other technology equipment could be installed there as panel board of low voltage electro-distribution network, components of the tunnel control system, etc.

4.6.2.1 Position

The tunnel ECUs shall be installed in tunnel niches to enable the motorists to speak to an operator at any OMC.

The niches will be located on the side of the cross passages at 125-meter intervals. Additional ECUs are located at the lay-bys on the other side at 750-meter intervals.

Illuminated signs (or pennant signs) will indicate the locations of the emergency phones for the motorists.

4.6.2.2 Function

The ECU interior is permanently illuminated with an orientation light. When entering an ECU, the main interior lighting is automatically activated.

Emergency calls shall be initiated by pressing the push button of the ECU. Pressing the emergency call button will cause:

- The indicator LED to flash in order to confirm the call
- The issuance of an appeasement message
- An automatic dial-up to the operators phone at the assigned OM centre (no need for the user to dial a number manually)
- An audible and visible warning for the operator by means of ECS GUI and loudspeakers
- Identification of the location of the call on the synoptic layout of the tunnel
- Optionally, interfacing with the CCTV for automatically displaying camera images to predefined screens (monitors and GUI)

Opening the door of the booth (door open contact) shall trigger an alarm at ECS GUI for the operator.

Handling of calls and operator interaction is the same as it is described in the open road section.

The ECU shall allow for immediate call initiation upon pressing the push-button. The call shall then be answered or put on the waiting list of calls list by the operator according to the current status of the ECS.

All ECS equipment (central and peripheral) shall be connected to uninterruptible power supplies (tunnel-UPS).

4.6.2.3 Housing and Fabrication

Emergency call units are assembled in modular design especially based on customer specifications and made from stainless steel (V4A) with degree of protection lP 65.

They can be fitted into the tunnel niches; remaining openings can be covered with apertures.

ECUs have to withstand various types of stress or strain like pressure, temperature, corrosion, moisture and exhaust.

The tunnel ECUs shall be constructed as hands-free equipment that provides a speaker, a microphone near the speaker, and operating instruction labels for the user.

All user-accessible equipment shall be of a rugged design, vandal resistant and includes tamper detection and alerting.

Secure fasteners and locks shall prevent unauthorized access to the electronic equipment.

The ECU will be marked by expressive numeral labelling and by outstanding inscription with the following text in the local language and English: "This area does not provide protection from fire!!!".

The emergency call system shall be based upon VoIP communication protocol.

Emergency phones shall have the capability of self-diagnostics based upon continuous periodic interrogation of the phones (checking of loopback test signals).

Phones shall be designed to enable intelligible conversation at the prevailing noise levels by means of:

- Automatic active noise reduction
- Automatic active echo cancellation
- Automatic digital voice amplification
- Noise suppression algorithms

The ECBs shall operate under the following ambient climatic conditions:

- Minimum temperature: -30°C
- Maximum temperature: +60°C
- Relative non-condensing humidity: up to 100%

4.6.3 Emergency Push Buttons

The emergency push buttons shall be installed into all emergency call units (tunnel niches).

They provide potential free alarm contacts (opening contacts) and are monitored according to the principle of quiescent power.

The buttons are also illuminated (continuous light). In case of an alarm, the devices must be switched to a flashing light. Upon acknowledgment by the operator, the lights must be switched back to continuous light.

4.6.4 Central Monitoring and Control Unit

A central monitoring unit shall manage the full ECS network. The software (source code) has to be provided for future changes.

4.6.4.1 Position

Two operator workplaces shall be provided for the use of the Motorway Operator at each OMC. Any operator can answer a call.

The central monitoring and control unit shall be composed of active equipment such as appropriate communication gateways, operator workstations and telephone sets. These shall be located in the traffic control room at the OMCs.

4.6.4.2 Function

A computerized visual schematic of the installed units shall indicate the current status of each remote ECU, i.e. active, standby or faulty. The central unit shall instantly detect the call box from which a call or alarm originated, and allow the call to be answered immediately if no other calls are in progress. It shall be capable of handling multiple calls and provide for call holding and call queuing.

The central monitoring unit shall be provided with administrative functions in terms of system configuration, fault notification and audible alarms, message traffic and statistical information. It shall output all incidents and events to an audit printer. Self-test diagnostics features shall be applied to test call boxes for correct operation.

Two-way communication between the traffic controller and each roadside unit shall be recorded digitally and retained for at least 6 months on a data storage device suitable for selecting and replaying any recorded conversation. The date and time of calls, faults and incidents are to be registered on the central monitoring unit. All calls and general alarm conditions shall be logged in a database.

The system diagnostic utilities are designed to check the operational functionality of any individual emergency call box in the system at a regular defined interval or as a deliberate query.

When an ECU is to be checked, the central monitoring unit shall initiate a call to that unit. After establishing the call, it shall send various queries to the ECU to check its health status. The ECU shall receive the query, decode it and send the appropriate reply to the central monitoring unit based on its present status. These replies from the ECU are stored in the central database with the time, date and ECU ID stamp. If an ECU fails to respond to the query or the call could not be established to the ECU, then that particular ECU is marked as faulty. The appropriate message is displayed on the console and the database is updated with the status of the ECU.

The diagnostic test for each ECU in the system is performed automatically at a defined time, normally twice a day. In addition, the operator at the central monitoring unit using the system GUI can also perform these interrogations as an ad hoc on-demand enquiry.

A system failure is reported if a central unit initiated call is not responded to.

The real-time software of the operator station:

- Manages calls from the ECUs: talking to an ECU that is already involved in a call, placing on hold, call release
- Permits to manage several simultaneous calls by means of placing the call on hold
- Calls an ECU
- Displays alarms from the various components of the ECS (gateways, ECU, etc.).

The operator station comprises:

- 1 PC, which acts as the main ECS Server and includes a GUI for the Operator Station.
- 1 monitor screen
- 1 keyboard
- 1 mouse
- 1 telephone set on IP network
- 1 loudspeaker connected to the sound card of the PC
- 1 printer connected to the parallel port of the PC
- 1 SWITCH/HUB (IP local Ethernet network) for interconnecting the operator station, the gateway and IP phone.

4.6.4.3 Housing and Fabrication

Gateways of the ECS shall be standard 19" rack mountable units to be placed in the rack cabinet located in the server room of the OMCs.

Operator station elements shall be manufactured by a reputable manufacturer and shall be installed on the built-in operator desk/counter.

4.6.4.4 Performance

The ECS central monitoring and control station shall manage an arbitrary number of concurrent calls by immediately answering incoming calls and setting up lists of waiting

calls put to hold. The voice communication and voice recording shall be performed in real-time (so that human users do not experience any delay in voice processing).

4.7 Communication Systems

The following communication systems shall be installed:

- Tunnel radio system
- Internal telephone system
- Sound system

For a basic graphical description see drawing "ELEMENTARY DIAGRAM OF SAFETY INSTALLATIONS"; “TYPICAL CROSS SECTION INSTALLATIONS” and “OPERATORS WORKPLACES – MAIN CONTROL CENTRE”.

4.7.1 Tunnel Radio System

The wireless communication system serves the communication of emergency intervention teams and service attendance personnel. lt should also be equipped to NHIDCLadcast public radio and mobile phone signals.

The maintenance radio equipment shall be located at the OMC server rooms, as well in the tunnel niches.

Radio towers shall be erected near the OMC buildings; they shall hold the necessary antennas to cover the open road communications, the FM communication bands and mobile phone operators' frequencies.

The processing units should make it possible to synthesize and split up all the communication signals.

In both tunnels leaky cables shall be mounted on the top of the tunnel bore.

The maintenance radio system shall cover the tunnel Project Highwayand an additional 5 km distances at the end of the sections.

A switchboard of the wireless communication system is placed on the operator's workplaces. In emergency situations, it should be possible to verbally enter messages into the transmission of the NHIDCLadcasting station.

The fixed traffic signs indicating the transmitted frequency of the NHIDCLadcasting station shall be placed at the entrance of the tunnel.

4.7.1.1 Maintenance Radio

The maintenance radio system shall cover both tunnels (main tunnel and egress tunnel), all rooms in the service buildings, and the two control centres (main control centre and the reserve control centre). In the two control centres fixed radio equipment shall be installed.

Terminal portables (transmitter-receiver) shall be provided for maintenance workers who shall be on the highway, in the tunnel or in the service buildings.

4.7.1.2 Emergency Service Radio

The radio system shall re-NHIDCLadcast all the frequencies for the emergency services in the tunnel.

The radio communication for emergency services shall also cover the control centres and the service buildings.

The emergency services concern the fire brigade, the ambulance and the police.

Contact and coordination with the concerned services and compliance with their requirements will be made during the design and construction phase.

4.7.1.3 Public Radio

A public radio NHIDCLadcast breakthrough system and a public address system shall be provided in the tunnel.

A system to insert messages on the FM band shall be installed in the two control centres.

This system shall allow the operator to interrupt in the FM re-NHIDCLadcast and to send safety messages.

The operator shall be able to announce a specific message or a pre-recorded message.

The radio system shall be able to re-NHIDCLadcast up to 5 radio channels.

Radio frequencies shall be determined later during the design and construction phase with the relevant authorities.

4.7.1.4 Cellular Phone

Facilities for re-transmission of signals for at least four cellular telephone service providers shall be included.

This shall include but is not limited to mounting facilities for antennas, cable paths and furnished equipment rooms with electricity supply, air conditioning and other required installations. The costs of re-transmission equipment - including electricity costs – are not included in this report; so these shall be covered by each service provider respectively.

4.7.2 Internal Telephone System

An internal telephone system, based on VoIP technology, shall be employed to ensure reliable, cost-effective communication for staff at all locations.

Each control centre shall be provided with a telephone system that enables telephone communication between the control centres and the service telephone sockets (situated in the emergency telephone niches, in the power supply niches and in the ventilation caverns).

It shall also enable operators to access the public switched telephone network and provide direct-dial facilities to emergency services and other key numbers.

4.7.3 Sound System

The sound system (amplifier and speaker system) is used for transmitting signals and announcements in the driving area, in the egress tunnel and in the area of the tunnel portals.

The sound system informs drivers, in case of an emergency, to leave their cars immediately and leave the tunnel tube (following the evacuation route lamps to the next cross passage).

Moreover, it is used for provision of traffic information, e.g. in case of traffic stopping by tricolored traffic lights with red signal active.

4.7.3.1 Position

Horn loudspeakers in the tunnel shall be installed on the tunnel wall and those in the area before and after the tunnel are installed on poles. The amplifiers shall be situated in tunnel niches.

Speakers shall be situated:

- At each lay-by
- At the tunnel portals
- In the egress tunnel (at each cross passage)
- in the open field next to the over height vehicle detection

The operator workplaces have to be equipped with central units with an amplifier and microphone to make it possible to transmit verbal messages.

4.7.3.2 Function

A system to generate signals and announcements for the sound system shall be installed in the two control centres.

The system shall be able to address the speaker locations individually or in groups.

The sound system shall be designed for the transmission of verbal messages from the operator and also pre-recorded phonetic messages as well. ln case of a confirmed fire inside the tunnel tube, an appropriate message shall be automatically transmitted. The message will be repeatedly transmitted in local and English languages.

4.7.3.3 Housing and Fabrication

Components of the sound system shall be standard 19" rack mountable units to be placed in the rack cabinet located at the server room of the OMCs or in the tunnel niches.

Sound system equipment shall operate under the following ambient climatic conditions:

- Minimum temperature: -30°C
- Maximum temperature: +60°C
- Relative non-condensing humidity: up to 100%

4.8 Fire Safety Equipment

All tunnel service buildings, buildings with control rooms and rooms with electro-technical equipment shall be equipped with a fire detection system.

The following equipment shall be provided in the tunnel:

- Linear heat detection (main tunnel and egress tunnel)
- Manual call point fire alarm according to the EU standard

All these fire detection systems shall be connected to the fire alarm units. The system consists of ten fire alarm units (in the control centres, in the ventilation caverns and in five power supply niches inside the tunnel). The fire alarm units are connected with addressable line fire detector with fibre laser sensor, discrete automatic smoke and heat detectors and manual button detectors. As soon as a fire is detected, an alarm and location information shall be sent to the operator.

For the tunnel, linear heat detection system shall provide the location of the fire, a relevant scenario shall be automatically proposed to the operator.

For a basic graphical description see drawing "ELEMENTARY DIAGRAM OF SAFETY INSTALLATIONS" and "SCHEMATIC DIAGRAM OF THE FIRE ALARM AND DETECTION SYSTEM".

4.8.1 Fire Alarm System in buildings

In OMCs, in the ventilation caverns and in rooms with electro-technical equipment (power supply niches, transformer niches, jet-fan niches) ionisation smoke detectors shall be installed.

In addition, manual fire alarm push buttons shall be installed at all exits of those buildings.

The main fire alarm unit should be situated in the OMC and connected to the SCADA system.

4.8.2 Automatic Fire Detection System in the tunnel

For linear fire detection in the tunnel there shall be a linear fire detection cabling mounted on the ceiling of the tunnel. The linear fire detection system is divided to nine sections in the main tunnel and nine sections in the egress tunnel. The maximum measuring point distance in the tunnel longitudinal direction shall not exceed 10m. The sensors shall be summarized in reporting sections. Evaluation units of the system are placed in technology and control buildings, in the ventilation caverns and in five power supply niches inside the tunnel.

In case of a line break or failure of a control unit, a maximum of 1000m length monitoring is allowed to fail.

The same system shall be installed in the main tunnel and the egress tunnel.

Linear heat detection systems shall be connected the SCADA system through its own control system. Specific views on the SCADA system shall be developed to assume a complete monitoring and remote control.

4.8.3 Emergency Telephone Niches

Emergency call niches shall be located, according to the EU standard, in the tunnel at intervals of less than 125 m each to other in the tunnel and in all lay-bys.

The emergency points shall have the following equipment:

- Fire alarm push buttons
- Fire extinguishers

Manual fire alarm push buttons and portable fire extinguishers shall be at the disposal of all drivers. This equipment shall be monitored by the SCADA through the fire system control unit.

A telephone shall be also installed at the emergency call niches (see description in the relevant chapter – Emergency Call System).

4.8.4 Hydrants and Hydrant Niches

Hydrants with fire-fighting water shall be installed on both portals and in the hydrant niches in the tunnel.
The fire-fighting water will be provided by a water reservoir building at the east portal of the tunnel. The water level shall be monitored by the SCADA system. If the water level falls below the minimum level an alarm is displayed in the OMC.

Hydrant niches shall be located according to the EU standard in the tunnel opposite the emergency call niches also at intervals less than 125 m each to other in the tunnel and in all lay-bys.

The hydrant niches shall have the following equipment:

- A connection for the water hose
- Lighting (switched by a door opening contact)
- Sockets combination for power supply

4.8.5 Fire Extinguishers

Portable fire extinguishers shall be installed in the tunnel at each emergency niche. Removal of a fire extinguisher at the emergency niche shall trigger an alarm to the SCADA system.

Additional extinguishers shall be provided in the service and control buildings, in the medium voltage cell rooms and in the transformer rooms. Portable extinguishers shall be suitable for use on all types of fire.

4.9 Tunnel Lighting Systems

The Tunnel Lighting System represents the most significant part of the tunnel traffic safety and shall cover the following needs:

- Entrance lighting (in the accommodation sections at both ends of the tunnel)
- Interior lighting (through the whole tunnel)
- Lay-bys lighting
- Egress tunnel lighting
- Street lighting (in front of the tunnel portals)

- Luminance measurement
- Escape direction lamps
- Evacuation route lamps
- Evacuation route signs

The lamps of all lighting segments, except the street lighting, are installed in the inner area of the tunnel.

All covers and mechanical parts should be resistant to the aggressive tunnel environment.

Lighting operation:

In the standard traffic status of the tunnel operation, the main tunnel lighting (entrance and interior lighting), the lay-bys lighting, the escape direction lamps and evacuation route lamps shall be permanently switched on and the egress tunnel lighting shall be switched off. ln the emergency status of the tunnel operation the egress tunnel lighting shall be immediately switched on. The operator in the OMC shall also be able to switch the egress tunnel lighting on for services in the tunnel. The street lighting is also regulated by a program of the integrated control system of the tunnel based on data from the luminance cameras in front of tunnel portals.

Main tunnel lighting calculation:

The size and design of tunnel lighting shall be calculated on basis of supplier's data and according to the Austrian standard RVS 09.02.41 - Tunnel Lighting (RVS = guidelines and regulations for road construction).

For a basic graphical description see drawing "TYPICAL CROSS SECTION INSTALLATIONS"; “SCHEMATIC LAY-OUT OF TECHNICAL EQUIPMENT IN THE INNER AREA OF THE TUNNEL” and “MAIN TUNNEL LIGHTING – SCHEMATIC LAY-OUT” and Product Information Sheets.

4.9.1 Entrance Lighting

The adaptable lighting serves the driver when entering the inner area of the tunnel without a drastic change of lighting intensity on the cross border between the open highway area and the first part of the tunnel.

Entrance lighting fixtures will be set with asymmetric counter beam optic and with a nominal power of the lighting source of 400 W and 150 W (high-pressure sodium lamp).

Lighting fixtures and cable trays: Casings and hanging structures are made of stainless steel.

Tunnel lighting sources: high-pressure sodium discharge lamps with an operating lifetime of min. 16,000 hours.

The lighting intensity should be calculated for the maximum projected speed inside the tunnel (80 kph).

The required luminance depends on:

- Lighting fixture specifications
- Nominal power of light sources
- Execution of the tunnel tube
- Location of lighting fixtures inside the tunnel tube
- Spacing of lighting fixtures

For example the following lighting fixture types and length of the accommodation sections were determined:

- Threshold Zone 1: length of the zone is 35m and lamp nominal power is 400W
- Threshold Zone 2: length of the zone is 35m and lamp nominal power is 400W
- Transition Zone 1: length of the zone is 50m and lamp nominal power is 400W and 150W
- Transition Zone 2: length of the zone is 40m and lamp nominal power is 150W

The entrance lamps shall be situated on the roof of the tunnel tube centred above each lane driveway.

The entrance lighting regulation is implemented by a program of the integrated control system of the tunnel based on data from luminance cameras which are located in front of tunnel portals and in the tunnel.

The entrance lighting shall be regulated in 9 steps:

Step 1	100%
Step 2	87.5%
Step 3	75%
Step 4	62.5%
Step 5	50%
Step 6	37.5%
Step 7	25%
Step 8	12.5%
OFF	0%

The adaptable lighting sections are symmetrical on both entry parts of the tunnel.

4.9.2 Interior Lighting

The interior lighting or main lighting covers the internal area of the tunnel between two sections of entrance lighting near both entries.

The calculation of the intensity of lighting depends on the tunnel profile and the projected speed in the tunnel. For the Zojila Tunnel Project Highwaya luminance of 4.8 cd/m2 was determined. The luminance for the interior zone was calculated based on the supplier's data and according to the Austrian standard RVS 09.02.41 - Tunnel Lighting (RVS = guidelines and regulations for road construction).

The lighting characteristic is symmetric and is set for a nominal power of the lighting source of 150 W (high-pressure sodium lamp). Luminaire spacing of the lighting fixtures is 15 m.

Lighting fixtures and cable trays: Casings and hanging structures are made of stainless steel.

Tunnel Lighting Sources: high pressure sodium discharge lamps with operating life time of min. 16,000 hours.

The interior lighting is located at the tunnel ceiling, 0.5 m away from the centre of the two lanes on the second lane.

The interior lighting together with all additional lighting segments are controlled by their own lighting control system and report the actual status of the lighting module of the tunnel to SCADA.

Every second lighting fixture shall be connected to uninterruptible power supplies (UPS). A backup time for a minimum of 60 minutes must be guaranteed.

In the tunnel, emergency lighting aids drivers when the main lighting system is not in operation.

In these situations, the speed of the traffic is limited and the lighting intensity will be lower.

4.9.3 Lay-by Lighting

Each lay-by shall be equipped with 4 lighting fixtures. They shall be the same lights as the interior lighting.

Every second lighting fixture shall be connected to uninterruptible power supplies (UPS). A backup time for a minimum of 60 minutes must be guaranteed.

4.9.4 Egress Tunnel Lighting

The egress tunnel and the cross passages shall be provided with lighting. They shall have the same lights and the same luminaire spacing (15 m) as the interior lighting.

The interior lighting is 0.5 m away from the centre of the lane and located on the tunnel ceiling.

Every second lighting fixture shall be connected to uninterruptible power supplies (UPS). A backup time for a minimum of 60 minutes must be guaranteed.

4.9.5 Street Lighting

The street lighting shall be set up in the access zone over a length of 200 m before the tunnel portals.

Street lighting fixtures will be set with LED light source with nominal power of 150 W; lighting poles shall be 10 m in height with span of 30 m.

The street lighting is controlled by the external luminance measurement and a time program. The actual status of the street lighting shall be reported to the SCADA system.

4.9.6 Luminance Measurement

The interior lighting together with the entrance lighting are controlled by their own lighting control system. The control of the lighting depends on the external luminance and the luminance in the tunnel.

Luminance cameras shall be used to detect the luminance. The luminance cameras in the tunnel shall be installed on the tunnel wall and the cameras in the area before and after the tunnel are installed on poles.

In the event of a failure of a luminance camera, the value from the luminance camera from the other tunnel portal shall be used. If both luminance cameras fail, the lighting is controlled via a time program.

The actual status of the street lighting shall be reported to the SCADA system.

4.9.7 Escape Direction Lamps

At every cross passage internally illuminated escape direction lamps with symbols of the escape exit direction shall be installed on the tunnel wall above the exit.

The escape direction lamps will be set with a LED light source and shall be powered by UPS. A backup time for a minimum of 60 minutes must be guaranteed.

4.9.8 Evacuation Route Lamps

Internally illuminated evacuation route lamps with symbols of escape direction to the right and to the left and with marked intervals shall be installed on the tunnel wall on the side of the emergency call niches (main tunnel).

In the main tunnel the evacuation route lamps shall be located in intervals less than 50 m each to other or to the next emergency call niche.
In the egress tunnel the evacuation route lamps shall be located at each cross passage.

The mounting height of the lamps is 1.0 m above the sidewalk.

The evacuation route lamps will be set with LED light source and shall be powered by UPS. A backup time for a minimum of 60 minutes must be guaranteed.

4.9.9 Evacuation Route Signs

Evacuation route signs with symbols of the escape direction to the right and to the left and with marked intervals shall be positioned in accordance with the EU standard:

- In the egress tunnel between the evacuation route lamps at intervals less than 25 m apart (one sided).
- In the main tunnel on the side of the emergency call niches in the middle between the evacuation route lamps.
- In the main tunnel on the other tunnel wall opposite of the evacuation route lamps and signs (at about intervals less than 25 m apart).

The mounting height of the signs is also 1.0 m above the sidewalk.

4.10 Integrated Tunnel Control System - SCADA

The integrated tunnel control system (SCADA - Supervisory Control and Data Acquisition) serves to monitor the status of all tunnel technical systems and to automatically or manually control them.

lt shall be realised by an integrated control program which is implemented in the main control PLC stations in the OMCs.

The main control PLC stations and the local PLC stations in the power supply niches shall be connected via fibre optic cables.

The traffic control and monitoring system shall be able to interact with all open road and tunnel FOE and records all the states of monitored elements and all the activities and faults.

For a basic graphical description see drawing "SCHEMATIC DIAGRAM OF THE INTEGRATED TUNNEL CONTROL SYSTEM":

4.10.1 System Configuration

The control system is composed of two redundant main PLC stations in each control centre and several PLC field substations.

The main PLC stations shall operate in a hot stand-by (automatic back-jump) mode of operation. One main PLC station shall operate above all the systems and shall constantly communicate with the second main PLC station. In the event of a failure of the first main PLC station, the second one will undertake its activity without any disturbance to the control process.

The PLC substations in the power supply niches control the local electrical appliances like lighting, ventilation and traffic control.

The main stations shall be connected with the substations by a double ring industrial bus via optical cables.

The control monitoring System (SCADA) offers the operators the means to control and monitor open road and tunnel technology equipment from the control rooms and locally (automatically) in the tunnel.

The SCADA will help the operators to control and monitor all technology on the highway including the tunnel technology by showing the status of equipment, giving the possibility to control them and also by proposing automatic functions.

The operator workplaces in the main control centre shall be equipped for permanent attendance; the operator workplace in the sub control centre shall be a stand-by operator's workplace, without permanent attendance. Their function shall be identical.

The SCADA system shall be equipped with two redundant servers and a video wall which makes it possible to handle all the monitoring and control functions required for safe traffic conditions on operated motorway route in case of a total failure of the SCADA system. The two servers shall operate in a hot stand-by mode operation.

This video wall shall be located in control room at the main control centre so that the monitoring and control function can be carried out in a safe and ergonomically acceptable manner.

Power supply to all the components of the integrated tunnel control system shall be supplied by online UPS systems.

4.10.1.1 Monitoring Requirements for the SCADA System

The system shall enable operators to monitor the tunnel and receive information that enables decisions to be taken and actions made for controlling and influencing traffic behaviour or mobilising appropriate responses in order to increase safety and efficiency in the operation of the tunnel.

Monitoring of the tunnel shall be achieved using a variety of information sources including the use of traffic-monitoring outstations (overheight vehicle detection, CCTV cameras and emergency roadside columns).

Monitoring shall be used to support the identification of a range of situations that potentially reduce safety where action may need to be taken including:

- Accidents or other incidents on the carriageway
- Recurrent or non-recurrent congestion
- NHIDCLken-down vehicles on the hard shoulder
- Adverse weather or visibility conditions
- Debris, animals or other unusual objects on the road
- Damage to road infrastructure
- Other unusual or unexpected events

Decision-making shall be based on the information gathered from these sources. The system shall support manual decision processes, semi-automatic and automatic processes. Safety functionality, commensurate with the type of support systems provided, shall be included in the decision support facilities to ensure that consistent and safe responses are made. As far as possible, the decision support process shall determine the scope of the event identified, the effect on road capacity and the expected duration of the event.

4.10.1.2 Functional Requirements to the SCADA System

At the very least, the SCADA system shall be provided with the following man-Machine Interface (MMI) equipment at the control centres:

- Two operator stations equipped with the technology required. The two operator stations shall function independently of each other so that two operators can work concurrently. It shall be possible to handle all monitoring and control functions by means of one operator station.
- An event log printer to provide a hard copy of all events and commands issued.

4.10.1.3 Availability of the SCADA System

In general, any switching or reconfiguration that is required in order to uphold the functionality of the SCADA system in the event of a failure shall be executed automatically with no noticeable effect on the operator.

No data shall be lost in case of a sudden failure.

4.10.1.4 SCADA System Interfaces

The SCADA System shall be able to interact with external systems and organizations:

- Police and fire brigade
- Vehicle drivers

4.10.2 Performance and Requirements of IT equipment

Operation shall be straightforward and easily understandable by suitably trained, non-technical personnel with "help" frames for guidance of operators.

The system shall be able to restart automatically after a power failure without the need for specialist operator intervention provided that the system shut down procedure has been performed successfully.

It shall be safeguarded against accidental loss of data.

All systems access shall be controlled by a login and password for every user.

The central unit shall be based on a redundant server with multiple workstations and multitasking operating systems.

4.11 Doors and Gates

All doors and gates in the buildings and in the tunnel shall be delivered and installed.

This includes:

- Doors and gates to the egress tunnel
- Doors and gates to the cross passages
- Doors to the power supply niches
- Doors to the transformer rooms (in the tunnel and in the ventilation caverns)
- Doors to the hydrant niches
- Doors and gates in the ventilation caverns
- Doors to the transformer rooms (in the tunnel)

- Doors to the transformer rooms and HV control rooms in the control centres
- Doors and gates in the ventilation buildings

4.11.1 Technical Spezifications

4.11.1.1 Function

All doors and gates in the tunnel shall be equipped with a door-opening contact. Opening any door shall trigger an alarm to the SCADA system.

Larger doors or gates, which are equipped with an electrical or hydraulic drive, shall be operated with a key switch on the spot or by the operator from the OMC.

A yellow flashing light on both sides of the door shall indicate the movement of the door. These warning lights shall be switched on automatically before the door starts to move.
A protection gear, ensuring that neither people nor vehicles can get caught, has to be provided.

4.11.1.2 Housing and Fabrication

All doors and gates in the tunnel shall be resistant to the aggressive tunnel environment (stainless steel).

All doors and gates shall be delivered as a complete unit with door frame.

Doors near the driving area must be designed for the transport-related pressure and suction loads.

Emergency exit doors must open in the direction of escape and be equipped with emergency exit push bars.

All doors and gates must be labelled according to the regulations of the client.

4.12 Building Installation and Equipment

Two control centres shall be erected in the technology buildings next to the tunnel portals. One of them, the main local control centre, shall be designated for non-stop attendance. The second one shall serve as a reserve one.

The electrical system must be installed in and the equipment delivered to the control centres, ventilation buildings and the niches in the tunnel.

These services include:

- Lighting installation

- Emergency lighting
- Outlets installation
- Air conditioning and ventilation
- Computer cabling
- Lightning protection system
- Cable trays, raised floor
- Furnishings

In the control rooms, the lighting must be suitable for computer workstations.

4.12.1 Main Control Room

The main control room shall be equipped with two operator workplaces for two permanent operators. It shall be possible to control and monitor all tunnel traffic and operation of technical accessories from the operator workplaces.

Furthermore, it includes a video wall for installation of 36 video-monitors and 8 large-screen displays as part of the video surveillance system.

For a basic graphical description see drawing "OPERATORS WORKPLACES – MAIN CONTROL CENTRE (VARIANT 1 and 2)".

4.12.2 Sub Control Room

The sub control room shall be equipped with only one operator workplace. It shall be also possible to control and monitor all tunnel traffic and operation of technical accessories from the reserve operator workplace.

4.13 Testing and Approvals, Engineering

The planning and design layout of the entire system has to be done by the contractor.

4.13.1 Management and Coordination

The responsibilities of the contractor include:

- Stocktaking
- Coordination with the client

- Coordination with the local authorities
- Coordination with the energy supplier
- Participating in meetings
- Creation of continuous documentation throughout the construction

4.13.2 Acceptance Testing and Approvals

This section covers the minimum requirements for system functional and performance testing, mechanical, electrical, electronic testing of hardware, and computer software testing.

The FOE contractor shall be required to submit a number of documents that record the status for the process relating to equipment and system interfaces, approvals, drawings, prototypes and system developed reports to the client for their comment.

The FOE contractor shall be also required to supply all test equipment necessary to prove compliance of the system to the requirements of the specifications. In addition, the FOE contractor shall supply all site test equipment and tools.

4.13.3 Commissioning of the tunnel; Function Check

Commissioning and testing of the entire system is performed upon completion of the tunnel.

It must be proven that the tunnel (installed as a complete system) meets the requested requirements.

The commissioning and testing has to be documented and done before the trial run starts.

Defects during the commissioning have to be repaired as soon as possible.

4.13.4 Probation and System Testing

Upon completion of the tunnel, a trial run and system testing have to be performed. The trial run without traffic has to last for 90 days and must be documented.

After this, a trial run with traffic has to last for 90 days and must also be documented.

Should deficiencies be detected during the trial run, the trial run shall stop and start again for 90 days.

During the test run the acceptance test shall be made by the client.

During the trial run typical malfunctions shall be simulated (power failure, fire test, etc.). The response of the system regarding the specifications shall be checked.

At the end of the trial run, the operating and supervisory staff shall be instructed.

4.13.5 Maintenance and Spare Parts

The FOE contractor is required to ensure that the system is maintainable throughout its useful life.

Therefore, a sufficient stock of spare parts must be supplied to support the system. The FOE contractor shall be held fully responsible for the repair and replacement of all equipment.

4.14 Documentation

The as-built documentation of the contractor must present the actual running state of the acceptance test at the time.

The documentation shall be divided into folders in accordance with the client.

The FOE contractor is required to supply and draw up the following general types of documents:

- As-built documentation
- Functional analysis
- Installation method statements
- Technical specification
- Acceptance test procedures
- User manuals (hardware and software manuals)
- Maintenance and service manuals
- Tunnel operation and traffic control manual
- Tunnel safety documentation and manual
- Photo documentation

The FOE contractor shall draw up the documentation in the local language and in English.

SCHEDULE – E

(See Clauses 2.1 and 14.2)

MAINTENANCE REQUIREMENTS

1 **Maintenance Requirements**

1.1 The Contractor shall, at all times maintain the Project Highway in accordance with the provisions of this Agreement, Applicable Laws and Applicable Permits.

1.2 The Contractor shall repair or rectify any Defect or deficiency set forth in Paragraph 2 of this Schedule-E within the time limit specified therein and any failure in this behalf shall constitute non-fulfillment of the Maintenance obligations by the Contractor. Upon occurrence of any breach hereunder, the Authority shall be entitled to effect reduction in monthly lump sum payment as set forth in Clause 14.6 of this Agreement, without prejudice to the rights of the Authority under this Agreement, including Termination thereof.

1.3 All Materials, works and construction operations shall conform to the MORTH Specifications for Road and Bridge Works, and the relevant IRC publications. Where the specifications for a work are not given, PIARC Guidelines / Good Industry Practice shall be adopted.

2 **Repair/rectification of Defects and deficiencies**

The obligations of the Contractor in respect of Maintenance Requirements shall include repair and rectification of the Defects and deficiencies specified in Annex - I of this Schedule-E within the time limit set forth therein.

3 **Other Defects and deficiencies**

In respect of any Defect or deficiency not specified in Annex - I of this Schedule-E, the Authority's Engineer may, in conformity with Good Industry Practice, specify the permissible limit of deviation or deterioration with reference to the Specifications and Standards, and any deviation or deterioration beyond the permissible limit shall be repaired or rectified by the Contractor within the time limit specified by the Authority's Engineer.

4 **Extension of time limit**

Notwithstanding anything to the contrary specified in this Schedule-E, if the nature and extent of any Defect or deficiency justifies more time for its repair or rectification than the time specified herein, the Contractor shall be entitled to additional time in conformity with Good Industry Practice. Such additional time shall

be determined by the Authority's Engineer andconveyed to the Contractor and the Authority with reasons thereof.

5 **Emergency repairs/restoration**

Notwithstanding anything to the contrary contained in this Schedule-E, if any Defect, deficiency or deterioration in the Project Highway poses a hazard to safety or risk of damage to property, the Contractor shall promptly take all reasonable measures for eliminating or minimizing such danger.

6 **Daily inspection by the Contractor**

The Contractor shall, through its engineer, undertake a daily visual inspection of the Project Highway and maintain a record thereof in a register to be kept in such form and manner as the Authority's Engineer may specify. Such record shall be kept in safe custody of the Contractor and shall be open to inspection by the Authority and the Authority's Engineer at any time during office hours.

7. Pre-monsoon inspection / Post-monsoon inspection

The Contractor shall carry out a detailed pre-monsoon inspection of all bridges, culverts and drainage system before [1st June] every year in accordance with the guidelines contained in IRC: SP35. Report of this inspection together with details of proposed maintenance works as required on the basis of this inspection shall be sent to the Authority's Engineer before the [10th June] every year. The Contractor shall complete the required repairs before the onset of the monsoon and send to the Authority's Engineer a compliance report. Post monsoon inspection shall be done by the [30th September] and the inspection report together with details of any damages observed and proposed action to remedy the same shall be sent to the Authority's Engineer.

8. Repairs on account of natural calamities

All damages occurring to the Project Highway on account of a Force Majeure Event or default or neglect of the Authority shall be undertaken by the Authority at its own cost. The Authority may instruct the Contractor to undertake the repairs at the rates agreed between the Parties.

Annex - I
(Schedule-E)

Repair/rectification of Defects and deficiencies

The Contractor shall repair and rectify the Defects and deficiencies specified in this Annex-I of Schedule-E within the time limit set forth in the table below.

Nature of Defect or deficiency		Time Limit for repair/rectification
ROADS		
(a)	**Carriageway and paved shoulders**	
(i)	Breach or blockade	Temporary restoration of traffic within 24 hours; permanent restoration within 15 (fifteen) days
(ii)	Roughness value exceeding 2,200 mm in a stretch of 1 km (as measured by a calibrated bump integrator)	120 (one hundred and twenty) days
(iii)	Pot holes	24 hours
(iv)	Any cracks in road surface	15 (fifteen) days
(v)	Any depressions, rutting exceeding 10 mm in road surface	30 (thirty) days
(vi)	Bleeding/skidding	7 (seven) days
(vii)	Any other defect/distress on the road	15 (fifteen) days
(viii)	Damage to pavement edges	15 (fifteen) days
(ix)	Removal of debris, dead animals	6 hours
(b)	**Granular Earth shoulders, side slopes, drains and culverts**	
(i)	Variation by more than 1 % in the prescribed slope of camber/cross fall (shall not be less than the camber on the main carriageway)	7 (seven) days
(ii)	Edge drop at shoulders exceeding	7 (seven) days
(iii)	Variation by more than 15% in the prescribed side(embankment) 40 mm	30 (thirty) days
(iv)	Rain cuts/gullies in slope slopes	7 (seven) days
(v)	Damage to or silting of culverts	7 (seven) Days
(vi)	Desilting of drains in urban/semi- urban areas and side drains	24 Hours

(vii)	Railing, parapets, crash barriers	7 (seven) Days (Restore immediately)
(c)	**Road side furniture including road sign and pavement marking**	
(i)	Damage to shape or position, poor visibility or loss of retro-reflectivity	48 hours
(ii)	Painting of km stone, railing, parapets, crash barriers	As and when required/Once every year
(iii)	Damaged/missing road signs requiring replacement	7 (seven) days
(iv)	Damage to road mark ups	7 (seven) days
(d)	**Road lighting(Street lighting and Telecom ATMS)**	
(i)	Any major failure of the system	24 hrs.
(ii)	Faults and minor failures	8 hours
(e)	**Tunnel Ventilation System**	
(i)	Any major Failure of the system	24 hrs.
(ii)	Faults and minor failures	Immediate
(f)	**Tunnel Traffic Control System**	
	Any major Failure of the system	24 hrs.
	Faults and minor failures	Immediately within 1 hour
(g)	**Tunnel Power Supply System(Mains)**	
	Any major Failure of the system	24 hrs.
	Faults and minor failures	½ Hour
(h)	**Tunnel CCTV Monitiring System**	
	Any major Failure of the system	24 hrs.
	Faults and minor failures	1 Hour
(i)	**Tunnel Fire Safety System**	Contingency plan involving routine checkup so as to ensure that there is no major Failure
	Any major Failure of the system	

(j)	**Integrated Tunnel Control System (SCADA)**	
	Any major Failure of the system	24 hrs.
	Faults and minor failures	Immediate
(k)	Trees and Plantation	
(i)	Obstruction in a minimum head- room of 5 m above carriageway or obstruction in visibility of road signs	24 hours
(ii)	Removal of fallen trees from carriageway	4 hours
(iii)	Deterioration in health of trees and bushes	Timely watering and treatment
(iv)	Trees And bushes requiring replacement	30 (thirty) days
(v)	Removal of vegetation Affecting sight line and road structures	15 (fifteen) days
(f)	**Rest areas**	
(i)	Cleaning of toilets	Every 4 hours
(ii)	Defects in electrical, water and sanitary installations	24 hours
(g)	**[Toll Plaza]**	-
(h)	**Other Project Facilities and Approach roads**	
(i)	Damage in approach roads, pedestrian facilities, truck lay- byes, bus-bays, bus-shelters, cattle crossings, [Traffic Aid Post Medical Aid Posts] and service roads	15 (fifteen) days
(ii)	Damaged vehicles or debris on the road	4 (four) hours
(iii)	Malfunctioning of the mobile crane	4 (four) hours
(g)	**Hill Roads**	
(i)	Damage to wall/breast retaining wall	7 (seven) days
(ii)	Landslides requiring clearance	12 (twelve) hours
(iii)	Snow requiring clearance	24(twenty four) hours

SCHEDULE - F

(See Clause 3.1.7(a))

APPLICABLE PERMITS

1 **Applicable Permits**

1.1 The Contractor shall obtain, as required under the Applicable Laws, the following Applicable Permits:

(a) Permission of the State Government for extraction of boulders from quarry;

(b) Permission of Village Panchayats and Pollution Control Board for installation of crushers;

(c) Licence for use of explosives;

(d) Permission of the State Government for drawing water from river/reservoir;

(e) Licence from inspector of factories or other competent Authority for setting up batching plant;

(f) Clearance of Pollution Control Board for setting up batching plant;

(g) Clearance of Village Panchayats and Pollution Control Board for setting up asphalt plant;

(h) Permission of Village Panchayats and State Government for borrow earth; and

(i) Any other permits or clearances required under Applicable Laws.

1.2 Applicable Permits, as required, relating to environmental protection and conservation shall have been procured by the Authority in accordance with the provisions of this Agreement.

SCHEDULE - G

(See Clauses 7.1.1, 7.5.3 and 19.2)

FORM OF BANK GUARANTEE

Annex-I

(See Clause 7.1.1)

[Performance Security/Additional Performance Security]

The Managing Director,
National Highways & Infrastructure Development Corporation Limited
New Delhi

WHEREAS:

(A) _____ [name and address of contractor] (hereinafter called the "**Contractor**") and [name and address of the authority], (hereinafter called the **"Authority"**) have entered into an agreement (hereinafter called the "**Agreement**") for the construction of the ***** section of [National Highway No. **] on Engineering, Procurement and Construction (the "**EPC**") basis, subject to and in accordance with the provisions of the Agreement

(B) The Agreement requires the Contractor to furnish a Performance Security for due and faithful performance of its obligations, under and in accordance with the Agreement, during the {Construction Period/ Defects Liability Period and Maintenance Period} (as defined in the Agreement) in a sum of Rs….. cr. (Rupees ……..….. crore) (the "**Guarantee Amount**").

(C) We, …….. through our branch at ……. (the "**Bank**") have agreed to furnish this bank guarantee (*hereinafter called the* **"Guarantee**") by way of Performance Security.

NOW, THEREFORE, the Bank hereby, unconditionally and irrevocably, guarantees and affirms as follows:

1. The Bank hereby unconditionally and irrevocably guarantees the due and faithful performance of the Contractor's obligations during the {Construction Period/ Defects Liability Period and Maintenance Period} under and in accordance with the Agreement, and agrees and undertakes to pay to the Authority, upon its mere first written demand, and without any demur, reservation, recourse, contest or protest, and without any reference to the Contractor, such sum or sums up to an aggregate sum of the Guarantee Amount as the Authority shall claim, without the Authority being required to prove or to show grounds or reasons for its demand and/or for the sum specified therein.

2. A letter from the Authority, under the hand of an officer not below the rank of General Manager in the National Highways Infrastructure Development Corporation Limited (NHIDCL) that the Contractor has committed default in the due and faithful performance of all or any of its obligations under and in accordance with the Agreement shall be conclusive, final and binding on the Bank. The Bank further agrees that the Authority shall be the sole judge as to whether the Contractor is in default in due and faithful performance of its obligations during and under the Agreement and its decision that the Contractor is in default shall be final and binding on the Bank, notwithstanding any differences between the Authority and the Contractor, or any dispute between them pending before any court, tribunal, arbitrators or any other authority or body, or by the discharge of the Contractor for any reason whatsoever.

3. In order to give effect to this Guarantee, the Authority shall be entitled to act as if the Bank were the principal debtor and any change in the constitution of the Contractor and/or the Bank, whether by their absorption with any other body or corporation or otherwise, shall not in any way or manner affect the liability or obligation of the Bank under this Guarantee.

4. It shall not be necessary, and the Bank hereby waives any necessity, for the Authority to proceed against the Contractor before presenting to the Bank its demand under this Guarantee.

5. The Authority shall have the liberty, without affecting in any manner the liability of the Bank under this Guarantee, to vary at any time, the terms and conditions of the Agreement or to extend the time or period for the compliance with, fulfillment and/ or performance of all or any of the obligations of the Contractor contained in the Agreement or to postpone for any time, and from time to time, any of the rights and powers exercisable by the Authority against the Contractor, and either to enforce or forbear from enforcing any of the terms and conditions contained in the Agreement and/or the securities available to the Authority, and the Bank shall not be released from its liability and obligation under these presents by any exercise by the Authority of the liberty with reference to the matters aforesaid or by reason of time being given to the Contractor or any other forbearance, indulgence, act or omission on the part of the Authority or of any other matter or thing whatsoever which under any law relating to sureties and guarantors would but for this provision have the effect of releasing the Bank from its liability and obligation under this Guarantee and the Bank hereby waives all of its rights under any such law.

6. This Guarantee is in addition to and not in substitution of any other guarantee or security now or which may hereafter be held by the Authority in respect of or relating to the Agreement or for the fulfillment, compliance and/or performance of all or any of the obligations of the Contractor under the Agreement.

7. Notwithstanding anything contained hereinbefore, the liability of the Bank under this Guarantee is restricted to the Guarantee Amount and this Guarantee will remain

in force for the period specified in paragraph 8 below and unless a demand or claim in writing is made by the Authority on the Bank under this Guarantee all rights of the Authority under this Guarantee shall be forfeited and the Bank shall be relieved from its liabilities hereunder.

8. The Guarantee shall cease to be in force and effect on ****[$]. Unless a demand or claim under this Guarantee is made in writing before expiry of the Guarantee, the Bank shall be discharged from its liabilities hereunder.

9. The Bank undertakes not to revoke this Guarantee during its currency, except with the previous express consent of the Authority in writing, and declares and warrants that it has the power to issue this Guarantee and the undersigned has full powers to do so on behalf of the Bank.

10. Any notice by way of request, demand or otherwise hereunder may be sent by post addressed to the Bank at its above referred branch, which shall be deemed to have been duly authorized to receive such notice and to effect payment thereof forthwith, and if sent by post it shall be deemed to have been given at the time when it ought to have been delivered in due course of post and in proving such notice, when given by post, it shall be sufficient to prove that the envelope containing the notice was posted and a certificate signed by an officer of the Authority that the envelope was so posted shall be conclusive.

11. This Guarantee shall come into force with immediate effect and shall remain in force and effect for up to the date specified in paragraph 8 above or until it is released earlier by the Authority pursuant to the provisions of the Agreement.

Signed and sealed this ……. day of …….., 20…… at ……..

SIGNED, SEALED AND DELIVERED For and
on behalf of the Bank by:

(Signature)
(Name) (Designation)

[$] Insert date being 2 (two) years from the date of issuance of this Guarantee (in accordance with Clause 7.2 of the Agreement).

(Code Number)
(Address)

NOTES:

(i) The bank guarantee should contain the name, designation and code number of the officer(s) signing the guarantee.

(ii) The address, telephone number and other details of the head office of the Bank as well as of issuing branch should be mentioned on the covering letter of issuing branch.

Annex – II

(Schedule - G)
(See Clause 7.5.3)

Form for Guarantee for Withdrawal of Retention Money

The Managing Director,
National Highways & Infrastructure Development Corporation Limited
New Delhi

WHEREAS:

(A) [name and address of contractor] (hereinafter called the "**Contractor**") has executed an agreement (hereinafter called the "Agreement") with the [name and address of the authority], (hereinafter called the "**Authority**") for the construction of the ***** section of [National Highway No. **] on Engineering, Procurement and Construction (the "**EPC**") basis, subject to and in accordance with the provisions of the Agreement.

(B) In accordance with Clause 7.5.3 of the Agreement, the Contractor may withdraw the retention money (hereinafter called the "**Retention Money**") after furnishing to the Authority a bank guarantee for an amount equal to the proposed withdrawal.

(C) We, …….. through our branch at ……. (the "**Bank**") have agreed to furnish this bank guarantee (hereinafter called the "**Guarantee**") for the amount of Rs. --------- cr. (Rs.----------crore) (the "**Guarantee Amount**").

NOW, THEREFORE, the Bank hereby unconditionally and irrevocably guarantees and affirms as follows:

1. The Bank hereby unconditionally and irrevocably undertakes to pay to the Authority, upon its mere first written demand, and without any demur, reservation, recourse, contest or protest, and without any reference to the Contractor, such sum or sums up to an aggregate sum of the Guarantee Amount as the Authority shall claim, without the Authority being required to prove or to show grounds or reasons for its demand and/or for the sum specified therein.

2. A letter from the Authority, under the hand of an officer not below the rank of General Manager in the National Highways & Infrastructure Development Corporation Limited (NHIDCL) , that the Contractor has committed default in the due and faithful performance of all or any of its obligations for under and in accordance with the Agreement shall be conclusive, final and binding on the Bank. The Bank further agrees that the Authority shall be the sole judge as to whether the

Contractor is in default in due and faithful performance of its obligations during and under the Agreement and its decision that the Contractor is in default shall be final, and binding on the Bank, notwithstanding any differences between the Authority and the Contractor, or any dispute between them pending before any court, tribunal, arbitrators or any other authority or body, or by the discharge of the Contractor for any reason whatsoever.

3. In order to give effect to this Guarantee, the Authority shall be entitled to act as if the Bank were the principal debtor and any change in the constitution of the Contractor and/or the Bank, whether by their absorption with any other body or corporation or otherwise, shall not in any way or manner affect the liability or obligation of the Bank under this Guarantee.

4. It shall not be necessary, and the Bank hereby waives any necessity, for the Authority to proceed against the Contractor before presenting to the Bank its demand under this Guarantee.

5. The Authority shall have the liberty, without affecting in any manner the liability of the Bank under this Guarantee, to vary at any time, the terms and conditions of the Retention Money and any of the rights and powers exercisable by the Authority against the Contractor, and either to enforce or forbear from enforcing any of the terms and conditions contained in the Agreement and/or the securities available to the Authority, and the Bank shall not be released from its liability and obligation under these presents by any exercise by the Authority of the liberty with reference to the matters aforesaid or by reason of time being given to the Contractor or any other forbearance, indulgence, act or omission on the part of the Authority or of any other matter or thing whatsoever which under any law relating to sureties and guarantors would but for this provision have the effect of releasing the Bank from its liability and obligation under this Guarantee and the Bank hereby waives all of its rights under any such law.

6. This Guarantee is in addition to and not in substitution of any other guarantee or security now or which may hereafter be held by the Authority in respect of or relating to the Retention Money.

7. Notwithstanding anything contained hereinbefore, the liability of the Bank under this Guarantee is restricted to the Guarantee Amount and this Guarantee will remain in force for the period specified in paragraph 8 below and unless a demand or claim in writing is made by the Authority on the Bank under this Guarantee all rights of the Authority under this Guarantee shall be forfeited and the Bank shall be relieved from its liabilities hereunder.

8. The Guarantee shall cease to be in force and effect 90 (ninety) days after the date of the Completion Certificate specified in Clause 12.4 of the Agreement.

9. The Bank undertakes not to revoke this Guarantee during its currency, except with the previous express consent of the Authority in writing, and declares and warrants that it has the power to issue this Guarantee and the undersigned has full powers to do so on behalf of the Bank.
10. Any notice by way of request, demand or otherwise hereunder may be sent by post addressed to the Bank at its above referred branch, which shall be deemed to have been duly authorized to receive such notice and to effect payment thereof forthwith, and if sent by post it shall be deemed to have been given at the time when it ought to have been delivered in due course of post and in proving such notice, when given by post, it shall be sufficient to prove that the envelope containing the notice was posted and a certificate signed by an officer of the Authority that the envelope was so posted shall be conclusive.

11. This Guarantee shall come into force with immediate effect and shall remain in force and effect up to the date specified in paragraph 8 above or until it is released earlier by the Authority pursuant to the provisions of the Agreement.

Signed and sealed this ……. day of …….., 20…… at ……..

SIGNED, SEALED AND DELIVERED For and
on behalf of the Bank by:

(Signature)

(Name)

(Designation) (Code
Number) (Address)
NOTES:

(i) The bank guarantee should contain the name, designation and code number of the officer(s) signing the guarantee.

(ii) The address, telephone number and other details of the head office of the Bank as well as of issuing branch should be mentioned on the covering letter of issuing branch.

Annex – III

(Schedule - G)
(See Clause 19.2)

Form for Guarantee for Advance Payment

The Managing Director,
National Highways & Infrastructure Development Corporation Limited
New Delhi

WHEREAS:

(A) [name and address of contractor] (hereinafter called the "**Contractor**") has executed an agreement (hereinafter called the "**Agreement**") with the [name and address of the authority], (hereinafter called the "**Authority**") for the construction of the ***** section of [National Highway No. **] on Engineering, Procurement and Construction (the "**EPC**") basis, subject to and in accordance with the provisions of the Agreement

(B) In accordance with Clause 19.2 of the Agreement, the Authority shall make to the Contractor an interest free advance payment (herein after called "**Advance Payment**") equal to 10% (ten per cent) of the Contract Price; and that the Advance Payment shall be made in three installments subject to the Contractor furnishing an irrevocable and unconditional guarantee by a scheduled bank for an amount equivalent to 110% (one hundred and ten percent) of such installment to remain effective till the complete and full repayment of the installment of the Advance Payment as security for compliance with its obligations in accordance with the Agreement. The amount of {first/second/third} installment of the Advance Payment is Rs. ---- -- cr. (Rupees ------ crore) and the amount of this Guarantee is Rs. ------- cr. (Rupees ------ crore) (the **"Guarantee Amount")**[$]**.**

(C) We, …….. through our branch at ……. (the "**Bank"**) have agreed to furnish this bank guarantee (*hereinafter called the* **"Guarantee"**) for the Guarantee Amount.

NOW, THEREFORE, the Bank hereby, unconditionally and irrevocably, guarantees and affirms as follows:

1. The Bank hereby unconditionally and irrevocably guarantees the due and faithful repayment on time of the aforesaid instalment of the Advance Payment under and in accordance with the Agreement, and agrees and undertakes to pay to the Authority, upon its mere first written demand, and without any demur, reservation, recourse,

contest or protest, and without any reference to the Contractor, such sum or sums up to an aggregate sum of the Guarantee Amount as the Authority shall claim, without the Authority being required to prove or to show grounds or reasons for its demand and/or for the sum specified therein.

[$] The Guarantee Amount should be equivalent to 110% of the value of the applicable instalment.

2. A letter from the Authority, under the hand of an officer not below the rank of General Manager in the National Highways & Infrastructure Development Corporation Limited(NHIDCL), that the Contractor has committed default in the due and faithful performance of all or any of its obligations for the repayment of the instalment of the Advance Payment under and in accordance with the Agreement shall be conclusive, final and binding on the Bank. The Bank further agrees that the Authority shall be the sole judge as to whether the Contractor is in default in due and faithful performance of its obligations during and under the Agreement and its decision that the Contractor is in default shall be final and binding on the Bank, notwithstanding any differences between the Authority and the Contractor, or any dispute between them pending before any court, tribunal, arbitrators or any other authority or body, or by the discharge of the Contractor for any reason whatsoever.

3. In order to give effect to this Guarantee, the Authority shall be entitled to act as if the Bank were the principal debtor and any change in the constitution of the Contractor and/or the Bank, whether by their absorption with any other body or corporation or otherwise, shall not in any way or manner affect the liability or obligation of the Bank under this Guarantee.

4. It shall not be necessary, and the Bank hereby waives any necessity, for the Authority to proceed against the Contractor before presenting to the Bank its demand under this Guarantee.

5. The Authority shall have the liberty, without affecting in any manner the liability of the Bank under this Guarantee, to vary at any time, the terms and conditions of the Advance Payment or to extend the time or period of its repayment or to postpone for any time, and from time to time, any of the rights and powers exercisable by the Authority against the Contractor, and either to enforce or forbear from enforcing any of the terms and conditions contained in the Agreement and/or the securities available to the Authority, and the Bank shall not be released from its liability and obligation under these presents by any exercise by the Authority of the liberty with reference to the matters aforesaid or by reason of time being given to the Contractor or any other forbearance, indulgence, act or omission on the part of the Authority or of any other matter or thing whatsoever which under any law relating to sureties and guarantors would but for this provision have the effect of releasing the Bank from its liability and obligation under this Guarantee and the Bank hereby waives all of its rights under any such law.

6. This Guarantee is in addition to and not in substitution of any other guarantee or

security now or which may hereafter be held by the Authority in respect of or relating to the Advance Payment.

7. Notwithstanding anything contained hereinbefore, the liability of the Bank under this Guarantee is restricted to the Guarantee Amount and this Guarantee will remain in force for the period specified in paragraph 8 below and unless a demand or claim in writing is made by the Authority on the Bank under this Guarantee all rights of the Authority under this Guarantee shall be forfeited and the Bank shall be relieved from its liabilities hereunder.

8. The Guarantee shall cease to be in force and effect on ****.[$] Unless a demand or claim under this Guarantee is made in writing on or before the aforesaid date, the Bank shall be discharged from its liabilities hereunder.

9. The Bank undertakes not to revoke this Guarantee during its currency, except with the previous express consent of the Authority in writing, and declares and warrants that it has the power to issue this Guarantee and the undersigned has full powers to do so on behalf of the Bank.

10. Any notice by way of request, demand or otherwise hereunder may be sent by post addressed to the Bank at its above referred branch, which shall be deemed to have been duly authorized to receive such notice and to effect payment thereof forthwith, and if sent by post it shall be deemed to have been given at the time when it ought to have been delivered in due course of post and in proving such notice, when given by post, it shall be sufficient to prove that the envelope containing the notice was posted and a certificate signed by an officer of the Authority that the envelope was so posted shall be conclusive.

11. This Guarantee shall come into force with immediate effect and shall remain in force and effect up to the date specified in paragraph 8 above or until it is released earlier by the Authority pursuant to the provisions of the Agreement.

Signed and sealed this ……. day of …….., 20…… at ……..

SIGNED, SEALED AND DELIVERED

For and on behalf of the Bank by:

(Signature)
(Name)
(Designation)

[$] Insert a date being 90 (ninety) days after the end of one year from the date of payment of the Advance payment to the Contractor (in accordance with Clause 19.2 of the Agreement).

(Code Number)
(Address)

NOTES:

(i) The bank guarantee should contain the name, designation and code number of the officer(s) signing the guarantee.

(ii) The address, telephone number and other details of the head office of the Bank as well as of issuing branch should be mentioned on the covering letter of issuing branch.

SCHEDULE - H

(See Clauses10.1.4 and 19.3)

Contract Price Weightages

1.1 The Contract Price for this Agreement is Rs (…….)

1.2 Proportions of the Contract Price for different stages of Construction of the Project Highway shall be as specified below:

Sl No.	Item	Weightage in percentage to the Contract Price		Stage for Payment	Percentage weightage to Particular item(col.2)
1	2	3		4	5
1.Investigation and Design					
1.1: Investigation & Detailed Design (Project Layout, Mined Tunnel, Egress Tunnel, West and East Portals, Ventilation, Ventilation Shafts 1&2, Ventilation Shaft 3, Ventilation Cavern, Service Buildings, E&M Works, Drainage works, Approach roads to both West and East Portal including design of structures and approach road alignment and design etc.)		**1.903%**			**1.903%**
2	**Portals including Cut and Cover Tunnel**	**West**	**0.698%**	**A1- Temporary Dewatering Arrangement**	**9.04%**
				A2- Permanent Dewatering (PVC pipes, perforated PVC pipes, precast concrete slots channel elements, dimpled sheets between permanent lines of C&C tunnel length and backfill material, water-proofing membrane etc)	**1.16%**
				A3- Open Excavation and Earthwork (Loose excavation, rock excavation, embankments and back- fillings in area of open excavation, rip-rap layer on embankments and filling,	**21.87%**

				Gabion cage, Filter membrane etc.)	
				A4- Primary support measures (i) Supply, drilling, installation and grouting of SN type rock bolts of the specified length. (ii) Supply, drilling, installation, grouting and pre-stressing of pre-stressed anchors with double corrosion protection at slopes. (iii)Shotcreting with designed mix cement concrete. (iv)Sprayed Concrete for temporary surface drains. (v)Sprayed Concrete for shotcrete beam including reinforcement. (vi) Installation of welded wire fabric of specified dimensions as reinforcement in slopes.	**10.81%**
				A5-Concrete Works: (Concrete works including reinforcement and PVC water stop etc. in foundation and along the length of cut & cover tunnel, wing wall and attic, ventilation building, ventilation shafts, reinforcement steel and water stop etc.)	**7.28%**
				A6- Pavement: (Granular sub base, DLC base layer, cement concrete pavement, pre-cast footpath elements and bituminous layer, in the length of C&C tunnel, on length of road on final portal to junction of service road, area of vehicle hard standing etc)	**4.51%**
				A7-Construction of buildings (Main control center, Ventilation Building, Fire Brigade Post, O&M Building, Traffic Aid port/ Medical/ Rescue(12 Nos.)	**45.34%**
		East	**0.813%**	**B1- Temporary Dewatering Arrangement**	**5.30%**
				B2- Permanent Dewatering Arrangement:	**0.84%**

				(PVC pipes, perforated PVC pipes, precast concrete slots channel elements, dimpled sheets between permanent lines of C&C tunnel length and backfill material, water-proofing membrane etc,)	
				B3- Open Excavation and Earthwork: (Loose excavation, rock excavation, embankments and back- fillings in area of open excavation, rip-rap layer on embankments and filling, Gabion cage, Filter membrane etc.)	**45.07%**
				B4- Primary support measures: (i) Supply, drilling, installation and grouting reinforcement bars of specified dia as soil nails at slopes. (ii) Supply, drilling, installation, grouting and pre-stressing of pre-stressed anchors with double corrosion protection at slopes. (iii) Supply, drilling, installation, grouting and glass fibre plastic (GFP) self-drilling bolts at slopes. (iv) Shotcreting with designed mix cement concrete. (v) Installation of welded wire fabric as reinforcement in slopes.	**6.00%**
				B5-Concrete Works: (Concrete works including reinforcement and PVC water stop etc. in foundation and along the length of cut & cover tunnel, wing wall and attic, ventilation building, ventilation shafts, reinforcement steel and water stop etc.)	**5.69%**
				B6- Pavement: (Granular sub base, DLC base layer, cement concrete pavement, pre-cast footpath elements and bituminous pavement, in the length of C&C tunnel, on length of road on final portal to junction of service road, area of vehicle hard standing etc)	**3.57%**
				B7-Construction of buildings: (Main	**33.53%**

				control center, Ventilation Building, O&M Building, Traffic Aid port/ Medical/ Rescue(12 Nos.)	
3	**Egress Tunnel**	**18.369%**		**A1- Temporary Dewatering Arrangement**	**0.36%**
				A2- Permanent Dewatering Arrangement	**3.18%**
				A3-Underground Excavation: (i) Underground Excavation for support categories A, B, C, D, E & F (Top Heading, Bench and Invert) (ii) Drivable Cross Passages, Pedestrian Cross Passages, Geological Overbreak, Additional Underground Excavation and Re-profiling of tunnel due to deformations including predicted suspensions of work. (iii) Drilling and Grouting in the tunnel perimeter and face and strata grouting.	**42.78%**
				A4- Primary and final support measures: **Bolts & Anchors** (a) Drilling and Installation of Frictional Rock Bolts for the complete job in category A & B including pedestrian Cross passage. (b) Supply, Drilling, Installation and Grouting of Rock Bolts in support category C in the mined tunnel length & cross passages in support categories C, D, E & F. (c) Supply, Drilling, Installation and Grouting of Forepoling in support category C, D and E in the tunnel length and cross passages. (d) Steel pipe umbrella in support category F in the tunnel length. **Shotcrete, Lattice Girder, Lining Stress Controller and Wire mesh** (a) Shotcreting of primary lining (tunnel, niches, caverns in all support categories A, B, C, D, E &	**29.83%**

			F) (b) Shotcreting of primary invert lining in support categories D, E & F along the tunnel length. (c) Shotcreting of permanent lining along the perimeter and mining egress tunnel length. (d) Shotcreting of face sealing, filling of cavities and geological Overbreak in support categories A & B and along cross passage. (e) Welded wire fabric in support categories C, D, E & F (top heading and invert) along the mined egress tunnel length. (f) Fabrication and erection of lattice girders and all accessories in support categories C, D, E & F (top heading) along the tunnel length. (g) Lining stress controllers in support category E along the mined tunnel length.	
			A5-Concrete Works: (i) Cement concrete in : (a) Inner lining of tunnel foundations, inner lining of tunnel invert, inner lining of tunnel and niches- vault with radial formwork (with and without invert) along the tunnel length. (b) Fill concrete in tunnel along the tunnel length with and without invert including binding concrete in tunnel and no-fines porous concrete including reinforcements for inner lining foundation, reinforcement grate, inner lining invert and inner lining vault including reinforcements for inner lining tunnel ceiling and ventilation vault.	**21.64%**
			A6-Instrumentation and Monitoring (i) Install, read and maintain 3D monitoring targets (reflectors) in Top heading , bench and invert in	**1.19%**

			all support Categories A,B,C,D,E,F. (ii) Drill, install, grout, read and maintain of bore hole extensometer in the tunnel perimeter in support Categories B,C,D,E,F. (iii) Install, read and maintain of load cells for rock bolts in support Category B,C,D,E,F. (iv) Install, read and maintain of strain gauges for shotcrete in support Categories B,C,D,E,F. (v) Install, read and maintain of strain gauges for concrete in support Categories B,C,D,E,F. (vi) Install, read and maintain of radial pressure cells in support Categories B,C,D,E,F. (vii) Install, read and maintain tangential pressures cells in support Categories B,C,D,E,F. (viii)Install, read and maintain temperature gauges per formwork block length.	
			A7-Pavement (i) Granular sub base in lay bys (ii) Dry lean cement concrete base layer in number of lay bys. (iii) Cement concrete pavements in number of lay bys.	**1.03%**
4	**Main Tunnel**	**33.103%**	**A1- Temporary Dewatering Arrangement**	**0.20%**
			A2- Permanent Dewatering Arrangement	**5.99%**
			A3- Underground Excavation **(a)Excavation** Underground excavation for tunnel in support categories (A,B,C,D,E,F,G,H) dominating the face area (Heading, Bending and Invert) including all types of niches and lay bye including drilling, blasting or other means of excavation including widening of Top Heading, Footings, provision of	**34.38%**

			surface drainage, construction, ventilation, lighting arrangement during construction, temporary backfilling for traffic in tunnel and re filling geological Overbreak and its including re-profiling of tunnel due to deformation and including temporary suspension of D & B excavation. **(b) Drilling of drainage, drilling in tunnel perimeter and face and strata grouting as per Technical specifications**.	
			A4- Primary & Final Support Measures **(i) Bolts & Anchors:** (a) Drilling and installation frictional rock bolts for the complete job on Category A & B. (b) Drilling, installation and grouting of rock bolts in support Category C in the Mined tunnel length. (c) Drilling, installation and grouting of self-drilling bolts in support Category H(Top Heading, Bench) in the tunnel length. (d) Drilling , installation and grouting of forepoling in support Category C,D,E,F,G. (e) Steel pipe umbrella in support Category H in the excavation length. **(ii)Shotcrete, Lattice girder, Lining stress controller & Wire Mesh:** (a) Shotcreting of primary lining (Tunnels, Niches, Caverns) in all support Categories A,B,C,D,E,F,G,H. (b) Shotcreting of primary invert lining in support Categories D,E,F,G,H along tunnel length. (c) Shotcreting of face ceiling and widening of Top heading footing in support Category H (Top heading, Bench & Invert) along mined tunnel including steel fibre re-	**29.49%**

			inforcement along the perimeter of shotcrete in support Category A (Top Heading,Bench.) (d) Welded wire fabric in support Categories B,C,D,E,F,G,H along mined tunnel length. (e) Fabrication and erection of lattice girders and all accessories in support Categories C,D,E,F,G,H (Top heading, Bench) along mined tunnel length. (f) Lining stress controllers in support Categories F & G along mined tunnel length.	
			A5-Concrete Works (i) Cement concrete in : (a) Inner lining of tunnel foundations, inner lining of tunnel invert, inner lining of tunnel and niches- vault with radial formwork (with and without invert) along the tunnel length. (b) Fill concrete in tunnel along the tunnel length with and without invert including binding concrete in tunnel and no-fines porous concrete including reinforcements for inner lining foundation, inner lining invert and inner lining vault including reinforcements for inner lining tunnel ceiling and ventilation vault.	**25.48%**
			A6-Instrumentation and Monitoring (i) Install, read and maintain 3D monitoring targets (reflectors) in Top heading , bench and invert in all support Categories A,B,C,D,E,F,G,H. (ii) Drill, install, grout, read and maintain of bore hole extensometer in the tunnel perimeter in support Categories B,C,D,E,F,GH. (iii) Install, read and maintain of load cells for rock bolts in support Category B,C,D,E,F,G,H. (iv)Install, read and maintain of strain gauges for shotcrete in support	**0.91%**

			Categories B,C,D,E,F,G,H. (v) Install, read and maintain of strain gauges for concrete in support Categories B,C,D,E,F,G,H. (vi) Install, read and maintain of radial pressure cells in support Categories B,C,D,E,F,G,H. (vii) Install, read and maintain tangential pressures cells in support Categories B,C,D,E,F,G,H. (viii)Install, read and maintain temperature gauges per formwork block length.	
			A7-Pavement **(**i) Granular sub base in lay bys (ii) Dry lean cement concrete base layer in number of lay bys. (iii) Cement concrete pavements in number of lay bys. (iv) Pre-cast footpath elements in the mined tunnel length.	**3.55%**
5	**Ventilation Shaft and Ventilation Cavern**	**3.573%**	**A1- Temporary Dewatering Arrangement**	**4.21%**
			A2- Permanent Dewatering Arrangement	**2.56%**
			A3- Underground Excavation for tunnel in Support Category (1,2,3,4 & 5) dominating the Face Area including Drilling, Blasting, provision of surface drainage, construction, ventilation, lighting arrangements during construction, temporary back filling and removal of same. (i) Shafts 1&2 and Bored pile section per shaft: (a)In shaft 1&2 (Top shaft excavation in support Category 01). (b)In shaft 1&2 (Top shaft excavation in support Category 02). (c)In shaft 1&2 (Top shaft excavation in support Category 03).	**34.91%**

			(d)In shaft 1&2 (Top shaft excavation in support Category 04). (e)In shaft 1&2 (Top shaft excavation in support Category 05). (f) Bored pile excavation in bored pile section per shaft. (g) Excavation for ventilation cavern. (h) Raise Boring in the length of Shaft 3. **(ii) Drilling and Grouting:** (a) Drilling and grouting in shaft perimeter with and without core recovery including strata grouting.	
			A4- Primary Support Measures **(i)Bolts & Anchors:** a) Drilling and Installation of Frictional Rock Bolts in support category 1 & 2 including caverns. (b)Drilling, Installation and Grouting of Rock Bolts in support category 4 for Shafts 1&2 of appropriate lengths. **(ii)Shotcrete & Wire Mesh:** (a) Shotcreting of primary lining (Shafts and Caverns) of appropriate thickness along the perimeter of Shafts1, 2 & 3. (b) Welded wire fabric in primary lining in support categories 1,2,3,4 & 5 of Shafts 1,2 & 3. (c) Fabrication and erection of Lattice Girder with all accessories and installation of accessories for joining the lattice girder in support Category 4&5 of Shafts 1&2.	**18.68%**
			A5-Concrete Work (i) Cement concrete in : (a) Inner lining of ventilation shaft (Shaft 1&2) and ventilation shaft raise boring (Shaft 3) along area of cross section. (b) Inner lining of Ventilation cavern (foundation, vaults, ventilation ducts) along the area of cross section.	**38.80%**

			(c) Inner lining of bored piles along the length . (d) Reinforcements for inner lining of ventilation tunnel and cavern (ventilation shaft, ventilation shaft raise boring, ventilation cavern - foundation, ventilation cavern - vaults, ventilation cavern- ventilation ducts) along with reinforcement for bored piles.	
			A6- Instrumentation and Monitoring (i) Install, read and maintain 3D monitoring targets (reflectors) in Top heading, bench and invert in support Categories 1, 2,3,4,5 of Shaft 1 & 2. (ii) Drill, install, grout, read and maintain of bore hole extensometer in the tunnel perimeter in support Categories 2,3,4,5 of Shaft 1& 2. (iii) Install, read and maintain of load cells for rock bolts in support Categories 2,3,4,5 of Shaft 1& 2. (iv)Install, read and maintain of strain gauges for shotcrete in support Categories 2,3,4,5 of Shaft 1& 2. (v) Install, read and maintain of strain gauges for concrete in support Categories 2,3,4,5 of Shaft 1& 2. (vi) Install, read and maintain of radial pressure cells in support Categories 2,3,4,5 of Shaft 1& 2. (vii) Install, read and maintain tangential pressures cells in support Categories 2,3,4,5 of Shaft 1& 2. (viii)Install, read and maintain temperature gauges per formwork block length of Shaft 1& 2.	**0.31%**
			A7- Pavement (i) Granular sub base along length of Caverns. (ii) Dry lean cement concrete base layer in number of Caverns. (iii) Cement concrete pavements in	**0.53%**

			number of Caverns.	
6	**Site Facility and Time Dependent Costs**	**24.603%**	**S&T:A- Site Facility***	**75.44%**
			Avalanche protection Measures for West and East Portals	**4.39%**
			S&T:B- Time Dependent Costs**	**20.17%**
7	**Electro and Mechanical Equipment (Shaft Tunnels including Cut & Cover Tunnel)**	**11.282%**	**Delivery of equipment at site***	**40%**
			Installation of equipment at site*	**20%**
			Commissioning of equipment at site*	**40%**
			1. Site installation & Site Clearance	
			2. Power Supply System	
			3. Ventilation Measuring System	
			4. Traffic Control:-	
			(a) Traffic Lights	
			(b) Over height Vehicle detection	
			(c)Traffic Logging Equipment	
			(d)Guidance System	
			(e)Variable Message Signs	
			(f)Cabling	
			5. CCTV System	
			6. Emergency call system	
			7. Communication system	
			8. Fire Safety Equipment	
			9. Tunnel Lighting System (Entrance Lighting Interior Lighting Lay-Bys Lighting Egress Tunnel Lighting Street lighting Luminance Measurement Escape Direction Lamps Evacuation Route Lamps and Signs Cabling)	
			10. Integrated Tunnel Control System (SCADA)	
			11. Doors and gates	
			12. Building Installation and Equipment (Local control centre installation Local control centre ventilation, Ventilation Building Installation Tunnel Niches Installation Cabling) Including Testing and approvals, Engineering, Documentation etc.	

8	**Ventilation System**	**5.655%**	**Delivery of equipment at site***	**40%**
			Installation of equipment at site*	**20%**
			Commissioning of equipment at site* Main exhaust air ventilator (E1, E2, E3, E4, E5, E6, E7, E8) incl. accessories and structures, Main fresh air ventilator (F1, F2, F3, F4, F5, F6, F7, F8) incl. accessories and structures, Butterfly flap, vanes in the exhaust air ducts, vanes in the fresh air ducts, Fresh air regulator metal sheet, Exhaust air damper, Jet fan (traffic room), incl. accessories and structures, Rescue tunnel ventilator incl. accessories and structures, Rescue tunnel flap incl. accessories and structures, Crossway tunnel overpressure flap incl. accessories and structures, Crossway tunnel fire flap incl. accessories and structures, Crossway tunnel pressure difference measurement incl. accessories and structures, Jet fan (Crossway tunnel) incl. accessories and structures, Velocity measurement system, Probation and system testing, Implementation design documentation, As-built documentation, Metrological detection system, Doors in exhaust air and fresh air ducts, Doors in crossway tunnels and in the lock, Gate in locks, Crane facility etc.	**40%**

***** Site Facility cost @ 30% of the Cost shall be paid on the commencement of mined tunnel excavation and completion of excavation upto 25 m along the length of the tunnels, provided the Contractor has completed the components of works to the extent mentioned in the Milestone-I of Schedule-J of this Agreement. The remaining cost shall be payable quarterly in equal installments each year for the remaining 6 years.

****** The payment for Time Dependent Cost (20.17%) from commencement of construction to the end of construction shall be paid as under:

(i) Commencement of construction to commencement of mined tunnel excavation and completion of excavation upto 25m along the length of the tunnels shall be paid at the end of first year.

(ii) Commencement of tunnel excavation to end of concrete works shall be paid per month for (60+3 months).

(iii) From the end if concrete works to the end of construction work (12+3 months) shall be paid per month.

1.1 Procedure of estimating the value of work done.

1.1.1 Road works including approaches to minor bridges, Major Bridges and Structures (excluding service roads).

Procedure for estimating the value of tunnel works done shall be as follows:

Table 1.3.1

Stage of Payment	Percentage - weightage	Payment Procedure
A-Investigation and Design		
(a) Investigation & Detailed Design	**1.903%**	Unit of measurement is the submission of Detailed Design and Investigation Report complete. Payment shall be made on the completion and approval of the same.
B-Portals including Cut & Cover Tunnel		
(a) West	**0.698%**	**A1: Temporary Dewatering:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal. **A2: Open Excavation:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal. **A3: Primary Support Measures:** Unit of measurement is West Portal. Payment shall be made on the completion of each sub group of construction under primary support measures. **A4: Permanent Dewatering:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal. **A5: Concrete Works:** Unit of measurement is completion of the West Portal. The payment shall be made

		on the completion of West Portal **A6: Pavement:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal **A7: Construction of Buildings:** The unit of measurement shall be square meter. The payment shall be made on pro-rata basis on the completion of 1 (one) building.
(b) East	**0.813%**	**A1: Temporary Dewatering:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal. **A2: Open Excavation:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal. **A3: Primary Support Measures:** Unit of measurement is West Portal. Payment shall be made on the completion of each sub group of construction under primary support measures. **A4: Permanent Dewatering:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal. **A5: Concrete Works:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal **A6: Pavement:** Unit of measurement is completion of the West Portal. The payment shall be made on the completion of West Portal **A7: Construction of Buildings:** The unit of measurement shall be square meter. The payment shall be made on pro-rata basis on the

		completion of 1 (one) building.
C- Main Tunnel	**33.103 %**	Unit of measurement is linear length-meter. Payment of each stage shall be made on pro rata basis on completion of a stage in a continuous length of 50 meter.
D- Egress Tunnel	**18.369 %**	Unit of measurement is linear length-meter. Payment of each stage shall be made on pro rata basis on completion of a stage in a continuous length of 75 meter.
E-Ventilation shafts and Ventilation Caverns	**3.573%**	Unit of measurement is linear length-meter. Payment of each stage shall be made on pro rata basis on completion of a stage in a continuous length of 10 meter.
F- Site Facility and Time Dependent Costs	**24.603%**	(a) Site Facility cost @ 30% of the Cost shall be paid on the commencement of mined tunnel excavation and completion of excavation upto 25 m along the length of the tunnels, provided the Contractor has completed the components of works to the extent mentioned in the Milestone-I of Schedule-J of this Agreement. The remaining cost shall be payable quarterly in equal instalments each year for the remaining 6 years. (b) The payment for Time Dependent Cost (20.17%) from commencement of construction to the end of construction shall be paid as under: (i) Commencement of construction to commencement of mined tunnel excavation and completion of excavation upto 25m along the length of the tunnels shall be paid at the end of first year. (ii) Commencement of tunnel excavation to end of concrete works shall be paid per month. (iii) From the end if concrete works to the end of construction work shall be paid per month.
G- Electro and Mechanical Equipment	**11.282%**	On delivery, installation and commissioning of E&M equipment in

		the ratio of 40:20:40.
H- Ventilation System	**5.655%**	On delivery, installation and commissioning of E&M equipment in the ratio of 40:20:40.

@ For example, if the total length of excavation work (e.g. Mined Tunnel) to be done is 14083 m, the cost per km of excavation work shall be determined as follows:

Cost per km = P x weightage for Main Tunnel x weightage for Underground excavation x (1/L)

Where P = Contract Price.

L = Total length in meters.

Similarly, the rates per km for stages (1), (2) (3) and (4) above shall be worked out.

1. Procedure for payment for Maintenance

1.1 The cost for maintenance shall be as stated in Clause 14.1.1.

1.2 Payment for Maintenance shall be monthly lump sum amount payable and shall be 1/12th (one-twelfth) of the annual cost of Operation and Maintenance in accordance with the provisions of Clause 19.7.

SCHEDULE - I

(See Clause 10.2.4)

DRAWINGS

1 **Drawings**

In compliance of the obligations set forth in Clause 10.2 of this Agreement, the Contractor shall furnish to the Authority's Engineer, free of cost, all Drawings listed in Annex-I of this Schedule-I.

2 **Additional Drawings**

If the Authority's Engineer determines that for discharging its duties and functions under this Agreement, it requires any drawings other than those listed in Annex-I, it may by notice require the Contractor to prepare and furnish such drawings forthwith. Upon receiving a requisition to this effect, the Contractor shall promptly prepare and furnish such drawings to the Authority's Engineer, as if such drawings formed part of Annex-I of this Schedule-I.

(Schedule - I)

List of Drawings

List of Drawings

1. The Project Highway drawings, as defined in Clause 1.1, Definitions, Article 1, Definitions and Interpretation, Part-I: Preliminary, of the Contract Agreement shall consist:

(a) Working Drawings of all the components/elements of the Project Highway as determined by Authority Engineer/Authority, and

(b) As-built drawings for the Project Highway components/elements as determined by AE/Authority. As-built drawings shall be duly certified by Authority Engineer.

2. A minimum list of the drawings of the various components/elements of the Project Highway and Project facilities required to be submitted by the Contractor is given below:

(i) General Layout Tunnel - Plan View

(ii) General Layout Tunnel- Longitudinal Section

(iii) Drawings of clearance profile and installations without invert slab

(iv) Drawings of clearance profile and installations with invert slab

(v) Drawings of cut & cover tunnel general layout and clearance profile

(vi) Drawings of egress tunnel

(vii) Drawings of Tunnel system and installations

(viii) Drawings of Ventilation Shaft 1, 2 & 3

(ix) Drawings of ventilation cavern plan view

(x) Drawings of ventilation cavern longitudinal section

(xi) Drawings of hydraulic scheme plan view

(xii) Drawings of hydraulic scheme general layout western portal

(xiii) Drawings of hydraulic scheme general layout eastern portal

(xiv) Detail of road

(xv) Detailed drawings of Bridges

(xvi) Details and drawings of Culverts

(xvii) Drawings of horizontal alignment, vertical profile and cross sections

(xviii) Drawings of cross drainage works

(xix) Drawings of Control Centre

(xx) Drawings of bus-bay and bus shelters with furniture and drainage system

(xxi) Drawing of a truck parking lay bye with furniture and drainage system

(xxii) Drawings of road furniture items including traffic signage, markings, safety barriers, etc.

(xxiii) Drawings of traffic diversion plans and traffic control measures

(xxiv) Drawings of road drainage measures

(xxv) Drawings of typical details slope protection measures

(xxvi) Drawings of landscaping and horticulture

(xxvii) Drawings of pedestrian crossings

(xxviii) Drawings of street lighting

(xxix) Layout/Configuration of HTMS

(xxx) General arrangement showing area of Base camp and Administrative Block

(xxxi) Diagram Of Safety Installations

SCHEDULE - J

(See Clause 10.3.2)

PROJECT COMPLETION SCHEDULE

1 **Project Completion Schedule**

During Construction period, the Contractor shall comply with the requirements set forth in this Schedule-J for each of the Project Milestones and the **Scheduled Completion Date**. Within 15 (fifteen) days of the date of each Project Milestone, the Contractor shall notify the Authority of such compliance along with necessary particulars thereof.

2 **Project Milestone-I**

2.1 Project Milestone-I shall occur on the date falling on the 365th (three hundred and sixty fifth) day from the Appointed Date (the "**Project Milestone-I**").

2.2 Prior to the occurrence of Project Milestone-I, the Contractor shall have commenced construction of the Project and expended not less than 10% (ten per cent) of the Contract Price.

2.3 On occurrence of Project Milestone –I, the Contractor ought to have completed the following activities:-

S No	Construction Activity	%
1	Site Installation	100
2	Excavation and Primary Support of Portals	100
3	Construction of Access Shaft-1	40
4	Construction of Access Shaft-2	60
5	Excavation and Primary Support of Egress Tunnel	06
6	Excavation and Primary Support of Main Tunnel(Including Laybys and caverns)	02
7	Construction of Inner Lining	0
8	E & M Installation and facilities	0

3 Project Milestone-II

3.1 Project Milestone-II shall occur on the date falling on the 730th (seven hundred and thirtieth) day from the Appointed Date (the "**Project Milestone-II**").

3.2 Prior to the occurrence of Project Milestone-II, the Contractor shall have commenced [construction of all bridges and expended not less than 26% (twenty six per cent)] of the Contract price.

3.3 On occurrence of Project Milestone –II, the Contractor ought to have completed the following activities:-

S No	Construction Activity	%
1	Site Installation	100
2	Excavation and Primary Support of Portals	100
3	Construction of Access Shaft-1	90
4	Construction of Access Shaft-2	100
5	Excavation and Primary Support of Egress Tunnel	18
6	Excavation and Primary Support of Main Tunnel(Including Laybys and caverns)	11
7	Construction of Inner Lining	0
8	E & M Installation and facilities	0

4 Project Milestone-III

4.1 Project Milestone-III shall occur on the date falling on the 1095th th (one thousand and ninety fifth) day from the Appointed Date (the "**Project Milestone-III**").

4.2 Prior to the occurrence of Project Milestone-III, the Contractor shall have commenced [construction of all Project Facilities and expended not less than 42% (forty two per cent)] of the Contract price.

4.3 On occurrence of Project Milestone –III, the Contractor ought to have completed the following activities:-

S No	Construction Activity	%
1	Site Installation	100
2	Excavation and Primary Support of Portals	100
3	Construction of Access Shaft-1	100
4	Construction of Access Shaft-2	100
5	Excavation and Primary Support of Egress Tunnel	49
6	Excavation and Primary Support of Main Tunnel(Including Laybys and caverns)	32
7	Construction of Inner Lining	7
8	E & M Installation and facilities	0

4A Project Milestone-IV

4A.1 Project Milestone-IV shall occur on the date falling on the 1460th (one thousand four hundred and sixtieth) day from the Appointed Date (the "**Project Milestone-IV**").

4A.2 Prior to the occurrence of Project Milestone-IV, the Contractor shall have commenced [construction of all Project Facilities and expended not less than 58% (fifty eight per cent)] of the Contract price.

4A.3. On occurrence of Project Milestone –IV, the Contractor ought to have completed the following activities:

S No	Construction Activity	%
1	Site Installation	100
2	Excavation and Primary Support of Portals	100
3	Construction of Access Shaft-1	100
4	Construction of Access Shaft-2	100
5	Excavation and Primary Support of Egress Tunnel	93
6	Excavation and Primary Support of Main Tunnel(Including Laybys and caverns)	78
7	Construction of Inner Lining	35
8	E & M Installation and facilities	0

4B Project Milestone-V

4B.1 Project Milestone-V shall occur on the date falling on the 1825th (one thousand eight hundred and twenty fifth) day from the Appointed Date (the "**Project Milestone-V**").

4B.2 Prior to the occurrence of Project Milestone-V, the Contractor shall have commenced [construction of all Project Facilities and expended not less than 74% (seventy four per cent)] of the Contract Price.

4B.3. On occurrence of Project Milestone –V, the Contractor ought to have completed the following activities:-

S No	Construction Activity	%
1	Site Installation	100
2	Excavation and Primary Support of Portals	100
3	Construction of Access Shaft-1	100
4	Construction of Access Shaft-2	100
5	Excavation and Primary Support of Egress Tunnel	100
6	Excavation and Primary Support of Main Tunnel(Including Laybys and caverns)	100
7	Construction of Inner Lining	73
8	E & M Installation and facilities	0

4C Project Milestone-VI

4C.1 Project Milestone-VI shall occur on the date falling on the 2190th (two thousand one hundred and ninetieth) day from the Appointed Date (the "**Project Milestone-VI**").

4C.2 Prior to the occurrence of Project Milestone-VI, the Contractor shall have commenced [construction of all Project Facilities and expended not less than 90% (ninety per cent)] of the Contract Price.

4C.3. On occurrence of Project Milestone –VI, the Contractor ought to have completed the following activities:-

S No	Construction Activity	%
1	Site Installation	100
2	Excavation and Primary Support of Portals	100

3	Construction of Access Shaft-1	100
4	Construction of Access Shaft-2	100
5	Excavation and Primary Support of Egress Tunnel	100
6	Excavation and Primary Support of Main Tunnel(Including Laybys and caverns)	100
7	Construction of Inner Lining	100
8	E & M Installation and facilities	20

5 Scheduled Project Completion Date

5.1 The Scheduled Two-Laning Date shall occur on the 2555th (two thousand five hundred and fifty fifth) day from the Appointed Date.

5.2 On or before the Scheduled Two-Laning Date, the Contractor shall have completed Two-Laning in accordance with this Agreement.

5.3. On Schedule Completion Date, the Contractor ought to have completed the following activities:-

S No	Construction Activity	%
1	Site Installation	100
2	Excavation and Primary Support of Portals	100
3	Construction of Access Shaft-1	100
4	Construction of Access Shaft-2	100
5	Excavation and Primary Support of Egress Tunnel	100
6	Excavation and Primary Support of Main Tunnel(Including Laybys and caverns)	100
7	Construction of Inner Lining	100
8	E & M Installation and facilities	100

6 Extension of period

Upon extension of any or all of the aforesaid Project Milestones or the Scheduled Two-Laning Date, as the case may be, under and in accordance with the provisions of this Agreement, the Project Completion Schedule shall be deemed to have been amended accordingly.

SCHEDULE - K

(See Clause 12.1.2)

Tests on Completion

1 **Schedule for Tests**

1.1 The Contractor shall, no later than 30 (thirty) days prior to the likely completion of construction, notify the Authority's Engineer and the Authority of its intent to subject the Project Highway to Tests, and no later than 10 (ten) days prior to the actual date of Tests, furnish to the Authority's Engineer and the Authority detailed inventory and particulars of all works and equipment forming part of Works.

1.2 The Contractor shall notify the Authority's Engineer of its readiness to subject the Project Highway to Tests at any time after 10 (ten) days from the date of such notice, and upon receipt of such notice, the Authority's Engineer shall, in consultation with the Contractor, determine the date and time for each Test and notify the same to the Authority who may designate its representative to witness the Tests. The Authority's Engineer shall thereupon conduct the Tests itself or cause any of the Tests to be conducted in accordance with Article 12 and this Schedule-K.

2 **Tests**

2.1 Visual and physical test: The Authority's Engineer shall conduct a visual and physical check of construction to determine that all works and equipment forming part thereof conform to the provisions of this Agreement.

2.2 Riding quality test: Riding quality of each lane of the carriageway shall be checked with the help of a calibrated bump integrator and the maximum permissible roughness for purposes of this Test shall be [2,000 (two thousand)] mm for each kilometre.

2.3 Tests for bridges: All major and minor bridges shall be subjected to the rebound hammer and ultrasonic pulse velocity tests, to be conducted in accordance with the procedure described in Special Report No. 17: 1996 of the IRC Highway Research Board on Nondestructive Testing Techniques, at two spots in every span, to be chosen at random by the Authority's Engineer. Bridges with a span of 15 (fifteen) metres or more shall also be subjected to load testing.

2.4 Other tests: The Authority's Engineer may require the Contractor to carry out or cause to be carried additional tests, in accordance with Good Industry Practice, for determining the compliance of the Project Highway with Specifications and Standards.

2.5 Environmental audit: The Authority's Engineer shall carry out a check to determine conformity of the Project Highway with the environmental requirements set forth in Applicable Laws and Applicable Permits.

2.6 Safety Audit: The Authority's Engineer shall carry out, or cause to be carried out, a safety audit to determine conformity of the Project Highway with the safety requirements and Good Industry Practice.

3 **Agency for conducting Tests**

All Tests set forth in this Schedule-K shall be conducted by the Authority's Engineer or such other agency or person as it may specify in consultation with the Authority.

4 **Completion Certificate**

Upon successful completion of Tests, the Authority's Engineer shall issue the Completion Certificate in accordance with the provisions of Article 12.

SCHEDULE - L

(See Clause 12.2 and 12.4)

COMPLETION CERTIFICATE

1 I, ……. (Name of the Authority's Engineer), acting as the Authority's Engineer, under and in accordance with the Agreement dated ……. (the **"Agreement"**), for construction of the [****section (km ** to km **) of National- Highway No. ***] (the **"Project Highway"**) on Engineering, Procurement and Construction (EPC) basis through …… (Name of Contractor), hereby certify that the Tests in accordance with Article 12 of the Agreement have been undertaken to determine compliance of the Project Highway with the provisions of the Agreement and I am satisfied that the Project Highway can be safely and reliably placed in service of the Users thereof.

2 It is certified that, in terms of the aforesaid Agreement, all works forming part of Project Highway have been completed, and the Project Highway is hereby declared fit for entry into operation on this the …… day of …… 20….. , Scheduled Completed Date for which was the …… day of ……20…..

SIGNED, SEALED AND DELIVERED

For and on behalf of Authority's Engineer by:

(Signature)
(Name)
(Designation) (Address)

SCHEDULE - M

(See Clauses 14.6, 15.2 and 19.7)

PAYMENT REDUCTION FOR NON-COMPLIANCE

1. Payment reduction for non-compliance with the Maintenance Requirements

1.1 Monthly lump sum payments for maintenance shall be reduced in the case of non-compliance with the Maintenance Requirements set forth in Schedule-E.

1.2 Any deduction made on account of non-compliance with the Maintenance Requirements shall not be paid even after compliance subsequently. The deductions shall continue to be made every month until compliance is done.

1.3 The Authority's Engineer shall calculate the amount of payment reduction on the basis of weightage in percentage assigned to non-conforming items as given in Paragraph 2.

2. Percentage reductions in lump sum payments

2.1 The following percentages shall govern the payment reduction:

S. No.	Item/Defect/Deficiency	Percentage
(a)	**Carriageway/Pavement**	
(i)	Potholes, cracks, other surface and Repairs of Edges, Rutting	2.5%
(b)	**Roadside Drains**	
(i)	Cleaning and repair of drains	2.5%
(c)	**Road Furniture**	
(i)	Cleaning, painting, replacement of road signs, delineators, road markings, 200 m/km/5th km stones	2.5%
(d)	**Tunnel lighting (Street lighting and Telecom ATMS)**	
(i)	Any major/ minor faults and failure of the system	15%
(e)	**Tunnel Ventilation system**	
(i)	Any major/ minor faults and failure of the system	12.5%
(f)	**Tunnel Traffic Control system**	
(i)	Any major/ minor faults and failure of the system	10%
(g)	**Tunnel Power Supply system**	

(i)	Any major/ minor faults and failure of the system	12.5%
(h)	**Tunnel CCTV monitoring system**	
(i)	Any major/ minor faults and failure of the system	12.5%
(i)	**Tunnel Fire Safety system**	
(i)	Any major/ minor faults and failure of the system	12.5%
(j)	**Integrated Tunnel Control system(SCADA)**	
(i)	Any major/ minor faults and failure of the system	5%
(k)	**Rest Areas**	
(i)	Cleaning of toilets and defects in electrical, water and sanitary installations	2%
(l)	**Other Project facilities and Approach roads**	
(i)	Damage in approach roads pedestrian facilities, truck lay byes. Bus-bays, bus shelters ,cattle crossings[Traffic Aid posts, Medical Aid posts] and roads, Damaged vehicles of debris on the roads and malfunctioning of the mobile crane	2%
(m)	**Hill Roads**	
(i)	Damage to retaining wall/breats wall, Landslides requiring clearance and Snow requiring clearance.	3.5%
(f)	**Miscellaneous Items**	
(i)	Removal of dead animals, broken down/accidented vehicles, fallen trees, road blockades or malfunctioning of mobile crane	2.5%
(ii)	Any other Defects in accordance with paragraph 1.	2.5%

2.2 The amount to be deducted from monthly lump-sum payment for non compliance of particular item shall be calculated as under:

R=P/IOO x M x L1/L

Where P = Percentage of particular item/Defect/deficiency for deduction
M = Monthly lump-sum payment in accordance with the Bid

L1 = Non-complying length L =
Total length of the road,

R = Reduction (the amount to be deducted for non compliance for a particular item/Defect/deficiency

The total amount of reduction shall be arrived at by summation of reductions for such items/Defects/deficiency or non compliance.

For any Defect in a part of one kilometer, the non-conforming length shall be taken as one kilometer.

SCHEDULE - N

(See Clause 18.1.1)

SELECTION OF AUTHORITY'S ENGINEER

1 **Selection of Authority's Engineer**

1.1 The provisions of the Model Request for Proposal for Selection of Technical Consultants, issued by the Ministry of Finance in May 2009, or any substitute thereof shall apply for selection of an experienced firm to discharge the functions and duties of an Authority's Engineer.

1.2 In the event of termination of the Technical Consultants appointed in accordance with the provisions of Paragraph 1.1, the Authority shall appoint another firm of Technical Consultants forthwith and may engage a government-owned entity in accordance with the provisions of Paragraph 3 of this Schedule-N.

2 **Terms of Reference**

The Terms of Reference for the Authority's Engineer (the "**TOR**") shall substantially conform with Annex 1 to this Schedule N.

3 **Appointment of Government entity as Authority's Engineer**

Notwithstanding anything to the contrary contained in this Schedule, the Authority may in its discretion appoint a government-owned entity as the Authority's Engineer; provided that such entity shall be a body corporate having as one of its primary functions the provision of consulting, advisory and supervisory services for engineering projects; provided further that a government-owned entity which is owned or controlled by the Authority shall not be eligible for appointment as Authority's Engineer.

Annex – I

(Schedule - N)

TERMS OF REFERENCE FOR AUTHORITY'S ENGINEER

1 **Scope**

1.1 These Terms of Reference (the "**TOR**") for the Authority's Engineer are being specified pursuant to the EPC Agreement dated ..... (the "**Agreement**), which has been entered into between the [name and address of the Authority] (the "**Authority**") and ..... (the "**Contractor**") for [Two-Laning] of the **** section (km ** to km **) of National Highway No. ** in the State of *** on Engineering, Procurement, Construction (EPC) basis, and a copy of which is annexed hereto and marked as Annex-A to form part of this TOR.

1.2 The TOR shall apply to construction and maintenance of the Project.

2 **Definitions and interpretation**

2.1 The words and expressions beginning with or in capital letters and not defined herein but defined in the Agreement shall have, unless repugnant to the context, the meaning respectively assigned to them in the Agreement.

2.2 References to Articles, Clauses and Schedules in this TOR shall, except where the context otherwise requires, be deemed to be references to the Articles, Clauses and Schedules of the Agreement, and references to Paragraphs shall be deemed to be references to Paragraphs of this TOR.

2.3 The rules of interpretation stated in Clauses 1.2, 1.3 and 1.4 of the Agreement shall apply, *mutatis mutandis*, to this TOR.

3. General

3.1 The Authority's Engineer shall discharge its duties in a fair, impartial and efficient manner, consistent with the highest standards of professional integrity and Good Industry Practice.

3.2 The Authority's Engineer shall perform the duties and exercise the authority in

accordance with the provisions of this Agreement, but subject to obtaining prior written approval of the Authority before determining:

(a) any Time Extension;

(b) any additional cost to be paid by the Authority to the Contractor;

(c) the Termination Payment; or

(d) any other matter which is not specified in (a), (b) or (c) above and which creates an obligation or liability on either Party for a sum exceeding Rs. 5,000,000 (Rs. fifty lakh).

3.3 The Authority's Engineer shall submit regular periodic reports, at least once every month, to the Authority in respect of its duties and functions under this Agreement. Such reports shall be submitted by the Authority's Engineer within 10 (ten) days of the beginning of every month.

3.4 The Authority's Engineer shall inform the Contractor of any delegation of its duties and responsibilities to its suitably qualified and experienced personnel; provided, however, that it shall not delegate the authority to refer any matter for the Authority's prior approval in accordance with the provisions of Clause 18.2.

3.5 The Authority's Engineer shall aid and advise the Authority on any proposal for Change of Scope under Article 13.

3.6 In the event of any disagreement between the Parties regarding the meaning, scope and nature of Good Industry Practice, as set forth in any provision of the Agreement, the Authority's Engineer shall specify such meaning, scope and nature by issuing a reasoned written statement relying on good industry practice and authentic literature.

4 Construction Period

4.1 During the Construction Period, the Authority's Engineer shall review the Drawings furnished by the Contractor along with supporting data, including the geo-technical and hydrological investigations, characteristics of materials from borrow areas and quarry sites, topographical surveys, and the recommendations of the Safety Consultant in accordance with the provisions of Clause 10.1.6. The Authority's Engineer shall complete such review and send its observations to the Authority and the Contractor within 15 (fifteen) days of receipt of such Drawings; provided, however that in case of a Major Bridge or Structure, the aforesaid period of 15 (fifteen) days may be extended upto 30 (thirty) days. In particular, such comments shall specify the conformity or otherwise of such Drawings with the Scope of the

Project Highway and Specifications and Standards.

4.2 The Authority's Engineer shall review any revised Drawings sent to it by the Contractor and furnish its comments within 10 (ten) days of receiving such Drawings.

4.3 The Authority's Engineer shall review the Quality Assurance Plan submitted by the Contractor and shall convey its comments to the Contractor within a period of 21 (twenty-one) days stating the modifications, if any, required thereto.

4.4 The Authority's Engineer shall complete the review of the methodology proposed to be adopted by the Contractor for executing the Works, and convey its comments to the Contractor within a period of 10 (ten) days from the date of receipt of the proposed methodology from the Contractor.

4.5 The Authority's Engineer shall grant written approval to the Contractor, where necessary, for interruption and diversion of the flow of traffic in the existing lane(s) of the Project Highway for purposes of maintenance during the Construction Period in accordance with the provisions of Clause 10.4.

4.6 The Authority's Engineer shall review the monthly progress report furnished by the Contractor and send its comments thereon to the Authority and the Contractor within 7 (seven) days of receipt of such report.

4.7 The Authority's Engineer shall inspect the Construction Works and the Project Highway and shall submit a monthly Inspection Report bringing out the results of inspections and the remedial action taken by the Contractor in respect of Defects or deficiencies. In particular, the Authority's Engineer shall include in its Inspection Report, the compliance of the recommendations made by the Safety Consultant.

4.8 The Authority's Engineer shall conduct the pre-construction review of manufacturer's test reports and standard samples of manufactured Materials, and such other Materials as the Authority's Engineer may require.

4.9 For determining that the Works conform to Specifications and Standards, the Authority's Engineer shall require the Contractor to carry out, or cause to be carried out, tests at such time and frequency and in such manner as specified in the Agreement and in accordance with Good Industry Practice for quality assurance. For purposes of this Paragraph 4.9, the tests specified in the IRC Special Publication-11 (Handbook of Quality Control for Construction of Roads and Runways) and the Specifications for Road and Bridge Works issued by MORTH (the "Quality Control Manuals") or any modification/substitution thereof shall be deemed to be tests conforming to Good Industry Practice for quality assurance.

4.10 The Authority's Engineer shall test check at least 20 (twenty) percent of the quantity or number of tests prescribed for each category or type of test for quality control by the Contractor.

4.11 The timing of tests referred to in Paragraph 4.9, and the criteria for acceptance/ rejection of their results shall be determined by the Authority's Engineer in accordance with the Quality Control Manuals. The tests shall be undertaken on a random sample basis and shall be in addition to, and independent of, the tests that may be carried out by the Contractor for its own quality assurance in accordance with Good Industry Practice.

4.12 In the event that results of any tests conducted under Clause 11.10 establish any Defects or deficiencies in the Works, the Authority's Engineer shall require the Contractor to carry out remedial measures.

4.13 The Authority's Engineer may instruct the Contractor to execute any work which is urgently required for the safety of the Project, whether because of an accident, unforeseeable event or otherwise; provided that in case of any work required on account of a Force Majeure Event, the provisions of Clause 21.6 shall apply.

4.14 In the event that the Contractor fails to achieve any of the Project Milestones, the Authority's Engineer shall undertake a review of the progress of construction and identify potential delays, if any. If the Authority's Engineer shall determine that completion of the Project is not feasible within the time specified in the Agreement, it shall require the Contractor to indicate within 15 (fifteen) days the steps proposed to be taken to expedite progress, and the period within which the Project Completion Date shall be achieved. Upon receipt of a report from the Contractor, the Authority's Engineer shall review the same and send its comments to the Authority and the Contractor forthwith.

4.15 The Authority's Engineer shall obtain from the Contractor a copy of all the Contractor's quality control records and documents before the Completion Certificate is issued pursuant to Clause 12.4.

4.16 Authority's Engineer may recommend to the Authority suspension of the whole or part of the Works if the work threatens the safety of the Users and pedestrians. After the Contractor has carried out remedial measure, the Authority's Engineer shall inspect such remedial measures forthwith and make a report to the Authority recommending whether or not the suspension hereunder may be revoked.

4.17 In the event that the Contractor carries out any remedial measures to secure the safety of suspended works and Users, and requires the Authority's Engineer to inspect such works, the Authority's Engineer shall inspect the suspended works within 3 (three) days of receiving such notice, and make a report to the Authority

forthwith, recommending whether or not such suspension may be revoked by the Authority.

4.18 The Authority's Engineer shall carry out, or cause to be carried out, all the Tests specified in Schedule-K and issue a Completion Certificate or Provisional Certificate, as the case may be. For carrying out its functions under this Paragraph 4.18 and all matters incidental thereto, the Authority's Engineer shall act under and in accordance with the provisions of Article 12 and Schedule-K.

5. Maintenance Period

5.1 The Authority's Engineer shall aid and advise the Contractor in the preparation of its monthly Maintenance Programme and for this purpose carry out a joint monthly inspection with the Contractor.

5.2 The Authority's Engineer shall undertake regular inspections, at least once every month, to evaluate compliance with the Maintenance Requirements and submit a Maintenance Inspection Report to the Authority and the Contractor.

5.3 The Authority's Engineer shall specify the tests, if any, that the Contractor shall carry out, or cause to be carried out, for the purpose of determining that the Project Highway is in conformity with the Maintenance Requirements. It shall monitor and review the results of such tests and the remedial measures, if any, taken by the Contractor in this behalf.

5.4 In respect of any defect or deficiency referred to in Paragraph 3 of Schedule-E, the Authority's Engineer shall, in conformity with Good Industry Practice, specify the permissible limit of deviation or deterioration with reference to the Specifications and Standards and shall also specify the time limit for repair or rectification of any deviation or deterioration beyond the permissible limit.

5.5 The Authority's Engineer shall examine the request of the Contractor for closure of any lane(s) of the Project Highway for undertaking maintenance/repair thereof, and shall grant permission with such modifications, as it may deem necessary, within 5 (five) days of receiving a request from the Contractor. Upon expiry of the permitted period of closure, the Authority's Engineer shall monitor the reopening of such lane(s), and in case of delay, determine the Damages payable by the Contractor to the Authority under Clause 14.5.

6 **Determination of costs and time**

6.1 The Authority's Engineer shall determine the costs, and/or their reasonableness, that are required to be determined by it under the Agreement.

6.2 The Authority's Engineer shall determine the period of Time Extension that is required to be determined by it under the Agreement.

6.3 The Authority's Engineer shall consult each Party in every case of determination in accordance with the provisions of Clause 18.5.

7. Payments

7.1 The Authority's Engineer shall withhold payments for the affected works for which the Contractor fails to revise and resubmit the Drawings to the Authority's Engineer in accordance with the provisions of Clause 10.2.4 (d).

7.2 Authority's Engineer shall -

(a) within 10 (ten) days of receipt of the Stage Payment Statement from the Contractor pursuant to Clause 19.4, determine the amount due to the Contractor and recommend the release of 90 (ninety) percent of the amount so determined as part payment, pending issue of the Interim Payment Certificate; and

(b) within 15 (fifteen) days of the receipt of the Stage Payment Statement referred to in Clause 19.4, deliver to the Authority and the Contractor an Interim Payment Certificate certifying the amount due and payable to the Contractor, after adjustments in accordance with the provisions of Clause 19.10.

7.3 The Authority's Engineer shall, within 15 (fifteen) days of receipt of the Monthly Maintenance Statement from the Contractor pursuant to Clause 19.6, verify the Contractor's monthly statement and certify the amount to be paid to the Contractor in accordance with the provisions of the Agreement.

7.4 The Authority's Engineer shall certify final payment within 30 (thirty) days of the receipt of the final payment statement of Maintenance in accordance with the provisions of Clause 19.16.

8. Other duties and functions

The Authority's Engineer shall perform all other duties and functions as specified in the Agreement.

9 **Miscellaneous**

9.1 A copy of all communications, comments, instructions, Drawings or Documents sent by the Authority's Engineer to the Contractor pursuant to this TOR, and a copy of all the test results with comments of the Authority's Engineer thereon, shall be furnished by the Authority's Engineer to the Authority forthwith.

9.2 The Authority's Engineer shall retain at least one copy each of all Drawings and Documents received by it, including 'as-built' Drawings, and keep them in its safe custody.

9.3 Within 90 (ninety) days of the Project Completion Date, the Authority's Engineer shall obtain a complete set of as-built Drawings, in 2 (two) hard copies and in micro film form or in such other medium as may be acceptable to the Authority, reflecting the Project Highway as actually designed, engineered and constructed, including an as-built survey illustrating the layout of the Project Highwayand setback lines, if any, of the buildings and structures forming part of Project Facilities; and shall hand them over to the Authority against receipt thereof.

9.4 The Authority's Engineer, if called upon by the Authority or the Contractor or both, shall mediate and assist the Parties in arriving at an amicable settlement of any Dispute between the Parties.

9.5 The Authority's Engineer shall inform the Authority and the Contractor of any event of Contractor's Default within one week of its occurrence.

SCHEDULE - O

(See Clauses 19.4.1, 19.6.1, and 19.8.1)

Forms of Payment Statements

1. Stage Payment Statement for Works

The Stage Payment Statement for Works shall state:

(a) the estimated amount for the Works executed in accordance with Clause 19.3.1 subsequent to the last claim;
(b) amounts reflecting adjustments in price for the aforesaid claim;
(c) the estimated amount of each Change of Scope Order executed subsequent to the last claim;
(d) amounts reflecting adjustment in price, if any, for (c) above in accordance with the provisions of Clause 13.2.3 (a);
(e) total of (a), (b), (c) and (d) above;
(f) Deductions:
  (i) Any amount to be deducted in accordance with the provisions of the Agreement except taxes;
  (ii) Any amount towards deduction of taxes; and
  (iii) Total of (i) and (ii) above.
(g) Net claim: (e) – (f) (iii);
(h) The amounts received by the Contractor upto the last claim:
  (i) For the Works executed (excluding Change of Scope orders);
  (ii) For Change of Scope Orders, and
  (iii) Taxes deducted

2. Monthly Maintenance Payment Statement

The monthly Statement for Maintenance Payment shall state:

(a) the monthly payment admissible in accordance with the provisions of the Agreement;
(b) the deductions for maintenance work not done;
(c) net payment for maintenance due, (a) minus (b);
(d) amounts reflecting adjustments in price under Clause 19.12; and
(e) amount towards deduction of taxes

3. Contractor's claim for Damages

Note: The Contractor shall submit its claims in a form acceptable to the Authority.

SCHEDULE - P
(See Clause 20.1)

INSURANCE

1. Insurance during Construction Period

1.1 The Contractor shall effect and maintain at its own cost, from the Appointed Date till the date of issue of the Completion Certificate, the following insurances for any loss or damage occurring on account of Non Political Event of Force Majeure, malicious act, accidental damage, explosion, fire and terrorism:

(a) insurance of Works, Plant and Materials and an additional sum of [15 (fifteen)] per cent of such replacement cost to cover any additional costs of and incidental to the rectification of loss or damage including professional fees and the cost of demolishing and removing any part of the Works and of removing debris of whatsoever nature; and

(b) insurance for the Contractor's equipment and Documents brought onto the Site by the Contractor, for a sum sufficient to provide for their replacement at the Site.

1.2 The insurance under paragraph 1.1 (a) and (b) above shall cover the Authority and the Contractor against all loss or damage from any cause arising under paragraph 1.1 other than risks which are not insurable at commercial terms.

2. Insurance for Contractor's Defects Liability

The Contractor shall effect and maintain insurance cover for the Works from the date of issue of the Completion Certificate until the end of the Defects Liability Period for any loss or damage for which the Contractor is liable and which arises from a cause occurring prior to the issue of the Completion Certificate. The Contractor shall also maintain other insurances for maximum sums as may be required under the Applicable Laws and in accordance with Good Industry Practice.

3. Insurance against injury to persons and damage to property

3.1 The Contractor shall insure against its liability for any loss, damage, death or bodily injury, or damage to any property (except things insured under Paragraphs 1 and 2 of this Schedule or to any person (except persons insured under Clause 20.9), which may arise out of the Contractor's performance of this Agreement. This insurance shall be for a limit per occurrence of not less than the amount stated below with no limit on the number of occurrences.

The insurance cover shall be not less than: Rs. [2,00,00,000.00/-]Subject to the minimum amount as above , it shall be the Contractor's responsibility for any liability beyond this amount.

3.2 The insurance shall be extended to cover liability for all loss and damage to the Authority's property arising out of the Contractor's performance of this Agreement excluding:

(a) the Authority's right to have the construction works executed on, over, under, in or through any land, and to occupy this land for the Works; and

(b) damage which is an unavoidable result of the Contractor's obligations to execute the Works.

4. Insurance to be in joint names

The insurance under paragraphs 1 to 3 above shall be in the joint names of the Contractor and the Authority.

Schedule-Q

(See Clause 14.10)

Tests on Completion of Maintenance Period

1. Riding Quality test:

Riding quality test: Riding quality of each lane of the carriageway shall be checked with the help of a calibrated bump integrator and the maximum permissible roughness for purposes of this Test shall be [2,200 (two thousand and two hundred only)] mm for each kilometre.

2. Visual and physical test:

The Authority's Engineer shall conduct a visual and physical check of construction to determine that all works and equipment forming part thereof conform to the provisions of this Agreement. The physical tests shall include measurement of cracking, rutting, stripping and potholes and shall be as per the requirement of maintenance mentioned in Schedule-E.

Schedule-R

(See Clause 14.10)

Taking Over Certificate

I, ... (Name and designation of the Authority's Representative) under and in accordance with the Agreement dated ..... (the "**Agreement**"), for [construction of the ****section (km ** to km **) of

****] (the "**Project Highway**") on Engineering, Procurement and Construction (EPC) basis through (Name of Contractor), hereby certify that the Tests on completion of Maintenance Period in accordance with Article 14 of the Agreement have been successfully undertaken to determine compliance of the Project Highway with the provisions of the Agreement and I hereby certify that the Authority has taken over the Project highway from the Contractor on this day

SIGNED, SEALED AND DELIVERED

(Signature)

(Name and designation of Authority's Representative)

(Address)