Contract Code. : 7200037432

Brihanmumbai Municipal Corporation

Design and Build Contract

Construction of 45m wide Elevated Road from Link Road at Dahisar (West) in BMC limit to Bhayander (West) in MBMC limit (Coastal Road Last Leg)

Volume 4

Outline Design Specifications

(Section 1 to 5)

Contract Code. : 7200037432

Volume 4

Outline Design Specifications

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Outline Design Specifications

Section 1

ROADS

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

1 GENERAL

This Document sets forth the Specifications and Standards adopted for Road design of the Project Road from Extension of Link Road in Dahisar (West) in BMC Limit to Bhayander in MBMC Limit. This reach consists of grade road, CD works, Road on Stilt and Obligatory Span Bridge with 80/100m. The tenderer shall make himself fully aware of the Project Site with regard to the features of the proposed works, such as location, layout, geometry, right of way, existing accesses, cross drainage work etc. including the constraints at the site such as limitation of right of way, existence of adjoining property, existing structures, utilities etc.

The Project report and any other information provided by the Employer shall be used by the Contractor only for reference purpose and for carrying out further investigations. The Contractor shall be solely responsible for undertaking all the activities, that are necessary for the delivery of the project, such as planning, surveys, investigations, design, construction planning and management, traffic operation, safety to the users/abutting property holders and shall have no claim against the Employer for any loss, damage, risk, costs, liabilities or obligations arising out of or in relation to the project report and other information provided by the Employer.

For Codes and Standards refer to Section 1, Volume 5.

1.1 General consideration of planning, design and construction

The Contractor shall take measures to overcome the physical and operational constraints and plan, design and construct the Project Highway using appropriate methods, management techniques and technologies.

2 DESIGN

2.1 General

This Outline Specification for Road Works shall be read in conjunction of complete Bid Document including NIT, ITT, Employer's Requirements, and General Conditions of Contract (FIDIC), Particular Conditions of Contract, Outline Design and Constructions Specifications, Tender / Employer's Drawings, Addendum etc.

The Design Specifications and parameters are in reference to IRC and MORTH Specifications. If a specification of any item is not available in this tender document, it should be referred from the relevant IRC /MORTH Publications.

2.2 Geometric Design for Main Carriageway

Geometric design of Alignment for as indicated in the Tender / Employer's Drawings are indicative.

The project has the alignment which passes through the CRZ affected areas and also has mangroves and salt pan lands. There is a possibility of change of alignment on recommendations of government departments which the execution agency has to make during construction.

Geometric Design of the Alignment

Table 1: Geometric Design of the Alignment

Si No	Road Geometrics	Details
1	Design speed	80 Km/hr
2	Lane Configuration	4+4 laning
3	Single Lane width	3.5 m
4	Median Width	5.00m / 9.00m
5	Paved Shoulder (Side Strip)	3.00m
6	Median side paved Edge Strip	0.50m
7	Camber	2.50%
8	Max. Super elevation	4%
9	Max Vertical Gradient	3.5%
10	Horizontal Curve- Minimum Radius	230 m
11	Min length Vertical Curve	50 m
12	Stopping Site distance	Max 240 m
		Min 120 m (Based on SSD)
13	Min Vertical Gradient	0.50%

The Geometric design of the project elements including section, horizontal alignment and vertical profile conform to IRC: 86 (latest revision), IRC: SP 90 (latest revision), IRC 38 and IRC SP 23 unless otherwise indicated in this document. The alignment is shown in the Tender / Employer's Drawings. The Contractor shall:

1) Verify and develop a detailed alignment to meet the standard operational and technical criteria referred elsewhere in this Contract.
2) Review the alignment with respect to the design and construction proposals and shall also satisfy him that there is no conflict with any existing structures (both underground and above ground) which are to be preserved.
3) The Contractor is permitted to propose minor deviations in horizontal & vertical alignment to suit his construction proposals, but he must demonstrate that any such deviations do not reduce the technical and operational performance. The Contractor needs to verify the Contract boundaries while proposing any change in vertical and/or horizontal alignment. Such deviations shall require a Notice to Proceed from the Engineer subject to the following conditions:-

    - There is no extra cost to the Employer,

- Changes proposed are absolutely essential to suit the specific design.
- The deviation shall be better than the reference design given in the Employer's Drawings.
- There is no change to the Contract boundaries.
- The Contractor should note that due to existing land constraints and that no further land/additional space for reclamation will be made available by the Employer.

2.3 Intersection

The intersections shall be designed having regard to flow, speed, composition, distribution and future growth of traffic. Design shall be specific to each site with due regard to physical conditions of the site available. The design of different elements of intersection shall be done as per IRC: SP: 41 "Guidelines on Design of At-grade Intersections in Rural and Urban Areas" including other criteria given in this Document. MORTH-Type Designs for Intersection on National Highways may also be referred to, wherever required to develop suitable layout and Design of at grade intersections.

2.4 Drainage System

This stretch of Road is having considerable gradient to the road. The design of road drainage system such as surface drainage for pavement, median, shoulder shall be carried out in accordance with IRC: SP: 42 and IRC: SP: 50.

Surface runoff from the main Highway shall be discharged through longitudinal side drains, which shall be designed for adequate cross section, bed slopes, invert levels, Runoff Storage underground tank of sufficient capacity and stored drain water shall be pumped off with proper manner. Dimensions of the drain shall be wide enough to take the runoff.

3 PAVEMENT DESIGN

3.1 Type of Pavement & Parameters of Pavement Design

Flexible pavements if required should meet the following parameters.

Table 2: **Design Parameters for Flexible Pavement**

Si No.	Description	Details
1	Design Life	20 Years
2	Design Traffic Axle Load	60 MSA
3	Subgrade Strength	CBR value 8%
4	Traffic Growth Rate	5%
5	Lane Distribution Factor	45%

Rigid pavements if required should meet the following parameters.

Table 3: Design Parameters for Rigid Pavement

Si No.	Description	Details
1	Design Life	30 Years
2	Traffic Intensity per day (CVPD)	40,000 vehicle/ day *
3	Annual Traffic Growth Rate	5%
4	Temperature Differential	19.2 ºC
5	Flexural Strength of Concrete	4.5 MPa
6	Subgrade CBR	8%

* As per the estimates of CTS Updation Study of MMRDA.

3.2 Design Life

Design life for concrete pavements shall be 30 years and for Flexible pavement shall be 20 years. For design life of other structures refer to relevant section.

3.3 Flexible Pavement

The flexible pavement shall be designed as per IRC 37 to withstand the design CVPD. The minimum thickness of various layers of the flexible pavement shall be as stated in the Employer's Drawings. If the design thickness based on the traffic study projected for the design life, carried out during detailed design stage is found to be more than the minimum thickness mentioned in Employer's drawings, higher of the two shall be provided.

3.4 Rigid Pavement

The rigid pavement shall be designed as per IRC 58 to withstand the design CVPD. The minimum thickness of various layers of the rigid pavement shall be as stated in the Employer's Drawings. If the design thickness based on the traffic projected for the design life, carried out during detailed design stage is found to be more than the minimum thickness mentioned in Employer's drawings, higher of the two shall be provided

3.5 Durability

Project shall not only be safe but also durable. This would mean that deteriorating effects of climate and environment in addition to the traffic shall be duly considered in design. The pavement structure shall be designed such that deterioration over its design service life does not impair the performance below that intended, having due regard to the service environment and anticipated level of performance. Durability recommendation for a concrete mix with 20 mm size aggregate for 'severe' exposure conditions, maximum water cement ratio shall be 0.45 , minimum cement content shall be 360 kg/cu.m, minimum grade of concrete shall be M-30 and minimum cover shall be 45 mm.

3.6 Safety and Serviceability of Design

In order to achieve safety and serviceability, all designs furnished by the Contractor shall be safe to ensure that the Project or any part thereof (for example embankment, pavement, retaining structures, bridges, culverts etc.) does not collapse (global stability) nor its serviceability/performance (for example settlement, roughness, undulations, deflections etc.) deteriorates below acceptable level as prescribed in MORTH /IRC publications.

3.7 Design Traffic

An initial traffic intensity of 40,000 vehicles per day on the proposed Highway is adopted As per CTS Updation Study of MMRDA. As per IRC: 58-2015 guidelines, 25% of the total traffic in the direction of predominant traffic may be considered for the bottom up cracking fatigue damage analysis where in the case of top down cracking 50% of design traffic of bottom up cracking analysis is considered.

Traffic growth rate shall be established for each category of commercial vehicles to be considered for design of pavement. For traffic projections, the procedure outlined in IRC: 108 may be followed. The Contractor shall adopt a realistic value of the rate of traffic growth, provided that annual rate of growth of commercial vehicles shall not be adopted less than 5 per cent.

3.8 Concrete Strength

The design of concrete slab shall be based on the flexural strength value of 4.5 MPa. It shall be derived from the characteristic compressive strength of concrete.

3.9 Rigid Pavement Design

- The flexural strength of Pavement Quality Concrete (PQC) shall be 4.5 MPa (MORTH 602.3.3) and minimum cement content should be 360 kg/cu.m. The PQC shall rest over Dry Lean Concrete (DLC) sub base of designed thickness.
- The DLC will meet the minimum cement content and compressive strength of 15 MPa in 28 days, and 10 MPa within seven days, and minimum cement content should be 150 kg / cu.m, as prescribed in IRC: SP: 49. The DLC will extend beyond the edge of PQC at a slope of 1:2 on either side.
- Below DLC layer, a properly designed drainage layer Granular Sub Base (GSB) of designed thickness shall be provided throughout the road width. It shall be designed to obtain a drainage coefficient of not less than 300m per day.

Rigid pavement has to be designed for the critical stress condition. Stresses due to combined action traffic load and temperature differential between the top and bottom fibres of the slab is considered for the design of concrete slab. Fatigue damage analysis is to be done for following two stress combinations

- Bottom up cracking – Load + Positive temperature differential
- Top down cracking – Load+ Negative temperature differential

3.10 Details of Joints

One of the major components of concrete pavement is the spacing and layout of joints as it has significant effect on the pavement performance. All the joints also need to be effectively sealed, and maintained well for its better performance.

i) Contraction Joints

Contraction joints are transverse joints which relieve the tensile stresses in concrete pavements. The joint spacing of a concrete pavement depends upon the type of coarse aggregates and the average temperature fluctuation in different seasons. The spacing of contraction joints should be limited to 4.5 m to prevent top-down cracking during the night hours.

ii) Construction Joints

Construction joints should, as far as possible, be placed at the location of contraction joints except in case of emergency when a key joint may be used.

iii) Expansion Joints

Expansion joints are transverse joints to allow expansion of concrete slab due to rise in average temperature in summer months. Expansion joints shall be as per latest IRC 58.

iv) Longitudinal Joints

Longitudinal joints are required in pavements of width greater than 4.5 m to allow for transverse contraction and warping.

3.11 Dowel Bars & Tie Bar

Dowel bars shall be built as an integral part of transverse joints. They are usually mild steel round bars of short length, whose half-length is bonded into concrete on one side of the joint and its other half-length is prevented from bonding with concrete. Detail design of dowel bars is to be done by Contractor as per IRC 58: 2015.

Tie bars shall use across the joints of concrete pavements wherever it is necessary or desirable to ensure firm contact between slab faces or to prevent abutting slabs from separating. Deformed tie bars are proposed at joints. Detail design of Tie bar is to be done by Contractor as per IRC 58: 2015.

4 MATERIALS

4.1 General

Sourcing of all materials as well as compliance with environmental requirements under the applicable laws in respect of all works to be executed under the Bid Document shall be the sole responsibility of the Contractor. All materials, whether natural (such as earth, gravel,

sand, aggregates etc.), processed (such as bituminous and concrete mixes), or manufactured (such as cement, steel, bitumen etc.) shall be incorporated into the work only if they are tested and found to meet the requirements of this Tender Document or, in the absence of any provision in this Tender Document, conform to the best industry practice.

4.2 For Rigid Pavement Work

4.2.1 Cement

- The cement 43 grade and 53 grade conforming to IS 1182 -1989, IS 12269 - 1987, IS 455 and IS 1489 – Part 1 shall be used.
- The Engineer may give Notice for usage of Sulphate Resistance Portland cement conforming to IS 12330, if the soil around concrete pavement has soluble salts like sulphates in excess of 0.5 per cent.
- In all cases cement shall meet 28 days strength requirements of IS 1182 -1989 and 12269-1987

4.2.2 Aggregates

· **Fine Aggregates**

The fine aggregate shall comply with Clause 602.2.6.3 of MORTH Specifications for Road and Bridge Works.

· **Coarse Aggregates**

Coarse aggregates shall comply with Clause 602.2.6.2 of MORTH Specification except that the maximum size of the coarse aggregate shall be 26.5 mm, and aggregate gradation shall comply with Table 600-1 and Table 600-2 of MORTH Specification for Road and Bridge Works.

4.2.3 Dry Lean Cement Concrete

· **Moisture Content:** The optimum water content shall be determined and demonstrated by rolling during trial length construction and the optimum moisture content and degree of compaction shall be got approved from Engineer. While laying in the main work, the lean concrete shall have a moisture content between the optimum and optimum +2 percent, keeping in view the effectiveness of compaction achieved and to compensate for evaporation losses.

· **Cement Content:** The minimum cement content in the lean concrete shall not be less than 150 Kg./cu.m of concrete. If this minimum cement content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary without additional cost compensation to the Contractor.

· **Concrete Strength**: The average compressive strength of each consecutive group of 5 cubes made in accordance with Clause No. 903.5.1.1 of MORTH specification

shall not be less than 10 MPa at 7 days. In addition, the minimum compressive strength of any individual cube shall not be less than 10 MPa at 7 days. The design mix complying with the above Clauses shall be got approved from the Engineer before 30 days of commencement of work and it shall be demonstrated in the trial length for construction of 150 mm thick Dry Lean Concrete.

4.2.4 Cement Concrete Pavement

- **Cement Content**

  Cement as per Clause 4.2.1 above is used, and the quantity of cement shall not be less than 360 kg/cu.m. If this minimum cement content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary by the Contractor at his own cost.

- **Concrete Strength**

  The characteristic flexural strength of Pavement Quality concrete shall not be less than 4.5 MPa unless specified otherwise. Target mean flexural strength for mix design shall be more than 4.5 MPa + 1.65s, where s is standard deviation of flexural strength derived by conducting test on minimum 30 beams. The design mix complying with the above Clauses shall be got Noticed from the Engineer before 30 days of commencement of work and it shall be demonstrated in the trial length for construction for 300 mm thick Pavement Quality Concrete.

- **Steel for Dowels and Tie Bars**

  Steel shall conform to the requirements of IS: 432 and IS: 1786 as relevant. The dowel bars shall round MS Bars conform to IS: 432 of Grade I. Tie bars shall be High yield Strength Deformed bars conforming to IS: 1786 and grade of Fe 500 or plain bars conforming to IS: 432 of Grade I.

4.3 Flexible Pavement Work

The flexible pavement is proposed for Hard Shoulder for at-grade section and Ramp with RE Wall only and wherever required and as directed by the Engineer.

4.3.1 Materials

Sub grade:

A sub grade CBR value of 8 % has been considered for the design of pavement. Sub grade is to be compacted in layers of loose thickness of 200 mm to a minimum of 98 % of maximum dry density of modified proctor compaction tests.

Sub Base:

Sub base 200mm thick granular sub base (GSB) has been recommended for the

pavement. The GSB layer which also acts as drainage layer shall be continued over the full formation width. The sub base material should have a minimum CBR of 30% at the highest anticipated moisture content when compacted to a minimum of 98 % of maximum dry density in the modified proctor Compaction Tests. Particle size and plasticity requirements of sub base materials should be as specified in the technical specification.

Base:

250mm thick Wet Mix Macadam (WMM) has been proposed as base for carriageway. The minimum CBR value of granular base material should be 100% and the Plasticity Index less than 5 %. The gradation and compaction criteria of base materials should be as per the technical specification.

Surfacing Course;

For new carriageway Dense Bituminous Macadam (DBM) has been proposed as Binder Course for the pavement. 50 mm DBM has been proposed for this Project. The grading and the bitumen content of DBM shall be as per the relevant clause of the Technical Specifications. Binder course will be provided over the profile corrective course for existing carriageway.

30 mm thick Bituminous Concrete (BC) has been proposed for as wearing course. The grading and bitumen content of BC shall be as per the relevant clause of MORTH Specifications.

Micro surfacing

This work shall consist of constructing Type-2 Microsurfacing (4-6mm thickness) and Type-3 Microsurfacing (6-8mm) for road pavements and bridge deck.

5 PAVER BLOCKS

The inter locking concrete paver tiles shall conform to IRC SP-63. They shall be tested as per the code.

The compressive strength requirement of concrete paver block shall be minimum 47.2 MPa (N/sq.mm) for 28 days (Testing as per IS-15658) after applying the correction factor as per IS-15658:2006. The concrete grade of paver tiles shall not be less than M40. Design mix concrete shall be adopted. Size, shape colour, laying pattern etc. shall be noticed by the Engineer. For acceptance, the average of compressive strengths of 8 pavers shall be minimum 47.2 MPa. Any paver in the tested lot shall not have compressive strength less than 40.1 MPa.

6 STENCIL CONCRETE

For all roads having drain in footpath R.C.C. slab of thickness 150 mm will be raised upto

footpath top to full width of footpath in M-20 concrete in such a way that height of footpath above finished road level is not more than 150mm except at plot entry/ Property gate. For footpath not having storm water drain beneath it / dummy footpath, M-20 concrete of thickness 125 mm will be provided except at plot entry/ Property gate. The transverse joints shall be provided along the width at every chamber by making necessary cutting for same. The plot entry/ Property gate M-40 grade concrete to be used. Stencil pattern & colour as approved by executive engineer will be provided in freshly laid above said concrete footpath. Extra over for Stencil pattern & colour, newly created item in USOR shall be operated.

7 C.C WITH TOP IN MARBLE CHIPS FINISHING

For all roads having drain in footpath drain R.C.C. slab of thickness 150 mm will be raised up to footpath top to full width of footpath in M-20 concrete in such a way that height of footpath above finished road level is not more than 150mm except at plot entry/ Property gate. For footpath not having storm water drain beneath it / dummy footpath, M-20 concrete of thickness 125 mm will be provided except at plot entry/ Property gate where no chips will be laid. The transverse joints shall be provided along the width at every chamber by making necessary cutting for same. The plot entry/ Property gate M-40 grade concrete to be used. Marble Chips of size & pattern as per the item will be provided in freshly laid above said concrete footpath. Extra over for the same, newly created item in USOR shall be operated.

8 PLAIN C.C WITH BROOMING TEXTURE

For all roads having drain in footpath drain R.C.C. slab of thickness 150 mm will be raised upto footpath top to full width of footpath in M-20 concrete in such a way that height of footpath above finished road level is not more than 150mm except at plot entry/ Property gate. For footpath not having storm water drain beneath it / dummy footpath, M-20 concrete of thickness 125 mm will be provided except at plot entry/ Property gate. The transverse joints shall be provided along the width at every chamber by making necessary cutting for same. The plot entry/ Property gate M-40 grade concrete to be used. Brooming texture shall be provided on finished top concrete surface.

9 SIGNAGE, ROAD MARKINGS AND SAFETY APPURTENANCES

The signage, road marking and safety appurtenances details are provided in the Employer's Drawings are indicative. The road sign, marking drawings, etc. provided therein are for reference purpose and the Contractor shall design the sign and markings as per IRC 67, 35 and other relevant IRC and get the same Noticed by the Engineer.

Volume 4

Outline Design Specifications

Section 2

BRIDGES

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

1 GENERAL

The purpose of this document is to highlight the general requirements, guidelines and design philosophy and design parameters for the design of bridges of the Project. The structural design shall be based on relevant IRC codes. International standards shall be followed in case the relevant specification is not found in Indian codes. Bridges and structures along the Project shall be designed for service life of 100 years or more.

2 DESIGN CODES AND STANDARDS

Except where specifically permitted otherwise by the Engineer in writing, the Contractor's design of the Bridge structure shall be in strict accordance with the following design standards and/or specifications applicable.

Code No.	Title
IRC:5-2015	Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design
IRC: 6-2017	Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Stresses
IRC: 112-2020	Code of Practice for Concrete Road Bridges
IRC: 22-2015	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction
IRC: 45-1972(reprint 1996)	Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges
IRC: 78-2014	Standard Specifications and Code of Practice for Road Bridges, Section VII- Foundations and Substructures
IRC:27-2009	Specifications for Bituminous Macadam
IRC:83-2015 (Part-I)	Standard Specifications and Code of Practice for Road Bridges, Section IX Bearings, Part I : Roller & Rocker Bearings (Second Revision)
IRC:83-2018 (Part II)	Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings (Elastomeric Bearings), Part II (Second Revision)
IRC:83-2018 (Part III)	Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings, Part III: POT, POT-CUM-PTFE, PIN and Metallic Guide and plane sliding Bearings (First Revision)
IRC: SP:60-2002	An Approach Document for Assessment of Remaining Life of Concrete Bridges
IRC:SP:61-2004	An Approach Document on Whole Life Costing for Bridges in India

Code No.	Title
IRC: SP: 84 - 2014	Manual for Specifications & Standards for Four Laning of Highways Through Public Private Partnership (First Revision)
IRC SP -13-2014	Guidelines for the design of small bridges & culverts (First Revision)
IRC-24-2010	Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method)Third Revision)
IRC:22-2015	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design) (Third Revision)
	Durability Provisions for Reinforced & Pre stressed Concrete Structures" by Indian Institution of Bridge Engineers- 1994.
IS 6403	Code of practice for determination of bearing capacity of shallow foundations
IS 2911 (Part 1/Sec 2): 2010:	Design and construction of Pile Foundations - Code of practice
IS 456	Code of practice for design of Reinforced Concrete Structures
IS 800:2007	Code of practice for design of Steel Structures
IS 14268 : 1995	Uncoated stress relieved low Relaxation seven-Ply strand for Pre-stressed concrete- Specification
IS 14593: 1998	Design and construction of Bored Cast-In-Situ Piles founded on Rocks– Guidelines
IS 1786 – 1985 –Third Revision	Specification for High strength deformed steel bars and wires for concrete reinforcement.
IS 2062 – 2011	Hot rolled medium and high tensile structural steel-specifications
EN 10338 – 2009	Hot rolled and cold rolled non-coated products of multiphase steels for cold forming. Technical delivery conditions
	MORTH Specifications
IRC: 30 - 1968	Standard Letter and Numbers of Different Heights for use on Highway Signs
IRC: 35 - 2015	Code of Practice for Road Marking (with Paints)
IRC: 67 - 2012	Code of Practice for Road Signs
IRC: 79 - 1981	Recommended Practice for Road Delineators
IRC: 93 - 1985	Guidelines on Design and Installation of Road Traffic Signals
IRC:SP:31-1997	New Traffic Signs

IRC: 73 - 1980	Geometric Design Standards for Rural (Non-Urban) Highways
IRC SP: 41- 1994	Guidelines for the Design of At-Grade Intersection in Rural and Urban Areas

Note:

IRC Codes and Guidelines maybe subject to review. Hence the latest revision shall be adopted for the design. Where design standards are not specifically mentioned, the priority order of Design Standards and Codes for Pre-stressed Concrete Bridge is,

1).Indian Road Congress (IRC), IS Codes

2).British Standards (BS) or AASHTO LRFD

3).Internationally-recognized standards

If there is no standards for specific design items for the Project in the codes listed above, equivalent international standards shall be applied after obtaining Notice to Proceed from the Engineer.

3 DESCRIPTION ABOUT STRUCTURE

3.1 General

Bridges and all associated structures along the Project shall be designed for service life of 100 years or more. It is recommended to use precast construction technology for various elements of bridges and flyovers at interchanges of Project. Majority of the superstructures in the reference design of the project is of precast pre-stressed multi-cell box girder type. Furthermore, it is recommended that the Designer should develop schemes that seek to minimize whole life cycle cost, namely construction plus maintenance cost rather than just initial construction cost. Cross drainage structures along the alignment and across the alignment are also proposed at suitable locations. The main bridge comprises of 4 lane carriageway in each direction. Other allied and miscellaneous structures such as retaining wall, toe wall, friction slab, crash barrier, approach slab, railings etc. shall conform to relevant IRC codal requirements and MORTH specifications. Interchange structures are of 2 traffic lanes having overall superstructure width as per Employer Drawings. When proposing any changes to the horizontal / vertical alignment, the Contractor must comply with the geometric design conditions, any site constraints in span arrangement as well as the clearance requirements mentioned in the Employer's Requirements - Functional.

3.2 General Arrangement Drawings

General arrangement drawings in Employer's Drawings is indicative, and has been developed considering the Development Plan / Regional Plan / Site conditions, etc. for estimation purposes, though efforts have been taken to optimise the alignment. However the various statutory authorities like environment department / govt. agencies may require

the alignment to be modified, then the agency shall be bound to modify the same and change the GAD / sizing / construction methodology / material for construction, etc. The tenderer may modify the arrangement to suite his own construction methodology, subjected to the site feasibility and other statutory constraints. Any such modifications may require change in the cost of the project which may be submitted to BMC for approval with proper estimates and justification. The BMC may accept such proposal after taking due approval from competent authority.

4 ANALYSIS, DESIGN AND DRAWING SOFTWARE

The computational and structural analysis software for the design of the Road shall be Noticed by the Engineer prior to commencement of the design works.

All of the Contractor's drawing for submission to the Engineer shall be prepared using the Autodesk of the version Noticed by the Engineer, unless otherwise permitted in writing by the Engineer.

5 DESIGN CRITERIA AND LOADS

5.1 Design Service Life

The bridge structures of the Project shall be designed for the service life of one hundred (100) years on the conditions that regular inspection and maintenance is properly conducted during the operation period. Certain elements may require replacement during the design service life. The minimum Target design services life of the main bridge components are given in the following table:

Table 4: Design Service Life Required as Target

Bridge Component	Design Service Life (years)
Foundations	100
Piers	100
Deck	100
Bearings	40 (20 years for minor components only)
Expansion Joints	20 (10 years for minor components only)
Parapets (metal parts only)	40
Parapets (concrete parts only)	100
Drainage system	20

Before expiry of the Defects Liability Period, a joint visit to the Works by the Contractor and the Engineer/General Consultant shall be organized and conducted by the Contractor. In case

any of the elements, including but not limited to the bearings, expansion joints, parapets and drainage system, are found defective and need repair or replacement, the repair or replacement as agreed with the Engineer shall be done by the Contractor at no additional cost to the Employer.

6 BRIDGE LOADING

6.1 Dead Loads

The unit weights of the construction materials shall be as defined in IRC: 6-2014, unless otherwise confirmed using weights of representative samples.

Material	Density
Plain Cement Concrete	25 kN/cu.m
Reinforced Cement Concrete (RCC)	25 kN/cu.m
Pre-stressed concrete	25 kN/cu.m
Structural steel	78 kN/cu.m
Earth compacted	20 kN/cu.m
Asphaltic concrete in wearing coat	22 kN/cu.m

6.2 Super Imposed Dead Load

Wearing course shall consist of 50mm thick DBM, and 40 mm thick CRMB 60 with Microsurfacing over water proofing membrane. Superimposed Dead Load (SIDL) due to Crash barrier, kerbs; services etc. shall be taken based upon density of materials and cross sections as specified in IRC codes.

Adequacy of all SIDL's shall be re-confirmed in the detailed design against actual loads involved in the Works.

6.3 Live Load

Live Loads shall be calculated based upon Cl. No 204 of IRC6-2014 with appropriate impact factors. All associated loads like braking, centrifugal forces etc. to be calculated as stipulated in IRC 6-2014. Footpath live load as stipulated shall be considered. Where structures are provided with footpath on one side, they will be designed for live load considering appropriate vehicular lanes loading and without any footpath. For 4 lane carriageway, the following load configuration shall be adopted.

- Four lanes of IRC Class A.
- One lane of IRC Class 70R (wheeled) with two lane of IRC Class A
- Two lane of IRC Class 70R (wheeled)
- Minimum clear distance between 70R vehicle and Class A vehicle, when placed side by side in combination, shall be 1.2 m for design.
- Resultant live load stresses shall be reduced by 20% in case all the lanes are loaded i.e. in case of four lanes of IRC Class 'A', one lane of IRC Class 70R (wheeled) with two lane of IRC Class A or two lane IRC Class 70R (wheeled).

- Impact factor shall be as per Cl. 211 of IRC: 6 2014 for the relevant load combinations.

6.4 Water Current Forces

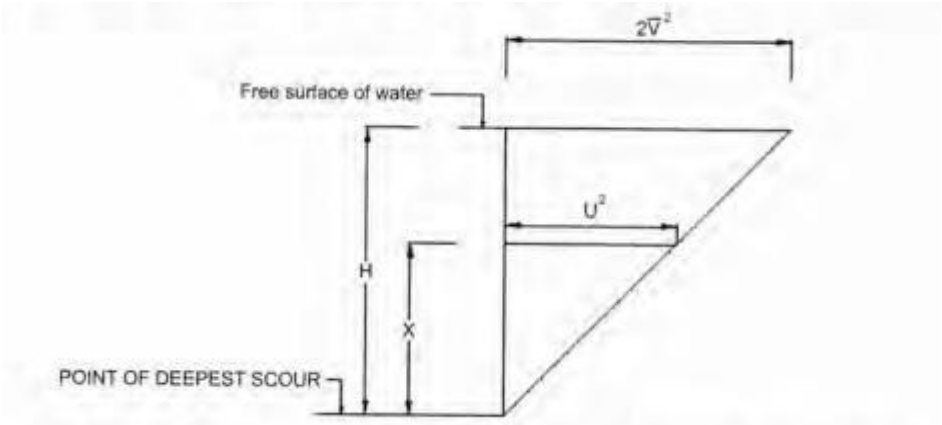
The portion of bridge which may be submerged in running water shall be designed to sustain the horizontal pressure due to force of water current as per the stipulations of IRC: 6-2014.

Intensity of pressure, $P = 52kV^2$

K is the coefficient depending upon shape of obstruction. For circular & semi-circular pier the value is 0.66

V is the current velocity. (For current velocity refer Cl. 213.3, IRC 6: 2000)

This shall be calculated from Figure below with respect to maximum mean velocity of current. The Contractor shall measure the actual current speed for consideration in the designs and verified as per Cl. 213.3 of IRC 6: 2014. For return period velocity, it is to be considered 1 in 100 years based on the data available.



Square of velocity at a height 'X' from the point of deepest Scour, $U^2 = \frac{2V^2X}{H}$

All piers or sub-structures for elevated viaduct and bridges which are immersed in to sea are to be designed for scour velocity.

The data to analysis maximum discharge that occurs at flood or ebb tide, variation of tides etc. shall be collected from NIO or relevant authority by the Contractor. The state of the art software shall be used to analyse scour

6.5 Earth Load

The engineering properties of backfill materials shall be as per MORTH specifications. Dry and saturated condition of the soil will be considered for design.

a) All earth retaining structures (Bridges & box culverts, Abutments, Return walls, Wing Walls) shall be designed for earth pressure as per Cl. No 214 of IRC 6-2014.

b) Box structures for culverts, minor bridges shall be checked for earth pressure at rest due to its rigidity. Abutments, Return walls, Wing walls etc. shall be designed for

active earth pressure. Passive resistance of soil below permanent ground level / protected bed level / scour level may be considered, if desired.

c) Earth pressure due to surcharge on account of live load and dead loads shall be considered as per Cl. No. 214 of IRC 6-2014.

d) Increase in the earth pressure due to earthquake effect, i.e., dynamic effect will be calculated as per IRC 6 – 2014. Provisions While calculating the earth pressure, both saturated backfill condition and submerged condition (for structures not provided with drainage arrangements) of earth shall be considered and water pressure from outside shall also be considered at submerged condition.

Parameters	Values
Type of soil assumed for backfilling	Dry density of 2.00 t/cu.m submerged density of 1.0 t/cu.m.
Angle of Internal Friction	**f** = 30 degree
Angle of Wall Friction	d = 20 degree
Coefficient of Friction 'P' at base	tan (2/3 **f**), while **f** is the angle of internal friction of substrata immediately under the foundations.
Coefficient of Friction 'P' at base	tan (2/3 **f**), while **f** is the angle of internal friction of substrata immediatel under the foundations.

Abutments and return walls shall be designed for 1.2m LL surcharge.

6.6 Centrifugal Forces

Centrifugal forces shall be calculated as per the provisions of IRC: 6-2014 for road bridges for a design speed applicable at horizontal curves.

6.7 Wind Loads

Wind forces are to be considered as per as per Cl. No 209 of IRC 6-2014. Basic wind speed that will be considered in the design is 44 m/sec. The intensity of wind force shall be based upon hourly mean wind speed and pressures. The hourly mean wind speed and pressure values given in Table 5 of IRC 6 – 2014 correspond to basic wind speed of 33 m/sec. These will be calculated for the basic wind speed of 44 m/sec and other terrain conditions.

6.8 Temperature Loads

The temperature loads shall be considered as per Cl. 215 of IRC 6-2014. Critical temperature and differential temperature effects shall be determined and applied. For the purpose of calculating temperature effects, the coefficient of thermal expansion for RCC, PSC and steel structures may be taken as 12.0x 10 -6 /°C A temperature variation of +5°C to +42.5°C will be considered for all structures. The Superstructure shall also be designed for effects of distribution of temperature across the deck depth as given in Fig. 10 of IRC6-2000,

suitably modified for the surfacing thickness.

Temperature effects shall be considered as follows:

- Effects of non-linear profile of temperature shall be combined with 50% live load and full value of 'E' shall be considered.
- Effects of global fall and rise of temperature shall be combined with 100% live load and full value of 'E' shall be considered.

6.9 Seismic Actions

The seismic force on structure shall be calculated as per Cl. No 219 of IRC 6 - 2014. This project is located in zone III. Thus zone factor (z) to be considered is 0.16. The importance factor shall be 1.5 as per Table 8 of IRC: 6-2014. Appropriate Response reduction factors for various elements of bridge structure shall be taken as per Table 9 of IRC 6-2014. Soil structure interaction shall be considered wherever applicable. The seismic forces calculated in longitudinal and transverse direction will be combined as per Cl. No 219.4 of IRC 6-2014. For slope stability of high embankment and earth retaining structure, dynamic increment shall be calculated as per the guidelines in IS 1893-1984. However, the value of horizontal earthquake coefficient (ah) shall be considered as per IRC 112. Ductile detailing shall be carried out as per section 17 of IRC 112-2011.

6.10 Longitudinal forces due to Live Load

Following effects shall be considered in the design.

- Braking forces as per the provision of IRC: 6 2014.
- Distribution of longitudinal forces due to horizontal deformation of bearings/frictional resistance offered to the movement of free bearings as per IRC: 6.

6.11 Barge Impact

Piers on either side of navigation channels shall be designed for Barge impact as per the Clause 220 (IRC: 6 - 2014). Also refer to BS6349-1-1:2012: Code of practice for planning, design, construction and maintenance of structures set in the maritime environment – Planning and operational considerations. Reference may also be made to PIANC, CIRIA or US Standards associated with vessel Collision.

Vessel Impact Protection Systems shall be provided for the piers adjacent to the navigation channels. Other piers may either be provided with the Vessel Impact Protection Systems or be designed to resist the impact force.

Approval of the Vessel Impact Protection System and the design ship impact forces adopted must be obtained from the Engineer.

Collision energy, KE (N-m) $= 500 \times CH \times W \times V^2$

W = Barge displacement tonnage (T) V = Barge impact speed

CH= Hydraulic coefficient shall be considered 1.05 to 1.25 depending upon the under keel clearance.

6.12 Construction Loads

Construction loads shall be considered according to the method to be used for construction/erection.

In addition, for deck structures subject to mobile construction plant and/or equipment essential for the assumed method of construction, the structures shall also be designed for the assumed temporary loads of the construction plant and/or equipment at each construction stage. However, a uniformly distributed load of 3.6 kN/m2 of the form area shall be considered to account for construction stage loadings in the design of superstructure elements, wherever applicable, as per IRC: 87-2011.

A minimum dynamic amplification of 50% of the loads during normal lifting operations shall be assumed, unless a lower factor can be justified to the approval of the Engineer considering the specific construction method and the actual construction plant and/or equipment which will be used.

Where precast or pre-fabricated segments are installed, the consequences to the stability of the structure due to sudden loss of a segment (failure of the lifting equipment) shall be determined. The consequences shall not be disproportionate to the event. A minimum dynamic amplification of 100% of the loads due to the sudden loss of a deck segment (as a construction condition) shall be assumed.

6.13 Buoyancy

100% buoyancy shall be considered while checking stability of foundation irrespective of their resting on soil/weathered rock/or hard rock. However, the maximum base pressures shall also be checked under an additional condition with 50% buoyancy in cases where foundations are embedded into hard rock. Pore pressure uplift limited to 15% shall be considered while checking stresses of the substructure elements.

6.14 Creep & Shrinkage Effects

Effect of creep and shrinkage on structures shall be considered as per IRC 112-2011 provisions.

6.15 Hydrodynamic force:

Hydrodynamic forces are considered as per Cl. No 219.5.4 of IRC 6-2014. Also can be referred to DMRB standards such as BA 59/94 and BD 100/16.

7 LOAD COMBINATION

All members shall be designed to sustain safely the most critical combinations of various loads and forces that can coexist. Various load combinations as relevant with increase in permissible stresses considered in the design shall be as per IRC: 6 and IRC: 78. In

addition, the stability of bridge supporting two superstructures (with an expansion joint) shall be checked under one span dislodged condition also.

Load combinations as per Annex B , IRC 6-2014 shall be considered which are as follows.

IRC:6-2010

Table 3.1 Partial Safety Factor for Verification of Equilibrium

Loads	Basic Combination		Accidental Combination		Seismic Combination	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect
Permanent Loads: Dead Load, Snow load if present, SIDL except surfacing, Backfill weight, settlement, creep and shrinkage effect	1.05	0.95	1.0	1.0	1.0	1.0
Surfacing	1.35	1.0	1.0	1.0	1.0	1.0
Prestress and Secondary effect of prestress (Refer Note 5)						
Earth pressure due to Back Fill	1.50	-	1.0	-	1.0	-
Variable Loads : Carriageway Live Load, associated loads (braking, tractive and centrifugal forces) and Pedestrian Live Load						
(a) As Leading Load	1.5	0	0.75	0	-	-
(b) As accompanying Load	1.15	0	0.2	0	0.2	0
(c) Construction Live Load	1.35	0	1.0	0	1.0	0
Thermal Loads						
(a) As Leading Load	1.50	0	-	-	-	-
(b) As accompanying Load	0.9	0	0.5	0	0.5	0
Wind						
(a) As Leading Load	1.5	0	-	-	-	-
(b) As accompanying Load	0.9	0	-	-	-	-
Live Load Surcharge effects (as accompanying load)	1.20	0	-	-	-	-
Accidental effects: i) Vehicle collision (or) ii) Barge Impact (or) iii) Impact due to floating bodies	-	-	1.0	-	-	-
Seismic Effect						
(a) During Service	-	-	-	-	1.0	-
(b) During Construction	-	-	-	-	0.5	-
Construction Condition:						
Counter Weights:						
a) When density or self weight is well defined	-	0.9	-	1.0	-	1.0
b) When density or self weight is not well defined	-	0.8	-	1.0	-	1.0
c) Erection effects	1.05	0.95	-	-	-	-
Wind						
(a) Leading Load	1.50	0	-	-	-	-
(b) Accompanying Load	1.20	0	-	-	-	-
Hydraulic Loads: (Accompanying Load):	1.0					
Water current forces		0	1.0	-	1.0	-
Wave Pressure	1.0	0	1.0	-	1.0	-
Hydrodynamic effect	-	-	-	-	1.0	-
Buoyancy	1.0	-	1.0	-	1.0	-

Table 3.2 Partial Safety Factor for Verification of Structural Strength

Loads	Ultimate Limit State		
	Basic Combination	Accidental Combination	Seismic Combination
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load, Snow load if present, SIDL except surfacing			
a) Adding to the effect of variable loads	1.35	1.0	1.0
b) Relieving the effect of variable loads	1.0	1.0	1.0
Surfacing:			
Adding to the effect of variable loads	1.75	1.0	1.0
Relieving the effect of variable loads	1.0	1.0	1.0
Prestress and Secondary effect of prestress (refer note no. 2)			
Back fill Weight	1.50	1.0	1.0
Earth pressure due to Back Fill			
a) Leading Load	1.50	-	1.0
b) Accompanying Load	1.0	1.0	1.0
Variable Loads: Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and ***Pedestrian Live Load:***			
a) Leading Load	1.5	0.75	0
b) Accompanying Load	1.15	0.2	0.2
c) Construction Live Load	1.35	1.0	1.0
Wind during service and construction			
a) Leading Load	1.50	-	-
b) Accompanying Load	0.9	-	-
Live Load Surcharge (as accompanying load)	1.2	0.2	0.2
Erection effects	1.0	1.0	1.0
Accidental Effects: i) Vehicle Collision (or) ii) Barge Impact (or) iii) Impact due to floating bodies	-	1.0	-
Seismic Effect			
a) During Service	-	-	1.0
b) During Construction	-	-	0.5
Hydraulic Loads (Accompanying Load):			
Water Current Forces	1.0	1.0	1.0
Wave Pressure	1.0	1.0	1.0
Hydrodynamic effect	-	-	1.0
Buoyancy	0.15	0.15	0.15

Table 3.3 Partial Safety Factor for Verification of Serviceability Limit State

Loads	Rare Combination	Frequent Combination	Quasi-permanent Combination
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load, Snow load if present, SIDL including surfacing	1.0	1.0	1.0
Back fill Weight	1.0	1.0	1.0
Prestress and Secondary effect of prestress (refer note no. 4)			
Shrinkage and Creep Effects	1.0	1.0	1.0
Earth Pressure due to Back Fill	1.0	1.0	1.0
Settlement Effects			
a) Adding to the permanent loads	1.0	1.0	1.0
b) Opposing the permanent loads	0	0	0
Variable Loads:			
Carriageway Live Load and associated loads(braking, tractive and centrifugal forces) and Pedestrian Live Load			
a) Leading Load	1.0	0.75	-
b) Accompanying Load	0.75	0.2	0
Thermal Loads			
a) Leading Load	1.0	0.6	-
b) Accompanying Load	0.6	0.5	0.5
Wind			
a) Leading Load	1.0	0.60	-
b) Accompanying Load	0.60	0.50	0
Live Load Surcharge (Accompanying Load)	0.80	0	0
Hydraulic Loads (Accompanying Load):			
Water Current Forces	1.0	1.0	-
Wave Pressure	1.0	1.0	-
Buoyancy	0.15	0.15	0.15

Table 3.4 Combination for Base Pressure and Design of Foundation

Loads	Combination (1)	Combination (2)	Seismic / Accidental Combination
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load, Snow load if present, SIDL except surfacing, Back Fill earth filling	1.35	1.0	1.0
SIDL Surfacing	1.75	1.0	1.0
Prestress Effect (refer note 4)			
Settlement Effect	1.0 or 0	1.0 or 0	1.0 or 0
Earth Pressure due to back fill			
a) Leading Load	1.50	1.30	-
b) Accompanying Load	1.0	0.85	1.0
Variable Loads:			
All carriageway loads and associated loads (braking, tractive and centrifugal) and pedestrian load			
a) Leading Load	1.5	1.3	(0.75 if applicable) or 0
b) Accompanying Load	1.15	1.0	0.2
Thermal Loads as accompanying load	0.90	0.80	0.5
Wind			
a) Leading Load	1.5	1.3	-
b) Accompanying Load	0.9	0.80	0
Live Load Surcharge as Accompanying Load (if applicable)	1.2	1.0	0.2
Accidental Effect or Seismic Effect	-	-	1.0
Seismic effect during construction	-	-	0.5
Erection effects	1.0	1.0	1.0
Hydraulic Loads:			
Water Current	1.0 or 0	1.0 or 0	1.0 or 0
Wave Pressure	1.0 or 0	1.0 or 0	1.0 or 0
Hydrodynamic effect	-	-	1.0 or 0
Buoyancy:			
For Base Pressure	1.0	1.0	1.0
For Structural Design	0.15	0.15	0.15

8 GENERAL REQUIREMENTS OF BRIDGE STRUCTURE DESIGN

8.1 Restriction on Bridge Type/Structure

Span arrangement for Main Carriageway, bridges of PSC box girder type shall be adopted. For the ramps of the interchanges, PSC box girder / I girder / any new type for superstructure which may be proven over time and is demonstrated to be safe in design shall be adopted and shall be demonstrated in technical proposal.

Reinforced concrete superstructures spanning in the direction of main span of viaducts and bridges should not be adopted, except at locations where the viaduct span is 15.0m or less.

Any proposed use of new solutions and technologies which are proven and demonstrated to be acceptable for a large number of projects may be allowed subjected to the approval from IIT Bombay (third party vetting agency) and notice to Proceed by the Engineer and liable to rejection by the Engineer at his sole discretion.

Also refer to CIRIA C674 - The use of concrete in maritime engineering – A guide to good practice, and BS6349-1-1:2012: Code of practice for planning, design, construction & maintenance of structures set in the maritime environment – Planning and operational considerations.

8.2 Aesthetic Requirements for Bridges/Viaducts

Aesthetic Strategy Report

Overall aesthetics and architectural detailing of the structural and non-structural members shall be given proper attention. The Tenderer shall develop an Aesthetic Strategy Report for the Road presenting a comprehensive aesthetic strategy and theme, together with supporting design guidelines. The theme concept shall include architectural elements such as railings, fences, building facades, tollbooths, lighting standards, finishes, aesthetic lighting and other significant visual elements. An architect experienced with similar major public development shall develop the Aesthetic Strategy Report with the bird's-eye animation showing the aesthetic appearance for the Road. Appointment of the architect/aesthetic designer shall be subject to prior Notice by the Engineer.

The Contractor shall coordinate and interface with the contractors of other agencies as needed to unify the aesthetic strategy for the whole Road.

Final Design Consistency with Aesthetic Strategy Report

The Aesthetic Strategy Report shall be subject to the approval of the Engineer after coordination with the Contractors in other agencies. The final design of the Works shall be consistent in all material respects with the approved Aesthetic Strategy Report.

Aesthetic Design Requirements

In general, the aesthetic design of the viaduct and bridge structures for the Road should comply with the following requirements.

- Lighter and visually pleasant structural profile shall be proposed. All proposed structures shall ensure a simple and elegant structural form.
- The span length of the bridges/viaducts shall be designed with regular rhythm and odd span length shall be minimized given that all site constraints and requirements need to be satisfied.
- The visual experience from the main carriageway by users and outside of the Project shall be considered in the aesthetic design of the viaduct structure.

9 REQUIREMENTS FOR CONCRETE SUPERSTRUCTURE, SUBSTRUCTURE AND FOUNDATION

9.1 Substructures and Foundations

The following requirements shall apply to the design and construction of the piers and foundations:

i. At the time of Tender, for the purpose of preparing the preliminary/bidding design, the Contractor has to set an estimated line of bearing stratum based on the geological/subsoil investigation report issued by the Employer in Volume 7, reference document.

   After award of the Contract, the Contractor shall determine the final bearing stratum elevations at the proposed locations of the piers, abutments etc. based on additional geological/subsoil investigation to be performed by the Contractor at his own cost. The Contractor is expected to carry out sufficient geotechnical investigations as per IRC requirements to design the foundations during the Detailed Design stage. The Contractor shall carry out geotechnical/subsoil investigations involving boreholes at least at every proposed pier and abutment location, to assess the nature and characteristic of founding strata to finalize the pile/base design. Additional boreholes shall also be taken, at no additional cost to the Employer, as may be directed by the Engineer, as needed to confirm the strata as per requirement emerging during the design stage or execution of the Works.

ii. Pile End Bearing Capacity and Rock Socket Friction Capacity

   The pile end bearing capacity and rock socket friction capacity in the founding strata shall be finally verified based on Dynamic loading test (2% of the total number of piles) as specified in the relevant clauses in IRC 78 & IS 2911. The pile end bearing capacity and rock socket friction capacity analysis shall be submitted to and Noticed by the Engineer before commencing the permanent piling work.

iii. The concrete piles shall be verified for the integrity by Sonic echo test. Sonic tubes shall be installed in all of piles, and the test shall be carried out randomly at one pile per one pier according to the Engineer's decision.

iv. Where concrete is to be placed under the slurry or water, such as piles and barrettes, the design compressive strength and shear strength of structural concrete shall be reduced. The characteristic strength of the compression and shear stress shall be taken to be 80% of the characteristic strength of the concrete grade.

v. Foundation types shall generally be end bearing pile foundation on hard rock. Skin friction within the socket in hard rock may be considered depending on the site conditions and geology, subject to the Engineer's Notice. Skin friction along weathered rock shall not be allowed in the design. Spread foundation shall be permitted on the land area if founding stratum is at a shallow depth. Other types of

foundation can be proposed to the Engineer by the Contractor for his approval, but no raker pile will be accepted.

vi. The construction method for installation of piles within the inter-tidal zone shall not cause significant disturbance to the mud-flats.

vii. Piles shall be provided with permanent steel liners which thickness shown as follows;

- Up to and including 1.5m dia : 6mm
- Greater than 1.5m dia and up to and including 2.0m dia : 12mm
- Greater than 2.0m dia : 16mm

The liner plate shall be embedded in concrete to at least 50mm from the bottom of the pile cap. The structural design of the piles shall not rely on any structural capacity contribution from the permanent steel liners in its structural analysis of the piles

viii. Plan shape of single piers shall be rectangular with round edges. Piers shall keep uniformity in shape throughout the Project, except for unavoidable cases such as changes to the width of road or pier interval for reasons of reducing the adverse effect on landscape or aesthetics.

ix. Bridge piers/foundations flanking the navigation channels shall be designed to resist potential barge impact forces or alternatively shall be protected by dolphins structurally independent from the bridge piers/foundations.

x. Rock/soil anchors of prestressed or non-prestressed type should not be applied for resisting tension and/or anchoring foundations to rock/soil for piers and abutments.

The following requirements shall apply to the design and construction of concrete superstructure:

i. Superstructure for the pre-stressed concrete (PSC) bridges for the Road is proposed to be of box girder type. The girder should have a diagonal web with angle and the length of the cantilever slab shall be uniform with 1.5m to 3.0m, except for the unavoidable case, such as changes to the width of road or pier interval for reasons of reducing the adverse effect on landscape or aesthetics.

ii. The minimum thickness of concrete deck slab shall be 250mm except for the edge of cantilever slab.

iii. Both superstructures and piers for the main carriageway of each direction shall be structurally independent from the other in order to meet the security requirements.

iv. Where possible, an abutment for a ramp bridge for interchange shall be set as lower as possible unless the girder depth of the superstructure does not disturb the finishing ground level around the abutment.

v. Should the pre-stress design of PSC bridges be based on post-tensioning by the use of internal pre-stress tendons only or a combination of internal and external prestress tendons, then provision shall be made in the design to replace at least 25% of the internal prestress tendons with structurally equivalent external pre-stress tendons, should replacement of internal tendons become necessary due to

deterioration of some of the internal prestress tendons.

vi. Full pre-stressed system should be applied but not application of partially pre-stressed structures.

vii. Over the inter-tidal zones, the construction of the superstructure shall be by overhead gantry methods only in order to avoid or minimize disturbance to the mud flats and the marine ecology

viii. Facilities for inspection and maintenance activities shall be included in the bridge design. Access to the inside of the box girders for main carriageway and ramps shall be located in the soffit of the box girders and shall be provided at minimum intervals of 1.0 km.

10 SPECIFIC REQUIREMENTS

10.1 Reinforced Concrete

Concrete Grades

All the concrete to be used in the Works shall be of a minimum of Grade 45 MPa, and the minimum concrete grades to be used for components of the bridge shall be as per the following table.

Table 5: Concrete Grades

Structural Elements	Minimum Grade, in MPa
Concrete for foundation including bored pile	45
Pile caps	45
Walls , Abutments	35
Piers, pier cap	50
PSC Box Girder	50
Parapets, Approaches slab, pedestals and median	40
Levelling course	M15

Density of Concrete

Mass concrete - 24 kN/m3

Reinforced / pre stressed concrete - 25 kN/m3

Green Concrete - 26 kN/m3

Elastic Modulus of Concrete

Elastic modulus of concrete for short term & long term shall be calculated depending upon the shrinkage & creep parameter as specified in IRC 112:2011.

Shrinkage

Shrinkage shall be calculated as per IRC 112:2011. The value of total shrinkage strain ε_{cs} is given by:

$\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca}$ where,

ε_{cd} = drying shrinkage strain

ε_{ca} = autogenous shrinkage strain

The value of the autogenous shrinkage strain shall be as per Table 6.15.

Creep

The creep shall be calculated as per IRC:112-2011. The creep coefficient,

φ = ecc (t)/ eci(t), where ecc (t) is the creep strain at $t>t_0$, eci(t) is the initial strain at loading.

Exposure condition

Very severe exposure conditions shall be considered while designing various components of the bridge and other structures in the viaduct portion and extreme conditions shall be considered in the structures lying in intertidal zone. For durability conditions the provisions stated in section 14 of IRC: 112-2011 shall be followed.

Cover to reinforcement & Crack Width

For the targeted service life of 100 years, the durability recommendation given under Clause 14 of IRC:112-2011 for "extreme condition" for structures lying in intertidal zone and for land viaduct prone under "very severe" condition shall be modified as given in the following table.

Table 6: Cover to reinforcement & Crack Width

Elements	IRC Exposure Category	Max. Crack Width (mm)	Nominal Cover for Crack Width Determination (mm)	Actual Cover (for Durability) (mm)
Piles, Foundations	Very Severe and Extreme	0.3	45	75
Pile caps	Extreme	0.2	45	75
Pier, Abutments, Pier Cap, Abutment cap, Wing wall etc.	Very Severe	0.2	30	50

Prestressed Concrete Decks, Approach slab, RCC crash Barrier & other RCC works	Very Severe	0.2	30	50

For post tensioned tendons, the minimum clear cover measured from the outside of the sheathing shall be 75 mm.

Coefficient of Thermal expansion

The following values shall be adopted as coefficient of thermal expansion for reinforced cement Concrete: 12 x 10^{-6} / ^{o}C.

10.2 Reinforcement

HYSD reinforcement bars of grade Fe 500 conforming to IS: 1786 and IRC: 112 shall be adopted.

Young's Modulus: Es=200,000 MPa; Yield Stress: fy = 500 MPa.

10.3 Structural Steel

Unless otherwise stated, hot rolled and hollow section structural steel shall be E410 Fe540 grade conforming to IS 2062-2011. Steel sections conforming to E250 grade will be used for Hand-railing and Cutting Edge. All structural steel works and fasteners to be protected in accordance with BS EN ISO 12944 and 14713 where applicable. The first protective maintenance shall be assumed to be executed 15 years as of the works completion.

10.4 Prestressing Steel

The pre stressing system used shall be VSL system or DSI system or any other equivalent approved system.

The following are defined for the pre stressing system:-

- Multi-strand system comprising the required number of strands in a circular duct.
- Anchorage and coupling system for the anchoring of the pre stressing forces at the ends or for continuing the force by coupling.
- Internal tendons comprising of High Density Polyethylene (HDPE) sheathing around the strands of bars, external to the concrete shall be used. Once the force is locked off, the orifice is filled with cementitious grout for corrosion protection as well as for bonding of the strands to the concrete to form a bonded system.

For pre stressing strands, 7 wire low-relaxation strands complying with IS: 14268-1995 or

IRC 112-2011 whichever appropriate, will be used. The following strand types are proposed to be used on the project according to the details and design requirements for various structure types.

Material property	Normal Strands
Strand Type	Uncoated stress relieved low relaxation Class II conforming to IS 14268
Yield strength (MPa)	1560
Ultimate strength (MPa)	1770
The breaking strength	0.2 % proof load
Young's Modulus (GPa)	195
Relaxation (After 1000h)	Maximum 4.5%

Other Design Parameters of Strands shall be as per IRC 112.

10.5 Bearings

i) Elastomeric Bearings

Laminated elastomeric bearings conforming to IRC: 83 (Part II) and shall conform to clause 2005 of MORTH specification for Road and Bridge Works shall be used for load transfer from superstructure to substructure of bridge.

ii) POT cum PTFE Bearings

POT cum PTFE bearings shall be provided where there will be requirement to cater large loads.

iii) Metallic and Spherical Bearings

Metallic and Spherical Bearings are to be provided as per requirement.

10.6 Expansion Joints

Strip seal type expansion joints shall be provided on the bridge expansion gap as per MORTH specification for road and bridge. U-Type Copper expansion joint shall be provided in between dirt wall and approach slab.

10.7 Navigation Aid Facilities

Appropriate navigation aids shall be equipped to the spans crossing over the navigational channels in accordance with the regulations and directions by port authorities including Mumbai Maritime Board (MMB) and other institutions responsible for safe navigation in Mumbai Bay. Typical navigation aids to be attached to the bridge over the navigation lane is a set of center mark (light), left edge mark (light), and right edge mark (light) indicating the location of the navigation lane. They must be visible and effective in both daytime and night time.

The Contractor shall consult with MMB to select the necessary types and locations of such equipment and obtain the approval of the authorities if requested. The Contractor shall submit the design of the navigation aids to the Engineer for approval prior to commencement of the work.

10.8 Anti-vision and Noise Barrier

Contractor shall submit detailed report covering the locations where anti vision and noise barriers are to be provided. The report shall also cover the design of the barriers. This shall be based standard international practices. Among other locations noise barriers will be required to the interface between the existing roads and interchanges.

Contract Code. : 7200037432

Volume 4

Outline Design Specifications

Section 3

CIVIL STRUCTURES

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

1 INTRODUCTION

This section covers the Outline Design Specifications for civil structures including cut and cover box culverts, etc. The Specifications given herein shall apply for all structures (above ground and below ground), except bridge structures, unless noted otherwise.

For Codes and Standards, refer to Volume 5, Section 3.

For bridge structures Section 2 of Volume 4 shall be followed. For bridge structures, this Section 3 should be referred only when a specific requirement is not covered in Section 2, and the Engineer's decision shall be final in this regard.

For Codes and Standards, refer to Section 3, Volume 5.

2 CUT & COVER STRUCTURES

2.1 General Principles

1) Cut-and-cover structures include box culverts, utility services, and like, that are required to be constructed below ground surface (partly or fully) under this Contract.
2) The cut-and-cover structure is a rigid box section or a U trough with permanent walls as external wall support system. The roof slab of box section shall support the soil and vehicular surcharge. The Vehicular traffic loads shall be supported by the base slab. The permanent walls shall resist the lateral earth and hydrostatic pressures in addition to the surcharge.
3) The completed cut and cover structure shall be water-tight as specified.
4) Where temporary shoring (excavation – support – wall), and excavation & lateral support system are intended as part of the Permanent Works Design and involve public safety, the Contractor shall justify the feasibility and suitability of such works to the Engineer.
5) The Contractor shall take into account the following in the design of his cut-and-cover structures.
    a) Method of construction, including temporary works and construction sequence.
    b) Ground/structure interaction, including the effects of temporary works.
    c) Ground pressure, shear force and bending moment distribution during construction and in the long-term.
    d) Short- and long-term ground and groundwater response.
    e) Other static loads changes such as; excavation, surcharge, traffic loadings the like.
    f) Long-term surface water level changes
    g) Dynamic (such as seismic or vibratory plant) loads and displacements.
6) For the purposes of assessing ground and groundwater pressures, the cut-and-cover

structures shall be considered to be effectively impermeable rigid box structures subject to “at rest” (K0) earth pressure.

7) The Contractor shall design to minimise the effects (such as movement, distortion of the ground and the like) on all Existing Building Structures (EBS) that may be affected by the Works. Where necessary the Contractor shall provide additional support for these EBS.

8) Temporary ground support shall be designed in accordance with the requirements of the Contract.

2.2 Design Principles

(1) The design of all cut-and-cover structures shall take into account, but not be limited to the following.

a) The variation in ground conditions along the alignment.
b) The variation in engineering properties of soil or rock within the influence of the proposed Works.
c) All dewatering and groundwater cut-off systems required to maintain dry and stable conditions within all excavations required for these Works.
d) Any ground treatment before, during or after construction of the Works (e.g. groundwater recharge) which is required to stabilise the ground and EBS in order to minimize adjacent ground and EBS movement and distortion
e) Methods by which the completed structure shall be secured against flotation. Any temporary dewatering system shall not be turned off unless the structure will not be subject to leakage or flotation when the groundwater returns to the design levels.
f) Differential groundwater pressures.
g) Methods of waterproofing the completed structure.
h) The magnitude of ground and EBS movements and distortions, and changes in loading conditions on these EBS that might be expected as a result of the Works and how these will be mitigated so at to comply with any imposed constraints or so at to minimize disturbance to these EBS.
i) Any difficulties that the Contractor’s intended plant might meet with in respect of access, clearances, working space and obstruction to excavation.
j) Maintenance of traffic flows along roads including access to adjoining properties and roads.
k) Noise levels produced during construction, and subsequent operation of the road.
l) Control of heave, swell, piping and instability of the excavations.
m) The effects of vibration and vibration induced movements.
n) Impact of seismic effects

(2) The following methods of shoring construction should be considered, especially

in soft ground either individually or in combination depending upon the particular requirements of the location, size and type of structure.

a) Diaphragm Walls: Particular attention shall be given to the wall and panel alignment, the stability of excavation, the mix and condition of the slurry, placement of the reinforcement cage, methods for forming and locating box-outs, waterproofing of the vertical panel joints, placement of concrete, and the overall integrity and water-tightness of the formed wall.

b) Secant Piles/Sheet Piles/Soldier Piles and Horizontal Planks : Particular attention shall be given to the construction/installation of the piles and ground support systems to ensure their integrity and water-tightness and to provide adequate support to the ground during excavation.

2.3 Excavation Support

(1) General

a) The Contractor shall prepare and submit to the Engineer for his Notice a Detailed Design Report including calculations schedules and drawings for each proposed excavation support wall construction, prior to the commencement of any such works. This Design Report shall take into account but not be limited to the following.

i) Earth pressure.
ii) Hydrostatic pressure.
iii) Deck load.
iv) Surcharge loads.
v) Seismic and/or vibratory loads
vi) Support types and arrangement.
vii) Any other incidental load.
viii) Construction/deconstruction sequence.
ix) Calculated ground and adjacent EBS movements and distortions.
x) Calculated fluctuations in groundwater levels both within and outside of the excavation - support - walls.
xi) Calculated changes in EBS loading conditions.

(2) Method Statement

a) The Contractor shall prepare a Method Statement giving the full details of materials, plant and operations involved in the construction of excavation - support - walls. This Method Statement shall be incorporated into the Design Report submission for the Engineer's Notice and shall include but not be limited to the following details.

i) Formation of the joints between panels and installation of water stops.
ii) Method of producing the durable concrete.
iii) Methods of handing within the excavations and disposing

of groundwater outside of the excavations

iv) Sequence of excavation and concreting of panels.

v) Methods of instrumenting, monitoring and reporting of the performance of all adjacent EBS that may be affected by the Works.

vi) Methods of instrumenting, monitoring and reporting on the performance of the excavation - support - walls.

vii) Type and construction of permanent lining wall.

viii) Emergency procedures to be implemented in the event that monitoring indicates tolerances associated with the excavation - support - wall may be exceeded.

b) Where temporary ground support is to be provided using bentonite slurry, the following additional information shall be provided in the Method Statement for these Works.

i) Mixing, transporting and placing equipment for the bentonite slurry.

ii) Method of disposal of contaminated bentonite slurry.

iii) Type, source, chemical and physical properties of the bentonite to be used.

iv) Stability, dimensions and details of guide walls.

v) Cleaning and re-use of the bentonite slurry.

vi) Calculations to show that the density of the bentonite and lowest head of slurry are sufficient to maintain the stability of the trench excavated for the support wall, in the ground conditions envisaged, to its full depth.

2.4 Design Life and Serviceability

General

The “design life” of a structure or component is that period for which the item is required to fulfil its intended function when maintained in accordance with agreed procedures to meet a required level of performance. The definition of a “design life” for a structure or component does not necessarily mean that the structure will no longer be fit for its intended purpose at the end of that period. Neither will it be expected to necessarily continue to be serviceable for that length of time without adequate maintenance to mitigate the demands of degradation.

Civil Engineering Structures

1) The design life of all permanent civil engineering structures shall be a minimum of 100 years unless otherwise specified or agreed upon.

2) Adequate measures shall be taken to ensure minimum of 100 years serviceability

of civil structures, producing durable concrete. Suitable property enhancers/ blending materials conforming to relevant BIS codes may be used as deemed appropriate and subject to Notice by the Engineer. As part of his design submission, the Contractor shall demonstrate his approach in design, construction and selection of materials so as to achieve 100 year design life.

2.5 Materials

Cement

1) The Cement of 43 grade and 53 grade conforming to IS 1182-1989, IS 12269-1987, IS 455 and IS 1489 – Part I shall be used.

2) Portland Pozzolana Cement (PPC) conforming to IS 1486 may also be used.

3) The Engineer may give Notice for the usage of sulphate-resistant Portland cement conforming to IS 12330 for structural elements exposed to soil.

4) In all cases the cement shall meet the 28 day strength requirement of IS 8112-1989 or IS 12269-1987.

Concrete

The material properties shall be as follows

Concrete Grade	**Minimum Compressive Strength of 150 millimetre cube at 28 days in MPa**	**Maximum Water: Cement ratio**	**Minimum Cement Content (kilograms per cubic metre)**	**Coefficient of Thermal Expansion per ^{o}Celsius**	**Poisson's Ratio**
M35	35	0.45	360	$1.17x10^{-5}$	0.15
M40	40				
M45	45				
M50	50				
M60	60				

a) Short term modulus of elasticity (Ec) shall be as per clause. 6.2.3.1 of IS 456-2000.

b) The modular ratio for all concrete grades shall be 10.

c) Density of concrete shall be 24 kilo Newtons per cubic metre for reinforced concrete, and 23 kilo Newtons per cubic metre for plain cement concrete Reinforcement

a) Only thermo-mechanically treated reinforcement bars of grade Fe415/Fe500 with minimum total elongation of 14.5% conforming to IS 1786 shall be adopted

b) The material properties shall be as follows.'

Young's Modulus MPa	Yield Stress MPa	Diameters mm	Density kN/m3	Poisson's Ratio	Thermal coefficient per ^{o} C
2,00,000	415 for Fe 415 500 for Fe 500	8, 10, 12, 16, 20, 25,28 32, 36 & 40,	78.5	0.3	$12X\ 10^{-6}$

Reinforcements shall be high strength deformed bars. The reinforcement steel shall be Corrosion Resistant Steel (CRS), from primary producers as approved by the Engineer. No re-rolled steel shall be use in the Works. CRS reinforcing steel manufactured through controlled steel making processes using latest technology shall be used

Structural Steel

General

(1) Design of Structural steelwork shall comply with IS 800.

(2) Two types of structural steel to be used and shall comply with the following standards:

a) IS: 4923-1997 " Hollow steel sections for structural use with Yst 310"

b) IS: 2062-2006 " Steel for General Structural Purposes (Grade B-Designation 410-B)"

(3) Hollow steel sections shall be square (SHS) or rectangular (RHS). Other traditional rolled sections like plates, angles, channels, joists can also be used where required.

(4) The connection with concrete shall be effected by internally threaded bolt sleeves (hot dipped galvanized @ 300 grams per square metres) manufactured from IS:2062 Grade B mild steel. The sleeve shall receive hexagon-head bolt M20 Class 8.8 as per IS:1364 (Part 1) with galvanized spring washer.

(5) The connections within the steel structure shall be designed as direct welded members with or without gusset plates. The minimum thickness of metal for SHS/RHS sections for main chord members as well bracings shall be 4 millimetres as applicable for steel tubes in Cl. 6.3 of IS: 806.

Material Properties

Material Properties shall be as follows.

Steel Type	Young's Modulus	Tensile Strength	Yield Strength	Density	Poisson's Ratio	Thermal Expansion Coefficient
For Hollow steel sections (conforming to IS: 4923)	200,000 MPa	450 MPa	310MPa 250MPa (for t <20mm), 240MPa (for 20mm < t < 40mm) , 230MPa (for t > 40mm)	78.5 kN/m3	0.30	$1.2x10^{-5}$ per °C
Structural Steel (Conforming to IS: 2062)		410 MPa				

2.6 Durability Criteria

(1) In carrying out structural designs the Contractor shall ensure that both the serviceability and ultimate limit states have been checked in accordance with the applicable standards and codes.

(2) In designing to achieve durability the Contractor shall take full account of the prevailing soil, groundwater exposure conditions and those predicted to occur at the site within the design life of the Works

Concrete Grade

1) The minimum grade of concrete shall be M35. The properties of concrete shall be as specified in this document, Section 2.5.2.

2) Where concrete is to be placed under the slurry or water, such as piles, diaphragm wall and barrettes, the design compressive strength and shear strength of structural concrete shall be reduced. The characteristic strength of the compression and shear stress shall be taken to be 80% of the characteristic strength of the concrete grade.

Fire Resistance Period

1) All structures shall be designed for fire protection as specified by the applicable standards and codes. Materials specified for the Works shall be non-combustible and nor emit toxic fumes when subject to heat or fire, except where permitted under the Contract. In all cases where there is significant fire risk materials shall be self-extinguishing, low flammability, low smoke and low toxicity

2) All elements of the Cut and Cover structures shall be designed for a minimum fire resistance period of 4 hours

3) The minimum FRP thicknesses for this fire resistance shall be as given in below Table.

4) The minimum values for the covers to reinforcement for this resistance period are specified in Table 7.

Table 7: Minimum Element Sizes for 4-hour Fire Protection

Element	Minimum Sizes for 4-hour FRP (millimetres)
RC Slab Thickness	170
RC Wall Thickness: <1% reinforcement	240
RC Wall Thickness: >1% reinforcement	180
Staircase (waists)	170
RC Beam Width	280
RC Column Sizes	450
Blockwork wall thickness	170

Crack Width

All structural concrete elements shall be designed to prevent excessive cracking due to flexure, early age thermal and shrinkage. The minimum crack widths shall be as specified in Table 2.2

Flexural Cracking

Flexural crack width shall be checked in accordance with Appendix F of IS 456:2000. The limits specified in Table 2.2 shall apply irrespective of whether any additional protection, such as waterproofing membrane, is provided to the members at the exposed face of the structure.

Early age Thermal and Shrinkage Cracking

(1) Suitable reinforcement shall be designed to prevent early age thermal and shrinkage cracking for walls and slabs more than 250 millimetres thick and subjected to internal and external restraints during construction. The thermal and shrinkage strains due to early age temperature differences and shrinkage shall be accounted for in the design of reinforcement for cracking.

(2) It is preferred that smaller diameter bars in any direction are placed at closer intervals to prevent early age thermal and shrinkage cracks. The limits specified in Table 8

shall be imposed. Guidance can be sought from CIRIA Report 91 on Early Age Thermal Control of Concrete.

Table 8: Cover and Crack Width Criteria

Element	Durability Exposure Condition	Maximum Crack Width (millimetres)	Actual Cover (for Durability) (millimetres)	Nominal Cover for determination of Crack Width (Note 2) (millimetres)
Pile Cap (side and bottom faces) resting on layer of blinding concrete not less than 50mm thick	Severe	0.2	80	45
Base Slab-Top Surface	Moderate	0.3	45*	30
Base Slab-Bottom Surface (cast against ground/blinding)	Severe	0.2	70	45
Basement Walls a) Face in contact with soil	Severe	0.2	50	45
b) Other face	Moderate	0.3	40	30
Stairs	Moderate	0.3	55*	30
Water Tank	Severe	0.2	45	45
Beams				
Top Surface (Contact with soil)	Severe	0.2	50	45
Top Surface (No Contact with soil)	Moderate	0.3	50	30
Bottom and sides				
- continuous	Moderate	0.3	50	30
- simply supported	Moderate	0.3	70	30
Slabs				
Top Surface (Contact with soil)	Severe	0.2	45*	45
Top Surface (No Contact with soil)	Moderate	0.3	45*	45
Bottom and sides				
- continuous	Moderate	0.3	45*	30
- simply supported	Moderate	0.3	55*	45

* - Wrapping mesh required in cover zone for fire protection requirements.

1. Nominal cover is measured to the outermost main reinforcement.
2. Nominal cover is according to Table 16 of IS 456:2000.
3. Nominal cover does not include any allowance for construction tolerance.

2.7 Design Groundwater Levels

- "Construction" stage groundwater level is at measured maximum elevation during monsoon.
- "Service/Operation" stage groundwater level is at ground level.
- "Accidental" stage groundwater level is at ground level.
- "Extreme" stage groundwater level at 1 in 50 year maximum plus 0.5m allowance for sea level rise.

For definition of stages mentioned above refer to clause 3.1.24 of this Section

2.8 Floatation

1) The minimum depth of cover to underground structures shall be 2 metres or depth to the underside of existing major utilities (e.g. sewer mains, storm water mains and the like) whichever is greater.
2) For protection against flotation in the fully dry internally condition following shall apply.
   a) A load factor of 1.0 shall be applied to the self-weight of the structure.
   b) A load factor of 1.0 shall be applied to the weight of backfill material over the structure.
   c) The top 500mm thick backfill shall not be considered in the flotation design.
   d) The overall factor of safety against flotation shall not be less than 1.1 for any of the conditions defined above.
   e) Side friction shall be ignored in floatation design calculations.
3) The Contractor shall check all proposed cut-and-cover structures for the possibility of flotation due to differential water pressure and shall design each and every underground structure such that the factors of safety against flotation are achieved for all load cases.
4) The Contractor shall ensure that his method and sequence of construction is such that an adequate resistance to uplift is maintained at all times, and shall put forward his proposal to this effect.
5) Suitable measures such as those listed below to counteract flotation forces for the Permanent Works shall be incorporated into the Contractor's design. The measure(s) chosen shall suit the particular conditions and the method of construction;

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

b) Increasing the dead weight of the structure by:

i) thickening of structural members; providing an extra thickness of concrete beneath the base slab tied into the structural base slab;
ii) extending the excavation support walls;
iii) providing counterweights in parts of the structure with high density material;
iv) providing tension piles.

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

2.9 Excavation Base Stability

(1) The Contractor's design shall include adequate precautions against base heave, piping and failure of his excavations during construction. The stability of the excavation bases shall be checked in accordance with an acceptable method of analysis which shall allow for all reasonable loads within and outside of the excavation.

(2) The Contractor shall show in his calculations the contribution made to the base stability of the excavation by his proposed method of construction and shall state the factor(s) of safety used in the design. The factor(s) of safety shall relate to the method of construction and to the particular location of the Works, and shall be subject to the Notice of the Engineer.

2.10 Waterproofing

1) Groundwater leakage rates into the completed Permanent structures shall be limited to damp patches only and shall not under any circumstances exceed a general value of 0.1 litres per square metre per day.

2) The quality and grade of the concrete, treatment of construction joints, areas of slab pours and external membranes shall be chosen such that the required standard of waterproofing can be achieved and maintained. Waterproofing membrane shall be provided to base slabs of all cut-and-cover structures and to walls where the structure is built in an open excavation.

3) An external membrane shall be provided over the roof of the structure so that the roof of the permanent underground structure is completely watertight.

4) Detailing of structure shall include provision of splays, chamfers and fillets as appropriate to facilitate the laying and performance of waterproofing membranes.

5) Materials for expansion joints, caulking, grouting and the like shall have acceptable fire performance for use on an underground transport infrastructure

6) Diaphragm walls if adopted, shall be rendered or shotcreted and trowelled, as necessary, to provide a uniform finish without distinct changes in colour or line.

All rendered or shotcreted walls shall be provided with a controlled drainage system to direct any seepage permitted under the Contract to the floor drainage system.

2.11 Water Control in Excavations

(1) During construction in water-bearing ground, seepage water shall be controlled by suitable means and the design shall provide for the same. The Contractor shall obtain the Engineer's prior Notice to the process he intends to adopt to control groundwater inflow, and the treatment and disposal of any groundwater collected.

(2) The piezometric pressure outside of the excavations shall at all times remain within the normal expected groundwater variation and permissible safe limits. The Contractor shall be responsible for all local authority approvals required for his groundwater control methods.

(3) Notwithstanding the limits on groundwater leakage rates, the design shall aim to ensure that no loss of ground or groundwater occurs through any part of the structure.

2.12 Underpinning of Existing Building Structures (EBS)

(1) Where the construction of underground works necessitates the removal of existing support or foundations to existing buildings, structures, utilities, services, wells, pavements, road furniture and the like (collectively termed EBS) the Contractor shall carry out investigations on the extent of the existing works, their design and loading conditions.

(2) The Contractor shall design and carry out such works as are necessary to maintain the integrity of the EBS at all times including its design life. No work shall commence prior to the Notice of the Engineer being given. Cost of design and provision of any support/strengthening of such structures will be deemed as included in the Contractor's Price.

For EBS protection refer to Annexure 1 of this Section.

2.13 Drainage and Flood Protection

Structures located on flat land shall have a minimum flood protection of 1.5 metres above the surrounding ground level/road level. For return period velocity refer to IRC 6 – 2014 and also can be referred to BS 6349-1-1:2013, CIRIA C624 – Development and flood risk for the construction industry.

2.14 Temporary Works

General Principles

(1) In general Temporary Works shall be designed in accordance with the same design

standards as the Permanent Works. However, Temporary Works design may take into account the limited duration over which such temporary works are expected to function. The calculations and drawings shall make clear where provision for limited duration has been allowed for, particularly where this may have a substantial influence on the stability of the Temporary Works.

(2) The design of Temporary Works shall take account of all the applied external forces and imposed structural deformations and, where applicable, the effects of removal of load from the ground.

Design of Temporary Excavation Support

(1) Excavations for cut-and-cover structures in soft ground shall be supported by secant piles or similar which may be incorporated into the Permanent Works. Design of these elements shall include full step-by-step analyses of the progressive change in the loading and required temporary support conditions as the excavation proceeds and subsequently as these temporary elements are integrated into the Permanent Works.

(2) Braced excavations shall be analysed by finite element or similar methods in which the changes in ground stresses are properly related to the deflections which occur in the structural elements, by the use of appropriate stiffness and other parameters. Relevant empirical evidence from similar excavations must be referred to in support of the conclusions of the analyses. Simplified analytical models and methods shall be employed to calibrate and support finite element analyses of the various permutations of structure geometry and loading.

(3) Temporary works shall be designed as far as possible to be removed when no longer required, and shall not be left in the ground. Temporary works which are viewed as being impossible to remove on completion of the Permanent Works shall be dismantled to a minimum depth of 2 metres below the finished ground surface and designed so that there will be no risk of ground settlement or other deleterious effects as a consequence of decay and/or collapse of these Temporary Works.

Ground Movements

(1) In accordance with Annexure 1 of this Volume the Temporary and Permanent Works designs shall limit ground movement and distortions around the site and to avoid damage to adjacent EBS.

(2) The Contractor shall carry out a risk assessment for all EBS within the influence of the Works in accordance with Annexure 1 of this Volume. The analyses for the Temporary Works shall be properly related to the conclusions of this risk assessment.

Construction Dewatering

(1) Temporary dewatering of construction excavations will be required to provide an undisturbed, stable and dry subgrade to permit construction and backfilling of the Permanent Works under dry conditions.

(2) In general, the groundwater within the excavations shall be maintained at a level that permits achievement of the above, and avoids heave, piping or base failure of the excavation.

(3) Temporary dewatering methods and system operations, along with other required temporary works, shall not lower the groundwater outside the walls supporting the excavations, nor result in settlement, distortion or loss of ground at adjacent EBS.

(4) The Contractor shall prepare and submit his design of his construction dewatering system to the Engineer for his Notice. The construction dewatering design shall include determination of subsurface conditions and geotechnical design parameters, analyses to establish feasible methods, and system definition in sufficient detail to demonstrate that the general objectives can be achieved without adverse effect on adjacent EBS. The selected system shall generally provide for continuous (24-hour- per-day) operation, adequate reserve equipment, and standby power.

Ground Improvement

(1) Ground-improvement may be required along certain alignment segments of the Project to control ground and EBS movement and distortion that may be induced by excavation works.

(2) The Contractor shall prepare and submit his designs and method statements supported by analysis for all ground improvement to the Engineer for his Notice.

These designs shall define performance objectives for the ground improvement

(3) Instrumentation, monitoring and reporting details for verifying achievement of ground improvement performance objectives in accordance with Annexure 1 of this Volume shall be included in the ground improvement design submission.

(4) The information and assumptions on which the ground improvement is based shall be shown on the design drawings.

2.15 Connection Details

Corners

The Contractor shall pay particular attention corner joints of large structural members. External wall/slab junctions shall be provided with crack control steel and transverse ties.

Radius of bend of main tension bars shall be increased to cater for the high bearing stresses within the bend.

Construction Joints

The design and detailing of construction joints shall be sufficient for the proposed works and minimised to reduce the risk of leakage.

Slab to Wall Connections

For top-down construction in particular, attention shall be paid to the practicalities of the design and detailing of the slab to wall connections and the means by which the integrity of the construction joints at these connections will be assured.

2.16 Instrumentation

For instrumentation of cut & cover structures, refer to Annexure 1 of this Volume.

2.17 Box Culverts.

(1) Box Culverts shall be constructed in the positions shown in the Drawings in Volume 6 and unless shown otherwise the minimum dimensions shall be as follows,

Box Culverts

a. Minimum clear dimensions
As shown in Tender / Employer's Drawings.

3 CIVIL STRUCTURES

3.1 Loads and Requirements

General

Unless specified otherwise the design of concrete and steel elements shall conform to IS 456 and IS 800, respectively.

Nominal Loads

For the purpose of computing stresses and deformations, the following minimum load types and consequential effects shall be taken into account as applicable.

Dead loads (including notional loads)	DL Superimposed Dead loads
SIDL Imposed Loads	IL Vehicular loads
RL Fatigue	FG Dynamic
DY Wind Loads	WL Temperature loads
TE Seismic Loads	EQ Construction/Erection
ER Shrinkage	SH Creep

CP

Movement/ Distortion MD Earth Pressure

EP Surcharge SR Hydrostatic

WP Accidental AC Redundancy

R

Design Loads

Design shall include all of the following loads

Dead Loads

Self-weight of the materials shall be calculated in accordance with IS 875:1987 Part 1

Superimposed Dead Loads

Super imposed dead load includes:

(1) Plain Cement Concrete fill having a minimum thickness of 300mm (cut and cover and transition ramp structures)
(2) Curbs and Railing loads.
(3) Any finishes/toppings on structure.

Imposed Loads

Pedestrian imposed load shall be not less than 6 KPa. For other imposed loads refer to NBC.

Vehicular Live Load

Vertical Load

(1) Each component of the structure shall be designed/checked for all possible combinations of loads in accordance with IRC 6 - 2014.The structure shall resist the effect of the worst combination.
(2) Maximum number of axles will be loaded on the structure to arrive at maximum longitudinal force, maximum shear and maximum bending moments. The structure shall be checked for one-lane load condition as well as (both) 2-lane load condition.

Horizontal Load

(A) Braking and Traction

Braking load is taken as 15% of the unfactored vertical loads. Traction load is taken as 18% of the unfactored vertical loads.

Transverse/ longitudinal seismic condition, only 50% of gross tractive effort/braking force shall be considered.

(B) Centrifugal Force

Design Speed for various radii of curvature shall be as stipulated in the Schedule of Dimensions – refer Volume 3, Appendix 18.

Fatigue

The nominal loading for the design of members in accordance with fatigue requirements shall comprise trains with six individual cars each having four axles, the axle loads and vehicle lengths as specified in IRC 6 : 2014.

Fatigue load histories shall be evaluated to provide valid and representative design spectra, with stress histories analysed by the rain flow or equivalent method, both in conjunction with the projected annual tonnages of rail traffic per track. The provisions of BS 5400 Part 10
Clause 9.3.3 or other relevant methods may be used as a rigorous method of evaluation of compliance with fatigue criteria.

Dynamic

Impact factor for longitudinal analysis shall be 1.2 while for transverse analysis the same shall be 1.67

Vehicle Collision Load

The impact on crash barrier due to collision shall be considered at critical locations for the appropriate quanta of impact loads specified in IRC 6: 2014 It is required to mitigate impact effects on elements that may be adversely affected without enhancements.

Wind

IS 875: Part 3 shall be applied to determine the appropriate design wind loads in combination of other loads. Wind effects from venting in below-ground areas shall be designed appropriately.

Wave Surge

The impact of tidal behaviour, wave surge etc. shall be considered as specified. in BS 6349 – Part 1-2.

Temperature

Forces may arise from a thermal gradient within a structural element; this may be from external sources or, in the case of fresh concrete, from the internal heat of hydration during curing.
These forces shall be considered in combination with those from other types of loads to determine the worst loading condition. “Locked-in” forces from temperature effects (e.g. from curing of concrete) shall be considered as a permanent load and due allowance made in the design for such.

Temporary works with structural steel bracing elements or similar may also suffer adverse effects from thermal strains. These strains shall be mitigated to avoid losses in preloading and subsequent excessive deformations in structural members.

Seismic Loads

Seismic effects shall be considered on all structures, including underground structures. Evaluation of seismic loads shall conform to the relevant Indian Standards or to other relevant seismic standards or references where the Indian Standards do not provide sufficient guidance.

The zonal demarcations for levels of seismicity shall be evaluated as per IS 1893-2002.

The structure is required to be evaluated as an “important service and community building” for the purpose of "functional use” as stated in IS 1893:2002.

The effects of load changes and deformation as a result of soil behaviour (e.g. liquefaction) shall be allowed for in the assessment and design.

Seismic design for above-ground structures

Earthquake design shall follow the seismic requirements of IS 1893: 2002

(1) Design Base Shear

(a) The design base shear shall be calculated based on recommendation given in IS:1893.The total design lateral force or design seismic base shear (VB) along any principal direction shall be determined by the following expression:

$$V_B = A_h W$$

Where

A_h = Design horizontal acceleration spectrum value, using the fundamental natural period T_a calculated according to clause 7.6 of IS 1893-2002 (Part 1) in the considered direction of vibration, and;

W = Seismic weight of the building calculated according to cl. 7.4.2 of IS1893-2002 Part 1

The design horizontal seismic coefficient A_h for a structure shall be determined by the following expression:

$$A_h = \frac{Z}{2} \times \frac{Sa}{g} \times I \quad ----$$

Provided that for any structure with T ≤ 0.1 s, the value of Ah will not be taken less than Z/2 whatever be the value of *I/R*

Where

Z = Zone factor. The project site falls within Zone III. Zone factor

(Z) of 0.16 shall be taken as per IS 1893-2002 (Part 1).

I = Importance factor shall be taken as 1.5.

R = Response reduction factor shall be as per Table 7 of IS 1893,

S_a/g = Average response acceleration coefficient for rock or soil sites as given by Fig. 2 and Table 3 of IS 1893 based on appropriate natural periods (Ta) and damping of the structure. These curves represent free field ground motion.

Damping for the concrete structure shall be assumed as 5%.based on type of foundations provided for the structure and soil strata type, the appropriate spectral coefficient shall be selected from Fig. 2 of IS 1893-2002 Part 1.The vertical seismic coefficient will be taken as two thirds of the design horizontal acceleration as per clause. 6.4.5 of IS 1893-2002 Part 1.

Seismic design for underground structures

The lateral earth pressure for external walls of underground structures for seismic load case shall be evaluated in accordance with Section 8 of IS1893-1984.

Evaluation of seismic loads shall conform to the relevant Indian Standards or to other relevant seismic standards when the Indian Standards may not be applicable.

Construction/Erection

The weight of all permanent and temporary materials together with all other forces and effects which can operate on any part of structure during construction shall be taken into account. Allowances shall be made in the permanent design for “locked-in” stresses caused in any member during construction.

Shrinkage and Creep

Provisions shall be made for the effects of shrinkage and creep within concrete structures. This includes interface shear transfer mechanisms as a result of differential creep and residual shrinkage effects from staged casting of concrete elements. The shrinkage and creep strains shall be included in calculation of long term deflection of all structural elements in accordance with Annexure C of IS 456-2000 and the limits specified in Section 2.8 shall be applied.

Movement and Distortion

Consideration of the forces resulting from differential movement (distortion) of foundation elements shall be checked as appropriate. All movements and distortions must not be greater than limits adhered to in the relevant codes or acceptable to the relevant Authority. These may be architectural, structural, performance or other types of limitations

currently in force.

Earth Pressure

Underground vertical elements that are in direct contact with the ground shall be designed as permanent retaining walls to resist the lateral earth pressure. The Contractor shall deduce the earth pressure coefficients based on his geotechnical investigations. The available ground investigation records are provided in Volume 7 of the Contract for reference purposes only.'

Surcharge

Soil and vehicular load surcharge on each element of Cut and Cover structure shall be considered in the design.

Groundwater

Loads due to water pressure shall be calculated using a unit weight of 10 Kilo Newton per cubic metre for fresh water and a unit weight of 10.3 Kilo Newton per cubic metre for sea-water.

Should liquefaction of soils be a potential risk then the design water table level for permanent structures shall include layers affected by liquefaction if this is above the design groundwater levels.

The effects of temporary drawdown, seepage and base heave effects shall be considered in design of the temporary works, and catered for in the permanent works if there is a "locked- in" effect from carry-over forces. The extent of the temporary walls shall be sufficient to mitigate the effects of such loads during construction.

The effects of flotation loads shall be allowed for in the design both in the temporary and permanent design stages.

Accidental

The design shall allow for a minimum impact loading of 50 KN acting at any position and at any direction on temporary works or on partially completed permanent works.

Redundancy loads

The temporary structure shall allow for the effects of a "one-strut failure" condition. A single strut failing at any position and at any stage shall be evaluated Ultimate Limit State (ULS) condition with a FOS of not less than 1.05.

Differential Movement Between In-Line Structures

Differential movement between adjacent in-line structures arising from static and/or dynamic loading shall be evaluated. Due allowance for such shall be incorporated into the size of the structures and detailing of joints to ensure that the total and differential movements, including distortion and relative rotation, between in-line structures shall not

the serviceability of the structures for the design life of the structures.

Loading Combinations

Each component of the structure shall be designed and checked for all possible combinations of applied loads and forces. The load factors and load combinations for ultimate and serviceability limit states are specified in the Tables 9 & 10 below

Table 9:Ultimate Limit State Load Combinations

Load Combination	Dead Load (DL)	Imposed Load (IL)		Earth and Water Loads			Wind Load[7] (WL)	Seismic Load[4] (EQ)
1.DL + IL	1.5	-	1.5	-	1.5	-	-	-
2.DL + EQ	1.5	0.9	-	-	-	-	1.5	1.5
3..DL + IL+EQ	1.2	-	1.2	-	1.2	-	1.2	1.2
4.Construction	1.5	-	1.3	-	-	-	-	-
5.Collision	1.5	1.0	1.5	-	1.5	1.0	-	-

Notes

1) Load combination 4 will be used in checking temporary works proposals and checking the structure during temporary construction stages. The imposed load is the construction imposed load.
2) For checking structures at the accidental water levels, the reduced partial factors of safety for water loads are to be 1.1.
3) Structural steel design load combinations and partial factors of safety for the design of structural steelwork are to be in accordance with IS 800 - Code of Practice for the Structural Use of Steel Work
4) Earthquake loads are reversible.
5) 50% imposed load is to be used in line with the building mass calculated for seismic loads in load case 2 & 3.
6) Creep, shrinkage, temperature and differential settlement are not considered in combination with the lateral loads at ultimate limit state. Creep and shrinkage effects will usually be minor for building type structures, no specific calculation will be necessary for Ultimate limit state.
7) Wind load combinations are applicable for above-ground structures and shall be considered in addition to the other combinations.

Table 10: Serviceability Limit State Load Combinations

Load Combination	Dead Load	Imposed Load	Earth & Water Loads	Wind Load	Earthquake Load

1.DL + IL	1.0	1.0	1.0	-	-
2.DL +EQ	1.0	-	-	1.0	1.0
3.DL+IL +EQ	1.0	1.0	1.0	1.0	1.0

Design Conditions

(1) The Contractor shall define the partial load factors and overall design factors of safety in accordance with the relevant Standards and Codes for the following four main conditions.

"Construction" - during and immediately after construction of the Works. "Service/Operation"- during general operation of the completed facility.

"Accidental" - during "Construction and/or "Service/Operation" when adjacent work and future development (where known) may alter loading conditions.

"Extreme" - during "Construction and/or "Service/Operation" when groundwater may rise to unusually high level.

(2) The assumed partial load factors and overall design factors of safety for the four main conditions shall be included with the calculations to determine and design for the most critical cases as provided in his design submissions.

(3) For ground loads on cut-and-cover structures, the worst combination of lateral loading shall be considered for the "Construction" and "Service/Operation" condition.

3.2 Deflection Criteria

The deflection limitations imposed in IS 456 and IS 800 shall be followed for Concrete and Structural Steel elements respectively.

Vertical Deflection Limits

The deflection of a structure or part thereof shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. The deflection shall be limited to the following.

a) Concrete structures

i. The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the, supports of floors, roofs and all other horizontal members, should not exceed span/250.

ii. The deflection including the effects of temperature, creep and

shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 millimetres whichever is less.

b) Steel structures

Designs shall comply with the limits defined in IS 800.

3.3 Durability

For above-ground and structures the following contents shall be adopted.

(1) The exposure condition for the above-ground structures shall be “severe” as defined in Table 3 of IS :456-2000

(2) The minimum grade of concrete shall be M30

(3) Fire Resistance Period

All the structural elements shall be designed for a minimum fire resistance period of 2 hours. The minimum element thicknesses for this fire resistance shall be as follows.

Sl. No.	Element	Minimum Dimension (mm)
1	RC Slab	125
2	RC Beam	200
3	RC Walls	160
4	RC Columns	300
5	Blockwork Wall	100

(4) Crack Width Check

Crack width in concrete shall be checked in accordance with Appendix F of IS 456-2000.The maximum allowable crack width shall be as given in Table 2.2 above.

3.4 Concrete Sub-Structure

(1) The pile design capacity shall be based on pile end bearing and friction along rock socketed length of pile. The pile design shall conform to IRC 78/ IS 2911 and Notice obtained from the Engineer before commencement of work.

(2) Piles shall be end bearing on hard rock, and as a minimum socketed into hard rock for a depth of 1.5 times the diameter of the piles.

(3) The pile end bearing capacity and rock socket friction capacity in the founding strata shall be verified based on Dynamic loading test (2% of the total number of piles) as specified in the IRC 78 /IS 2911.

(4) The integrity of concrete piles shall be verified by sonic echo test. Sonic tubes shall be installed in all of piles, and the test shall be carried out randomly at one pile per one pier. Test piles will be chosen by the Engineer.

(5) Foundation types shall generally be End bearing pile foundation. Spread foundation shall be permitted if founding stratum is at a shallow depth. Other types of foundation can be proposed to the Engineer by the Contractor for his approval, but no raking pile will be permitted.

(6) The construction method for installation of piles within the inter-tidal zone shall not cause significant disturbance to the mud-flats.

(7) Piles shall be provided with permanent steel liners with corrosion protected coating with a minimum thickness of 6mm.

(8) The liner plate shall be embedded in concrete to at least 50mm from the bottom of the pile cap.

(9) The structural design of the piles shall not rely on any structural capacity contribution from the permanent steel liners in its structural analysis of the piles.

Volume 4

Outline Design Specifications

Section 4

MEP WORKS

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

1 INTRODUCTION

The Project is proposed to decongest Western Express Highway (WEH) in order to reduce travel time, allow bus rapid transport and eventually raise quality of the citizens. The road is planned to also create new public places and redefine western coast line characteristics.

Safety in bridges requires a number of measures relating, amongst other things, to the geometry of the bridges and roads and its design, safety equipment, including road signs, traffic management, training of the emergency services, incident management, the provision of information to users on how best to behave , and better communication between the authorities in charge and emergency services such as the police, fire-brigades and rescue teams.

2 CODES AND STANDARDS

The requirement of E&M services shall be based on best international practices and following codes shall be referred:

- NFPA 502: Standard for Road Bridges, and other limited access highways
- European Directive 2004/EC/54 of the European Parliament and council Members
- United Kingdom: Highway agency standard BD78/99 Design of Road
- Indian Road Congress Code IRC 91

In case of any conflict between requirements, the more onerous one shall be followed and other codes shall be referred in case, all the requirements are not covered in the first code.

The relevant list of Indian standards and International standards are mentioned in the relevant specifications (Standards produced by Bureau of Indian Standards shall always be considered first; in case the above standards are silent on the subject other standards shall be considered). Except where otherwise directed, all materials, workmanship, designs and assessments are to comply with standards mentioned above.

3 SCOPE OF WORK

The following section establishes design criteria of mechanical & electrical systems for Roads and Bridges sections of the project. The basis goal of the design criteria is to develop a safe, reliable, maintainable, energy efficient and economical Mechanical and Electrical system.

The design of M&E services shall meet the following objectives:

- Provides the appropriate level of equipment and operation to contribute towards a safe

environment for road users, local inhabitants, operators, maintenance staff, police and emergency services.

- Reduces Operational Risks.
- Increases Structural and Network resilience.
- Provide adequate visibility levels in all conditions at all times of the day and night;
- Provide emergency response facilities in accordance with operational standards required by the authority;
- Minimize whole life costs;
- Incorporate mitigation measures from risk analysis as per EU directive
- The strategy for design of services shall be to adopt minimum acceptable provisions, with due regard to international best practices.

The Works defined and outlined in this Specification constitutes the proposed M&E Systems Works associated with the installation of Mechanical and Electrical Systems. This Specification establishes the technical standards and quality demands for workmanship and materials of the Works.

The M&E Systems Scope of Works includes the following areas:

- Power Supply System
- Lighting System
- Water Supply and Drainage system
- Communications and Traffic Control
- Operation and Control/ SCADA
- Buildings and Control room
- Maintenance vehicles

This Specification which covers M&E Systems Works is divided into sections, as indicated above, with each section aimed at a specific type of work. The various sections of the Works may thus be dealt with in several areas of this Specification.

The Contractor shall develop the operational strategy, maintenance regimes and procedures for both during the works and for post construction. However it is essential the design provides a high degree of operational flexibility. This will be in the form of an interim Approval in Principle (AIP) and supported by a Risk Analysis identifying the operational risks and proposed mitigation or risk reduction measures. Agreement of the operational strategy and control philosophy should be reached in agreement with the Employer's Engineer.

The plans for maintenance, day to day operation and response to emergencies play a vital part in the development of the detailed design of mechanical and electrical functions. AIP proposals shall, therefore, outline the operating & control procedures on which the equipment will be based. To accompany the M&E AIP submission a detailed control philosophy document shall be produced which will form the basis for the production of

the operational procedures.

4 ELECTRICAL SYSTEM

4.1 Introduction

This document describes the design, supply, manufacture, delivery, erection, operational maintenance, testing and commissioning of the Electrical Systems for the bridges and roads in Project.

A detailed design shall be completed for the whole of the works described in this performance specification, together with coordination with other services and compliance with all Authorities having jurisdiction over the works. This performance specification describes the intent and extent of works and standards of work required.

Reference shall also be made to any commercial documents which may be applicable to these works.

4.2 Extent of Work

The scope covers Design, Supply, installation/erection, operation, maintenance and commissioning of all Mechanical and Electrical equipment required for the efficient and safe operation of the electric supply and distribution system.

The primary design objectives are as follows:

- To ensure that the electrical distribution system meets the requirements of BD78/99, PIARC, EU directive and NFPA.
- To install a secure power system, that has improved versatility to deal with loss of supplies without significant effect on operation.
- To improve flexibility allowing maintenance and fault repairs to be carried out without significant effect on operation.
- To provide Uninterruptible Power Supply (UPS) systems to allow routine maintenance to be carried out safely and effectively.
- To introduce energy saving measures where appropriate.

The design of the power supply system shall be in compliance with the services design objectives listed out in Section 3.

The work covered shall include, but not be limited to the following:

HV Equipment

HV system consists of the followings:

Design, supply and install Receiving Substation, appropriate to the site conditions complete, at

facilities area including all metering, disconnects, circuit breakers, protection and control, main transformer and auxiliary (facilities) transformer.

Overhead Line (OHL) from Receiving Substation to Service/Control buildings including all poles, wires, landings, OHL to U/G transitions, trenches and related equipment.

Design, supply and install sets of dry type transformers located at substations at the Service/Control buildings.

Design, supply and install HT switchgear at the Service/Control buildings.

Design, supply, install and termination of HT cable connecting above mentioned HT switchgear.

Design, supply and install Ring Main Units (RMUs) and dry type transformers.

Design, supply, install and termination of HT cables connecting RMU‘s together and to the HT switchgear.

Design, supply and install lightning protection system to external buildings and areas.

LV Equipment

Design, supply and install power factor correction units and related control systems. Design, supply and install all plant and bridges and roads distribution boards, related control system and telemetry systems

Design, manufacture, factory test, supply, install and commission the emergency diesel generators and related control system and telemetry systems.

Design, supply and install uninterruptible power supply (UPS) units and associated UPS distribution board.

Design, supply and install surge diverters on the main switchboards.

Design and supply Pump-station distribution, motor control and telemetry equipment Design, supply and install surge reduction filters. Design, supply and install harmonic filters

Design, supply, install and terminate consumer mains cables or busbar trunking from the supply authority transformers to the Main Switchboards.

Design, supply, install and terminate sub main cables from switchboards and control panels.

Design, supply, install and terminate all sub-circuit cables from UPS, plant and distribution boards.

Design, supply and install all cable support systems to above cables.

Design, supply and install any additional cable systems that may be required for the operation of the bridges and roads

Lighting and Power

Design, supply and install the bridges and roads lighting.

Design, supply and install the bridges and roads lighting control system.

Design, supply and install the lighting for all services buildings, Pump Stations.

Design, supply and install exit signs and emergency lighting for bridges and roads, passageways and services buildings.

Design, supply, install and relocate street lights.

Design, supply and install miscellaneous power outlets throughout the bridges and roads and services buildings.

Design, supply and install dedicated power outlets and permanent power connection to control equipment, monitoring equipment, instruments and alarm devices throughout the bridges and roads, services buildings and Administration Control, mobile phone rooms, radio re-broadcast rooms and Computer Room.

Design, supply and install all equipment support structures.

4.3 Rules, Regulations and Codes

All works performed under this Contract shall comply with the requirements of the Supply Authority, Local Government and other authorities having jurisdiction over work.

Due to interdependency of IEC/BS bridges and roads related guidelines and specifications and other IEC/BS categories for specifications referenced in those documents, all works performed and equipment supplied under this Contract shall conform in design, material, construction, workmanship and performance to the latest edition of the appropriate British Standards with reference to Indian standards or, if there is no British Standard applicable, with the current relevant International Electro technical Commission (IEC).

Installations and installation materials must conform to relevant Indian regulations.

The following list indicates those standards most relevant to this Contract. It must be noted that standards related to sub-component parts that are not listed below are to be complied with:

BS 159	Specification for high-voltage busbars and busbar connections
BS 5266	Emergency lighting
BS 5308	Instrumentation Cables
BS 5467	Electric cables. Thermosetting insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V
BS 5489	Code of practice for the design of road lighting

BS 5958	Code of practice for control of undesirable static electricity
BS 6134	Specification for pressure and vacuum switches
BS 6346	Electric cables. PVC insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V
BS 6387	maintain circuit integrity under fire conditions
BS 7430	Code of practice for earthing
BS 7671	Requirements for electrical installations
BS EN 12464	Lighting of indoor work places
BS EN 13201	Road lighting
BS EN 50131	Alarm systems - Intrusion and hold-up systems
IEC/BS EN 60439-1:1999	and partially type-tested assemblies.
CIE 88	Guide for the Lighting of Road Tunnels and Underpasses
CISPR 14-1	Electromagnetic compatibility - Requirements for household
IEC 60034	Rotating electrical machines
IEC 60044	Instrument transformers
IEC 60051	and Their Accessories
IEC 60056	High-voltage alternating-current circuit-breakers
IEC 60071	Insulation Coordination
IEC 60076	Power transformers
IEC 60081	Double-capped fluorescent lamps - Performance specifications
IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 61000	Electromagnetic compatibility (EMC)
IEC 60127	Miniature fuses
IEC 60129	Specification for alternating current disconnectors and earthing switches
IEC 60137	Bushings for alternating voltage above 1000 V
IEC 60189	Low-frequency cables and wires with PVC insulation and PVC sheath
IEC 60258	Direct acting recording electrical measuring instruments and their accessories
IEC 60265	High voltage switches
IEC 60269	Low-voltage fuses
IEC 60273	Dimensions of indoor and outdoor post insulators and post insulator units for systems with nominal voltage greater than 1000 V
IEC 60287	Electric cables - Calculation of the current rating
IEC 60298	A.C. Metal-enclosed Switchgear And Control gear For Rated Voltages Above 1 kV And Up To And Including 52 kV
IEC 60335	Household and similar electrical appliances - Safety
IEC 60352	Solderless connections
IEC 60364	Low-voltage electrical installations
IEC 60376	Specification of technical grade sulphur hexafluoride (SF6) for use in electrical equipment
IEC 60423	Conduit systems for cable management - Outside diameters of conduits for electrical installations and threads for conduits and fittings

IEC 60439	Low-voltage switchgear and controlgear assemblies
IEC 60470	High-Voltage Alternating Current Contactors and Contactor-Based Motor-Starters
IEC 60502	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)
IEC 60529	Degrees of protection provided by enclosures(IP code)
IEC 60598	Luminaires - General Requirements and Testing
IEC 60617	Graphical Symbols for Diagrams
IEC 60623	Secondary Cells and Batteries Containing Alkaline or Other Non- Acid Electrolytes - Vented Nickel-Cadmium Prismatic Rechargeable Single Cells
IEC 60662	High-pressure sodium vapour lamps - Performance specifications
IEC 60664	Insulation coordination for equipment within low-voltage systems
IEC 60669	Switches for household and similar fixed-electrical installations
IEC 60896	Stationary lead-acid batteries - General requirements and methods of test
IEC 60921	Ballasts for tubular fluorescent lamps – Performance requirements
IEC 60947	Low-voltage switchgear and control gear
IEC 61131	Programmable controllers
IEC 61386	Conduit systems for cable management
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 61537	Cable management - Cable tray systems and cable ladder systems
IEC 62271-200	High-voltage switchgear and control gear
IEC 62271-100	HV Circuit breakers
IEC 62305	Protection against lightning
IEEE 80	Guide for Safety in AC Substation Grounding
IEEE 802	Standards for Local and Metropolitan Networks
ISO 128	Technical drawings
ISO 1219	Fluid power systems and components - Graphic symbols and circuit diagrams
ISO 1996	Acoustics- Description, measurement and assessment of
	environmental noise
ISO 2063	Thermal spraying -- Metallic and other inorganic coatings -- Zinc, aluminium and their alloys
ISO 3046	Reciprocating internal combustion engines
ISO 10012	Quality assurance requirements for measuring equipment
ISO 11801	Information technology — Generic cabling for customer premises
NEMA ICS 1	General Standards for Industrial Control and Systems
NEMA ICS 2 –230	Components for Solid-State Logic Systems
NEMA ICS 6	Enclosures for Industrial Controls and Systems
	Supply Authority Wiring Rules

4.4 Low Voltage Distribution

Low voltage 400/230 volt supplies shall be distributed throughout the bridges and roads for lighting, controls, monitoring, water supply pumping and other operational requirements.

Distribution panels shall be divided into two sections —normal‘ and —essential‘ with power supply to the —essentialll loads being backed up by the diesel generators located at the service buildings. Uninterruptible power supplies (UPS) shall be provided to supply critical loads. Where UPS are installed they shall be powered from the —essentialll section of the supply busbar so that power supply to the UPS will be backed up by the diesel generators.

4.5 Diesel Generators

Scope

The Contractor shall provide standby diesel generating sets capable of black start, in service building, complete with local control panel, automatic start/stop equipment and fuel supply system.

The generators shall be of sufficient size to each supply the relevant service building and the bridges and roads under emergency conditions and/or a loss of external supply from authority.

Duty and Rating

The diesel generator shall be required to automatically start and load immediately on detection of loss of main supplies. The Contractor shall determine the rating of the generators which shall be based on the emergency load level, the bridges and roads and service buildings in the event that all other supplies to the bridges and roads have failed.

The rated voltage of the generators shall be 400 V, 50 Hz, 0.85 or better power factor lagging, three-phase and neutral.

The diesel generator shall supply any load within its continuous rating at any power factor between unity and 0.85 lagging.

The Contractor shall submit the associated calculations to the Engineer for approval.

Environmental Condition

The generators shall comply with the following environmental design criteria (As per ASHRAE for Mumbai):

Max Temp (summer): (to be confirmed prior to order)

Min Temp (winter): (to be confirmed prior to order)

Height above sea level: (to be confirmed prior to order)

Air density – 1.2 kg/m3

Derating considerations will be submitted by the Contractor (with tender)

Standards and Codes

The generator shall comply with the requirements detailed in the latest revisions of the following standards, where applicable.

IEC 60034	Rotating electrical machines
IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 60529	Degrees of protection provided by enclosures(IP code)
ISO 1996	Acoustics- Description, measurement and assessment of environmental noise
ISO 3046	Reciprocating internal combustion engines

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

Diesel Engine

The diesel engine shall be of the four-cycle, 1,500 rpm, solid injection, water-cooling type with air cooled radiator. The engine shall be suitable for operation on light diesel fuel and give satisfactory performance.

The engine shall be coupled to a 400 volt, 50 Hz, three phase, generator. The engine and alternator shall be direct coupled and mounted on a common bed-plate and the bed-plate shall be isolated from the concrete floor by elastomeric type bearings.

The engine shall comply with ISO 3046, and the governing shall be Class 1. The governor speed droop setting shall be adjustable down to zero.

The generator water cooling system shall be closed circuit systems with radiator cooling. The Contractor shall describe the measures necessary to protect the cooling system from corrosion.

The hot cooling air from the engines and auxiliaries shall be exhausted to the outside of the

building via suitable duct work and fans. Exhaust gases shall not enter the Diesel Generator Room. The exhaust system shall be fitted with a gravity closed flap or other means of preventing the entry of rain and vermin and the nesting of birds whilst the generators are not running.

The ventilation system shall comprise of a supply air filter either natural or fan forced to provide sufficient direct air flow to the generator, when the generator is operating at full load over 24 hours and testing conditions for 110% full load.

Each engine shall be equipped with the following accessories:

- full flow lubricating oil filter
- fuel filters
- air filter
- fuel spill return
- water jacket heater (if required for the environmental conditions)
- exhaust piping and silencer
- temperature high, shutdown switch (adjustable range)
- lubricating oil pressure low, shutdown switch (adjustable range)
- over speed shutdown device
- closed loop water cooling system with heat exchangers
- automatic lubrication oil priming system (if required)
- gauge panel complete with the following:
  - o lubricating oil pressure gauge
  - o lubricating oil temperature gauge o cooling water temperature gauges o tachometer.

The diesel engines shall be suitable for operation on one or more of the grades of fuel and lubricant available from local sources and the Contractor shall nominate the grades required.

Generator

Each generator shall be of the double bearing, screen protected type, flange mounted, drip proof, and self regulating, brushless excitation in accordance with IEC 60034.

The temperature rise of the generators shall comply with the requirements of IEC 60034.

The insulation of the generator stator windings shall be Class F material, to IEC 60085.

Although the generator output will generally be closely balanced between the three phases,

the possibility exists of this balance being upset due to single-phase loads. The generator shall operate satisfactorily when supplying unbalanced loads.

The generator winding shall be star-connected and the neutral shall be solidly earthed to the earthing busbar in the generator distribution board. Each end of the generator winding shall be brought out to separate terminals and they shall be arranged in a terminal box for convenient testing of the separate phases.

The generator shall withstand the mechanical forces at 120% of the rated speed for one minute under the condition of no-load and no-excitation without incurring any damage.

Automatic Voltage Regulator

Regulation of the generator set with its automatic voltage regulator shall be such that, at all loads from zero to rated load, at any power factor between unity and 0.85 lagging, and at rated speed, the terminal voltage is maintained to within ±2% under steady conditions.

The regulation shall also be such that with the generator set rotating under the control of the voltage regulator, the maximum terminal voltage change shall not exceed 10 per cent and the voltage shall be restored to within 3 per cent of 400 V in not more than one second under transient conditions.

The maximum terminal voltage change and the time for restoration to within 3 per cent of 400 V shall be stated and guaranteed by the Contractor.

The automatic voltage regulator shall be of a type not involving continuous pulsing of contacting devices (other than during periods of change) and shall be fitted with an adjusting device which shall permit the regulated voltage level to be adjusted between
+10 per cent and -5 per cent from nominal voltage. This device shall be mounted inside the associated standby generator control cubicle. For a given setting of the voltage adjusting device, the response of the regulator shall be independent of frequency.

Excitation

The Contractor shall provide all necessary equipment for automatically and manually controlling the generator excitation.

The excitation supply shall be preferably from a brushless excitation system but the Contractor may propose alternative excitation systems which satisfy the requirements of this Clause.

The excitation system shall be so arranged that the automatic voltage regulator may

be left in the "ON" position continuously, irrespective of whether the machine is starting up, running or shutting down. Provision shall be made to prevent excessive excitation of the generator during either the starting or stopping periods.

The generator shall be provided with a two stage —temperature highll thermostat; stage 1 for alarm and stage 2 for shutdown. The thermostat shall have an adjustable setting range.

The open-circuit waveform assessed as a telephone harmonic factor shall be within the limits specified in IEC 60034.

Control, Protection, Alarm and Indication Facilities

The diesel generating sets shall be capable of starting automatically and be available for load within 30 seconds of the start signal being given. And also the control of the generators shall always be possible from local control panel.

Manual operation of a generator shall be made locally at the front of the generator control cubicle. The generators will be run at least once a month in this mode to check starting and operation.

The Contractor shall provide and install the floor mounted, metal enclosed, generator control cubicles in the associated Generator Rooms. The cubicle shall contain all control, operation, alarm and indication facilities necessary for the satisfactory operation of the diesel generating set, including the following:

- Excitation and voltage regulation equipment;
- Manual and automatic control equipment;
- Protection and alarm equipment;
- Indicating lights and instruments; and
- Starting equipment.

All indicating instruments and control facilities (excluding voltage control) shall be mounted on the front panel. Controls for the voltage regulator and excitation equipment shall be located inside the cubicle. The generator control cubicles shall comply with IEC 60529 and IP54 and the general requirements.

All generator alarms and abnormalities shall be annunciated locally and shall input to the respective control rooms in the north and south portals as part of the OMCS system.

Protection and alarm relays shall be mounted on with drawable modules within flush- mounted cases located on the front panel of the cubicle. All fuses and terminal blocks shall be located on the side panels within the cubicle and shall be accessible from the rear door of the cubicle.

In the event of heavy fault on the engine or on a generator during operation, the diesel engine generator shall be shut down automatically and locked out to prevent re-start.

Acoustic Treatment

The supply air and exhaust air system shall be acoustically treated to confirm with the acoustic requirements. The acoustic treatment shall be accommodated within the room envelope.

Suitable silencers shall be installed at the inlet point and within the air discharge ducting. The

silencers shall be a weatherproof type, if exposed to the external environment.

Only proven and tested acoustic corrosion resistant enclosures shall be provided.

Refurbished container type enclosures are not acceptable.

The Contractor shall submit a curve giving the calculated sound pressure levels in the vicinity of each standby generator, as a function of frequency (octave bands), and also weighted noise level according to ISO 1996. Actual noise level compliance shall be achieved by the Contractor during the commissioning period.

Electrical Starting System

A complete set of heavy duty long life batteries and battery chargers shall be provided for starting of the generators.

The starter batteries shall be a sealed lead acid type, voltage and minimum ampere- hour capacity as recommended by the generator manufacturer and suitable for the range of ambient temperatures.

The Contractor will propose suitable methods of in-situ battery testing, under load conditions.

The batteries shall be mounted on or next to the generator set in a suitable galvanized metal cradle with vibration isolation. The batteries shall enable the generator set to be cranked continuously for a minimum period of 3 minutes.

The battery charger shall be mounted within the control cubicle. The battery charger input voltage shall be 230 Volt 50Hz single phase fed from the nominated switchboard and the output voltage shall be matched to the battery voltage.
The unit shall provide a constant potential D.C. output and shall compensate for load current and supply voltage fluctuations. The dc.output stability shall be within ±1%.

The charger unit shall be capable of carrying the load and shall be matched to the recommended charging rate of the battery. The charger output shall automatically regulate the trickle (float) and fast (boost) rate depending on the charged state of the battery. The charger shall be self- protecting against overload and short-circuiting of the output.

Fuel Supply System

The fuel supply systems shall comply with relevant Standards and shall include the following:

Daily service tanks for each generator to be provided by the Contractor. The tank shall be complete with a level indicator, pump motor start/stop level switch and fuel level high/low alarm level switch. The tank shall be sized to provide a minimum of 8 hours fuel to the generator based on continuous operation at full load. Heating shall be provided for the daily service tank and lines if required by the environmental conditions and precaution shall be taken to ensure no risk of fire as a result.

Fuel supply lines between the daily service tank and the engine and Fuel spill return between

the engine and the daily service tank shall be provided.

All pipe work shall be of mild steel as per relevant standards.

The Contractor shall provide the first fill of diesel fuel for the daily service tank plus any fuel required for commissioning tests.

Bulk diesel fuel storage tanks and associated pumping equipment and connections to the daily service tank is be specified separately. Refer to bulk diesel fuel storage tank performance specification and associated drawings.

Ancillary Equipment

In addition to any ancillary equipment the Contractor may recommend, the following shall be provided for each standby generator:
Protective guards around exposed rotating parts.
A monorail, fixed to the roof, passing over the engine and generator and a manual hoist of sufficient capacity for handling engine & generator parts for maintenance.

Connections

Power Connections

All connections between the generator and the associated portal building switchboard shall be supplied and installed by the Contractor. The design shall allow for parallel operation of the two generators.

A main earth copper bar shall be installed in the diesel generator room. All earthing and bonding connections between the diesel generator, its auxiliary equipment and the earthing bar shall be supplied and installed by the Contractor

Tests

Tests and Inspections at the Place of Manufacture

Tests of the complete generating set shall be performed in accordance with the relevant Standards and shall include tests under actual load to demonstrate compliance with the Specification. The tests shall include a temperature rise test at rated load.

Tests & Inspections at Site

Tests and inspections on Site shall include:

- Check of mounting, connections etc.
- check of fuel lines, pumps, valves, exhaust system
- insulation resistance of generator windings and circuits
- operation and setting of control and protection devices

- power circuit phasing and rotation
- operation sequences and times for simulated supply failures and restorations
- proof of AVR operation by switching on and off of available loads
- temperature rise test at rated load, with the generator synchronised to the 400 V system
- full load rejection test

Load acceptance test by switching a load equal to the full load of the relevant portal building and nearest cavern transformer onto the unloaded diesel generator.

4.6 UPS and Batteries

General

Uninterruptible Power Supply (UPS) system shall maintain uninterrupted power to equipment continuously and during power failure. Dedicated UPS shall be provided for exit signs, traffic lights and all essential services in the bridges and roads, and service buildings.

UPS shall be provided to supply the following equipment:

- Emergency lighting, exit signs and strobe lights

Computer system including:

- Control centres
- All Remote Control Units
- All sensors and associated control equipment

All traffic control equipment, including:

- Variable message signs
- CCTV and surveillance system
- Advisory signs
- Loop detectors and vehicle height detectors
- All traffic lights
- Motorist emergency telephones
- Public address system

- Radio rebroadcast system
- Diesel generator control interfaces to other switchboards
- Building access control

UPS shall be installed at 2 control centres. The rating of the different UPS shall be sufficient to supply the connected loads for the specified backup period. The UPS for the emergency and exit sign lighting shall ensure uninterrupted power supply for a minimum period of 2 hours. The essential services UPS shall ensure uninterrupted power supply for a minimum period of 30 minutes.

The UPS system shall consist of a single UPS module or the appropriate number of UPS modules connected in parallel for operation in capacity or N+n redundancy mode. The UPS modules shall be located within a fully enclosed, free standing, system cabinet which shall contain automatic parallel connection terminals, communication cables, individual module isolators, input/output power terminals and an integral wrap around maintenance bypass switch.

For a parallel configurations single points of failure shall be eliminated whereby each UPS module is autonomous, incorporating individual active components such as Power Units, Static Bypass Switches, CPU‘s, Control Panels and Separate Battery Sets. All UPS modules shall operate simultaneously and equally share the load without utilising a centralised static bypass switch or system control module.

The static type UPS shall consist of the following components:

- 6 pulse rectifier/charger
- Static inverter
- Internal automatic bypass
- Microprocessor controlled logic and control panel with status indicators
- Digital metering display
- RS232/485 interface port
- UPS cabinet
- Input and battery circuit breaker
- Sealed maintenance free batteries
- Battery cabinet or stands
- DC cabling between UPS and batteries
- DC isolator
- External maintenance bypass switch, wall mounted enclosure

- AC cabling between UPS output and maintenance bypass switch
- Control cable to maintenance bypass switch (status indication)

Standards and Codes

The UPS and batteries shall comply with the requirements detailed in the latest revisions of the following standards, where applicable.

IEC 60950-1 Information technology equipment – Safety – Part 1: General requirements	IEC 60950-1 Information technology equipment – Safety – Part 1: General requirements
IEC 62040-1	Uninterruptible power systems (UPS) – Part1: General and safety requirements for UPS
IEC 62040-2	Uninterruptible power systems (UPS) – Part2: Electromagnetic Compatibility (EMC) Requirements.
IEC 62040-3	Uninterruptible power systems (UPS) – Part 3: Method of specifying the performance and test requirements.
EN 61000	Electromagnetic Compatibility Standard (EMC)
BS 6290-2	Lead-acid stationary cells and batteries. Specification for the high-performance positive type

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

UPS Ratings

The full connected load shall be a maximum of 80% of overall UPS rating at a power factor of 0.9. UPS shall be capable of starting up the connected load solely on the supply from the inverter. This is to allow for peak inrush currents associated with the switching of certain types of lamps from cold start.

The ratings of the UPS system shall be a minimum of:

- 00kVA with 30 minutes backup for the South and north control rooms
- 150kVA with 30 minute backup for electrical niches

- 10kVA with 2 hours backup for each emergency egress cuddy

UPS System Input

Nominal input voltage shall be 400V ac, 50 Hz, three phase, 4-wire plus earth. Operating input voltage range shall be +10% continuously to -20% of average nominal input voltage. Frequency range shall be ±1 Hz.

UPS module shall have a minimum power factor of 0.9 lagging at full load and nominal input voltage and frequency. UPS module input and output current total harmonic distortion (THD) shall be no greater than 5% at full load and nominal input voltage and frequency. Magnetising inrush current of the UPS module shall be limited to no more than 800% of the full load rectifier input current.

UPS System Output

Nominal output voltage shall be 400V ac, 50Hz, three-phase, 4-wire plus earth. Steady state voltage regulation shall be within ±1% of the average of the nominal output voltage.

Manual output voltage adjustment shall be ± 5% of the nominal output voltage.

Transient voltage response of the UPS output shall be within ±3% of the nominal output voltage for a 100% load step, full load retransfers and full load transfer to battery supply.

The transient voltage recovery time for the UPS module shall be no more than 5 mS to within ±2% of the nominal output voltage.

UPS output shall remain synchronised with the input voltage over an input frequency range of ± 1.0 hertz.

The free running frequency regulation shall be ±1.0% hertz

The frequency slew rate of the inverter shall be no more than 0.1 hertz/second.

UPS shall have an output voltage harmonic distortion of less than 5% THD (2% for any single harmonic) for 100% linear load, typically 10% THD at 100% non-linear load.

While maintaining voltage regulation the UPS shall have an overload current capacity of 150% for battery duration specified with normal input voltage and fully charged battery.

UPS module shall have a fault clearing capacity of 200% for 10 cycles.

UPS module shall have a make before break static switch transfer completed in less than 2 m/sec.

UPS shall be capable of supplying full rated load power into a linear and nonlinear load.

Protection shall be provided against:

- Over current

- Over voltage
- Over heating

UPS Batteries

The battery type shall be maintenance-free vent regulated sealed suitable to the heavy discharge requirements of a UPS system. Batteries shall have a guaranteed life expectancy of at least 5 years. The final minimum discharge cell voltage at full UPS load shall be limited to 1.66 V. Nominal battery float voltage shall be 2.25 V per cell. All necessary battery mounting corrosion resist frames or corrosion resist cubicles to accommodate the batteries shall be provided.

For single UPS modules the battery system shall consist of a minimum of 2 parallel strings of multiple cells. Each individual parallel string shall have its own dedicated means of electrical protection. For multiple UPS module connected in parallel the battery system shall comprise of a separate battery set for each individual UPS module. Each separate battery set may consist of one protected string of multiple cells. If two or more parallel strings are used then each individual string shall have its own dedicated means of electrical circuit protection.

The battery shall have adequate capacity to allow the UPS module to operate at full load unity power factor for a minimum period of 2 hours for emergency lighting and 30 minutes for control equipment. Battery charging current shall be limited to prevent battery overcharging. Battery shall be recharged to 90% of capacity within 10 times the actual discharge time. The batteries shall be series connected to get the required dc voltage and shall be insulated from earth and any supply conductor and shall be protected at its source.

UPS Static Bypass Switch

UPS module shall contain a fully rated, high speed solid state transfer device. UPS module shall initiate an automatic uninterrupted transfer to bypass for the following conditions:

- Output overload period
- Critical bus voltage out of limits
- Over temperature period

Provision for uninterrupted manual transfer from UPS module to bypass supply shall be available from the UPS control panel. UPS module shall be capable of performing an automatic uninterrupted retransfer whenever the inverter is able to assume the load. UPS module shall inhibit automatic uninterrupted retransfers for the following conditions:

When transfer to bypass is activated manually. UPS module failure.

All static bypass switch transfers and retransfers shall be inhibited for the following conditions:

- Bypass voltage out of limits (±10% of nominal).
- Bypass frequency out of limits (±1 Hz).

- Bypass out of synchronisation.
- Bypass phase rotation/installation error

The bypass shall be manually energised using the control panel or remotely through a building alarm input.

UPS Control

UPS module shall have full automatic control through the use of microprocessor controlled logic. Start up and transfer functions of the UPS module shall be an automatic function.

UPS module shall include the following status indicators on the panel and shall be extended to the control centre OMCS SCADA for monitoring:

- System Normal (green)
- Alarm (red)
- Low Battery (red)
- Battery Discharge (red)
- Output Overload (red)
- Sync Loss (red)
- AC Input Failure (red)
- Over temperature (red)
- Shutdown Imminent (red)
- On Bypass (red)
- Inverter Failure (red)
- Battery Fault (red)

UPS module shall have a single on/off control and alarm contacts for any abnormal condition detected. UPS shall have a serial interface to the SCADA system located at the control centres for status and condition monitoring. UPS module shall have digital panel meters capable of displaying the following and a serial communication facility for sending information:

- AC input voltage
- AC input current
- AC input frequency
- DC battery voltage
- DC battery current
- AC inverter output voltage
- AC inverter frequency
- AC load current.

UPS Mechanical Design

UPS shall be housed in freestanding sheet metal cubicles and the batteries shall be housed in freestanding corrosion resist cubicles or stands.

Refer to section 0of the specification on control panel construction for details of cubicle construction and size. UPS shall be designed with forced air cooling.

UPS and battery cubicle shall have non-removable warning plates indicating that hazardous AC and DC voltages are present. Rating plate(s) shall be permanently attached to the front of the cubicle. All major subassemblies shall be modular and replaceable from the front or the top of the cubicle. Provide sufficient room for cable entry and termination within cubicle.

Environmental Conditions

The UPS system shall be designed to operate continuously at full load without degradation of its reliability, operating characteristics or service life in the following environmental conditions:

- UPS ambient temperature range 0°C to 40°C
- Battery ambient temperature range 20°C to 25°C
- Relative Humidity 5 to 95% non-condensing allowed

The UPS system shall be designed for operation in altitudes up to 3000m without the need for derating or reduction of the above environmental operating temperatures.

4.7 Surge diverters and Surge reduction filters

General

Surge reduction filters and surge diverters shall design to protect electrical apparatus from high transient voltage and to limit the duration and frequently the amplitude of follow-current. The surge diverters and surge reduction filters also shall comprise coordinated protection against transients caused by lightning strikes, power switching, standby generator switching, capacitor switching and load switching.

Surge Diverters

Surge diverters shall be provided for all main switchboards primary protection. The surge diverters shall protect low voltage switchgear, control equipment, and downstream surge reduction filter.

Surge Reduction Filters

Surge reduction filter shall be provided for all control and monitoring system connected distribution boards. The surge reduction filter shall protect electronic apparatus, including computers and communications equipment.

Standards and Codes

The surge reduction filters and surge diverters shall comply with the requirements detailed in the latest revisions of the following standards, where applicable.

IEC 61643-1	Surge protection devices connected to low-voltage power distribution systems.
IEC 61000	Electromagnetic Compatibility Standard (EMC)
IEC 60099	Surge arresters
IEC 62308	Protection against Lightning

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

Performance

Current rating shall be determined by the Contractor and characteristics shall be similar to the nominated value.

Surge Diverter

Line protected	3 phases to earth
Operating voltage	230V, 50Hz
Maximum line voltage	275V, 50Hz
Protection modes	Transverse and common mode on the bus bar of the main switchboard
Impulse rating	Single pulse : 70kA
	5 pulses: 40kA
	10 pulses: 25kA
Residual voltage level	Category C: 10kA 8/20 microseconds > 1000V < 1500V
	Category D: 70kA 8/20 microseconds
MOV failure indication	Individual LED
MOV failure alarm signal	24V DC, 1A change over contacts

Surge Reduction Filter Performance

No. of phases	3
Rated mains voltage and frequency	230V, 50Hz
Voltage drop at rated current	<3V
Efficiency	99%
Crest factor	3:1
Protection modes	Common mode and transverse
Impulse rating Category – A, B, C	Single pulse: 100kA 5 pulses: 70kA 10 pulses: 35kA
Residual voltage level Category – B	6kV, 1.5/50 microseconds < 150V 3kA, 8/20 microseconds < 150V
Frequency response -3dB	< 1kHz
MOV failure alarm signal	24V DC, 1A change over contacts
MOV failure indication	Individual LED
MOV protection	Fuse
Capacitor protection	Fuse
Provide alarm input to residual current device (RCD)	

4.8 Distribution Panels

Scope

Distribution Panels (DP) shall be provided in the bridges and roads and the service buildings (LV Switch rooms). Panels and associated components shall comply with all relevant standards and shall be fully type tested.

Panels shall provide power distribution for bridges and roads and room lighting, small power, control and monitoring equipment and emergency power.

Standards and Codes

The distribution panels shall comply with the requirements detailed in the latest revisions of the following standards, where applicable.

IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 60364	Low-voltage electrical installations
IEC 60439	Low-voltage switchgear and control gear assemblies
IEC 60529	Degrees of protection provided by enclosures(IP code)

IEC 60947	Low-voltage switchgear and control gear

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

General

DPs in the bridges and roads are provided in bridges and roads niches at 300m intervals along the bridges and roads. Two (2) to three (3) panels shall be provided at each niche. These niches are generally set back so that the panel front is at minimum flush with the walkway. The depth of the panels shall be minimum 600mm.

DPs shall be surface mounted so that the top of the panels are all 2000mm above the finished floor. Cable recesses shall be provided below, and corrosion proof cable tray overhead.

DPs shall be fitted with circuit breakers, centre mounted, main switches, 3 phase busbars, contactors, and equipment as necessary to complete the installation. The panels shall be completely physically segregated into non-essential, essential and emergency sections.

Panels shall be the totally enclosed type, constructed from corrosion resistant stainless steel 316 and shall be suitably stiffened. The hinged front door shall have stainless steel front handle and be heavy duty key lockable with and a smooth finish non-flammable gasket for a continuous seal. All panels shall be keyed the same and shall be fitted with a three point locking system.

Gland plate shall be 6mm Brass with neoprene gasket.

All nuts, bolts, washers and spring" washers, if any, used in the assembly of components and cubicles shall be of adequate size for the duty required and shall be corrosion resistant stainless steel.

Door and gland-plate shall be earthed by flexible —earth cable minimum CSA 10mm sq

DPs shall be minimum IP65 rated in the bridges and roads and IP42 rated in plant areas.

Stainless steel escutcheon plates cut to expose circuit breaker toggles shall be fitted over all circuit breakers. The escutcheon plates shall be fitted with stainless steel lifting handles.

Push buttons, selection switches and indicator lights shall be mounted onto a hinged

escutcheon plate in a separate compartment.

Pilot devices shall be standard 22mm single mounting hole, to client Engineers approval.

Pilot light and shall contain; High intensity, wide angle full Voltage LED cluster bulb with BA9 fitting.

Lighting contactors shall be electrical release latching type.

The DP shall have at least one spare 20A single phase circuit breaker with additional spare spaces. For bridges and roads DPs spare capacity shall be the greater of either
10% or 3 spare spaces. For plant area DPs spare capacity shall be the greater of either 20% or 6 spare spaces.

The circuit breakers, main switches and contactors shall be monitored for ON/OFF status by the local Remote Control Unit (RCU). Doors shall be monitored for OPEN/CLOSED status.

All control devices shall be mounted in a separate compartment. Control and monitoring alarm cables shall be connected to terminal strips.

The cable zone within the panel shall be sufficient in size to accommodate cable radius bends and cable loading with 50% spare.

A typed circuit gauge schedule heavy gauge, Perspex covered card shall be securely fixed to the inside door of each DP. The circuit schedule shall show the following information:

- Circuit Number
- Rating of Circuit Breaker
- Size of Cable
- Description of Circuit
- Location of Circuit

Alternate DPs shall be supplied from different main switchboards A and B.

The DPs shall be designed and constructed to withstand nominal fault of 6kA for 0.1 seconds. The Contractor shall verify themselves the fault level through calculations and provide the protection as required accordingly.

DPs which supply the Control Centres and associated equipment shall be protected by main line surge reduction filter.

Busbars for DP's

The main vertical bars and the busbar links from the load side of the main control circuit breaker shall design to withstand 18kA for 1 second. The Contractor shall verify themselves the fault level through calculations and provide the protection as required accordingly.

Circuit Breakers for DP's

Moulded case Circuit Breakers (CB) shall be of approved manufacture, suitable for the specified fault rating and each shall be flush mounted behind an escutcheon. Allow for pole fillers in all spare spaces.

CB shall be of the thermal magnetic, approved compact type and shall fully comply with relevant standards (refer to clause 9.2 table). Moulded enclosing case should be designed for front connection of conductors and suitable for mounting on panels incorporated in a sheet metal enclosure.

The main control CB or switch shall be located at the top of each compartment of the DP.

The following features are to be incorporated:

- Arc interrupting device
- Toggle action quick make and break with lockable rotary handle where operation is external to enclosure
- Operate in any position
- Inverse time limit characteristics
- Trip-free handle
- Visual indication when in tripped position
- Contact to be non-welding
- Mechanism to be non tamperable
- Uniformity of style and construction in all sizes (three pole units interchangeable with three single pole units).
- Thermal magnetic tripping mechanism

For miniature circuit breakers (i.e. up to 6kA min. rupturing capacity), toggle tripping to the —off‖ position is acceptable in lieu of —Visual indication when in tripped position—.

Earth leakage circuit breakers shall have a 30mA trip and be in accordance with relevant standards (refer to clause 9.2 table). Earth leakage circuit breakers shall be no larger than two pole spaces and be able to be installed on the busbar chassis without enclosure modification.

4.9 Other electrical service requirements

Standards and Codes

The electrical services shall comply with the requirements detailed in the latest

revisions of the following standards, where applicable.

IEC 60034	Rotating electrical machines
IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 60470	High-Voltage Alternating Current Contactors and Contactor-Based Motor-Starters
IEC 60529	Degrees of protection provided by enclosures(IP code)
IEC 60947	Low-voltage switchgear and control gear
BS 546	Domestic AC power plugs and sockets

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

Power Outlets

Introduction

The following minimum level of Power Outlets shall be provided:

	GPO5A	**Single Phase 5A**	**Three Phase 15A**	
Fan Rooms		2	1	Emergency Supply
Control Equipment Room		2		Emergency Supply
Control Rooms		2		Emergency Supply
Training and Incident Management		2		Emergency Supply
Archives Stores		1		Normal Supply
Offices		1		Normal Supply
Staff Room and Kitchen		2		Normal Supply
Showers/WC		2		Normal Supply
HVACs		2	1	Emergency Supply
33/11 kV Transformer Rooms		2		Emergency Supply
33 kV Switchgear Rooms		2		Emergency Supply

Maintenance Rooms		6	1	Emergency Supply
DG Rooms		2		Emergency Supply
DG Stores		1		Emergency Supply
11 kV Switchgear and Motor Storage Rooms		2		Emergency Supply
Transfer Rooms		2		Emergency Supply
LV Rooms		2		Emergency Supply
UPS Rooms		1		Emergency Supply
Battery Rooms		1		Emergency Supply
Pump Room / Equipment Room		2	1	Emergency Supply
Electrical Pump Station Niches 1-6		2		Emergency Supply
WSC		2	1	Emergency Supply
Egress Cuddies 1-18 UPS and Battery Rooms		1		Emergency Supply
Egress Cuddies 1-18 Corridor		1		Emergency Supply
Bridges and roads Distribution Boards	1			Emergency Supply
All other rooms and corridors (every 10 m)	1			Normal Supply

*For Pump Room areas, a Class 1, Zone 1 gas II T6 5A single phase power outlet shall be provided.

Power connections to all electrical equipment shall be provided with the appropriate suitably rated power outlets and isolation switch.

All computer, monitoring, alarm control equipment and racks with plug tops shall have a suitably rated dedicated power outlet which is connected to the UPS emergency supply.

All power outlets shall be IP56 combination type, 5A single phase or 63A three phase.

General Purpose Outlets

Standard General Purpose Outlets shall be 5A IA6A3 type D single pole switch, with 3 pin receptacle and the flush combination type for 15A type M. Mouldings shall be impact resistant plastic coloured differently for normal supply, emergency supply and UPS supply in accordance with relevant standards. GPOs will be mounted into a recess wall box or within the escutcheon plate of the DP.

Single Phase Power Outlets

Single phase power outlets shall be industrial surface mounted combination switch socket outlet and have a minimum rating of 5A single pole with 3 pin receptacle and flap lid with

safety interlock to prevent lid from being opened if switch is on. Outlet shall be complete with screw ring for holding plug top in position. Moulding shall be high impact polycarbonate IP56.

Three Phase Power Outlets

The three phase power outlet shall be rated to suit the connected equipment rating and shall be a 5 pin high impact polycarbonate weatherproof IP 56, surface mounted with flap lid and safety interlock and shall be complete with screw ring for holding plug top in position.

The connecting equipment shall be fitted with a plug top suitable to the power outlet.

Permanent Connected Equipment

All Permanent Connected Equipment shall have dedicated isolation switches, suitably rated for the equipment, location and function, complying with the relevant standards.

The isolation switches shall be of the impact polycarbonate weatherproof, IP56 rated and surface mounted type.

Junction Boxes

All junction boxes shall have a minimum enclosure rating of IP 56D to IEC60529 and shall be fitted with terminals.

Access Control Systems

General

A security and access system shall consist of a centralised control system for access and monitoring alarms and shall be provided to the buildings and bridges and roads equipment locations.

The features of the system shall include:

- 10% spare terminal inputs for future access inputs and alarms with a minimum of two inputs
- Programmable system
- Manual and automatic isolation of individual areas and field devices
- Report logging and retrieval facilities
- Setup for prioritised alarm handling
- Online data base
- Keyboard coding facility
- Inputs shall include:

- Reed switches
- Status indicators, i.e. door locked or unlocked
- Motion detectors
- Keypad access for external doors
- Tamper switches shall be installed on the following:
- Data gathering panels
- Junction boxes and marshalling cubicles
- Card readers
- Detectors
- Siren enclosures
- Panel enclosures

Access Reader

Access reader shall be interfaced with electro-magnetic door locks. Security door shall only open when the access reader acknowledges an input or the when the opposite side of the door handle is operated. All external keypad readers shall be vandal resistant and weatherproof (IP66). Reader shall have fully operational LED indication and buzzer.

Reed Switches

Reed switches shall be concealed or surface arrangement type with the concealed type used on single and double leaf doors. The switches shall be press fitted into recess in the door and door frame. The switch shall be mounted in a box recessed into the door frame head only. The magnet to operate the switch shall be concealed by recessing into the door head. Reed switch and associated conduits shall not be surface mounted.

Motion Detectors

Motion detectors shall be a dual technology installed on walls or ceilings. Wall mounted type shall be a Wormald Dualtec motion sensor DT-4405 with swivel mount or similar. Ceiling mounted detectors shall be a Intelli-Sense motion sensor 5030 or similar. Detectors shall be located so as to minimise false alarm generation and shall not be directed or mounted in such a manner as to be affected by air vents, heating equipment etc.

Motors Specifications

All motors shall be in accordance with IEC 60034 and suitable for continuous running duty. The starting current at full voltage shall not exceed six times full load current. Motors larger than 0.37 kW shall be of three-phase type. Motors smaller than 7.5 kW shall be suitable for direct-on-line starting. Motors 7.5 kW and above shall be provided with soft start or VSD

facilities unless specified otherwise.

Motor rated outputs shall be at least 10% in excess of the continuous maximum power required by the respective driven equipment.

Materials and workmanship shall be of the highest quality. All motors shall in all respects be suitable for operation in the extreme site conditions.

Motors and auxiliary equipment shall be designed and manufactured such that no abnormal wear and no dangerous vibration can occur which will affect the steady operation of the complete set.

Operating Conditions

Direct-on-line starting of A.C. motors with the driven equipment connected shall be possible when, at rated frequency, the voltage at the motor terminals is not less than
85% of rated voltage.

A.C. motors shall be capable of operation for up to fifteen seconds under running conditions at rated load and frequency with a minimum of 70% of rated voltage at the motor terminals.

Unless otherwise required by the driven equipment, two consecutive starts from motor warm condition and three consecutive starts from motor cold condition, both with subsequent steady continuous operation for 20 minutes, shall be guaranteed without exceeding the specified temperature rise limit.

A.C. motors shall be capable of withstanding, without damage, unsynchronised automatic transfer of power supply with motor residual voltage of 100% and of 180 degree phase difference from the source voltage.

Motor insulation shall correspond to Class F.

Motors shall not suffer any damage when subjected to 120% nominal speed for

2 minutes. Motors will be subjected to significant frequency rises following generator load rejection. Motors shall be protected from damage in this event. Protection which trips the motor on overspeed and restores it to service when the speed falls will be accepted.

Degree of Protection

With the exception of the submersible motors of drainage pumps and motors to be used outdoors exposed to the weather, all other a.c. and d.c. motors shall have degree of protection IP 54 to IEC 60034. Openings of motors shall be effectively screened against ingress of vermin. Submersible motors for drainage pumps shall have degree of protection IP 57. Motors to be used outdoors exposed to the weather shall have degree of protection IP 54 and shall be equipped with heaters which shall maintain the temperature of the motors approximately 5°C above ambient. The heaters shall operate continuously when the motor is not running.

Thermal Protection

Motors larger than 0.37 kW shall be supplied from separate circuits which are provided with overcurrent protection. In addition to thermal protection, motors of rating 20 kW and above shall be fitted with embedded thermistors for thermal protection.

Motors 55kW and larger shall be fitted with approved multifunction protection relays

Grease Nipples

Where ball and roller bearing housings are fitted with grease nipples they shall incorporate an approved grease escape valve.

Terminal Box

The terminal box shall be weather and vermin proof and firmly fixed to the motor frame. The terminal studs shall be sized to be adequate for the current duty required and marked in accordance with IEC 60034 where applicable. All terminal boxes shall have approved cable adaptor plates, sealing chambers or conduit entries.

The arrangement of the terminal box shall be such as to facilitate installation of cables, and allow interchanging of any two phase leads, without disturbing the sealing compound, if this is used at cable terminations.

Contactors and Motor Starters

Specifications

The rated voltage, current and duty of contactors and motor starters shall be appropriate to the service conditions.

Starters and contactors shall comply with IEC 60947 and IEC 60470 and be suitable for continuous electrical duty and for direct on-line or soft starting as applicable. The utilisation category shall be not less than AC-3 IEC 60947 or IEC 60470 direct on- reversing as applicable. The utilisation category shall be not less than AC-4 IEC 60947 or IEC

Enclosure

Individual enclosures with degree of protection not less than IP 42 to IEC 60529 shall be provided for all contactors and motor starters, including those within cubicles.

Contactors

At any voltage at which pick-up occurs contactors shall close completely.

With 70 per cent voltage at the coil terminals, contactor main contacts shall not chatter nor part when the locked-rotor current is being conducted.

Latching contactors shall have a mechanical latching mechanism which is positive in operation under all conditions of service and with operating coil voltage range of 80% and 110% and trip coil voltage range from 50% to 110%. If both coils are energised at the same time the contactor shall trip.

Latching contactors shall not exceed the temperature rise limits specified when the coils are energised at rated voltage for 30 seconds.

Motor Protection

Motor starting equipment for ac motors shall include the following protection with ambient temperature compensation:

For motors under 20 kW rating - thermal overload relay with single-phasing detection fitted to each phase.

For motors above 20 kW rating - embedded thermistor protection and thermal overload relay with single-phasing detection fitted to each phase.

Motors with embedded thermistor protection shall have two sets of thermistors installed – one set to be used for protection and the other set spare.

Ammeters

Ammeters, to read current in one phase, shall be provided for all motors over 0.75 kW.

Running Hour Meters

Running hour counters shall be provided for all pump and compressor motors.

Motor Starters

General

Each of the motor starters where multiple units are required shall be of modular construction forming a functional unit as defined by IEC 60439 Form 3b, such that access to all components is safely available 'With the adjacent starter energised.

The line isolators shall be capable of Fault make and breaking stalled motor current, shall be externally operated, shall have mechanical "ON-OFF" indication, shall have facilities for padlocking in the "OFF" position, shall be pad-lockable without additional fittings and shall be interlocked such that the cell door can only be opened in the "OFF" position.

The line isolator shall be a moulded case circuit breaker suitable for motor starting use. Line

and control fuses where specified shall be HRC type complying with BS88

Contactors for motor operation shall be in accordance with IEC 947 category AC 3 with a minimum of 1,000,000 operating cycles. All contactors shall be magnetically operated and held, double break contacts. All contactors shall be fitted with arc chutes and shall be suitable for use with a single phase 240v ac control.

Thermal overload relays shall be triple pole, with single phasing protection. The reset buttons shall be flush mounted on the cell doors.

Where a PTC is provided on motor, a thermistor tripping relay for PTC thermal sensors shall be provided to operate when the resistance of anyone of the three (3) sensing devices embedded reaches 1000 ohms. The relay shall be fitted with a manual reset pushbutton accessible from outside the cubicle. A mechanical type reset mechanism shall be used.

All motors over 7.5 kW shall be connected to electronic soft starters or Variable Speed Drive (VSD‘s).

Motor Control Cell (functional unit)

Each motor starter shall have the following equipment:

Triple pole, load-breaking, fully interlocked isolating switch with two auxiliary contacts, arranged for pad locking in the "off" position.

Triple pole air break contactor/s of the electrically held type with contactor/s coil suitable for 240V ac, for DOL starting or for isolation and bypass during running of a soft start drive where these are required.

Control circuit facilities: For starters above 20kW excluding variable frequency drives, three number current transformers with suitable ratio, output and accuracy for motor protection, and matching electronic thermal motor protection relay. Variable frequency drives shall incorporate these features.

For starters below 20kW one direct connected thermal overload relay. Control relays (including auto start relay) as required.

Hours run meter.
72mm dial flush mounted ammeter (Or approved electronic relay embedded equivalent).

One set of start and stop pushes buttons (Or approved electronic relay embedded equivalent)...

Local/off/remote control selector switch lockable in each position. (Or approved electronic relay embedded equivalent).

Set of indication lamps for running, off and tripped on fault (Or approved electronic relay embedded equivalent).

Lamp test push button (Or approved electronic relay embedded equivalent)... Manual/off/auto

control selector switch.

Reversing starters, shall comply with direct-on-line starters as above with additional

2 main line reversing contactor rated AC4, mechanically and electrically interlocked to prevent simultaneous closure.

Time delay relay with nominal 0 - 30 s adjustable time delay, to prevent plugging of the

motor.

Reversing starters, shall comply soft starters as for motor starter with additional

Reduced voltage starters shall be of the soft starters type complying with AS 1202.2 and AS 1202.3 or equivalent.

Soft start (initially start motors on low speed). Adjustable maximum current limit.

Radio frequency suppression, external and self induced harmonic and line transient filtering.

Automatic reset of system after removal of fault or power failure condition.

Ability to immediately restart a motor following momentary interruption of supply, even if the motor is rotating.

Main line contacts.

Motor Protection

Provide over-current protection as part of the equipment assembly for each motor starter.

Provide thermal overload protection relays to ~~AS 1023.2 or AS 3~~IEC 60947.~~4.1.~~

For 3 phase operation provide triple pole relays with differential trip bar operation for single phase protection, and ambient temperature compensation. Provide the following:

One normally-open and one normally-closed set of auxiliary contacts with minimum operational current of 4 A at 240 V ac,

Thermal overloads connected directly to contactor using proprietary links, except where operated separately by currently transformers.

Current transformers to operate protection type thermal overloads, saturating at 10-15 x full load current, Class lOP.

Provide thermal overload protection relays for each 3 phase motor, or select one of the following:

- Thermistor overload relay with thermal overload relay, for small kW motors.
- Programmable electronic motor protection relay.

Motor Speed Controllers

Provide motor speed controllers of the Variable Voltage Variable frequency drive

(VVVF) starter‘s type for all axial ventilation building fans of microprocessor design in accordance with IEC 60947or equivalent. The VVVF shall be a solid state electronic type, motor speed control of 3 phase squirrel cage induction motors suitable for the load duties,

by means of variable frequency, step less sine wave output. Ensure stable operation under the following operating temperatures:

Full load: 50° C (maximum) ambient for continuous full load operation. Normal range: -10 to + 50°C.

Select to suit full load current stated on motor nameplate. Provide facilities for local display and control, including:

- Indication of run condition, motor speed or output frequency, input control parameters, output voltage, and alarm conditions.
- Light emitting diode indication of power on, zero speed, enable, earth fault, short circuit, overcurrent, under voltage, over temperature and remote trip.
- Facilities for automatic/off/manual control.
- Local and remote analogue/digital input, to control frequency output of controller when in local manual or remote automatic or manual mode; and
- For remote control, interfaces for analogue/digital input and output associated with speed control, start/stop, and voltage free contacts for common alarm fault indication.

Include protection against the following and provide a common alarm for wiring to the local RCU:

- Instantaneous power failure.
- Overload.
- Instantaneous over current.
- Under and over voltage.
- Single phasing protection and phase sequence protection.
- Thermal overload motor protection with volt free retention of thermal model.
- Loss of load protection.
- Excessive motor run-up and stall protection.
- Earth fault protection.
- Adjustable settings of protection parameters: LED indication of fault conditions.
- Manual reset.
- One normally-open and one normally-closed set of auxiliary contacts with minimum current rating of 4 A at 240 V ac.
- Facilities for relay testing.
- Suitable harmonics filters

- Provide electronic motor protection relays to IEC 60947or AS 3947or equivalent with the following characteristics: This requirement is intended for motor protection and may be additional to the inherent drive protection.
- Resistance Temperature Detectors (RTD) for front and rear bearing temperature
- RTDs for motor windings
- RTDs for motor cooling output duct

Emergency Lock-Off Stations

Provide a "lock-stop" station within one metre of each motor throughout the plant.

The "lock-stop" station shall include a 54mm diameter heavy duty emergency stop button incorporating "Pull to Reset". It shall feature a mushroom head and be provided with padlocking facilities. The emergency stop buttons shall be mounted in a heavy duty aluminium enclosure rated to IP 65D.

If no supporting structure is available for mounting the stop station adjacent to the respective motor, the Contractor shall supply and install a prior approved switch stand for the mounting of the stop button. Where wiring is via in pour conduits, the switch stand shall be constructed of 100 square mm RHS (Round Hollow Steel) steel post
900mm high, with gusseted mounting base, enclosed top, rear mounted gland plate for wiring to other control and protection devices. The switch stand shall be hot dip galvanised after fabrication.
Motor Isolator

A normally closed motor isolator switch shall be provided. This switch shall be connected with the control circuits in such a way that operation of the switch shall prevent any of the contactors closing and thereby energising the motor. If the unit is running and the motor isolate switch is operational the unit shall stop immediately.

The control circuit shall latch out following operation of the motor isolator switch until the control selector switch is returned to the —OFF/RESET‖ position.
An indicator light shall be provided to indicate operation of the motor isolator switch. This

indicator light shall be labelled "Motor Isolator Switch Operated".

4.10 Earthing System

General

Contractor shall provide an earthing system for the bridges and roads and other related buildings complying with IEEE 80:2000 and IEC standard: Electrical installations of

buildings, meeting the required touch and step potential criteria.

- Earthing system shall be provided to the following:
- All exposed metal parts forming part of this installation.
- Metal conduits, frames, cable trays, trunking, metal pipes, steel hand rails and ducts.
- Cable sheaths and armouring.
- All HV and LV electrical equipment and switchboards.
- All neutral terminals of transformers 11/0.4kV and two standby diesel generators at two portals shall be connected to the main earth electrode.

The bridges and roads earthing system shall also be interconnected with the earth grids at the AUTHORITY substations.

Main Earth Electrode

Main earth electrode shall be provided by laying a continuous length of 95 mm^2 bare, tinned-copper stranded conductor in the base of the road 0.5m below the bituminous concrete and macadam surface, both side of the road.

Both 95 mm^2 main copper conductors shall be connected each other at 100m intervals by exothermic joints.

The main earth electrode shall be connected to the reinforcement of the bridges at approximately 100 m interval along the length.

Copper earth raisers with not less than 95mm^2, from main earth electrode shall be provided at each distribution transformers which are 300m apart. The transformer and switchgear shall be connected by these earth raisers to the earthing system

All joints shall be brazed, cleaned after brazing and bitumen coated after cleaning, to avoid corrosion.

Earth Electrodes of Substations and Electrical Niches

Main earth Electrode shall be embedded in concrete, 0.5m below the finished surface in electrical niches, water storage cavern electrical niches, and electrical equipment rooms and those electrodes shall be connected to main earthing electrode, run along the bridge as shown on the drawings

Earthing rods of the earthing systems shall be installed in pre-drilled holes and backfilled with a conducting medium such as Bentonite clay/gypsum.

Earth raisers shall be provided to connect to the main protective earthing conductors.

Protective Earthing Distribution

Protective earthing copper conductors with not less than 95 mm^2 shall be provided to the two

portals. This protective earthing conductor shall be connected to the main earth copper earth electrode.

Earthing conductors shall be included in:

- the supply cables to each distribution panel in the bridges and roads and
- every outgoing cable from the distribution panels, and
- an earth connection shall be made to the frames of electrical equipment supplied from the panels

An earth conductor shall be run with every sub main and sub circuit emanating from all switchboards. Earth conductors shall be run to all plug socket outlets, appliances, lights, cameras and equipment required to be earthed.

Earthing links shall be mounted on insulated non-hygroscopic panels, isolated from metal in the switchboard.

4.11 Electrical services reticulation

Scope

The cabling reticulation system in the bridges and roads comprises LV sub-main power cables, final LV sub-circuit cables, CCTV cables, Traffic Management Control System (TMCS) equipment cables, Operation Management and Control System (OMCS) and other communication cables.

The cabling system shall generally comply with BS 6387, maintaining circuit integrity after exposure to fire for 2 hours and with a mechanical protection against moderate impact and water spray. All cables shall be Low smoke halogen free to prevent the release of toxic or corrosive fumes under fire conditions.

Generally all essential services cables for sub-circuits, activation/systems, communication and all other essential light and power distribution shall be halogen free insulated and 2 hour fire rated.

Standards and Codes

The services reticulation installation shall comply with the requirements detailed in the latest revisions of the following standards, where applicable.

IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 60189	Low-frequency cables and wires with PVC insulation and PVC
	sheath
IEC 60287	Electric cables - Calculation of the current rating
IEC 60352	Solderless connections

IEC 60364	Low-voltage electrical installations
IEC 60423	Conduit systems for cable management - Outside diameters of conduits for electrical installations and threads for conduits and fittings
Low-voltage switchgear and control gear assemblies	
Degrees of protection provided by enclosures(IP code)	
Conduit systems for cable management	
Cable management - Cable tray systems and cable ladder systems	
High-voltage switchgear and controlgear	
Instrumentation Cables	
Specification for performance requirements for cables required to	
maintain circuit integrity under fire conditions	
Electric cables. PVC insulated, armoured cables for voltages of	
600/1000 V and 1900/3300 V	

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

Cable Requirements

Cable Installation

Cables shall be installed in accordance with IEE Regulations 17th edition and in accordance with the following additional requirements:

Cables shall be installed in a neat and workmanlike manner free from kinks and unnecessary bends. The Contractor shall provide all necessary terminals, cable glands, ties, cleats, cable boxes and terminating facilities for the plant to which cables are to be connected and shall supply and install all facilities for the purpose of supporting cables.

Particular care shall be taken that the cable sheath is not damaged during installation. Any cable damaged during installation shall be replaced by the Contractor.

All cables shall generally be installed on cable ladders except where preformed cable trenches or ducts have been provided or cables are buried direct in the ground.

In plant areas the cables shall be run concealed in conduits within the walls or run in surface

mounted cable support system along ceiling, these include cable trays, conduits and galvanised metal ducting.

Unless otherwise approved by the Engineer power cables and control cables shall be separated physically.

Cables, cable enclosures and supports shall be located so that they do not obstruct doorways, passages, or any other space required for access through building or to equipment.

Where false ceilings are provided cables shall not be allowed to lie across the ceiling lining, but installed in cable support systems.

The bending radius of cables both during installation and the final set shall not be less than those recommended by the manufacturer for the individual cable types and in no case be less than eight times the outside diameter of the cable.

A minimum of 300mm clearance shall be maintained between low voltage power cables and extra low voltage cables, instrument cables, data cables and communication cables.

Segregation between non-essential and essential services cables shall be maintained.

Special Requirements

Cable compounds shall, in addition to complying with the requirements of the Standards, be of the halogen free fire retardant type with reduced flame-spread properties and reduced emission of smoke, corrosive and toxic fumes.

Power Cables

The requirements for power cables shall apply to all cables for 33 kV,11 kV, 400 V and 230 V ac service, as well as cables for 110 V, 48 V, 24V dc service which are frequently or continuously loaded to more than 35 per cent of the rated capacity of the cable.

Power cables shall be circular cables with copper conductors having not less than seven strands. Auxiliary power cables for 33 kV shall be XLPE insulated, steel wire armoured with over sheath. 400 V cables with a nominal conductor area of 95 mm^2 and above shall be XLPE insulated with over sheath. Power cables for 400 V or below (ac or dc service) shall be insulated, sheathed, 0.6/1 kV grade cables. Cables
for direct burial and in the duct between the Facilities area and portal shall be steel wire armoured and sheathed. The sheath colour of power cables shall be "electric orange" except that cables exposed outdoors shall have a black outdoor sheath.

The size of cable conductors for power cables shall be determined in accordance with IEC 60364, Electrical Installations of Buildings, except that the minimum conductor size shall be 4 mm^2.
All power cables shall be spaced apart to avoid derating. In some areas it may not be possible

to space the cabling to avoid derating, where derating is applicable cable shall be sized to include for derating losses.

Single-core power cables shall be installed in trefoil touching formation and the current rating shall be determined in accordance with IEC 60287.

Where armouring of single cables is required, the armouring shall be of non- magnetic alloy.

Multicore Control Cables

The requirements for multicore control cables shall apply to all cables for the control, protection, indication, instrumentation and alarm circuits, including cables from dc and ac. distribution boards where such circuits are loaded to less than 35 per cent of the rated capacity of the cable (for loading over 35 per cent continuously, these cables shall be regarded as power cables).

Multicore control cables shall be circular, copper conductor, insulated, sheathed, 0.6/1 kV grade cables to BS 6346, or approved equivalent. Cables for direct burial shall be steel wire armoured and sheathed.

Conductors of multicore control cables shall be adequately rated for the service conditions and shall consist of not less than seven strands. The minimum cross- sectional area shall, unless otherwise specified, be 1.5 mm^2. Untinned conductors may be used only with crimp-on terminal lugs.

Conductors for current transformer secondary circuits shall have a cross-sectional area not less than 2.5 mm^2 for transformers with 1 amp secondaries and 4 mm^2 for transformers with 5 amp secondaries. Where the burden of the leads associated with the current transformers requires to be further reduced to ensure correct operation of the equipment under all conditions, a larger cross-section shall be used. In these cases the required cross-sectional area of the conductors shall be shown on the circuit diagram.

For connections where screened cables are required the cables shall be bedded, screened over the bedding and served overall. The screen shall comprise a helical wrapping of 0.075 mm thick copper tape with at least 30 per cent overlap. The serving shall be identical to the cable sheath specified for unscreened cables.

The insulation of multicore control cables shall be light grey and each core shall be identified by means of black printed numbers repeated throughout the cable at longitudinal spacing of approximately 40 mm. The figure "9" shall be distinguished from the figure "6" thus "9", or by the word "nine" alternating with the figure. The sheath shall be coloured black.

Mineral-insulated metal-sheathed (MIMS) cable shall not be used except where specified or approved by the Engineer.

Multipair Instrumentation Cables

Instrument cables shall be copper conductor, twisted pair, aluminium foil screened, sheathed cables complying with BS 5308, or approved equivalent. If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards. The sheath shall be coloured black.

Applications shall be restricted to low signal and solid state circuits, and pairs shall be individually screened where required by the application.

Conductors shall be adequately rated for the duty and shall have a minimum of seven strands. The minimum cross-sectional area shall be 0.5 $mm^{2.}$

If untinned conductors are supplied, crimp on terminal lugs shall be used.

Communication-type Cables

Communication-type cables shall be twisted pair, single tinned copper conductors, insulated, bedded, aluminium foil screened, served and overall sheathed cables conforming where appropriate to IEC 60189 and BS 4808. If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards. Polythene insulation and sheathing may be used subject to the approval of the Employer.

The insulated conductors shall be uniformly twisted together in pairs with a right-hand lay. The direction of stranding shall alternate for successive layers, the first layer being right-hand.

Where fillers are necessary for satisfactory laying up of cable pairs, they shall be PVC free and halogen free.

The cables shall be made of the following standard numbers of pairs: 2, 6, 10, 20 or 50. The

identification of the manufacturer and the year of manufacture shall be printed on a plastic type tag beneath the sheath at not more than 1 m intervals.

The overall sheath shall be PVC free and halogen free and shall be coloured black.

Cable Identification Tags

The Contractor shall provide and firmly attach stainless steel or non-ferrous identification tags 50 mm long x 12 mm wide to each cable. The tag shall be fixed longitudinally along the cable by binding with 1.00 mm or larger diameter copper or approved non-corrodible wire through end holes in the tag.

Each identification tag shall be stamped indelibly with the appropriate cable number in accordance with the cable schedules, the letters and figures being not less than 5 mm high.

Cable Terminations

General

The termination of each end of each cable shall, unless otherwise specified, include the following:

Fixing the cable by an approved gland (or clamp for bottom entry into floor mounted indoor cubicles);

Fitting an approved lug to each core (except spare cores);

Fitting an approved phase or polarity identification to each power cable core and identification ferrule to each control, indication, protection and alarm cable core;

Connections to equipment terminals (except spare cores); and

Fitting two approved cable identification tags to each cable end, one within the equipment enclosure and the other clearly visible outside the enclosure.

Termination of Power Cables

Where possible, phase identification of multicore power cables shall be self-coloured cores. For cables where the cable cores are not self-coloured, the RYB phase identification shall be provided by insulated non-flammable heat shrinkable tubing coloured red, yellow, blue and black (neutral) as appropriate. Cables shall be installed in accordance with IEE Regulations 17th edition.

The Contractor shall ensure that ac cables are correctly phased and that polarity of dc cables is correct. Incorrect connections of power and control cables shall be rectified by the Contractor.

Termination of Multicore Control Cables

At both ends of each control cable all cable cores, except spare cores, shall be terminated on terminals. Each core shall be left sufficiently long and neatly looped to allow a fresh termination to be made should the original termination device break off. Where not enclosed in ducting the unsheathed portion of the cable shall be laced neatly with an approved non-flammable cabling strapping.

Spare cable cores need not be terminated but shall be left sufficiently long to reach the most remote terminal strip in the enclosure. Spare cores shall be loomed together and left neatly in the cable ducting inside the enclosure.

The Contractor shall provide and fit approved non-flammable wire-marking ferrules on each core of all multicore control cables. Spare cores shall be identified with the letter "S" followed by the cable number.

Where a separately mounted device to be connected cannot accommodate the specified cable or is not fitted with compliant terminals, the Contractor shall provide a junction box, complete with an approved type terminal block, adjacent to the device. The connection between the junction box and the device shall be made in PVC sheathed flexible steel conduit or

screened flexible cord with a suitable cable gland.

Cable cores in multicore control cables shall be terminated using crimp-on cable lugs of the insulated type.

Termination of Communication-type Cables

Where communication-type cables are terminated on stud type terminals the cable cores shall be terminated using crimp-on cable lugs or solder type cable lugs of approved make. Communication type cables terminating on pin type terminals shall be wire wrap terminations complying with IEC 60352.

Termination of Cable Screens

Unless otherwise specified, the screens of screened cable shall be earthed at one end only. This shall generally be the end at which the signal originates. Shielded control and instrumentation cable shall be earthed at the end furthest from the main control/instrumentation equipment. For shielded cable using separate electrostatic and electromagnetic shields, the electrostatic shield shall be earthed at the end furthest from the main control/instrumentation equipment and the electromagnetic shield shall be earthed at both ends.
Earthing of copper screens shall be by means of wrapping three or more turns of 1.0 mm2 stranded copper earthing conductor over the exposed screen and making an effective soldered joint with the screen. The earth conductor shall be terminated at the equipment by means of crimp-on terminal lugs. All earthing conductors shall be insulated.

Cable Joints

Cable joints will not be permitted, unless approved or where the length of the cable exceeds the maximum manufactured cable length, in which case cables shall be joined using the manufacturer's recommended procedure and equipment in accessible areas such as junction boxes or cable pits.

Cable Glands

Cable glands shall be of the weatherproof compression type, and for outdoor locations shall be of non-ferrous metal. Cable glands for cables with an overall diameter over 20 mm shall be of metal. For single core cable, glands and locknuts shall not be made of ferrous metal.

Underground Cabling

Cables to be laid underground shall be drawn into pipes or ducts where appropriate.

In all other places cables shall be laid direct in the ground at the following minimum depths:

Cables 0.6/1 kV, 600 mm under roadways and 500 mm other locations. Cables above 1 kV rating, 700 mm at all locations.

Before any bedding sand is placed in the trench the excavation shall be submitted to the

Engineer for approval. The lowest cables in a trench shall be laid in a 50 mm bed of sand. Sand shall then be added until the top of the uppermost cable is covered to a depth of 50 mm. Particular attention shall be paid to maintaining cable spacing‘s appropriate to the design cable rating.

Concrete or clay brick protective covering for cables shall be placed on top of the bedding and shall comprise either of the following:

Pre-cast concrete slabs of minimum thickness 38 mm and compressive strength 15 MPa minimum

Concrete slabs cast on site of 100 mm minimum thickness

Clay bricks laid close together lengthwise for cables rated 1 kV or lower and crosswise for cables rated above 1 kV.

A yellow polythene tape approximately 150 mm wide by 0.25 mm thick of continuous length and marked "ELECTRICITY CABLE" in 50 mm high black letters at intervals not exceeding 600 mm shall be buried approximately 100 mm above the cable slabs.

Before backfilling is commenced the works shall be submitted to the Engineer for inspection. Backfilling shall be carried out using soil from the excavation. It shall be placed in layers not exceeding 300 mm loose depth. Each layer shall be compacted by hand or power ramming until dense firm consolidation is obtained. Surplus soil shall be disposed of in approved disposal areas on the Site as specified elsewhere in the Employer‘s Requirements.

Cable marker posts for direct-laid cables shall be supplied and placed at intervals of 30 m to indicate the position of the buried cables and at every position where the cable changes direction. The marker shall be set in the ground to a depth of approximately 350 mm, directly over the buried cable.

Support of Cables

All cables shall be provided with supports located as close as is practicable to the point of termination of the cables. Cables run on perforated cable trays shall be fixed with profile shaped saddles at spacing‘s between 150 mm and 300 mm as required to ensure a neat installation without sagging between saddles. Cables leaving cable ladders over the side rail shall be fixed to the ladder at the point from where they start to lift. Where cables drop over a ladder rung, the sharp edge shall be fitted with a smooth radius drop-out fitting.

Expansion of cable ladders and trays will be considered in the design and will be provided with expansion joints where appropriate.

Sealing of Openings

Where cables, including cables in ducts, trays or trenches, pass through a concrete wall, floor

or ceiling or enter or leave pipes the space between the concrete or pipe and the cables shall be sealed with a fireproof sealing mixture of three-to-one by volume of granulated vermiculite and cement mixed with water to form a stiff mix, or other fireproof sealing approved by the Engineer. Cabling through concrete floors into bottom entry cubicles is included in this requirement.

Cable pipes and ducts entering buildings and pits shall be first fireproofed with the seal described above then sealed with plastic weatherproof compound.

Cable trenches entering buildings and openings between building interiors and external cable pits shall, at the point of entry, have the fireproof seal overlaid with a weatherproof compound on the external side.

The seals around the cables shall be trimmed as required to give a neat appearance, and match-painted by the Contractor when forming part of painted concrete surfaces.

Removal and Cutting of Trench Covers

Formed cable trenches for installation of cables shall be fitted with covers. Before commencing installation of cables, Contractor shall mark the covers to show their position on such trenches and where appropriate take those covers into safe keeping.

Immediately after cabling is completed the covers shall be replaced. During periods when installation is temporarily suspended, the trenches shall be made safe by replacing the covers or by other approved means.

Where necessary to permit the passage of cables, the covers shall be cut by the Contractor and lined in an approved way to prevent chafing of the cables.

Cable trenches shall be backfilled with suitable inert material to the approval of the Engineer

Pits shall be of suitable box type, and shall form common wall with cable trench ends, complete with penetrations for each conduit/pipe including spares and future. Used and unused penetrations shall be sealed with removable seal prior to backfilling.

Conduits/Pipes

General

Metallic conduit and fittings shall be hot dipped galvanised to approved zinc weight. Steel conduit shall be rigid screwed steel conduit with metric thread to IEC 60423.

Joining of conduit by means of welding is not permitted.

Steel conduit fittings shall be made of malleable cast iron, except that flush wall boxes may be made of sheet steel.

PVC conduit shall be heavy duty conduit to IEC 60614 and be halogen free low smoke. The

Contractor shall satisfy the Engineer that all metallic conduits are adequately protected against any corrosion which may arise due to wet conditions or otherwise.

Where wiring is to be concealed from view, the conduits shall be installed above suspended ceilings, embedded in concrete or chased in brick walls. The chasing of concrete walls and floors is not acceptable. Conduit chased in brick walls shall be covered by at least 10 mm of plaster.

The embedded conduits shall be hot dipped galvanised steel screwed conduit. The wall boxes to take switches and wall sockets shall be of a type suitable for the equipment proposed to be installed. Galvanised iron draw wires of 1.6 mm, diameter shall be left in all conduits. The embedded conduits shall be checked and cleared if necessary prior to or immediately after removal of formwork.

Junction boxes and draw-in boxes in concrete walls and ceilings shall be installed with the face of the box flush with the formed surface of the concrete unless otherwise approved by the Engineer.

In brick walls the bricks shall be cut neatly and the junction boxes shall be installed so as not to protrude beyond the finished surface. Each flush wall box shall be installed with its side horizontal and vertical to within two degrees of arc. Where two or more flush boxes are adjacent to each other the distance between them shall be not less than required for the satisfactory installation of the flush plates.

Neither plain nor inspection type elbows and tees shall be used in the concealed conduit installation.

Conduits shall be installed to allow safe and easy drawing in of cables. Where conduits are bent, the inside radius of the bend shall not be less than six (6) times the nominal size of the conduit. No more than two consecutive 90° bends or a multiple number of bends adding up to a total of 180° shall be installed between two conduit ends. Where more than the above numbers of bends are required an intermediate flush draw-in box shall be provided. Conduit runs in excess of 10 m shall also be provided with draw-in boxes.

Conduit exposed to view shall run parallel to the structural lines.

Where surface mounted conduit crosses an expansion joint approved expansion fittings shall be provided.

Where embedded conduits run across expansion or contraction joints in concrete, a 1 m section of flexible steel conduit equal to "Sealtite Anoconda Metal Hose", complete with connectors, shall be inserted across the joint. In addition the flexible conduit shall be taped with 2 layers of half lapped bitumen impregnated paper tape bedded in a bituminous

undercoat. An alternative arrangement using expansion/deflection couplings will also be acceptable subject to the approval of the Engineer.

All screwed joints in embedded conduit shall be made watertight by sealing with a plastic weatherproof compound. Conduits shall be electrically continuous between conduit ends. All ends of conduits shall be reamed with a conical reamer and all burrs and sharp edges shall be removed to prevent damage to the wire insulation.

All joints in PVC conduit shall be made waterproof by use of suitable adhesive compounds. Suitable moulded thread attachments shall be used for entry into equipment. Flexible expansion couplings shall be used to allow movement due to temperature variations.

The Contractor shall ensure that all embedded conduits and associated fittings are not damaged or displaced during the placing of concrete or the installation of reinforcing bars and embedded metal work and that the embedded conduits are kept clean of the ingress of concrete or mortar. To this end all embedded conduits shall be fitted with temporary caps.

Connections between embedded conduits and exposed conduits or cable troughs shall be made in an approved manner and in such a way that metallic and electric continuity is not impaired.

All surface mounted conduits shall be fixed in position with stand-off saddles and screws, spacing the conduit approximately 5 mm off the surface, at spacing‘s not more than 1.20 m for steel conduit and 0.80 m for PVC conduit.

The ends of conduits shall either terminate in a metal box or be screwed directly into a fitting.

Conduits shall be no smaller than 25 mm in diameter and 80mm within the cable trench and all external underground installations.

Connections between fixed conduit and electric motors, and other similar equipment shall be made by short runs of flexible steel, protected by a corrosion resistant non- toxic sheath conduit of sufficient length to allow full adjustment of the motor.

Conduits shall be run from cable tray to equipment in general.

No more than one power circuits shall be enclosed in one conduit.

It will be the responsibility of the E&M Contractor to ensure pipes and conduits installed by the civil Contractor are correctly installed without damage, kept clear of debris and that appropriate draw ropes sealing/draw clothes are in place.

Flexible Conduit and Fitting

Flexible steel with a corrosion resistant non-toxic sheathed conduit shall be installed for all final connections to motors from isolators, to control equipment and where conduits are subject to change due to vibration.

Rigid conduit to control equipment shall be run to a junction box adjacent to the item of

equipment, and thence in flexible conduit to the equipment. Flexible conduit connections shall be no less than 250 mm or more than 750 mm in length. Where isolating switches are required, they may take the place of the junction boxes.

Cable Trays/Ladder

General

Cable ladder systems shall be of an established design equal to Burndy or GKN type, complete with horizontal bends, tees, inside and outside risers and all the necessary accessories including splices, support brackets, hangers, clamps etc. Double hanger rods or single centre rail supports are acceptable. If designs other than standard known commercial types are proposed the Contractor shall show the adequacy of the design strength.

Cable ladders, and accessories shall be preferably manufactured from steel If manufactured from steel they shall be hot-dipped galvanised after forming and shall have rungs at a spacing not greater than 300 mm. Cable ladder rungs shall have slotted holes suitable for fixing cables with cable ties. The side rails of the cable ladders, and all bends, risers, tees and similar fittings shall have a rolled or double return top edge of at least 10 mm diameter (or width).

The loading of cable ladders shall in no case exceed the manufacturer's recommended design load.
The span deflection of cable ladders shall not exceed the ratio of 1 in 200.

Provision will be made in the form of expansion joints on the cable trays, suitable to their total length.
Each section of cable ladder will be individually earthed to common earth.

Where intrinsically safe circuits or cables rated at different voltage levels are run on the same tray they shall be separated by a steel divider strip.

Perforated Cable Trays
Perforated cable trays shall be hot dipped galvanised trays with returned edges not less than 12 mm high, made from not less than 1.5 mm thick sheet steel. Trays shall be installed with the returned edges against the wall or ceiling surface.

Cable saddles shall be fixed to the perforated cable trays with screws and nylon type nuts inserted from the cable side into the slotted holes.

Installation

Different services, including communication etc, shall be run on different cable tray/ladders. A minimum of 300mm segregation shall be maintained between services cable trays and between cables. Cable from other services shall cross at 90° and a minimum of 150mm segregation on crossover shall be maintained.

Trays/ ladders shall be installed perpendicular/parallel with structural lines, with a minimum

number of sets and bends, and fully supported over the entire width at intervals not exceeding 1 m. The maximum deflection occurring between supports shall not exceed 6mm with the tray/ ladder fully loaded with cables.

Trays/ ladder shall not be continuously mounted direct on a flat surface. Sufficient room shall always be allowed for air circulation around and throughout the tray/ ladder, and in any case shall not be less than 25 mm clear of such surfaces.

Air circulation around cables shall be a prime factor in determining the location of cable trays/ladders.

In locations where dirt and other foreign materials are likely to be present in sufficient quantities to foul the tray/ ladder, then the tray/ ladder shall be installed in a vertical plane, and supported on suitable brackets clear of fixed surfaces. These cables shall be cable-tied at intervals not exceeding 300 mm or closer as required to prevent sagging.

Cables run horizontally on cable trays shall be fastened to the tray at intervals not exceeding 1,500 mm using cable ties, where the cables .enter or leave and in other locations where the cables may tend to be dislodged, such as at bends.

All fastenings must be a proprietary type made for this purpose.

Cables shall be laid parallel in trays and crossovers shall be avoided as far as possible.

Trays/ladder shall not be cut or deformed to form cable exit points. Cables .shall leave the tray/ladder at an end, or over the side, and the end or edge of the tray/ ladder shall be suitably formed or protected to prevent damage to the cables.

Cable trays and ladders will be earthed at joins by means of 10mm min flexible earth cable or tray mounted earth clamp to ensure proper earth continuity.

Supporting Steel Work

All supporting steelwork shall be of adequate strength and hot dipped galvanised to approved zinc weight after manufacture

Covers

Cables tray/ ladder covers shall be installed to all vertical and horizontal runs that occur:

Below ceiling within the building

Exposed areas outside the building within the bridges and roads (subject to approval, where no other alternative is available).

Covers shall be of the same manufacture, matching the tray/ ladder, and fabricated from non-perforated sheet steel. Any fixing penetrations will be made prior to hot dip galvanising.

Cable Ducting

Cable ducting for plant areas shall be constructed from minimum 0.8 mm thick for plant

areas corrosion resistant mild steel or extruded aluminium. This excludes cable ducting for bridges and roads distribution boards, which shall comply with the requirements specified in the distribution board section.

The duct shall be flat, true and free from scale, rust, dents and blemishes. The duct shall be electro-galvanised.

Cable ducting shall be installed in horizontal or vertically true and straight runs with a minimum number of sets and bends and shall be provided with covers fixed by blunted corrosion resistant screws.

Cable ducting and support brackets shall be powder coated in the same colour to match the surrounding walls.

Cable Trunking

Cable trunking shall be hot dipped galvanised steel trunking not less than 1.5 mm thick, complete with removable cover and cable retaining clips.

The cable trunking system shall be an established system complete with fishplates, bends, risers and other associated fittings.

All trunking shall be spaced off the surface using 5 mm PVC spacers, and fixed at least every 1.50 m.

There shall be no sharp projections into the cable trunk, only the heads of mushroom head screws shall be permitted inside the cable trunk.

Bus-Trunking or Busducts

Where bus-trunking or busducts are used, proprietary type-tested systems shall be provided made up of integral lengths and fittings containing solid busbar conductors and housings, assembled in sections to form complete fully enclosed and insulated low impedance power distribution system, designed and manufactured in accordance with IEC 60439-2, IEC 62271-200.

Select low impedance type busduct to meet nominated current ratings and, if used as consumer's mains, to match the supply authority's substation equipment.

Ensure a degree of protection for the complete assembly of IP42.

Provide expansion joints in vertical runs, to allow for expansion and contraction of the busduct system.

Provide end caps or covers to fully enclose ends of busducts not connected to equipment. Support busducts at maximum intervals of 2m, using adjustable hangers and steel angle supports. The hangers shall be installed at least 300mm from joint centres. Secure busducts to angle supports using proprietary clamps.

Support using a combination of fixed and spring type hangers to allow for expansion and contraction of the busduct system.

Use elbows, offsets and junctions for changes in direction. If necessary, provide weatherproof covers and gaskets.

4.12 Transformer

Scope

This specification covers main transformers to step down the utility supply, and further dry type 11/0.4kV transformers as required to supply loads in the bridges and roads, service buildings, control rooms and other auxiliary loads.

All transformers must be appropriate for the sea side environment and temperature range stated below.

The load capacity of transformers will be dependent upon the final lighting and other system design solutions.

Each transformer will be sized to accept 100% of the relevant substation load. Under normal operating conditions both transformers will support the load accepting approximately 50% each.

Environmental Condition

All transformers shall comply with the following environmental design criteria: Max Temp

(summer): 45.0^{o}C

Min Temp (winter): -10.^{o}C

Height above sea level: 10m

Air density – 1.2 kg/m3

Lightning incidence

Note: Dielectric strength of the air in such a high altitude is less than sea level. Such effect need to be taken in to account when external insulation is designed and tested. De-rating calculation needs to be carried out by manufacturer and approved by the client.

Standards and Codes

The transformer shall comply with the requirements detailed in the latest revisions of the following standards, where applicable.

IEC 60076	Power transformers
IEC 60137	Bushings for alternating voltage above 1000 V

IEC 60273	Dimensions of indoor and outdoor post insulators and post insulator units for systems with nominal voltage greater than 1000 V
IEC 60664.1	Insulation coordination for equipment within low-voltage systems

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Manufacturer/supplier responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards.

Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Manufacturer/supplier.

Equipment proposed by the Manufacturer/supplier that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

The manufacturer shall make recommendations for surge arrestors, suitable for the lightning incidence of the area.

Specific Technical Requirement

Number of transformers	1	2	9
Type of installation	Outdoor		Indoor
Number of phases	3 Phase		
Voltage level	33/11kV		11/0.4kV
Rated capacity*	Various		
Vector group	Dyn11		
Frequency (Hz)	50		
Class/type of insulation			F / Dry type
Impedance	7% (To be confirmed prior to the order)		
Cooling	Air Natural		
Method of cooling	Oil Natural		Natural convection
Grounding	Solidly grounded		
Altitude of the Installation Site	3070m above the sea level		
Maximum ambient temperature (To be confirmed prior to the order)	25.0°C		
Tap-changer	Off load type, 5 steps (± 2x2.5%)		

Power frequency withstand voltage (LV/MV)	According to IEC 76.3	
Noise level at 1m distance (acoustic)	Vendor to Specify dB (A)	
Enclosure Ingress Protection Degree	IP66	IP45

*Rated capacity needs to be de-rated by Contractor based on the environmental condition provided in section three. The de-rating calculation shall be reviewed and approved by purchaser)

Transformer Design & Performance

General

All transformer assemblies of identical rating shall be constructed so that the internal assemblies can be replaced readily. Each enclosure shall be constructed so that the major internal assembly of the transformer, consisting of the core and coils and attached parts, can be removed, either by opening a door or removing a panel. The internal assemblies of the transformers of the same rating and voltage class shall be interchangeable. In the event of an internal fault in a transformer, it shall be possible to restore it to operating condition by replacement of the internal assembly with a spare internal assembly. The internal assemblies shall be equipped with bases designed to facilitate removal and replacement.

The transformer shall be able to operate safely for 30 seconds with a voltage of 1.3 times rated voltage imposed to the feeder winding. Further they shall be able to operate continuously at their nominal ratings within the limits of temperature rises, at voltage variations of ±10% at their feeder windings, at any frequency variation between -5% and +5% and at any combination of voltage and frequency variation together with any voltage ratio to be adjusted by the tap changer.

The short circuit capability of the transformers shall be such that they can safely withstand for 3 second without damage or deterioration secondary short circuits when fed from the primary side with the maximum possible fault current (I"K = 50KA for low voltage side of these transformers).

Windings

Transformers shall be provided with high conductivity Al / Cu /foil windings with the insulation material complying with either class F or H according to the manufacturers.

All the windings shall have full insulation strength on their entire length. The insulation material shall be free from compositions likely to soften, shrink or to collapse during long time service operation. Windings have to be braced such as to prevent distortions under any design load/fault conditions.

Dry Type

The MV (HV)/LV windings shall be baked with epoxy resin/powdered quartz mixture under

vacuum or other equivalent heat stabilized, fire resistant and self-extinguishing material.

Oil Type

The proportion of inter-turn and end turn insulation shall be in accordance with IEC60071 No insulating material, which can be deleteriously effected by the action of oil or dielectric as applicable under the operating conditions of the transformer, shall be used in the transformer or the leads.

Magnetic Core

The core and its clamping plates shall form a rigid unit structure which shall maintain its form and position under the severe stresses encountered during shipment, installation and short circuits. Care shall be taken to secure evenly distributed mechanical pressure over the whole laminations to prevent settling of the core and to eliminate noise and vibrations when the transformer is in operation.

Core laminations shall be made from cold rolled grain orientated, high permeability silicon steel free from burrs. The core joints shall be interleaved. Each lamination shall be insulated with a material that will not deteriorate due to pressure and the action of hot temperature.

Transformer Enclosure

Dry type

Transformers shall be enclosed in self-supporting, freestanding, metal housings and arranged for floor mounting. Ventilation openings shall be equipped with combination grilles and screens suitable to effectively prevent the entrance of vermin. The bases shall be suitable for moving the transformers by means of rollers. The enclosures shall effectively enclose the live parts. Access to the transformer be permitted by means of hinged doors or other approved methods The enclosure shall provide protection of IP 42 protection class. The wall thickness of doors and other metal enclosure shall not be less than 1.8 mm.

Each transformer enclosure shall contain an auxiliary compartment for housing the termination boards for any auxiliary devices and instrument transformers. The compartment shall be mounted at the front of the transformer enclosure. It shall be fully enclosed and shall have a door opening to the front and equipped with captive screws or acceptable equivalent devices for securing it closed. A plain, removable plate shall be provided, located at the bottom of the compartment, of adequate size for terminating all conduits leaving the compartment.

Each transformer cubicle shall be provided with anti-condensation heaters to be used for the purpose of keeping the windings dry when the transformer is not energised. The amount of heat to be provided shall be sufficient to maintain the temperature of the windings at least

10°C above ambient temperature, but well below the permissible maximum operating temperature of the windings.

Heating units shall be so distributed within the transformer enclosure as to supply heat to the transformer windings substantially uniformly. The heating units shall be of rugged construction, suitable for operation on 230 V ac. The heaters shall be provided with a supply switch affording overload and short-circuit protection and automatic on- off hygrostatic control designed to cut out when the humidity within the transformer enclosure rises to a pre-set value.

Oil type

Tanks and Covers:

All external tank bracing shall be continuously welded along upper line of contact with tank to prevent water lodging behind the bracing.

Tank covers shall be domed or sloped to prevent accumulation of water and shall be secured to the tank to form weather tight joint which is proof against oil leakage.

The transformer shall be provided with lifting lugs so that the oil filled transformer, enclosure and plinth can be handled as a complete unit. Suitable lugs shall be provided for removing the core and coils from the tank.

The core shall be readily removable from the tank for inspection and shall be secure from movement inside the tank during normal handling or transport.

The transformer shall be braced to withstand all mechanical shocks, which may occur under working conditions including those produced, by short circuits.

Cleaning and Painting:

The tank shall be thoroughly cleaned of rust and mills scale by shot blasting or other approved method. The exterior shall be de-greased before painting.

The manufactures standard painting procedures shall be submitted for approval by the client.

The following accessories shall be provided: Lugs for lifting the complete transformer

Rail stop as required

Voltage Adjustment

Ratio adjusters shall be provided for voltage adjustment as specified which shall be electrically and mechanically robust and arranged to ensure convenient inspection and maintenance.

Design and arrangement of leads and connections thereto shall safely withstand voltage surges according to the appertaining BIL level, and a continuous load current corresponding to 125% rated winding capacity without excessive heating, and short- circuits of specified duration and magnitude without injury.

The transformer taps shall be changed by means of disconnectable links bridging stud type,

tap terminals. The terminals shall be clearly marked, readily accessible and equipped with double lock-nut assemblies to prevent the transfer of tightening torque to the tap winding connection. The tap links and terminals shall be fabricated of high- strength, high-conductivity, noncorrosive materials with adequate section areas and contact surfaces for the transformer loadings.

Terminals

The high, medium, and low-voltage terminals on the transformers shall be suitable for connection of power cable terminations, or direct bus connections, as required.

Transformer connections shall be arranged such that it shall be possible to remove the transformer and install a replacement unit without disturbing the bus work.
Contractor shall supply all necessary high-conductivity and high-strength, nonferrous alloy, terminal connectors, suitably sized for the full rating of the transformers.

The connectors shall be of the bolted or clamp type which cannot cut or otherwise damage the conductors and shall provide at least two independent fixing means on each conductor.

Where bottom entry is required, cables shall be brought into the terminal boxes through nickel plated brass glands of the compression type. The dimensions of the terminal boxes shall be suitable for the size and number of cables, Gland plates will be 6mm brass. Glands and gland plates are to earthed

The arrangement of terminal boxes shall allow the easy and undisturbed approach of the power cables with the correct bending radius without touching the transformer at any part. The construction shall be rigid enough to take up the weight of the cables, potheads etc.

The transformer shall have the primary and secondary terminals plainly and indelibly marked in accordance with IEC60071 on the transformer case adjacent to the relevant terminal.

Where top entry is required, all porcelain bushings shall be in accordance with EN 50180/ESAA or suitable indoor bushings and shall be secured by means of bolts or metal clamps so as to facilitate removal. The HV Bushing arrangement shall be either Epoxy Pad termination or Elastimold (or equivalent) style plug-in well/insert bushing type.

The approach of power connections to transformers shall be provided by the Contractor for the specific case subject to approval by the Owner/Engineer.

Earthing

A copper ground bus shall be provided inside each transformer enclosure, to which all grounds shall be made. The enclosures, the transformer core and the metallic structural parts shall be effectively grounded to this ground bus. The neutral of the transformer low-voltage windings shall also be connected to this ground bus through a disconnecting link. Silver-plated terminal connectors suitable for copper conductor of adequate rating shall be provided on the ground bus for connection to the main station ground grid.

Two earthing terminals of adequate size shall be provided and installed diagonally at the bottom of each transformer housing. Earthing continuity of bolted parts shall be ensured by approved means (earthing leads etc.).

Gaskets

All gaskets provided for the oil type transformer shall be suitable for making oil or dielectric tight joints and there shall be no deleterious effects on either gaskets or oil or dielectric, when the gaskets are continuously in contact with the hot oil or dielectric. No gaskets shall be used in which the material of the gasket is mounted on a textile backing.

Oil

The oil type transformer shall be supplied complete with the first fill of oil, such oil to comply with IEC standards and approved by the client. Oil volume to be stated, along with fire precautions.

Instrumentation

Each transformer shall be equipped with an approved over temperature detection system with local indication and remote annunciation of winding temperature and automatic tripping of the transformer circuit breaker when the temperature exceeds the maximum safe winding temperature.

Transformer shall be provided with suitable thermal monitoring devices (e.g. thermistors) located inside winding coil for remote alarm and trip. One 4 wire PT100 shall be provided for remote alarm and trip and one 3 wire PT100 shall be provided for local monitoring for each individual LV winding.

All wiring shall be brought to a common terminal box suitably protected for the place of installation and amply sized to accept field cabling.

Rating Plate

A stainless steel rating plate bearing all the information called for in IEC60076 together with a diagram of the connections of the windings and vector diagrams showing the general phase relations of the transformer, plan of cover showing the terminal positions, markings etc., shall be furnished with the transformer, located in a readily visible position.

Painting

For those parts where hot-dipped galvanization is not applicable, a suitable painting procedure shall be applied subject to the Owner/Engineer approval.

The paint colour shall be RAL 7032 in accordance with RAL standards of colour from German

institute for Quality Assurance and labelling. Field touch-up paint shall be supplied by Contractor. For this purpose, 10L of each specified paint required for the work under this section shall be supplied in sealed containers identifying the type of paint and its purpose.

Inspection and Tests

Transformers shall be subject to inspection and testing, by and at the expense of Contractor, in the factory and on Site, in the presence of the Client for conformity to the requirements of this specification and to the relevant standards. Final Tests on Completion shall be performed to demonstrate the satisfactory performance of the various systems.

Contractor shall submit a schedule of the specified inspection and testing program for review and comment four weeks prior to the test.

Result of all tests shall be presented in Test reports. These test reports shall indicate the tests performed, the results obtained, instruments used, names of test personnel and provisions for witnesses' signatures. They shall also be numbered and dated.

The format of these reports shall be submitted at the same time as the test procedures specified above.

Type test certificates may be offered by Contractor, in lieu of actual testing, as specified above, Contractor shall provide satisfactory evidence as to the similarity of the equipment tested and the Contract equipment.

Impact measuring devices should be fitted during transportation and suitable for use in three axis.

Shop Tests

In case type tests are required by these specifications or in the relevant standards, valid, certified type test certificates on technically comparable material or equipment will be accepted in lieu of a repetition of the tests.

However, if the type test certificates are deemed to be invalid due to demonstrable design, material or procedural variations or discrepancies, Contractor shall carry out the required type tests in accordance with the relevant standard.

Contractor shall supply the Client with a complete set of detail drawings, which will be used to assist in the inspection during the construction of the unit, and which shall be retained at the shop and returned after completion of the Contract. Contractor shall provide suitable facilities in its shop for the accommodation of Employer's Representative, where he may examine drawings and prepare reports.

Contractor shall notify the Client of its intention to perform tests, giving sufficient notice to permit the Client to witness the tests. Contractor shall provide detailed manufacturing, quality control, and non-destructive testing procedures and shall notify the Client in writing at least 14 working days in advance of each date any material will be ready for inspection and

shop quality control tests.

Certified copies of all material tests for chemical analysis and for mechanical and electrical properties shall be furnished to Engineer/Client‘s Representative.

The Client reserves the right to require special material tests in addition to those specified in the Contract and Contractor shall perform such tests at Client‘s expense. Contractor will be advised in ample time to permit the preparation of test specimens.

In cases where doubt exists regarding Contractor's tests, the Client may request repetition of such tests in its presence. All retests, if required, shall be done by Contractor at no extra cost to Client in the event of defective materials or workmanship.

Specifically, Contractor's shop test programme for the transformers shall include the following:

Mechanical Tests

All contacts of all switches, relays and devices, including mounted equipment and such devices furnished as unmounted equipment and spare parts, shall be tested for contact operation device markings, nameplate markings, conductor identifications, terminal block wire designations and the scales of meters and instruments shall all be checked against the approved shop drawings.

Each panel shall be checked for alignment of enclosure and devices, for rigidity of structures, and for adequacy of fastenings and supports.

Electrical Tests

- Resistance measurement tests of all windings including taps
- ratio tests at rated voltage connection and all taps
- determination of vector group
- applied power frequency high voltage test
- determination of individual losses
- dielectric tests, including applied voltage, induced voltage and partial discharge

Visual Checks

- packing examination
- check of nameplate data
- check of accessories / arrangement etc against approved drawing

Site Inspections and Performance Tests

Site inspection and performance tests will be required to prove that equipment, as installed, meets the requirements of this specification and the guarantees. All inspections and tests shall be conducted by Contractor subject to acceptance by Client's Representative.

The Site inspection and performance testing programme shall include the following:

- test to check the continuity of all main and secondary buses, control and auxiliary circuit wiring and cables as installed
- testing of all current-carrying and ground connections to all conductors and terminal pad, to determine that full clamping pressure is applied to all contact surfaces and all bolted connections are tightly secured with lock washers; testing of all flexible connections to ensure that sufficient slack is available for expansion
- general inspection of the equipment, including checking of all connections/wires on relay terminals, and labels on terminal boards
- operational tests, under simulated service conditions to ensure operability of all components, proper mechanical functioning of all parts, and correct mutual functioning of interrelated components
- insulation resistance tests on secondary and control wiring and auxiliary circuits
- individual inspection and operation of all auxiliary devices to determine their condition.
- loop check of instrument/control/alarm circuit

Tests on Completion

The Client will tell to the Contractor when the plant is ready for the test on completion. The tests, which shall be carried out before the equipment is placed into regular service, shall demonstrate that all guarantees have been met by Contractor and, in addition, that the entire equipment, including all auxiliary equipment and accessories, is properly installed and correctly adjusted and ready for commercial operation.
The following tests shall be carried out in accordance with IEC 60076 on all transformers and shall include as a minimum:

- resistance measurement tests to determine winding resistance
- polarity and phase relation tests to determine angular displacement and relative phase sequence of the transformers
- transformers turns ratio test
- di-electric insulation tests
- functional test of the transformer temperature-monitoring instruments

Spare Parts

Contractor shall provide with its tender proposal, details of additional spare parts, individually priced, which it considers necessary for the successful operation of the equipment in the same time period. This will be recommended spares and the Client at his option may include some or all of these recommended spares in the Contract.

All spare parts shall be interchangeable with, and of the same material as, the original parts of the equipment furnished.

Spare parts and consumable for site testing and acceptance trials shall be provided by Contractor.

All spare parts shall be identical electrically and mechanically to the corresponding parts in the equipment and shall be suitably packed and clearly marked, ready for long-term storage.

Spare parts shall not include any components which will deteriorate in storage and all special storage requirements and environmental conditions shall be identified by Contractor.

Special Tools and Maintenance Equipment

Contractor shall propose a list of special tools and tackles required for installation and for normal maintenance and repair of this dry type transformer.

The Client will examine the list and may include some or all of these special tools and tackles as an integral part of this contract.

Test Equipment and Instruments

Contractor shall provide a list of recommended test equipment and instruments, applicable for maintenance and retesting of the transformers, for consideration and selection by Employer.

The test equipment and instruments shall be new or as new, complete with protective cases, power supply, test probes, operating manuals etc.

4.13 Main Switchgear

Scope (Primary Switchgear)

This specification covers the design, manufacture and testing of switchgear for a 11kV cable network system

Primary switchgear is defined for the purpose of the contract as 11kV main switchgear to be employed in the North and South Portal switch rooms and Main substations

Due to the altitude the preference is to utilise Gas Insulated Switchgear, conforming to the requirements of IEC62271-200 with the classification of IAC- AFL 25kA, 1s-LS2A- PM.

Additionally all HV cable connections to any GIS will be by means of Connex/Phisterer gas tight connections

If the existing main substation is to be utilised and uprated, the existing AIS switchgear may be utilised provided this equipment has been de-rated for use at 3070m and conform to the requirements of IEC62271-200 with the classification of IAC- AFL 25kA,
1s-LS2B- PM. The Contractor would be required to confirm this is the case. SYSTEM PARAMETERS

Nominal voltage - 11 kV

System highest voltage - 12 kV System frequency -

50 Hz ± 3% Number of phases - 3

Method of earthing - Solidly grounded

Short time withstand current (for 1s) - 25kA

Operational altitude -

Service Conditions

Annual average ambient - Maximum ambient temperature - Minimum ambient temperature -

Maximum relative humidity - Environmental conditions - 38°C

45°C (To be confirmed prior to the order) -10°C (To be confirmed prior to the order) 90%

10m above M.S.L

Insulation level

Lightning impulse withstand voltage (sea level rating)-85kV Power frequency withstand

voltage - (sea level rating)28kV

Applicable Standards

The equipment and the components supplied shall be in accordance with the standards specified below or later edition and/or amendments thereof.

BS 159	Specification for high-voltage busbars and busbar connections
BS 6134	Specification for pressure and vacuum switches
IEC 60044-1	Instrument transformers - Part 1: Current transformers
IEC 60056	High-voltage alternating-current circuit-breakers
IEC 60071	Insulation Coordination
IEC 60071-1	Insulation co-ordination - Part 1: Definitions, principles and rules
IEC 60071-2	Insulation co-ordination - Part 2: Application guide
IEC 60129	Specification for alternating current disconnectors and earthing switches
IEC 60137	Bushings for alternating voltage above 1000 V
IEC 60265	High voltage switches
IEC 60298	A.C. Metal-enclosed Switchgear And Control gear For Rated Voltages Above 1 kV And Up To And Including 52 kV
IEC 60376	Specification of technical grade sulphur hexafluoride (SF6) for use in electrical equipment
IEC 62271-1	High-voltage switchgear and control gear - Part 1: Common specifications

IEC 62271-100	High-voltage switchgear and control gear - Part 100: Alternating current circuit-breakers
IEC 62271-102	High-voltage switchgear and control gear - Part 102: Alternating current disconnectors and earthing switches
IEC 62271-200	High-voltage switchgear and control gear - Part 200: A.C. metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
ISO 2063	Thermal spraying -- Metallic and other inorganic coatings -- Zinc, aluminium and their alloys

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Basic Features GIS Design

Primary switchgear shall be designed to operate at rated voltage of 12kV and each section shall consist of one number of circuit breaker enclosed in the main tank using SF6 gas as insulating and vacuum as arc quenching medium A three way disconnect shall also be installed in the SF6 tank for the purpose of

- connecting the CB to busbar
- Disconnecting the CB from the Busbar
- Connecting the outgoing circuit to Earth via the CB.

Basic Constructional Aspects

The equipment offered shall be metal enclosed free standing.

The unit shall be provided with lifting facilities of proven design for easy handling. The

equipment shall be complete with necessary cable termination boxes, earth fault indicating device with current transformers, vacuum circuit breaker and disconnect / earthing switch with necessary safety interlocks and designed for minimum maintenance.

The mechanical design and strength of the unit and components shall be able to bear the mechanical stresses on the switch terminals when installed and in operation,
The equipment shall withstand the electro-dynamic forces without reduction of the switches reliability or current carrying capacity.
The main tank, busbar tank and cable housing shall be housed in a single compact metal clad suitable for either indoor application.

Temperature compensated loss of gas detection. Motor drives on disconnect/earthing functions.

Proven proprietary CB/disconnect/earth control function.

Enclosure (Tank)

Main tank which will use for SF6 as insulation and quenching medium (vacuum is however required for quenching in CB's) shall be welded stainless steel. The pressure system shall be defined as a sealed for life system with an operating life time exceeding 30 years. The leakage rate of SF6 gas shall maintain less than

0.25 % per year. In order to guarantee a reliable and tight welding, manufacturer shall make sure all welding work is carried out by computer controlled robots.. A temperature compensating gas pressure indicator offering a simple indication shall constantly monitor the SF6 insulating medium. The degree of protection of the inner enclosure shall be rated IP 67.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

Vacuum Circuit Breaker

The 3 pole circuit breaker for the protection of distribution transformers shall be enclosed in the main tank. The rated breaking and making current at rated voltage shall be as follows:

For 11kV system : Rated breaking capacity shall be 25kA for 3 second

Rated making capacity shall be 52.5kA for 3 second

The manual operation of the circuit breaker shall not have an effect on the spring charging mechanism.

Busbars

All busbars will be contained within a gas compartment, separate from the CB compartment, each section will be extendable in both directions

Cable compartment

All cable compartment shall be HV cable connections by means of Connex/Phisterer gas tight connections. De-ration and increased clearances due to altitude will be detailed by the Contractor

The Contractor will provide additional detail for the transition to connection of SWA armoured cable where this is required

Operational Switches

A three way disconnect shall also be installed in the SF6 tank for the purpose of connecting the CB to busbar

Disconnecting the CB from the Busbar

Connecting the outgoing circuit to Earth via the CB.

Live Line indicators

These shall facilitate quick detection of presence of High Voltage. The unit should be self-contained requiring no auxiliary power supply and will be self-checking including capacitive divider link and indicating unit .the capacitive divider may be housed in either CT or plug socket

Foundations

The floor fixing of the equipment shall allow for mounting on a simple rectangular plinth with a flat surface to manufacturers recommendation or to the recommendations of the manufacturer with the approval of the Engineer

Basic Operational Aspects

The operating mechanisms shall be of independent manual type and shall be integral with switches and interlocks. The movement of any operating handle against an interlock shall not by any means originate, store or activate the energy mechanism.

Padlocking Arrangements

The circuit breakers and switches can be locked in the open/closed or earth on position by 1 to 3 padlocks ESI size.

Testing Facilities

It shall be possible for each of the functions on the switchgear to be equipped with a voltage indication, to indicate voltage in the cables. The capacitive dividers will supply low voltage power to sockets at the front of the unit, an external lamp must be used to indicate active cables. Three outlets can be used to check the synchronisation of phases with the use of an external device. This device shall comply with IEC 62271-200.

Remote Control

Remote operation of the switchgear three way switches must be possible using motors fitted to the operating mechanism. Earthing

Current Transfomers

Suitable CTs will be installed in the SF6 tanks

Voltage Transfomers

Suitable VTs will be installed outside the SF6 tanks and will be plug-in u by means of Connex/Phisterer gas tight connections

Main circuit

The cables shall be earthed by an integral earthing switch with short-circuit making capacity, in compliance with IEC 60129. The earthing can only be operated when the switch is open. The earthing switch shall be operated through the main circuit mechanism and manual closing shall be driven by a fast-acting mechanism, independent of operator action.

Quality *Assurance*

Quality Assurance system conforming to ISO 9001 shall be followed in the manufacturer of Ring Main Unit and the manufacturer shall furnish ISO 9001 Quality Assurance Certification Document.

Protection

Protection will be by means of suitable multifunction protection relay

The relay will be of common type /manufacturer across the entire site

Details of protection system and component parts will be submitted for approval by the owners Engineer by the prospective contactor with tender documents.

4.14 Ring Main Units

Scope

This specification covers the design, manufacture and testing of Ring Main Units for a 11kV cable network system

SYSTEM PARAMETERS

Nominal voltage	-	11 kV
System highest voltage	-	12 kV
System frequency	-	50 Hz ±
3% Number of phases	-	3
Method of earthing	-	Solidly grounded
Short time withstand current (for 1s)	-	21kA

Service Conditions

Annual average ambient - Maximum ambient temperature -

Minimum ambient temperature - Maximum relative humidity -

Environmental conditions - Operational altitude -

38°C

45°C (To be confirmed prior to the order) -10°C (To be confirmed prior to the order) 90%

10m above M.S.L

Insulation level

Lightning impulse withstand voltage - 95kV Power frequency withstand voltage - 28kV

Applicable Standards

The equipment and the components supplied shall be in accordance with the standards specified below or later edition and/or amendments thereof.

BS 159	Specification for high-voltage busbars and busbar connections
BS 6134	Specification for pressure and vacuum switches
IEC 60044-1	Instrument transformers - Part 1: Current transformers
IEC 60056	High-voltage alternating-current circuit-breakers
IEC 60071	Insulation Coordination
IEC 60071-1	Insulation co-ordination - Part 1: Definitions, principles and rules
IEC 60071-2	Insulation co-ordination - Part 2: Application guide
IEC 60129	Specification for alternating current disconnectors and earthing switches
IEC 60137	Bushings for alternating voltage above 1000 V
IEC 60265	High voltage switches
IEC 60298	A.C. Metal-enclosed Switchgear And Control gear For Rated Voltages Above 1 kV And Up To And Including 52 kV
IEC 60376	Specification of technical grade sulphur hexafluoride (SF6) for use in electrical equipment
IEC 62271-1	High-voltage switchgear and control gear - Part 1: Common specifications
IEC 62271-100	High-voltage switchgear and control gear - Part 100: Alternating current circuit-breakers
IEC 62271-102	High-voltage switchgear and control gear - Part 102: Alternating current disconnectors and earthing switches
IEC 62271-200	High-voltage switchgear and control gear - Part 200: A.C. metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
ISO 2063	Thermal spraying -- Metallic and other inorganic coatings -- Zinc, aluminium and their alloys

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

Basic Features

Design

The Ring Main Unit (RMU) shall be designed to operate at rated voltage of 12kV and shall consist of two numbers of load break switches and one number of circuit breaker for transformer protection shall be enclosed in the main tank using SF6 gas as insulating and vacuum as arc quenching medium or SF6 gas as both insulating and arc quenching medium for control of 11/0.4kV transformers up to 500kVA.

Basic Constructional Aspects

The equipment offered shall be metal enclosed free standing or transformer mounted type.

The free standing RMU shall be stable and rigid on its own support.

The unit shall be provided with lifting facilities of proven design for easy handling.

The equipment shall be complete with necessary cable termination boxes, earth fault indicating device with current transformers, vacuum circuit breaker and disconnect or
earthing switch with necessary safety interlocks and designed for minimum maintenance.

The mechanical design and strength of the unit and components shall be able to bear the mechanical stresses on the switch terminals when installed and in operation,

The equipment shall withstand the electro-dynamic forces without reduction of the switches reliability or current carrying capacity.

The main tank (Inner enclosure of circuit breaker and ring main switches assembly) and all switchboard assembly shall be housed in a single compact metal clad suitable for either indoor or outdoor application.

Inner Enclosure (Main Tank)

Main tank which will use for SF6 as insulation and quenching medium (vacuum is however preferred for quenching in CB‘s) shall be welded stainless steel. The pressure system shall

be defined as a sealed for life system with an operating life time exceeding 30 years. The leakage rate of SF6 gas shall maintain less than 0.1 % per year. In order to guarantee a reliable and tight welding, manufacturer shall make sure all welding work is carried out by computer controlled robots. An absorption material such as activated alumina in the tank shall be provided to absorb the moisture from the SF6 gas to regenerate the SF6 gas following arc interruption. A temperature compensating gas pressure indicator offering a simple indication shall constantly monitor the SF6 insulating medium. The degree of protection of the inner enclosure shall be rated IP 67.

Vacuum Circuit Breaker

The 3 pole circuit breaker for the protection of distribution transformers shall be enclosed in the main tank. The rated breaking and making current at rated voltage shall be as follows:

For 11kV system: Rated breaking capacity shall be 21kA for 3 second

Rated making capacity shall be 52.5kA for 3 second

The manual operation of the circuit breaker shall not have an effect on the spring charging mechanism.

Bushing

All the bushings shall be of same height, parallel, on the equal distances from the ground and protected by a cable cover. It is preferable to have bushings accessible from the rear side of the RMU.

Cable Boxes

All cable boxes shall be air insulated suitable for dry type cable terminations. The cable boxes at each of the two load break switches suitable for HV cables up to 300mm² and circuit breaker cable suitable up to 300mm². The cable box shall be arc resistant as per IEC 62271-200. The internal arc fault test on cable box shall be carried out for 11kV system for 21kV for 1 second.

The clearance between phase to phase and phase to earth shall be as per IEC 61243-5. The cable termination and gland arrangements shall be appropriate for the type and style of cables used at the time. Deration and increased clearances due to altitude will be detailed by the Contractor

Operational Switches

The load break switches (isolator) for incoming and outgoing supply must be provided and must fully insulate by SF6 gas. The operating mechanism shall be spring assisted mechanism with operating handle for ON/OFF. Earth positions with arrangement for padlocking in each position. The earth switch shall be naturally interlocked to prevent the main and earth switch being switched ‗ON' at the same time. The selection of the main and earth switch is made by

a lever on the facia, which is allowed to move only if the main or earth switch is in the off position. The load break switches should have the facility for future remote operation. Each load break switch shall be of the triple pole, simultaneously operated, non automatic type with quick break contacts and with integral earthing arrangement. The rates current of isolator shall be 630A continuous at maximum ambient temperatures**.**

Earth Fault Indicators / Fault Passage Indicators (EFI/FPI)

These shall facilitate quick detection of faulty section of line. The fault indication may be on the basis of monitoring fault current flow through the device. The unit should be self contained requiring no auxiliary power supply. The EFI shall be integral part of RMU.

Contactors and Conductors

All the contactors and conductors shall be of high standard and should be able to withstand the cool weather conditions. The cable shall be in accordance to the circuit diagram for the proper functioning of the connected equipment.

Anti-Corrosive Prevention

The housing chamber interiors shall be cleaned of all scaled rust by shot blasting or any other approved chemical method and shall be coated with paint/enamel or suitable medium resistive to the electrical insulating medium adopted.

The exterior of the unit cleaned of all scale and rust by shot blasting or any other approved chemical method and shall be treated with zinc spray.

Every precautionary method should be taken to design and construct the unit for weatherproof against the service conditions indicated.

Foundations

The floor fixing of the equipment shall allow for mounting on a simple rectangular plinth with a flat surface.

Basic Operational Aspects

The operating mechanisms shall be of independent manual type and shall be integral with switches and interlocks. The movement of any operating handle against an interlock shall not by any means originate, store or activate the energy mechanism.

Padlocking Arrangements

The circuit breakers and switches can be locked in the open/closed or earth on position by 1 to 3 padlocks ESI size.

Testing Facilities

It shall be possible for each of the functions on the RMU to be equipped with a voltage indication, to indicate voltage in the cables. The capacitive dividers will supply low voltage power to sockets at the front of the unit, an external lamp must be used to indicate active

cables. Three outlets can be used to check the synchronisation of phases with the use of an external device. This device shall comply with IEC 62271-200.

Remote Control of the RMUs

Remote operation of the RMU‘s line switches must be possible using motors fitted to the operating mechanism. It shall be possible to fit the motors either directly in manufacturing plant or on site when required. RMU shall fully energised when install on site and manufacturer should provide detailed instructions for installation to the control mechanism. The fitting of the motors to the mechanism must not in any way impede or interfere with the manual operation of the switches or circuit breaker.

Earthing

Metallic parts

There shall be continuity between the cast resin earth screen and metallic parts of the switchboard and cables so that there is no electric field pattern in the surrounding air.

Main circuit

The cables shall be earthed by an integral earthing switch with short-circuit making capacity, in compliance with IEC 60129. The earthing can only be operated when the switch is open. The earthing switch shall be operated through the main circuit mechanism and manual closing shall be driven by a fast-acting mechanism, independent of operator action.

Quality Assurance

Quality Assurance system conforming to ISO 9001 shall be followed in the manufacturer of Ring Main Unit and the manufacturer shall furnish ISO 9001 Quality Assurance Certification Document.

Additional Requirements

Operating Lever

An anti-reflex mechanism on the operating lever shall prevent any attempts to re-open immediately after closing of the switch or earthing switch. All manual operations will be carried out on the front of the switchboard. The effort exerted on the lever by the operator should not be more than 250 N for the switch and circuit breaker. The overall dimensions of the RMU shall not be increased due to the use of the operating handle. The operating handle should have two workable positions 180° apart.

Tools

Any form of special tools or devices necessary for routine operation and maintenance of the unit shall be incorporated and supplied with the unit. The recommendation of the tools shall be for a period of five years operation.

Front Plate

The front shall include a clear mimic diagram which indicates different functions. The position indicators shall give a true reflection of the position of the main contacts. They shall be clearly visible to the operator. The lever operating direction shall be clearly indicated in the mimic diagram. The manufacturer‘s plate shall include switchboard‘s main electrical characteristics.

Rating Plate Markings

Each RMU and its associated equipments shall be provided with a rating plate legible and indelibly marked with at least the following information.

- Name of manufacturer
- Designation of type
- Serial number
- Rated voltage
- Rated normal current
- Rated frequency
- Symmetrical breaking capacity
- Making capacity
- Short time current and its duration
- Purchase order number and date
- Month and year of supply
- Rated lightning impulse withstand voltage

Packing

The equipment shall be packed in crates suitable for vertical or horizontal transport as the case may be and the packing shall be suitable to withstand handling during transport and outdoor storage during transit. The supplier shall be responsible for any damage to the equipment during transit, due to improper and inadequate packing.

Routine Tests

According to the composition of the switchboard, various type test certificates can be supplied:

- Impulse withstand test
- Temperature-rise test
- Short-time withstand current test
- Mechanical operation test
- Checking of degree of protection
- Switch, circuit breaker, earthing switch making capacity
- Switch, circuit breaker breaking capacity
- Internal arc withstand

- Checking of partial discharge on complete unit
- The routine tests carried out by the manufacturer shall be backed by test reports signed by the factory‘s quality control department.

They shall include the following:

- Conformity with drawings and diagram
- Measurement of closing and opening speeds
- Measurement of operating torque
- Checking of filling pressure
- Checking of gas-tightness
- Checking of partial discharges on individual components
- Dielectric testing and main circuit resistance measurement

5.16. Lightning Protection

Lightning Protection

This section specifies the minimum requirements for the provision of lightning protection system for the control building, and any other external structures such as telecom masts, lighting poles etc. The Contractor shall design, make calculations, supply, onsite install, test and commission the lightning protection system in accordance with the relevant codes and standards.

Standards and Codes

The lightning protection shall comply with the requirements detailed in the latest revisions of the following standards, where applicable.

BS 6651	Protection of Structures against Lightning
AS 1768	Lightning protection
IS 2309	Protection of Buildings and Allied Structures Against Lightning

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

Lightning Protection Materials

Lightning Protection system shall include but not limited to air terminals, down conductors,

earth terminations, joints, bonds, test joints etc.

Air Terminals

Air terminals shall be installed and shall be shown in layout plan drawings with relevant distances. Air termination rods shall be tinned copper with minimum diameter of 15mm dia, 0.8m long with top spike. The tip of the terminal shall not be less than 254mm above the object or area of protection.

Down Conductors

Loop/down conductors shall be provided with anchoring bolts to hold them in firm position. Conductors shall be securely fastened to the structure at intervals not exceeding 900mm. They generally are green colour PVC sheathed copper tape with a minimum 3mm x 20mm cross section.

They shall be as short as possible protected and directly connected to the earthing system through test links. Handrails and structures in the vicinity of lightning protection system shall be bonded to the system by a minimum 3mm x 20mm PVC sheathed copper tape.

Joints and Connections

All joints and connections such as connection to earth grid shall be by exothermic welding. All branch connections shall be by means of compression type devices or exothermic welding. Connections for rod electrodes shall be bolted type with bolts, washers and nuts made from high copper alloy or silicon bronze. Ferrous based hardware is not acceptable.

Where dissimilar materials are to be joined, the necessary bimetallic plates shall be inserted as required to ensure that electrolytic action is avoided.

Earth Electrodes

Earth electrodes shall be 19mm diameter steel core copper jacketed type having a high strength steel alloy core with welded molten copper covering with a minimum thickness of 0.25mm. Earth rods shall be free from paint or other nonconductive coatings.

Earth rod electrode shall be driven directly into the ground to a minimum depth of 2.0m without drilling or excavation to get maximum earth contact. Connection from earth rod to cable shall be made in a concrete inspection pit with cover having bolted clamps.

Earth electrode ground resistance shall meet the relevant standards. Earth copper conductor emerging from the ground shall be protected against mechanical damage by steel or PVC pipes.

Earthing Pits

Earth pit cover shall be of heavy duty cast iron with brass plate engraved —Electrical Earthǁ and shall have a recessed lifting hook.

Test Links

Removable test earth links shall be provided on every down conductor that is connected to each dedicated lightning protection earth pit to enable the electrode system to be disconnected for testing. They shall be installed in accessible location above ground near the earth electrode. Removable Earth Links shall consist of bolted copper link fixed on porcelain insulators complete with studs, nuts, washers and bolted lug which is adequately sized for connection of the earth electrode.

Installation

All lighting protection components shall be protected against corrosion. All exposed earthing cables shall be installed and located in a manner to provide maximum mechanical protection utilising building corners and webs of beams.

Installation of earthing and lightning protection system shall be coordinated with the installation of other building systems such as electrical wiring, supporting structures and metal bodies requiring bonding to earth.

5 LIGHTING

5.1 General

All luminaires and associated fittings/equipment/cabling shall be suitably rated and certified in compliance with the minimum relevant standards for their use.

The Contractor shall be responsible for ensuring that the arrangement of lighting and power outlets, and their rating, are adequate in all respects, particularly in respect to requirements for operational and maintenance purposes.

All lighting shall comply with relevant local government authorities, Supply Authority requirements, and the standards listed in this specification.

5.2 Standards and Codes

The lighting shall comply with the requirements detailed in the latest revisions of the following standards, where applicable.

IEC 60081	Double-capped fluorescent lamps - Performance specifications
IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 60529	Degrees of protection provided by enclosures(IP code)
IEC 60598	Luminaires - General Requirements and Testing
IEC 60662	High-pressure sodium vapour lamps – Performance specifications
IEC 60669	Switches for household and similar fixed-electrical installations
IEC 60921	Ballasts for tubular fluorescent lamps – Performance requirements
BS 5266	Emergency lighting
BS 5489	Code of practice for the design of road lighting

BS 5266	Emergency lighting
BS/EN 13201	Road lighting

If these specifications conflicts in any way with any of the referred standards and codes, British and International standards will take precedence over Indian standards.

It shall be the Contractors responsibility to be, or to become, knowledgeable of the requirements of these Codes and Standards. Any required changes or alterations to the equipment to meet the Codes and Standards requirements shall be at the expense of the Contractor.

Equipment proposed by the Contractor that cannot fully meet the requirements of this specification and above mentioned standards shall have all exceptions clearly stated in the proposal. No exception shall be allowed, unless approved by the Buyer in writing.

5.3 Preliminary Design

The primary design objectives are as follows:

- To enable traffic to flow with the same speed and degree of safety as on the approach roads.
- To ensure that the lighting installation and associated equipment meet the requirements of BD78/99, BS5489-2, BS EN 1838, EU Directive and NFPA
- To install an effective, versatile and energy efficient lighting installation designed to minimise future operating and maintenance costs.
- To minimise disruption to road users both during and following refurbishment.
- The system is not designed to cater for daytime contraflow conditions

Detail design of the lighting system shall be designed by qualified and experienced lighting designers with experience in designing similar installations. The Contractor shall submit their lighting design with detailed design calculations to the clients Engineer for approval.

All light posts erected on the railings of bridges, structures shall have adequate height such that a minimum illumination of 40 lux with uniformity of 40% should be available.

All high mast lights in the interchange area shall illuminate the interchange with intensity of minimum 40 lux with uniformity of 40% should be available.

All entry and exit ramp areas shall be uniformly illuminated with minimum 40 lux with uniformity of 40% should be available .

Luminaires will be fitted with toughened glass.

Final sub-circuits will be protected by MCB’s, not HRC fuses, for ease of re-setting.

The luminaires will be isolated at the EDP’s, for maintenance, or by disconnecting at the appropriate plug, no internal isolation limit switches are to be installed in the luminaires.

5.4 Fitting Details

Luminaires shall comply with the requirements of IEC 60598.

The Contractor shall recalculate all lighting/luminaire requirements in the detailed design and submit the details with calculations to the Owner‘s Engineer for approval.

Fitting shall be suitable for outdoor applications Refractor of the luminaires shall be laminated glass IP65 rating – vandal resistant, corrosion proof, robust

Gaskets shall be synthetic rubber and shall be temperature resistant, damp proof, non-ageing and resistant to the aggressive atmosphere Electronic control gear for fluorescent lamps

Any hinges, toggles, screws, and catches shall be captive type, stainless steel 316 Compliant with relevant standards

Control gear shall be designed to prevent HV pulsing during lamp failures. For two lamp fluorescents, luminaires shall be able to be switched per lamp.

Reasonable access to lamps and control gear shall be maintained without removing fitting.

Suitable large cable access facilities and termination shall be provided. The above designs are preliminary, for tender purposes

5.5 Photometers – Lighting Control

The luminance meters will be pole mounted at the start of the Access Zone (approximately 30m) from the end of each gallery subject to the final selection of the photometer control and aimed in the driver‘s direction of view, being positioned to avoid unintentional switching due to vehicle lights and other external light sources.
The lighting controller shall have a backup system if a fault occurs to the controller. In addition, at each outdoor distribution board a manual override switching facility for control of lighting control system shall be provided.

A failure of either the luminance or the illuminance meters shall cause an alarm, as will discrepancies between the two. Failure of an illuminance meter shall not affect the switching. In case of failure of a luminance meter, the control shall be done by adjustable switch steps.

Emergency Conditions

In case of prolonged mains power failure, or in an emergency evacuation scenario, where traffic into the bridge is stopped, the lighting level can be reduced to 1 in 4 of the fluorescent luminaires in each lane (Base Lighting). These shall remain energised by the UPS/Power backup for a duration of 0.5 hours.

Illuminated emergency lights shall also be located in front of each Distribution Panel. All

emergency and exit lighting shall be suitably rated and certified.

5.6 Electrical Niche/ Pump-Station Niche and Room Lighting

Interior lighting shall utilise 28W, T5 fluorescent lamps with high efficiency electronic ballasts.

All surface mounted luminaires shall be totally enclosed type with prismatic diffusers. Offices shall be at minimum 400 lux. Plant rooms, generator rooms and pump rooms shall be provided with IP66 corrosion and impact resistant luminaires with clear diffusers at minimum 200 lux. Switchrooms shall be at minimum 300 lux.

5.7 Illumination Requirements for Safety Signs

Safety signs shall be white with green background as the contrast colour. The ratio of luminance of the white colour to the green colour shall be between 5:1 and 15:1. The minimum luminance level of any 10mm patch area of the safety signs shall be 2cd/m2 and the ratio of maximum to minimum luminance shall be less than 10:1 for either colour. Positioning of the signs shall be based on the relevant standards as specified in Table at section 10.2.

Light Switches

Each room or area shall have a local light switch near the entry door. All light switches shall be surface mounted IP56 type.

5.8 External Lighting

Road Lighting

It is proposed to provide street lighting pole with standalone solar powered LED of required wattage after every 4 poles with electricity powered by service provider. This is to take care of illumination on project road in case of prolonged mains power failure during day and at night. Overall uniformity is to be 0.4 and longitudinal uniformity is 0.7.
Lighting and columns shall be of standard Indian design, should comply with relevant standards and be corrosion and vandal resistant type.
The use of outreach brackets on power poles or wooden lighting poles with overhead power supplies are unacceptable due to the unstable nature of the ground. The Contractor must provide evidence that lighting, structural and electrical clearance requirements are satisfied when using wooden poles or power poles for mounting lights.

The design shall incorporate the following criteria:

- Lamp and luminaires manufacturers shall match existing street lights.
- Fittings shall have glare control using semi-cut off louvers or other approved median
- Fittings shall be selected to minimise maintenance and running costs.
- Fittings shall be individually fused at supply entry, to provide continuity of supply to the lighting scheme should one or more fittings short circuit for any reason e.g. lightning strike, traffic accident,
- Lighting control shall be the same as the existing street lighting arrangement.

- Lighting shall be connected to the mains power at the portal buildings.
- Cables route through the concrete column base shall be via PVC conduit.
- Columns shall be individually earthed.

The pavement lighting shall be maintained to provide good visibility and clear delineation under night time conditions and other times of poor ambient lighting. Exterior lighting shall be controlled via the Sensors such as Ultrasonic sensors, IR Sensors and LDR sensors are used to control the LED lamp functionalities in order to achieve a more energy efficient system. In this case the light must have auto on and off and must have at least two state of dimming function to save energy, from dusk to dawn. The followings specifications related to individual components need to be complied:

PV MODULE

- Indian manufactured PV module should be used.
- The PV module should have crystalline silicon solar cells and must have a certificate of testing conforming to IEC 61215 Edition II / BIS 14286 from an NABL or IECQ accredited Laboratory.
- The power output of the module(s) under STC should be a minimum of 37 Wp at a load voltage* of 16.4 ± 0.2 V.
- The open circuit voltage* of the PV modules under STC should be at least 21.0 Volts.
- The module efficiency should not be less than 14 %.
- The terminal box on the module should have a provision for opening it for replacing the cable, if required.
- PV Junction box: IP 65
- The PV module must use a RF Identification tag (RFID), which must contain the following information:
  - i. Name of the manufacturer of PV Module
  - ii. Model or Type Number
  - iii. Serial Number
  - iv. Month and year of the manufacture
  - v. I-V curve for the module
  - vi. Peak Wattage of the module at 16.4 volts
  - vii. Im, Vm and FF for the module
  - viii. Unique Serial No and Model No of the module

  RFID shall be mandatorily placed inside the module laminate.

BATTERY

- Li-Ion battery.
- The battery will have a minimum rating of 11.1 V, 20 Ah at C/10 discharge rate.
- 75 % of the rated capacity of the battery should be between fully charged and load

cut off conditions.

- Battery should conform to the latest BIS/ International standards.
- Battery need to be housed in the luminaire fixture only along with proper ventilation. No separate battery box is allowed.

LIGHT SOURCE

- 60 W or 80 W LED light source with fixture along with proper heat sink to dissipate heat generated by LEDs.
- Minimum 140 lumens / watt @ 350mA.
- IP65 or above.
- The light source will be of white LED type
- The colour temperature of W-LEDs used in the system should be in the range of 5500 K–6500 K
- LEDs should not emit ultraviolet light.
- The lamp should be housed in an assembly suitable for outdoor use, with a reflector on its back.
- Bat wing type light output with even spread over the road by using proper diffusing lenses.
- To be certified in complying with LM 80 standards.

ELECTRONICS

- The total electronic efficiency should be at least 85%.
- Electronics should operate at 12 V and should have temperature compensation for proper charging of the battery throughout the year.
- No load current should be less than 20 mA.
- The PV module itself should be used to sense the ambient light level for switching ON and OFF the lamp.
- The PCB containing the electronics should be capable of solder free installation and replacement.
- Necessary lengths of wires/cables, switches suitable for DC use and fuses should be provided.

ELECTRONIC PROTECTIONS

- Adequate protection is to be incorporated under “No Load” conditions e.g. when the lamp is removed and the system is switched ON.
- The system should have protection against battery overcharge and deep discharge conditions.
- Fuse should be provided to protect against short circuit conditions.
- Protection for reverse flow of current through the PV module(s) should be provided.
- Electronics should have temperature compensation for proper charging of the battery throughout the year.

- Adequate protection should be provided against battery reverse polarity.
- Load reconnect should be provided at 80% of the battery capacity status. Solar reverse-charging protection, solar reverse-connection protection, battery over charge protection, battery over-discharge protection, battery reverse-connection protection

All the components and parts used in the solar street lighting systems should conform to the latest BIS or IEC specifications, wherever such specifications are available and applicable.

The PV module(s) will be warranted for a minimum period of 25 years from the date of supply. The PV modules must be warranted for their output peak watt capacity, which should not be less than 90% at the end of Ten (10) years and 80% at the end of Twenty five (25) years.

Standards to be complied: IEC 61215: Solar panel, EN 50530: MPPT performance, IEC 62124: Solar standalone system performance, IEC 61347- 213: LED driver safety, IEC 62384: LED driver performance, IEC 61547 : EMC immunity requirements.

Pedestrian Lighting

Exterior lighting shall be provided for security and means of egress at the doors and along walkways adjacent to the buildings. This lighting shall be provided through the use of building mounted, vandal proof fixtures.

Any site area, walkway (for walkways not adjacent to the building) and parking area lighting shall be addressed through the use of pole mounted, LED fixtures of 50W or 70W.

6 OPERATIONAL MANAGEMENT & CONTROLSYSTEM (OMCS)

Design, supply and install a Plant Control and Monitoring System (PCMS), Traffic Control and Monitoring System (TCMS) and Operational Management and Control System (OMCS). The OMCS shall integrate the plant management and traffic management system into one supervised and comprehensive operational system.

This shall include all interfaces to the Emergency Evacuation and Intercommunication System, Telecommunication Systems, Security system, Traffic Control Centre (TCC) equipment, Operational Maintenance System, OMS.

Design, supply and install Control Room desks, seats, terminals, colour printers and display panel, including all other necessary equipment.

Design, supply and install communication links via fibre optic cables to the plant Remote Control Units (RCU's) and Remote Terminal Units (RTUs) from the OMCS.

Design, supply, install and terminate all control, monitoring, alarm and instrumentation cables

associated with the OMCS, PCMS, TCMS RTUs and RCU's.

Design, supply, install and terminate all control, monitoring, alarm and instrumentation cables associated with the manual fallback ventilation control panels, including optical fibre communication links.

Design, supply and install all cable support systems associated with the above systems.

Design supply and install all power supplies connected to UPS systems for the OMCS.

System Design

Operational Control Philosophy, and Operational Risk Assessment documentation is being Produced by the Contractor in line with the overall design and in consultation with the Authority having jurisdiction.

The primary refurbishment objectives are as follows:

- To install a robust OMCS with sufficient resilience for use in both normal and incident conditions.
- To enable road users to use, as far as reasonable practical, the same degree of safety as on the approach roads.
- To install an effective and versatile system designed to minimise future operational and maintenance costs.
- To ensure that the plant monitoring & control system and associated equipment meets the requirements of BD78/99, EU directive, PIARC and NFPA.
- To provide a system with an appropriate level of safety using diversity of cable routing, duplication of equipment etc as appropriate.
- A SIL rating to BS EN 61508 will not be determined or validated for either the hardware, nor for the software applications of the OMCS.

Project operation shall be controlled from the main control centre. The system shall automatically monitor and control all functions including traffic incident management systems and all electrical and mechanical plant. Main control Centre is manned 24 hours a day and 7 days a week.

Overall control is subdivided into two systems. They are: Traffic Management Control System (TMCS) Operations Management Control System (OMCS)

These shall be achieved through a Distributed digital Control System (DCS), TMCS and OMCS form the sub control systems of the DCS. The platform used for the DCS shall be fully compatible with all elements of control namely OMCS and TMCS.

TMCS shall consist of traffic control and incident detection system through traffic lights, boom gates, variable message signs, variable speed limit signs, traffic counting using loop detectors, vehicle height detectors, CCTVs, PA and radio broadcast, and motorist emergency telephones.

OMCS integrates the plant management and traffic management system into one supervised and comprehensive operational system. The system shall be supported by local control systems, where if failure occurs in the central or associated control systems, local controls shall be able to go into a manual mode of control causing an alarm. OMCS shall also be the main processing and data storage centre for the operations.

The communication network shall consist of a dual redundant data bus, i.e. the two fibre optic communication cables shall run individually along the length to connect each of the remote equipment. Communication requirements for motorist emergency telephone system shall be by separate dedicated fibre optic or copper cables. Fibre optic cables shall be installed in underground ducts of sufficient cover to ensure a fire rated enclosure (minimum of 2hr fire rating).

Remote Control Units (RCU)

RCU shall be implemented with control logic in conjunction with the OMCS and TMCS. Each RCU shall consist of dual redundant PLCs (Programmable Logic Controllers) and dedicated control programs, field instruments and required interface, motor control units, lighting circuits, command validation, interlocks, data acquisition, multiplexers and fibre optic interface unit. In addition to the intelligent features, RCU shall also serve as a data concentrator and communication processor role.

The main functions of RCU:
Collect information from various sensors and alarm points
Perform signal conversions such as analogue to digital and vice versa as required Output signals to various controllers and actuators Receive and send data to central control room through fibre optic cables Perform programmed functions and run independently if communication fails

Programmable Logic Controllers (PLC) shall be installed to control, operate and monitor all equipment to the specified requirements independently as well as from control centre commands. Main and sub control centres and all PLCs are linked by a Wide Area network (WAN) through redundant optic fibre cables. They also carry service telephone and CCTV signals between respective equipment and control centres. Control centres shall have their own Local Area Networks (LAN) for data transfer between work stations, PLCs, printers, video displays etc.

All field equipment cabling from RCUs to individual items of plant shall be the fire rated type (minimum of 2hr fire rating). All field equipment cabling shall be either fibre optic cabling or the screened type.

Control Centres

Monitoring, manual and auto control of the entire operation shall be undertaken from these control centres. All equipment shall be able to operate automatically from local PLCs, and the

control centres can intervene as and when required. Input/output (I/O) signals from PLCs are transferred to north and south control centre SCADA system (Supervisory Control and Data Acquisition) through the fibre optic cables. SCADA system forms the nerve centre of the OMCS. Both main and sub control centres shall have identical SCADA equipment and configuration. Under normal conditions, only the main control centre at south portal shall be manned.

The items provided but not limited to each control centre are:

- Control Desk with operator terminal
- SCADA
- Work Stations, Printers
- Radio Control Panel
- Communication Panel
- Video Displays
- LAN and WAN

The design and specification shall require computer equipment to comply with open system standards. This shall ensure that there is no necessity to replace components with exactly the same make and type should this become necessary and avoid a permanent tie to the original equipment Contractor.

This approach shall permit ready equipment upgrades as they become appropriate, with the overall system design suitable for use for at least 20 years before complete system replacement is necessary.
The system software shall be designed to meet the requirements of the ultimate capacity of the OMCS SCADA system without further program development. Future additional equipment stations shall be added by defining their parameters interactively with the system generation/configuration software.

The importance of the control centres requires a high degree of system availability. In order to meet this requirement, redundant hot standby hardware and software support systems shall be provided and the system shall be designed to ensure that no single points of failure exist which may significantly degrade the availability of any of the basic SCADA functions.

All operator functions and actions shall be interchangeable between any and all workstations independent of which desk they are assigned to.

Both control centres shall collect their data directly from the RCU/PLC stations. The Contractor shall define exactly how the distributed database concept for the project will achieve data collection & synchronization between main and sub control centres. Care shall be given to the status of the historical data and its source. The specifications of the system behaviour to cover the different scenarios of a possible disaster shall be explained in detail by the Contractor. The system shall be able to recover from the disaster to the normal regime

of operation without loss of data or discontinuity of operation. It shall not be possible to control any equipment from both control centres simultaneously. Contractor shall state their method of ensuring that only one control centre has control, and how the control is passed between centres.

Although the two control centres will independently collect data from PLC stations, they shall also be linked by the communications network to allow other data to be shared between the systems. This shall include the databases, system configuration and operator entered parameters.

A plant layout based model shall be provided and be able to use information from the SCADA system.

The configurations of south and north control centres are based on preliminary information and are subject to detailed design.

The following stations shall be integrated into the SCADA system:

- main control centre
- Electrical Niches and pump station niche (Remote Control Units)
- sub control centre
- facilities
- SCADA system shall remotely control and monitor installed equipment at these stations and any future upgrade of these stations to which the standard SCADA I/O will be applicable.

6.1 Basic System Architecture

The core SCADA system shall comprise proven non-proprietary hardware and an open software structure, and shall require no further development work. Custom software may be appropriate to effectively implement plant management and incident management applications.

SCADA system shall also become a major source of information to the network operator in all aspects of its business operations. SCADA system shall therefore establish a framework for information management. An open, flexible design is required that shall support all processes.

Generic industry standards shall be followed for consistency with Open System design philosophy. SCADA system shall be organised in a two-tier structure. The lower level shall be based on process control equipment at RCUs which collect data from field devices, perform data validity checks and pass this information to the control centres. This level in return accepts control commands from the control centres and operates PLCs in the field.

The upper level shall comprise the main computer installations at main and sub control centres. This level performs functions to communicate with the RCUs to acquire data, maintain system database and perform all interaction with operators via the workstation GUI interfaces. The control centres perform alarm reporting, data and report logging, trending of measurements and historical archival of data. SCADA I/O requirements shall be estimated and this shall form the basis for sizing the SCADA system prior to making any provision for spare capacity.

The Contractor shall carry out investigations, studies, calculations, design and documentation as necessary to execute the distributed control.
The scope of work shall include:

- Investigations and Studies
- Engineering and detail design calculations
- Preparation of drawings and other documents for manufacture, installation, testing, commissioning and operation/maintenance
- Factory testing
- Procurement and delivery to site
- Preparation of as-built documents including drawings and project records
- Supply of spare parts
- Training of personnel
- Provision of a specified defects liability period

A block diagram of the SCADA system is shown on the drawings. The Contractor may propose a different arrangement to suit the equipment being offered provided the required functionality and availability is achieved. The Contractor shall submit the SCADA architecture, WAN and LAN design, RCU design, I/O calculations, software, workstation and PLC hardware details to Engineer for approval before procurement. Contractor shall include block diagrams showing the type of equipment and arrangement proposed.

At the south and north control centres, the following equipment shall be provided on the SCADA LAN:

User/Function	Required
3 x Operator Workstation	Dual screen workstation
2 x SCADA Applications Servers	Dual servers
Historian Server	Single server
Remote Communications	Dual routers / communications interfaces
Print Server	Single server
Printers	Laser, 2 monochrome, 2 colour
Large display screen interface	Single video driver for large screen display

Time Synchronisation server	Server to synchronise network PCs

In addition, two desktop computers shall be provided for the control centre office. Desktop software shall be provided. The desktops shall be connected to the control centre LAN.

Two notebook PCs shall be provided for use as engineering support and diagnostic tools. They shall be supplied complete with all interfaces and cables to allow them to be plugged into the WAN, as well as directly into the equipment they support. The system shall consist of the south and north control centres. They shall operate on a master/standby basis, but with distributed functionality so that the main centre normally controls. sub control centre workstations shall replicate the control centre workstations which are on the same communications loop and shall normally be used only for monitoring.

6.2 SCADA Hardware requirements

The SCADA system shall be configured with sufficient resources and computational power to meet the specified performance requirements. Particular emphasis shall be placed on configuring a system with non-proprietary hardware and an open software structure. Replacement of any hardware with equivalent hardware of different manufacture shall have no effect on the operation of the system.

The system design shall ensure that no single points of failure exist which may significantly degrade the availability of any of the basic critical SCADA functions. That is, the failure of any one major system component shall not impair the ability of the system to meet its performance objectives.
The system shall be capable of future growth with minimal disruption to existing hardware and software structures, including the database.

6.3 Local Area Network (LAN)

A dual redundant high speed data network operating at a speed no less than 100 Mbits/sec shall be provided and Ethernet network standard (IEEE 802.3) shall be used. The network shall be based on an open standard and shall not be proprietary. The access method for the network shall be Carrier Sense Multiple Access/Collision Detect (CSMA/CD) (IEEE 802.3).

All components connected to the network shall be able to access both LANs. However, the SCADA system shall be able to operate with only one LAN available. The interface between the components and the LANs shall be designed such that any failure of the components or its interface circuitry shall not disrupt the operation of the LANs. No single component shall be allowed to continuously access the LAN‘s for more than a specified time.

The medium used shall be fibre optic cable. Within the same building copper cables may be used. The cable shall be well protected against mechanical stresses, low smoke, halogen free and fire rated by installation underground in ducts. Two separate cable routes shall be used for running the two LAN cables. The protocol for the network data interchange shall be

the Transmission Control Protocol/Internet Protocol (TCP/IP). No proprietary protocol shall be employed.

The SCADA LAN shall be extended to all RCU stations that are connected by dual redundant fibre optic cable to allow layer 3 routed messages to be sent between all locations over the communications SDH network. LANs and network devices installed at RCU stations shall be of rugged industrial construction, able to operate without error in an electrically noisy environment and able to withstand the outdoor environmental conditions.

6.4 Workstations

Operator workstations shall:

present information in a clear and well organised manner. highlight exceptional data and network states.

abnormal conditions through alarm and event warnings.

have logical interactive operating procedures with short response times. have a dynamic network colouring system to indicate status of equipment.

The operator workstations shall work independently of each other, but each shall have access to all SCADA facilities.

Be equipped with the latest technology Intel microprocessor, latest technology graphics cards, latest technology Microsoft Windows and office suite, 6G memory and 1TB or more hard drive.

Have 23 inch flat screen technology type display with highest commercially available resolution

6.5 Large Screen Display

The Contractor shall provide a large-screen display as described in the CCTV section. The screen shall be minimum 2m x 2m size.

Comprehensive graphic diagrams with different levels of details shall be prepared to show the real time status of any equipment being controlled and monitored. Alarms shall be displayed in an alarm list with time/date tags in chronological order. High and low priority alarms shall be displayed in different manners to attract the operator‘s attention to more import alarms. All alarms shall require acknowledge by the operator. To minimise operator input, global acknowledge facilities shall be provided. All events such as alarms, status changes, operator commands etc shall be logged with time and date tags in chronological order.

6.6 System Clock

A Global Positioning System (GPS) time synchronisation system shall be provided for each

control centre. The clock system shall provide Indian local time with a resolution better than 1 millisecond. The two GPS systems shall monitor each other‘s performance, and shall have an alarm signal connected to their local RCU. Synchronisation shall occur through network time protocol NTP, and shall have the facility to failover to the standby server upon alarm.

The system clock shall be used in all time tagging operations and synchronising the time of the RCUs. If a Primary Reference Clock is supplied, it shall be used as the system clock. The system clock shall be battery backed. The battery shall enable the clock to operate for a minimum 24 hours without normal power supply. The computer system of the control centre shall not drift more than 5 milliseconds relative to the system clock between time synchronising. The clock system shall ensure that all control stations and RTUs do not drift by more than 5 milliseconds between time synchronising.
A wall clock showing system time to the nearest second shall be mounted in each control room adjacent to the large screen display. The size of the clock display shall be large enough to be read from any of the operator workstations.

6.7 Control Centre Input/Output

A local RTU (Remote Terminal Unit) shall be provided for each RCU for local interfaces such as building services, power supply alarms and general alarms.

6.8 Man Machine Interface

The system in general shall provide the following operator functions:

- System shall interpret all operator commands and data inputs as well as acknowledge operator actions
- Provide operator displays and messages, and printing
- Provide data recording
- Provide system maintenance and fault reporting facilities
- Provide operator override of automatic system
- Provide incident management in emergencies

All items of plant shall be displayed in a graphical manner. The graphical display shall be display all systems in their entirety. E.g. the ventilation system shall have all fans, dampers, sensors etc displayed with status/control icons beside each item of plant. The Plant equipment shall be controllable via Icons, for e.g., electrical and ventilation equipment can be selected in single or groups and switched on/off or have their operational plans changed.

Menu driven activity selection for all equipment, subsystems or systems Scope of operator interface shall include the following but not limited to:

Status reports

System status of:

1. Electrical LV equipment
2. Lighting
3. Traffic system equipment
4. Radio
5. CCTV
6. Telephones and Motorist emergency telephones Control functions for:
7. Signage
8. Emergency evacuation
9. LV switchboards
10. Rain deluge and drainage
11. Traffic equipment

6.9 Control Centre Furniture and floor

A control desk shall be provided for each control centre workstation. They shall be commercially available ergonomically designed furniture for computer workstation applications, and shall have facility to adjust the height of keyboards and display screens.

The operator desk shall be fitted with:

- workstation
- voice communications facilities
- office desktop computer

The office desktop computer shall match the equipment provided for the workstations. Gas-lift executive office chairs with side arms and five-way casters shall be provided for each control centre workstation.

A cabinet shall be provided in the control room on which the control centre printers are installed. The cabinet shall include space for storage of manuals and printer consumables. One fire proof cabinet shall be provided in each control room for storage of software and backup tapes.

A computer access floor shall be provided to allow all cabling to be installed under floor. The floor shall be complete with floor supporting structure, floor tiles and all cable support structures and cable guides under floor. The control equipment rooms shall also be provided with a computer access floor.

All cabling within the computer floor shall be installed on cable tray or in purpose made cable ducts.

6.10 Remote Terminal Unit (RTU)

The Remote Terminal Units (RTUs) are the interface between the SCADA system and the

field equipment at Remote Control Units. In general, PLC station RTUs shall comprise communications modules on PLC equipment. In some cases, a discrete RTU may be required. In this case, field equipment shall be connected to the RTU through a marshalling cabinet which has isolation facilities on its terminal blocks.

Discrete RTUs shall be of a rugged industrial type suitable for installation in an electrically noisy environment. RTUs incorporating office PC parts shall not be accepted. The RTU shall be of modular construction with separate replaceable functional subsystems. An arrangement with plug in modules is preferred mounted in a 19 inch rack.

6.11 SCADA Software Requirements

The computing system architecture shall be structured with the following objectives:

- open systems computing environment
- reliability and availability
- system performance
- expandability

The hardware and software systems shall be based on industry-accepted generic standards, issued or endorsed by independent international technical standards organisations or on de facto standards that have been adopted by multiple vendors and a large majority of users. Single vendor proprietary standards shall not be accepted.

Preference shall be given to systems based on major international standards such as:
UNIX Operating System - conforming to IEEE POSIX Standard 1003.1, the AT &T System V Interface Definition and the current revision level standards (SVR4).

Linux Operating System – conforming to Linux Base Standard, and Red Hat Enterprise Linux Version 3

Microsoft Windows

International Standards Organisation (ISO/Open System Interconnection (OSI) Standards - 7-Layer Computer Systems Architecture Recommendations for Open System Interconnection

Network Protocols - conforming to IEEE 802.3 and 802.4 or equivalent (EthernetR and Token RingR Local Area Networks Standard)

Transport Level Protocols - corresponding to TCP/IP transmission standards ISO Standards for Computer Networks - i.e.: X. 11, X.12, X.25 X.400 etc.

ANSI Standard Sequential Query Language - SQL interface for database management systems

The system supplied shall be based on modular hardware and software system components

ensuring:

- portability of software across diverse equipment platforms, ensuring hardware vendor independence
- scalability of all system software to allow operation without alteration or reconfiguration on small scale systems (desktop workstations) through to large computers
- interoperability of hardware from different vendors on the same network as well as compatibility of third party software packages on various hardware platforms
- flexibility to easily locate hardware and software units at the point where they can be most effectively used and managed
- reliability through network redundancy, client-server operations and distributed software

The key emphasis shall be to ensure that parts of the system can be upgraded without disturbing the integrity of the remaining items. The system shall have both vertical and horizontal upgrade paths with access to a wide range of third party software applications.

6.12 System Security

The system shall be implemented with multiple levels of security to prevent unauthorised access or malicious tampering. The operational SCADA network itself shall be segregated from external networks by a firewall set up with a policy of —"everything not specifically permitted is denied". The historian server shall act as a buffer between the SCADA LAN and external equipment.

Systems shall be implemented to guard against malicious attack such as computer viruses and trojans.

All computers that directly access or log into servers on the SCADA LAN shall operate under a controlled environment whereby the only users permitted to install software are those with system administrator capability.

6.13 IT Infrastructure

The SCADA system provided shall include all required IT services and supporting functions. The Contractor shall set up and configure all network hardware and software that is provided so that it performs all the required functions. The Contractor shall also reconfigure any existing equipment which is integrated into the SCADA network so that they interoperate correctly. The SCADA software shall include the ability to automatically send email to nominated addresses on the occurrence of defined events.

6.14 Historian Servers

A separate —data historianll server system shall be provided which shall store operational data for at least five years. It shall allow users to access subsets of the stored data on request in a variety of different formats.

The historian servers shall be arranged as a backup of the other such that failure of one

server shall be transparent to the system and shall not cause any loss of data. Reinstatement of a failed or offline server shall cause the reinstated server to be updated with all data missed while it was off line. Contractor may propose alternative redundancy arrangements for these servers.

6.15 SCADA Software Configuration

The system shall provide information storage, retrieval and display facilities. The storage facilities shall be in the form of a real time relational database management system, plus special modules for historical archival and retrieval to graphic screen based presentation displays.

SCADA system database shall preferably be based on the relational model optimised for real time system operation. SCADA system shall include a full graphic display system with a well-defined and consistent graphical user interface. All operator interaction shall occur via this facility. SCADA system shall automatically report abnormal conditions and alarms through a standardised alarm/event annunciation system. SCADA system shall include facilities for event/alarm logging, screen trending, recording and screen copying.

SCADA software shall include facilities for power demand and ventilation fan schedule planning. These facilities may be custom modules rather than part of the proprietary software.

6.16 Communications Requirements

The communications system shall comprise:

- SDH Fibre Optic Transmission System
- Network Management System
- SCADA Wide Area Network
- Closed Circuit Television (CCTV) Surveillance System
- Telephone System Facilities

The core communications is the SDH fibre optic transmission system, which shall interconnect all electrical niches, caverns and control stations. Other communications media shall be used only where use of the SDH fibre optic transmission system is not practical.

Existing telecommunications system facility to the site shall be investigated and the communication equipment shall be linked. The Contractor shall review the existing communication infrastructure and base the design on the Synchronous Transport Module (STM-16/4/1) telecommunications network.

Contractor shall provide details of the fibre optic cable (FOC) entry and exit to each control point. Contractor shall complete the FOC termination where necessary.

SCADA data communications network shall be designed according to the following criteria:

Each remote terminal unit (RTU) shall be connected to the control centres via two independent circuits to ensure maximum reliability: a —main‖ and a —backup‖ circuit via the digital network.

At stations serviced by two or more independent fibre optic circuits, the interface with the RTU or station shall be digital, e.g. two 10 Mbit/s IEEE 802.3 Ethernet ports, with the option of adding a third asynchronous serial port.

—Main‖ and —backup‖ circuits shall employ separate multiplex paths en route to the control station and shall terminate on separate primary multiplex units within the stations. This shall enhance system reliability.

6.17 Network Management Requirements

A complete telecommunications network management system (NMS) shall be installed at both centres to provide real time monitoring of communications equipment parameters and alarms and facilities for collecting communication statistics. NMS shall be configured as a master NMS located at south portal and a standby NMS located at the north portal. The NMS shall be based on workstation computers with graphic user type interface and text based menu systems. The configuration shall ensure that the NMS is operational at all times. One of the three workstations at the south control centre shall be designated as the main NMS workstation for this with full privileges at any time. A standby NMS workstation at the north portal shall have a monitoring role when the south workstation is the designated master station.

The network management system shall be based on Open Systems architecture conforming to the ITU-T Recommendations M.3010 and G.784. The individual network elements shall be interconnected as a managed SDH sub-network.

6.18 System Backup/Redundancy Requirements

The system shall be configured to ensure that no single point of failure can cause the loss of a critical function.

Critical functions defined for this system are:

- data acquisition
- data processing
- historical data storage
- supervisory control
- alarm/event processing
- network security subsystem

The system shall be provided with sufficient redundancy to meet the required availability figures and to avoid the loss of any critical function. The systems shall use redundant power

supplies, which shall be powered from two independent switchboards that are each powered by a separate UPS. Failure of one supply shall cause no loss of critical functions.

6.19 Computer System Redundancy

Computer system redundancy shall be achieved by providing dual server computer configurations for SCADA application servers. Either of the two computers shall be able to sustain all server functions independently of the other.

The IEEE 802.3 LAN cable and equipment shall be configured for circuit redundancy. The Contractor shall recommend their preferred configuration to meet the system availability specification (e.g. dual cable LAN, ring, linear or star topology).

6.20 Communications Redundancy

On failure of main communication path the software of the concerned subsystem shall automatically switch to the alternate path. The system shall periodically perform the polling of RTU/PLC on their alternate path in order to confirm the integrity of this path.

If valid data is not received from a data source in response to a scan command, the software shall issue another scan request for data from that source. If an invalid or no response occurs again then the RTU or data link is considered to have failed and this condition shall be alarmed. Additional details of the failure including the particular equipment or link that has failed shall be provided via the communications network management system.

If an entire source or its communication channel fails, individual points shall be marked in the database to indicate communication failure. In the event of communication failure, the SCADA shall retain in the database the last good value or status for any point experiencing such communication failure. For calculated data, the failure of any component data value shall not disrupt the continued processing of the calculated values using the failed point. Operator shall be provided with the capability to substitute a value in the database for any point that is experiencing communication failure. When communication returns to normal, the SCADA shall automatically resume updating the database with live data from the data source.

6.21 SCADA Functional Requirements

Supervisory Control

The system shall provide supervisory control functions via control commands to PLCs and RTUs. The control command shall be issued on a priority basis after the control request by the operator has been checked for validity and authorisation. The system shall be capable of executing "single-shot control", "regulatory control" or "continuous control" commands. Supervisory control commands of both the "select-before-operate" type and the "direct operate" type shall be provided. The assignment of a particular control type shall be defined on a point-by-point basis in the SCADA database.

The system shall be capable of issuing set-point commands after verification by the system. Verification to be performed includes comparison with nominated analogue values or digital

status points as well as confirmation of control circuit continuity.

If the control action is inhibited, the system shall request revalidation of the action from the operator. If the revalidation is confirmed, the control action shall be executed and treated as a system event. If the request is not confirmed, the system shall accept a revised target set-point.

All control operations shall be checked for completion. The system shall verify that the requested control action has occurred within a fixed completion time period. If the expected new status or analogue change is not detected within this period, a —control action failed to complete" alarm message shall be annunciated. Each controllable device may have a different completion time period. The system shall accommodate at least 16 different time periods. The status change as a result of a control action shall be immediately annunciated on receipt from the outstation.

Operator/System Interface Functions

This section describes the human/machine interface (HMI) functions required for the system. Typing activities required to execute functions shall be minimised.

The operator interface shall be via functionally identical workstations at each of the Workstations. All functions shall be capable of simultaneous utilisation on all workstations. Any display may be presented on any of the system VDUs (Video Display Unit) at any one time.

The operator shall monitor and control the equipment at all stations through the use of on-screen buttons via a cursor pointing device, keys on an alphanumeric keyboard and VDU displays with function activation points.

The Contractor shall provide a consistent graphical user interface (GUI), which maintains identical procedures from one application to another. The GUI shall allow the operator to switch from session to session without affecting the current operation in any session.

Workstation Modes

Workstations shall be assigned to different modes in accordance with the functional requirements of the users. The workstation modes shall restrict the users to specific functions of the SCADA system.

Workstation modes shall direct alarm information only to those workstations where the alarms are required. The functions of alarm display and alarm control shall be independent and separately assignable to one or more workstation modes.

Display access for viewing only, and display access for data entry shall be independent and separately assignable to different workstation modes.

The workstation modes system shall be:

- System Operator Mode
- Training Mode
- Maintenance Mode
- Engineer/Programmer Mode

System Operator Mode shall provide only those functions, alarms and events applicable to the monitoring and control functions required for secure and reliable operation.

Training Mode is generally identical to the on-line mode with the exception that all control functions are blocked for all points in the system. Control functions shall be allowed only to a designated Test RTU. No modifications to the on-line database, displays, applications or system configuration shall be allowed in Training Mode.

Maintenance Mode is a special mode used for testing stations or points that have been assigned by the operator to be in maintenance and are tagged with an "M" quality code. Any display may be viewed in this mode; however control functions shall be blocked to all points in the system other than those with an "M" quality code tag.

No modifications to the on-line database, display, applications or system configuration shall be allowed in Maintenance Mode.

System Engineer/Programmer Mode allows access to all facilities of the system, except control functions. All control functions shall be blocked to all points in the system other than those with an "M" maintenance quality code tag. Database and display maintenance, programming, application module testing and system configuration changes shall be undertaken in this mode.

Access Security

A password system shall be provided with a unique password for each user. For "logging-in" to the system, each user shall be given an access privilege from among the 3 security levels which are user (level1), supervisor (level 2) and administrator (level 3). For most users, the lower of the user or workstation privileges shall be assigned at logon.

The session "log-off" procedure shall cancel the current access privileges of the particular workstation; this is also applicable when during a session there is no input device activity for a set period of time resulting in automatic time out and log-off.

Information storage and Retrieval

It is required that the SCADA system maintain a non-proprietary, open computing environment. Fundamental to this is a flexible, modern database structure capable of operation in a real-time distributed computing system and supported by well-proven database management software.

The SCADA system shall include a group of information storage and retrieval functions to collect and store data periodically and on an event-initiated basis, and to provide facilities to retrieve, sort, analyse, display, and report the data. The data to be collected shall consist of measurement and status values that are communicated manually entered and calculated

together with their associated quality codes, as well as alarms and messages. The SCADA shall provide data storage and retrieval using auxiliary memory and magnetic tape. Transfer of selected stored data to other computer systems shall be feasible.

The stored data shall be time and date tagged and shall contain sufficient information to enable the retrieval functions to access the data and quality codes. Stored data shall not be affected by any future database changes, computer system failure recovery, or regeneration of the computer system configuration. All stored data shall be accessible from any time period regardless of SCADA changes after storage of that data.

Historical Data Collection

The historian facility shall collect SCADA data, store the data without loss of detail for at least five years and present the data in various formats for client to use. The stored data shall include values and quality flags.

The historian shall also store static reference data such as equipment ratings, lists of PLCs and RTUs and system documentation for easy access. It shall be possible to designate any SCADA database point for historical archival through a database point attribute.

6.22 SCADA Diagnostics

System Performance Monitoring Software

Facilities shall be provided to gather on-line statistics at specified time intervals about CPU utilisation, CPU idle time, input/output waits, number of input/output transfers and other useful information to enable system loading and performance to be analysed. It is desirable that this gathering process can be initiated by the operator on a single shot or repetitive basis, and for a time interval variable in increments of 1 minute. The resultant statistics shall be suitably formatted on an operator-selected VDU screen, and it shall be possible to obtain a printout of the screen image.

Hardware Diagnostics

Diagnostic routines shall be provided to enable all hardware components to be thoroughly tested. Diagnostics should as far as possible present a logical and consistent interface to the user so that they are as simple to operate as possible. They shall be comprehensive and shall where possible provide printout of the test performed and the results obtained.

On-line diagnostics or exercisers shall be provided which enable limited testing to be performed on-line. Such diagnostics shall not disrupt the operation of the real-time system, but shall enable devices having a relatively low level of usage to be exercised periodically or on demand.

Off-line diagnostics shall be provided to enable hardware malfunctions detected by the operator or by the on-line system to be pinpointed. In some cases, e.g. for malfunction, the device will be failed either automatically or by operator action and a backup device will be used. In such cases the device may be switched to the backup computer and off-line

diagnostics used to find the fault. In other cases, e.g. for main memory or bulk storage malfunctions, system failover may occur either automatically or as a result of operator action. In such cases the diagnostics will be executed in the previously on-line machine.

Engineering Order Wire

An engineering order wire facility shall be provided which provides communication between all control points on the optical fibre network.

6.23 Equipment Earthing

Earthing systems shall comply with the requirements of Indian Standards. Safety earth cabling shall be coloured green. All earth cabling shall be continuous throughout its length. Earth connections shall be made using machine threaded bolts fitted with spring washers. Cable terminations shall be rigidly bolted to the terminal strips/bars. Soldered connections and spade connectors are not acceptable. All terminal bars/strips shall be clearly labelled. All conductive devices, antenna cables, equipment racks, cable tray, centenary wires and cabinets shall be earthed by connecting a safety earth using 4 mm2 copper cable coloured green/yellow. The Contractor shall extend a low impedance earthing system from the main building earth bar, independent of, but bonded to, the general light and power earth system. The Contractor shall provide a separate earthing system provision for OMCS but common at the main earth only.

The entire system shall be earthed to provide the same potential including all devices and equipment.

6.24 Labelling

All equipment, patch panels, wall outlets and cables shall be labelled as to its designation and status. Equipment labels shall be conspicuous and manufactured from approved material engraved to approval, particularly in respect of size and lettering. All lettering and numbers shall be in metric SI units.

7 TRAFFIC MANAGEMENT CONTROL SYSTEM (TMCS)

The major works listed out hereafter is for reference only and for identification of its major components and necessary interfaces with OMCS and other systems. TMCS consists of the followings:

Design, supply and install two Variable Message Signs (VMS),

Design, supply and install pairs of Variable Speed Limit Signs (VSLS). Design, supply and

install Video Incident Detection System.

Design, supply and install CCTV surveillance system with PTZ dome cameras. Design,

supply and install an Emergency Telephone System.

Design, supply and install a Public Address System with loudspeakers.

Design, supply and install a Break-In to the Radio Rebroadcast Communications System

Design, supply and install a bridges and roads closure system comprising traffic signals and boom gates at ends.

Design and supply and install a Traffic Management and Control System to monitor and control all the above systems.

Design supply and install a fibre optic communications system to integrate the above systems.

Full documentation, Design Reports, —As-built drawings, Testing Plans and Procedures, Operation and Maintenance Manuals for all supplied equipment.

Testing and commissioning of all the above systems including Factory Acceptance Testing for each component, Integration Testing, Inspection testing, Site Acceptance Testing and Commissioning.

7.1 Scope

The OMCS shall include a TMCS to monitor and control traffic movements in the bridges and roads. The TMCS shall:

- Respond effectively to emergency situations in the shortest possible time frame
- Optimise the traffic flows to prevent flow breakdown that leads to congestion
- Manage incidents effectively, through a comprehensive Incident Response System, to mitigate the impacts of Incidents and prevent secondary Incidents occurring
- Provide creditable and timely driver information about traffic conditions and incident situations use standard internationally recognised protocols (NTCIP etc.) for communications between the TMCS, and field devices.
- Provide a secure interface for future integration with other control centres using internationally recognised protocols (NTCIP etc.) for communications standards.
- Operate independently of all other systems and have separate server, RCU‘s I/O processors and data network
- Be supported by secondary or manual systems to allow the TMCS to be safety operated in the event of a system failure
- Stopped Vehicle(s) Slow moving vehicle
- Automatically select the appropriate camera to monitor an incident and switch the images to the defined monitors in the control room.
- Implement ad hoc and planned traffic incident responses when incidents are logged.

- Monitor and control traffic control devices, including as a minimum:
    - Variable Speed Limit Signs (VSLS)
    - Variable Message Signs (VMS)
    - Automatic Video Incident Detection (VID) System
    - CCTV system including surveillance cameras
    - Traffic signals
    - Traffic data Loops

- Control voice communications to motorists over a radio rebroadcast system and public address system

- Provide data to a remote control centre workstations

- Manage the interface to and access by the backup system for operator training purposes by simulating device changes on the workstation without affecting the actual field device or other workstation operations

- Provide logging and reporting of all TMCS functions

- Continuously collate operational data for long term traffic planning and operational and maintenance service implantation

- Provide a comprehensive computer based control facilities through workstations using Windows 7 and a map-based Graphic User Interface (GUI) to monitor, command, control and report every functional component of the TMCS locally in the control rooms and at the remote control centre

- Have an internationally recognised open system architecture using Ethernet backbone to allowing a plug and play approach to device connection.

- Use proven systems for TMCS that are operating in at least six similar projects in developed countries and have a track record for reliability and availability

- Have an availability of 99.998%

- As part of the development process of the system must comply with ISO/IEC 61508 Parts 1,2,3,5 and 7 Set Functional Safety of Electrical/Electronic / programmable Safety-Related Systems and all other relevant IT, hardware and network development standards

8 CONTROL AND SERVICE BUILDINGS

Design, supply and install a complete lighting, power and communications system for

the control and service buildings.

General

Carry out Testing and Commissioning of all electrical systems and components. Carry out training of personnel.

Submission of Documentation.

Provision of As-Built documentation and manuals. Provision for sealing all penetrations.

Provision of spare parts and associated storage cabinets. Provision of tools and

associated
storage cabinets. Carry out maintenance during the warranty period. The Contractor shall be

responsible for the following:

Installing the work so as not to foul or interfere with the work of any other trade.
Completing all work in sufficient time so as not to delay any other trade.

Co-ordination with other trades and supplying details to other trades to enable them to make the necessary provisions for the installation.

Coordination with other bridges and roads services Contractors and supplying details to those
Contractors to enable them to make necessary provisions for the installation.

Provide and undertake all necessary modification, provisions and adjustments necessary to achieve the design intent as indicated on the drawings and the specifications.

Liaise and coordinate with all authorities having jurisdiction.

8.1 Lighting

The Contractor shall design, supply and install a complete lighting system for the buildings. All luminaires, fittings and accessories shall only be proprietary type. The Contractor shall install lamps in all luminaries and verify correct operation before completion. Emergency supply shall be connected to the lighting in the Buildings.

Contractor shall provide the following:

A) Lighting switches. B) Dimmers.

The Contractor shall mount luminaires on proprietary supports by means of battens, trims, noggings, roses or packing material to suit the location.

The lighting system shall utilise 2x28W fluorescent lighting with electronic ballasts. The lighting shall be designed to the following maintained lighting levels for the following areas:

Area	Lighting level (lux)	Lighting type
Control room	600	2x28W recessed troffer fittings with ultra-low brightness diffusers. Fittings to be dimmable type. Provide a digital dimming system in the control room.
Control equipment room	300	2x28W recessed troffer fittings with ultra-low brightness diffusers.
Offices/training room	400	2x28W recessed troffer fittings with ultra-low brightness diffusers.
Pantry	400	2x28W recessed troffer fittings with a sealed prismatic diffuser suitable for kitchen applications
Amenities	200	2x28W surface fittings with wrap around prismatic diffusers.
Store	100	2x28W surface fittings with wrap around prismatic diffusers.
Plant rooms	200	2x28W surface mounted weatherproof fittings (IP66).
Circulation space	100	As for plant rooms for external spaces. Internal spaces as for stores.
Parking	100	2x28W surface mounted weatherproof fittings (IP66).

8.2 Emergency Lighting

Design, supply and install a complete operational emergency evacuation lighting system, tested and commissioned in accordance with IEC/ISO standards for emergency lighting.

Visual indicator lights: Provide a red indicator, readily visible when the luminaire is in its operating location, which indicates that the battery is being charged.

Inverter system: Provide protection of the inverter system against damage in the event of failure, removal or replacement of the lamp, while in normal operation.

Local test switches: Provide a momentary action test switch, accessible from below the ceiling, on each luminaire to temporarily disconnect the mains supply and connect the battery to the lamp.

Common test switches: Provide a common test switch on the distribution board which disconnects main supply to the luminaries and tests for discharge performance, after testing;

this switch must automatically revert to normal operating mode.

Type: Lead-acid or nickel-cadmium batteries capable of operating each lamp at its rated output continuously at least 2 hours during completion tests and 1.5 hours during subsequent tests.

Battery life: At least 3 years when operating under normal conditions at an ambient temperature of 25ºC and subjected to charging and discharging at 6 monthly intervals.

Marking: Indelibly mark each battery with its date of manufacture.

General: Provide an unswitched active supply to each luminaire and exit sign, originating from the test switch control panel.

8.3 Power outlets

Design, supply and install a complete power system for the Buildings. All power outlets shall be connected to emergency supply. Power outlets shall be the double general purpose outlet type (DGPO). Outlets shall be the BS 546 IAI6A3 D type 5A three pin type with active, earth and neutral and rocker switch with additional facility for Type M 15A for areas where increased portable loads may be required. Outlets shall be fabricated from impact resistant plastic with different colours to identify outlets on normal and emergency circuits. Outlets shall be the recessed flush type in office areas and the weatherproof impact resistant type in control rooms.

Area	Number of outlets	Outlet type
Control room	As required but a minimum of 1 every 5m2.	Plug in type with captive lead for underfloor application.
Control equipment room	As required but a minimum of 1 every 5m2.	Plug in type with captive lead for underfloor
Offices/training room	As required but a minimum of 1 every 5m2.	Recessed flush type
Pantry	10	Recessed flush type
Amenities	2	Recessed flush type
Store	1	Weatherproof type
Plant rooms	2	Weatherproof type
Circulation space	1	Weatherproof type
Parking	1	Weatherproof type

8.4 Voice/data cabling and communications system

Design, supply and install a complete voice/data communications and cabling for the Buildings. Provide a complete operational telecommunications cabling system, tested and

commissioned in accordance with ISO/IEC standards for category 6 communications cabling systems. Provide accommodation for telecommunications cabling infrastructure complying with ISO/IEC standards. Include the following:

A. 45 RU cabinet complete with patch panels and power rails supplied from the UPS

B. Switches equal to HP or Cisco

C. Office server

D. Category 6 voice/data cabling to RJ45 outlets

E. Patch leads

F. Individual workstations shall be provided by the OMCS Contractor.

Application Class

Application class to ISO/IEC standards for category 6.
Conformance: Certify the design and installation for conformance with ISO/IEC standards. System warranty: Warrant the specified communications cabling performance for a minimum of 15 years.

Records

Record book: Provide a record book at each cross connect.

Records in pencil: Complete the records in pencil for each termination and jumper, providing origin and destination and type of service.

Location: Secure log books in each distribution frame records holder. Identification and

labelling, and record documentation:

Cable separation

Low voltage cables: Separate telecommunications cables not enclosed in conduits or ducts from low voltage services by at least 150 mm.

Electromagnetic interference (EMI): Provide clearance to minimise the effect of EMI where communications cables are installed parallel and adjacent to power cables carrying loads in excess of 200 A.

Installation

Crossover: Install cables neatly and without crossovers between cables.

Loom size: Loom cables into groups not exceeding 50 cables, and hold looms in place using reusable cable ties at least 20 mm wide. Do not exert compressive force on the cables when installing cable straps.

Outlets

Outlets: Provide RJ45 8 way modular jacks.

Pinouts: The pinouts vary with the application. Determine required pinouts before making cable terminations.

Flyleads

General: Provide fly leads to 50% of the outlets installed.

Earthing

Communication earth system (CES): Provide a communications earth terminal (CET) associated with the local protective earth (PE) system adjacent to each electrical distribution board.

9 PROJECT OPERATIONAL VEHICLES

This document describes the design, manufacture, delivery, installation, testing and commissioning and operational maintenance requirements of the Project Operational Vehicles for the Project.

A detailed design shall be completed for the whole of the works described in this performance specification, together with coordination with other services and compliance with all Authorities having jurisdiction over the works. This performance specification describes the intent and extent of works and standards of work required.

Reference shall also be made to any commercial documents which may be applicable to these works.

9.1 Maintenance Vehicles

The Maintenance Vehicles shall be as follows:

- Located at the control room for maintenance purposes only.
- One shall be supplied for the maintenance manager, one shall be supplied for the electrical maintenance staff and one shall be supplied for the mechanical maintenance staff.
- The maintenance vehicles shall be twin cab.
- Similar to TATA TL Crew Cab 4X4 or approved equivalent.
- 1950cc engine capacity
- run on diesel fuel
- provided with a lockable tool box.
- provided with a roof rack and rear frame for transporting equipment on the roof of the vehicle.
- provided with a first aid kit.
- Suited to the local weather conditions and altitude at the project site.
- Vehicles provided shall be brand new, not second hand or rebuilt in any way and supplied with dealers paperwork.

Volume 4

Outline Design Specifications

Section 5

STRUCTURAL HEALTH MONITORING OF BRIDGE

1 STRUCTURAL HEALTH MONITORING OF BRIDGE

- Installation of continuous vibration monitoring system on bridge with Tri-axial accelerometer fixed at pre-decided locations in with permission of client.
- Installation of notification system based on maximum peak particle velocity (PPV) or as may desired by structural consultant from time to time. Any exceedance of vibration value beyond allowable value will be intimated to client.
- For inspection of working conditions of whole system consisting data acquisition system, accelerometers, etc. and ensure the serviceability of installed system.
- It is expected that the contractor shall develop the system with control center for continuous monitoring. The contractor shall submit monthly comprehensive report based on the readings observed during DLP.
- After DLP, the system shall be handed over to BMC till end of design life.
- The contractor shall organize two day training program on completion of contract period and one day training program about the monitoring and reporting of the system in the last month of DLP.
- The training shall be conducted by the experts having more than 20 years of experience.