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 5

Outline Construction Specifications

Contract Code: 7200037432

Volume 5

Outline Construction Specifications

Employer:
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Volume 5

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Roads

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

VOLUME 5- OUTLINE TECHNICAL SPECIFICATIONS

Section 1

Technical Specifications

1 PREAMBLE

The Technical Specifications contained herein shall be read in conjunction with other contract documents.

1.1 Site Information

The information given hereunder and provided elsewhere in these documents is given in good faith by the Employer but the Contractor shall satisfy himself regarding all aspects of site conditions and no claim will be entertained on the plea that the information supplied by the Employer is erroneous or insufficient.

The area in which the work is located is in plain/rolling and hilly terrain, and lies in city limits of Greater Mumbai.

1.2 General Climatic Conditions

Mumbai experiences tropical coastal climate. January is invariably the coldest month and May the warmest. With the onset of monsoon in early June the temperature remains very nearly uniform at about 27deg. The slight raise in temperature falls gradually till it reaches the coldest month in January. The maximum temperatures during .summer and winter are

During summer months, the maximum temperature is 37 ˚c
During winter months, the minimum temperature is 11˚c
The maximum wind speeds for most of the time during the year is from North-West quarter with string winds predominant during South-West monsoon period. The wind speed varies between 4.8 km/hr to 12.7 km/hr. The relative humidity generally is lighter than 60% throughout the year. Average annual rainfall in Mumbai region is 2100 mm. The west coast is subject to occasional severe cyclonic storm. These storms normally occur in the period of May/June and October/November.

1.3 Selection of Material

The tender is prepared on the basis of Unified Schedule of Rates and specifications 2018. The specifications of the items of USOR are available on MCGM portal http://portal.mcgm.gov.inunder the Tender tab. Hence the deserving contractor shall either download the same from MCGM portal or the same may be collected in the soft copy format at the time of purchasing the tender from this office.

1. All materials brought on the site of work and meant to be used in the same, shall be the best of their respective kinds and to the approval of the Engineer. The Engineer or his representative will accept that the materials are really the best of their kinds, when it is proved be- yond doubt that no better materials of the particular kind in question are available in the market.
2. The contractor shall obtain the approval of the Engineer of samples of all materials to be used in the works and shall deposit these samples with him before placing an order for the materials with the suppliers. The materials brought on the works shall conform in every respect to their approved samples. Fresh samples shall be deposited with the Engineer when- ever the type or source of any material changes.
3. The contractor shall check each fresh consignment of materials as it is brought to the site of works to see that they conform in all respects to the Specifications of the samples approved by the Engineer, or both.
4. The Engineer will have the option to have any of the materials tested to find out whether they are in accordance with the Specifications and the Contractor will bear all expenses for such testing. All B bills, vouchers and test certificates, which in the opinion of the Engineer or his representative are necessary to convince him as to the quality of the materials or their suitability shall be produced for his inspection when required.
5. Any materials that have not been found to conform to the specifications will be rejected forthwith and shall be removed from the site by the contractor at his own cost within 24 hours.
6. The Engineer shall have power to cause the Contractors to purchase and use such materials from any particular source, as may in his opinion be necessary for the proper execution of the work.
7. Notwithstanding the source, the sand shall be washed using sand washing machine before use.

2 GENERAL TECHNICAL SPECIFICATIONS FOR ROAD WORKS

2.1 MORTH Specifications for Road Works

The General Technical Specifications for Road works shall be the “SPECIFICATIONS FOR ROAD AND BRIDGE WORKS” (Fifth Revision / Latest Revision) issued by the Ministry of Road Transport and Highways, (MORTH), Government of India, and published by the Indian Roads Congress (IRC). Latest editions with corrections and amendments up to date to the extent they are applicable to the Road works covered under scope of works. Further the specifications for Road works contained herein for some of the items of work will supersede the provisions of the MORTH Specifications for Road works to the extent of their applicability.

Where reference is made in the Contract to specific standards codes to be met by the materials, plant, and other supplies to be furnished, and work performed or tested, the provisions of the latest current edition or revision of the relevant standards as on date of tender and codes in effect shall apply, unless otherwise expressly stated in the Contract. Where such standards and codes are national, or relate to a particular country or region, other internationally recognised standards which ensure a substantially equal or higher performance than the standards and codes specified will be accepted subject to the Engineer's prior review and written Notice. Difference between the standards specified and the proposed alternative standards must be fully described in writing by the Contractor and submitted to the Engineer at least 28 days prior to the date when the Contractor desires the Engineer's Notice. In the event the Engineer determines that such proposed deviations do not ensure substantially equal performance, the Contractor shall comply with the standards specified in the documents.

2.2 Amendments/Modifications/Additions to Existing Clauses of General Technical Specifications.

The amendments to General Technical Specifications for Road works shall comprise of various Amendments/Modifications/Additions to the "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS" referred to in Para 2.1 above and Additional Specifications for particular item of Road works not already covered in General Technical Specification.

2.2.1 A particular Clause or a part thereof in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS (Fifth Revision / Latest Revision)", as corrected in the original referred in Para 2.1 above, where Amended/Modified/Added upon, and incorporated, such Amendment/Modification/Addition supersedes the relevant Clause or part of the Clause.

2.2.2 The Additional Specifications shall comprise of specifications for particular items of works not already covered in General Technical Specification.

2.2.3 When an Amended/Modified/Added Clause supersedes a Clause or part thereof in the said Specifications, then any reference to the superseded Clause shall be deemed to refer to the Amended/Modified/Added Clause or part thereof.

2.2.4 In so far as Amended/Modified/Added Clause may come in conflict or be inconsistent with any of the provisions of the said MORTH Specifications under reference, the Amended/Modified/Added Clause shall always prevail.

2.2.5 The following Clauses in the "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS (Fifth Revision / Latest Revision)" have been amended/modified/added upon: 101,102,107,108,110,111,112,120,201,202,301,304,305,401,409,501,502,503,507,601,602 ,803,811,901,903, 2702.

AMENDMENTS/MODIFICATIONS/ADDITIONS TO EXISTING CLAUSES OF GENERAL TECHNICAL SPECIFICATIONS FOR ROAD WORKS

SECTION 100	**GENERAL**
CLAUSE 101 **(Modification)**	Replace the second sentence of para 2 and shall read as under: The latest edition of all specifications/standards/codes of IRC till 3 months before the final date of submission of bid shall be adopted
CLAUSE 102 **(ADDITION)**	**DEFINITIONS** The following abbreviations shall be added in this Clause: "MORTH" : Ministry of Road Transport and Highways "BMC" : Brihanmumbai Municipal Corporation
CLAUSE 107	**CONTRACT DRAWINGS**
Clause 107.1 **(Modification)**	The first sentence of this Clause shall read as under: "The Drawings provided for bidding purpose shall be as contained in Volume-6 of the Bidding Documents and shall be used as reference only."
CLAUSE 108	**SITE INFORMATION**
Clause 108.4 **(Addition)**	"Identification of quarry sites and borrow areas shall be the responsibility of the Contractor. Materials procured from quarry sites and borrow areas identified by Contractor and to be used in Works must comply with the requirements of quality as stipulated in the Technical Specification for particular items of work."
Clause 110 **(Substitution)**	Public Utilities Replace whole of this clause with the following:
Clause 110.1	The contractor shall be responsible to coordinate with service provider / concerned authorities for shifting of utilities and removal of encroachments etc. and making the site unencumbered from the project construction area required for completion of work. This shall include initial and frequent follow-up meetings / actions / discussion with each involved service provider / concerned authorities. The contractor will not be entitled to any additional compensation for the delay in shifting of utilities. The expenses incurred for shifting of utilities as required by the respective departments shall be made by the contractor.
Clause 110.2	The information contained in the Bid Documents concerning the public utility services such as water, sewer, power transmission lines, telephone lines and oil/gas pipelines, OFC cables, etc. may not be exhaustive, and it shall be the responsibility of the Contractor to

ascertain the utilities that are likely to be affected by the works through site investigations and collection of information from the concerned utility owners.

Clause 110.3 The contractor will make payments to the respective service provider/authorities for shifting of utilities, wherever required. The Contractor will obtain necessary approvals from such authorities and also in cases where payments are not required to be made for such shifting.

Clause 110.4 Any utility likely to be affected by Contractor's work should be brought to the notice of the Engineer and such work shall be undertaken only after getting written clearance from the Engineer.

Clause 110.5 The Contractor may be required to carry out certain works for and on behalf of the various bodies and the Contractor shall also provide, with the prior Notice by the Engineer, such assistance to the various bodies as may be authorized by the Engineer.

Clause 110.6 The work of temporarily supporting and protecting the public utility services during the execution of the Works shall be deemed to be part of the Contract and no extra payment shall be made for the same.

Clause 110.7 The Contractor shall be responsible to co-ordinate with the services providers for cutting of trees, shifting of utilities, removal of encroachments etc., to make site unencumbered from the project construction area required for completion of work. This will include frequent follow up meeting/actions/discussions with each involved service provider/concerned authorities. The Contractor will not be entitled for any additional compensation for delay in cutting of trees, shifting of utilities and removal of encroachments by the service provider/concerned authorities. Co-ordination for making project site unencumbered shall be deemed to be part of the Contract and no extra payments shall be made for the same.

Clause 110.8 In some cases, the Contractor may be required to carry out the removal or shifting of certain services/utilities, which are unforeseen at the time of tender on specific orders from the Engineer for which payment shall be made to him as Variation to the Contract. Such works, however, shall be taken by the Contractor only after obtaining approvals from respective service provider/Authority and clearance from the Engineer and also ensuring adequate safety measures.

Clause 111.13 (Addition) **Dust Control During Construction**

The Contractor shall make adequate provision, including frequent spraying of water, to mitigate dust nuisance from on-site equipment during the construction of the works

Clause 111.14 (Addition)

Sanitation

The Contractor shall make adequate sanitation facilities for labour and Contractor's camp, including provision of lavatories, sewage disposal, and solid waste collection and disposal.

CLAUSE 120

FIELD LABORATORY

Clause 120.2 (Modification / Addition / Substitution)

Replace the words "shown in drawings" in the first sentence of first paragraph of this Clause with the words "per provisions indicated in this clause and at a location approved by the Engineer."

Add the words "including uninterrupted power supply" to the second sentence of first paragraph.

Delete the first sentence of second paragraph and substitute the following:

"The floor space required for the field laboratory shall be not less than 300 Sq.m" Delete the fourth sentence of second paragraph shall be read as under.

"A good semi furnished office accommodation shall be provided to each of the Material Engineers of the Supervision Team as per the direction of the Engineer." Add the following at the end of this Clause:

"There shall also be provided a concrete paved area, for storing samples adjacent to the laboratory, of about 300 Sq.m and another 200 Sq.m shall be suitably roofed with open sides giving protection against sun and rain.

Within 14 (fourteen) days of the commencement date, the Contractor shall prepare and submit a layout plan and details of the laboratory building and make/supplier of the equipment to the Engineer for his approval.

The field laboratory to be provided under the Contract shall be ready and finished and fully equipped condition not later than 2 months after the receipt of Notice to Commence Work, and the field laboratory with all equipment/instrument shall be to the entire satisfaction of the Engineer. On completion of the Project, the Laboratory set up together with testing equipment shall vest with the Contractor. During the period specified, the laboratory tests shall be performed in another laboratory proposed by the Contractor and Noticed by the Engineer."

Clause 120.3 (Substitution)

Laboratory Equipment

This Clause shall read as under:

The equipment and instruments shall be new and shall be quality certified by Bureau of Indian Standards (BIS).

The items of laboratory shall be agreed provided in the field laboratory depending upon the items of work to be executed under the scope of work and as per the directions of Engineer.

Clause 120.4 Maintenance

Replace the second sentence as follows:

"Maintenance includes the day to day upkeep of the building and the surroundings, attending to repairs to various parts of the buildings, furniture, fittings all office equipment and the related services as and when necessary, including technical support for servicing and maintenance of computer hardware and software and computer accessories, the periodic white/colour washing of building and painting of wood work, steel work, replacing the broken window/door/ventilator glasses, furniture, equipment and other hardware and maintaining necessary watch and ward during day and night. It shall also include maintenance of telephone and internet/WIFI gadgets and connections.

CLAUSE 201 **CLEARING AND GRUBBING**

Clause 201.1 **Scope**

Delete the last sentence and replace with the as under:

Clearing and Grubbing shall be performed less than one month in advance of earthwork operations and in accordance with the requirements of these specifications. If any vegetation grows after clearing and grubbing and before earthwork, the Contractor shall repeat the work to the satisfaction of the Engineer without any extra cost. Areas requiring clearing and grubbing shall be determined by the Engineer.

Clause 202.5 (Modification) **Disposal of Materials**

This Clause shall read as under

All materials obtained from dismantling structures including houses /bungalows etc. shall be the property of Employer and shall be removed and disposed off as per directions of Engineer.

SECTION 300 **EARTHWORK, EROSION CONTROL AND DRAINAGE**

CLAUSE 301 **EXCAVATION FOR ROADWAY AND DRAINS**

Clause 301.1 (Addition) **Scope**

Add the following as second paragraph under this clause:

"The work shall also include excavation for channel training at culverts/bridges/structures, excavation of existing shoulders and medians for purposes of widening the pavement and excavation of existing embankment for reconstruction to specification."

Clause 301.3.7 (Substitution) **This Clause shall read as under**

The title of this Clause shall read as under:

"Excavation of road shoulders/verge/median for widening of pavement or for providing treated/paved shoulders:"

This Clause shall read as under:

"In works involving widening of existing pavements or providing paved shoulders, the existing shoulders/verge/median shall be removed to its full width and to level as shown on drawing without disturbing the existing pavement. The subgrade material within 0.2m from the lowest part of the pavement for widened portion or paved shoulders shall be loosened and re-compacted as per Clause 305 to a density not less than 97% of maximum dry density determined according to IS: 2720 (Part 8). Any unsuitable material encountered in this portion of subgrade shall be removed and replaced with suitable material and compacted in accordance with Clause 305."

While removing the existing pavement shoulders/verge/median, care shall be taken to see that no portion of the existing pavement designated for retention is loosened or disturbed. If the existing pavement gets disturbed or loosened it shall be dismantled and cut to a regular shape with sides vertical and the disturbed/loosened portion removed completely and re-laid as directed by Engineer, at the cost of Contractor.

Clause 301.3.11 (Modification) **Disposal of Excavated Materials**

Delete this sub-clause and replace with" All the excavated materials shall be the property of the Employer. Suitable material obtained from the excavation of the roadway, shoulders, verge, drains, cross drainage works etc shall be used for

i) Filling for roadway embankments

ii) Filling existing pits in the right of way as directed by the Engineer including levelling and spreading with all leads and lifts.

iii) For landscaping of the road as directed by the Engineer, including levelling and spreading, with all leads and lifts.

Unsuitable and surplus material, which in the opinion of the Engineer cannot be used in the works, shall be removed from site by the Contractor and disposed-off including all lead &lifts. The contractor shall obtain the written prior permission from the land owners, where they propose to dispose-off the unsuitable excavated material. No place will be made available by the employer for disposing off the material and no claim will be entertained on that account.

Clause 301.6 (Modification)

Para 3, Replace the word "Granular base material" by M-15 grade cement concrete.

Clause 301.8 (Modification)

Measurement for Payment

Read item (iv) of the last para as "disposal of surplus material with all leads and lifts".

Clause 301.9 (Modification)

Deleted

CLAUSE 304 **EXCAVATION FOR STRUCTURES**

Clause 304.3.4 (Modification)

Preparation of Foundation

In para 2 and 3 of clause 304.3.4 substitute concrete M-20 in place of 1:3:6 nominal mix.

Clause 304.5 **Deleted**

CLAUSE 305 **EMBANKMENT CONSTRUCTION**

Clause 305.2.2.2 (Modification)

Borrow Materials

Para 1 of this Clause shall read as under:

"No borrow area shall be made available by the Employer for this work. The arrangement for the source of supply of the material for embankment and subgrade as well as compliance to the different environmental requirements in respect of excavation and borrow areas as stipulated, from time to time, by the Ministry of Environmental and Forest, Government of India and the local bodies, as applicable, shall be the sole responsibility of the Contractor. No earth, except when the road is in cutting, shall be borrowed from the Right of Way."

Paras given below Table 300-2 under **Clause 305.2.2.4** shall read as under:

"The contractor shall at least 21 working days before commencement of construction of embankment and the subgrade, submit the following to the Engineer for approval:

(i) The Values of maximum dry density and optimum moisture content obtained in accordance with IS: 2720 (Part 8) for each fill material proposed to be used in the construction of embankment and subgrade.

(ii) The graphs showing values of dry density against moisture content from which each of the values in (i) above (maximum dry density and optimum moisture content) was determined.

(iii) The dry density-moisture content-CBR relationships for each of the fill material proposed to be used in the subgrade.

(iv) Material to be used in the subgrade shall have a 4 day soaked CBR value of 8% at the unit weight applicable as per Table 300-2. The above information shall form the basis for compaction only upon its approval by the Engineer."

Clause 305.2.2.5 (New)	**Additional new Sub-clause** Material to be used in the subgrade shall have a 4 day soaked CBR value of 8% at the unit weight applicable as per Table 300-2
Clause 305.9.1 (Modification)	Insert "including removal of top soil after word materials appearing in first line of item (v)"
Clause 305.3.4	Add the following sentence at the end of para 2 Where necessary to facilitate Compaction of the subgrade to 97% relative Compaction as stated above, a further depth of maximum 0.2 m thickness shall be loosened, watered and compacted in accordance with Clause 305.3.5 and 305.3.6 to not less than 95% of maximum dry density, determined in accordance with IS 2720 (Part 8).
SECTION 400	**SUB-BASES, BASES (NON BITUMINOUS) AND SHOULDERS**
CLAUSE 401	**GRANULAR SUB-BASE**
Clause 401.1 (Addition)	**Scope** Add the following at the end of this Clause. "A site trial shall be performed in accordance with Clause 901.16".
Clause 401.2	**Materials**
Clause 401.2.1 (Modification)	First part of Para 1 of this Clause shall read as under. The material to be used for the work shall be crushed stone only. It shall be free from any organic matter and other deleterious substances and shall be of such nature that it can be compacted

readily under watering and rolling to form, firm, and stable base.

Clause 401.2.2	Physical requirements –
(Addition)	Add at the end of this clause:: “The material proposed to be used in the subbase course shall have a 4-day socked CBR value not less than 30 percent. Besides the CBR (not less than 30), the typical stipulations in regard to the physical characteristics of coarse fraction of sub-base materials shall be as under: • LA value of the material shall not exceed 50 or AIV shall not be more than 30 percent. • Ten percent fines value of 50 KN or more (soaked condition) when tasted as per BS : 812 (Part – III). • Combined Flakiness and Elongation Indices (Total) not more than 30 percent.
Clause:401.3	Construction operations
Clause: 401.3.2	Spreading and compacting
(Modification)	Second sentence of para 5 of this clause shall read as under. For a compacted single layer upto 150mm, the compaction shall be done with the help of vibratory roller of minimum static weight of 80 to 100 KN or pad foot- drum / heavy pneumatic tyred roller of minimum 200 to 300 KN weight having a minimum tyre pressure of 7 kg/cm2 or equivalent capacity roller capable of achieving the required compaction.
(Modification)	To be added at the end of Clause 401.3 “Sub base (for drainage layer only) shall continue over the full extent of the earthworks in cuttings (excluding rock) and embankments and the base of the sub-base shall at all times fall towards the drainage system.”
CLAUSE 409	**CEMENT CONCRETE KERB AND KERB WITH CHANNEL**
Clause: 409.2	M 25 shall be replaced with M 35
Clause 409.3	Delete existing Clause and replace with “Precast kerb manufactured in pre- casting factory having facilities of plate vibrator, hydraulic press, etc should only be used.
Clause 409.5.6	Add new Sub-Clause: After erection, kerbs shall be painted with one coat primer and two coats of colour paint (yellow and black). All colours shall be ready mix oil bound and shall be approved by the Engineer.
SECTION 500	**BASE AND SURFACE COURSES (Bituminous)**

CLAUSE:501	**GENERAL REQUIREMENTS FOR BITUMINOUS PAVEMENT LAYERS**
Clause : 501.3	Mixing
(Modification)	The first sentence of para I shall read as under: "Pre-mixed bituminous materials, including Bituminous Macadam, Dense Bituminous Macadam, Semi-dense Bituminous Concrete and Bituminous Concrete, shall be prepared in a hot mix plant of batch type of adequate capacity and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregates."
Clause : 501.5.3	Add at the beginning of the 4th para:
(Modification)	"The temperature of mix at the time of laying shall be in the range 120 - 145 degree Celsius."
Clause : 501.6	Compaction
(Modification)	Add at the end of 6th para : "Rolling shall be continued till the density achieved satisfies the requirements of Clause 903.4.2 and all roller marks are eliminated."
CLAUSE : 502	**PRIME COAT OVER GRANULAR BASE**
Clause : 502.8	**Rate**
(Modification)	Replace 0.6 by 1.0 in line 4.
CLAUSE : 503	**Tack Coat**
Clause : 503.8	Replace "0.2" by "0.3" in line 4.
(Modification)	
CLAUSE : 505	**DENSE GRADED BITUMINOUS MACADAM**
Clause : 505.2	**Materials**
Clause : 505.2.1	This clause shall read as under : The Bitumen shall be paving bitumen of Penetration Grade 60/70 as per Indian
(Substitution)	Standard Specifications for Paving Bitumen – IS:73
Clause: 505.2.2	**Coarse Aggregates**
(Modification)	i) Delete the words from 2nd line of 1st para "Crushed gravel or other hard material retained on the 2.36mm sieve". ii) Delete the entire para 2 of Clause 505.2.2
Clause 505.3.3	Insert the following paragraph between existing paragraph 3 and 4
(Modification)	Mix design shall be carried out in accordance with the modified Marshall method described in Asphalt Institute Manual MS – 2.
CLAUSE 507	**BITUMINOUS CONCRETE**
Clause 507.2.1	This clause shall be read as under :
(Addition)	The bitumen shall be paving bitumen of CRMB60 as per the Indian Standard Specification for Paving Bitumen – IS: 73 and Clause

501.2.1 of MORTH and as directed by Engineer.

Clause 507.2.4 (Substitution)

This Clause shall read as follows :

“Filler shall consist of cement minimum of 2% by weight of mix.

Clause 507.3.4 (Modification)

Aggregate Grading and binder content

Add the note below Table 500-18.

“The grading of the aggregate mix as used in work shall be a smooth curve within the approximate parallel of the envelope in Table 500.18”

Additional Specification:

(i) The Contractor shall obtain job mix formula as per Table 500.16 at his own cost and shall get the same approved from Engineer.

(ii) Bitumen Challan from the refinery shall be submitted in original to the Engineer.

(iii) Modern drum mix plant and paver finisher with electronic sensing device conforming to Clause 504.3.4 and 504.3.5 of MORTH Specification shall be used for the work.

(iv) The Contractor shall work out the super elevation required before laying bituminous layer.

(v) Cost of modified bitumen deemed to be included in the item and no separate payment for the modified bitumen will be made.

SECTION 600 **CONCRETE PAVEMENT**

CLAUSE 601 **DRY LEAN CEMENT CONCRETE SUB BASE**

Clause 601.3.4

This Clause is modified as under:

The strength of concrete shall be 15 MPa at 28 days when tested in accordance with IS: 456.

Clause 601.6.4 (Modification)

Replace first sentence of paragraph 4 by the following:

The Dry Lean Concrete shall be laid in such a way that it will extend beyond the edge of the proposed width including paved shoulders of the concrete pavement at a slope of 1:2 on each side.

Clause 601.6.7

Add the following Clause:

When curing compound is used, Wet curing shall be done as soon as the curing compound has lost its tackiness. This is mainly done to reduce the temperature of the concrete and avoid temperature induced curling of slabs.

CLAUSE 602 **CEMENT CONCRETE PAVEMENT**

Clause 602.2.3 (Modification)

To be added at the end of Clause 602.2.3

Clause 602.3.3 **Concrete Strength**

Clause 602.3.3.2

The Clause is modified as under:

The ratio between 7 and 28 day strengths shall be established for the mix to be used in the slab from results of the mix design trials. The average flexural strength of the 7 days cured specimens shall be divided by the average flexural strength of the 28 days cured specimens for each batch and the ratio "R" shall be determined to an accuracy of three decimal places.

Clause 602.5

The Clause is modified as under:

A separations membrane shall be used between the concrete slab (pavement) and dry lean concrete (DLC), as well as DLC and granular subbase. Separation membrane shall be impermeable plastic sheeting 125 micron thick laid flat without creases. It shall be white in colour and transparent. Before placing the separation membrane, the surface at which it is laid shall be swept clean of all the extraneous materials using the air compressor. Wherever overlap of plastic sheets is necessary, the same shall be at least 300 mm and any damaged sheeting shall be replaced at the Contractor's expense. The separation membrane may be nailed to the lower layer with nails. There shall be no standing water on or under the separation membrane when concrete is placed upon it.

Clause 602.6.2.1

Replace the first para as follows

Transverse joints shall be contraction and expansion joints. Contraction joint shall be provided at 4.5 m intervals, except where the expansion joints are provided. Expansion joints shall be provided at the junction of approach slabs and bridges and the rigid pavement. Furthermore, transverse joint shall be provided at special locations like transitions to structures, transition to flexible pavements, off carriageway areas as shown on the drawings. The exact position of transverse joints shall be coordinated and shall be proposed by the Contractor in writing for the Notice by the Engineer, Transverse joints shall be straight within the following tolerances along the intended line, which is the straight line perpendicular to the longitudinal axis of the carriageway at the position of the joint.

Clause 602.6.4.3
(New Clause)

Joints at the junction of rigid pavement and flexible pavements:

Joints shall be provided at the junction of rigid and flexible pavement as shown in the drawing

Clause 602.9.1

Add new paragraph at the end

Paving shall be laid in full lane width

Clause 602.10.3.1

Replace the first sentence with the following

When sealant is applied, an appropriate primer recommended by the manufacturer shall be applied in accordance with their recommendation

Clause 602.11.2

Add new paragraph at the end.

All trials shall be carried out using the same paving width and slab thickness as used in the permanent works.

Clause 602.11.5.3

The Clause shall read as under:

In-situ density shall be assessed as described in Clause 903.5.2.2 from at least 3 cores drilled when the concrete is not less than 7 days old. Should any of the cores show honey-combing in the concrete, the trial length shall be rejected and further use of the spreading and compacting unit shall not be permitted until further trials have shown that modification can be made which will result in adequate compaction.

Clause 602.11.5.5 (Additional)

Add at the end of the clause; Temperature Measurements

The temperature development in the concrete slab during the hardening shall be recorded. The temperature shall be measured in the middle of the slab (vertically) at a horizontal distance of at least 100 mm from any free edge. The temperature shall be recorded every 3 hours and temperature age relationship shall be determined. The maximum recorded temperature shall not exceed 70degC.If the temperature exceeds 70deg C the trial length shall be condemned and the Contractor shall propose methods to reduce the temperature development and carry out a new trial length at his own expense.

Clause 602.13

The Clause shall read as under.

No vehicular traffic (including Contractor's vehicles) shall be allowed on the finished surface until a field flexural strength of minimum 4.5 MPa has been achieved and until the joints are permanently sealed. It is the responsibility of the Contractor to produce a sufficient number of series of test specimens to verify the filed flexural strength.

Each series of test specimens for measurement of filed flexural strength shall consist of minimum 3 test specimens. The specimens shall be cured at conditions similar to the field conditions. The method for curing and storing of the test specimens in order to simulate field conditions shall be proposed by the Contractor and approved by the Engineer. Prior to the opening the road to vehicular traffic the areas adjacent to the pavement shall be completed to a degree that will ensure traffic safety. Opening to traffic shall not constitute a final acceptance of the pavement.

Clause 602.16

Add at the end of existing Clause

This will also include the cost of supplying and laying of separation membrane asper drawing and technical specification Clause 602.5.

SECTION 800 **TRAFFIC SIGNS, MARKINGS AND OTHER ROAD APPURTENANCES**

Clause 803 **ROAD MARKINGS**

Clause 803.6 Application

Add the following Sub-Clause at the end of this Clause:

Clause 803.6.6 **Tolerances**

i) General

Road traffic markings shall be constructed to accuracy within the tolerances given below:

- The width of lines and other markings shall not deviate from the specified width by more than 5%.
- The position of lines, letters, figures, arrows and other markings shall not deviate from the true position specified by more than 20 mm
- The alignment of any edge of a longitudinal line shall not deviate from the true alignment by more than 10 mm in 15 m.
- The length of segments of broken longitudinal lines shall not deviate from the specified length by more than 150 mm.

In broken lines, the length of segments and the gap between segments shall be as indicated on the Drawings. If these lengths are altered by the Engineer, the ratio of the lengths of the painted sections shall remain the same.

Line and curves, whether broken or unbroken, shall not consist of chords but shall follow the correct radius.

ii) Faulty Workmanship or Materials

If any materials not complying with the requirements is delivered at the Site or used in the Works, or if any sub-standard work is carried out, such material or work shall be removed, replaced or repaired as required by the Engineer, at the Contractor's own cost. Rejected traffic markings and paint that has been splashed or has dripped onto the surfacing, kerbs, structures or other such surfaces shall be removed by the Contractor at his own cost, in such a way that the markings of split paint will not show up again later."

Clause 803.6.3 In second line after 'material' add 'including sealing primer coat'.

CLAUSE 811 **CONCRETE CRASH BARRIER**

Clause 811.2.1.2 Replace "M-25 by M-40".

SECTION 900 **QUALITY CONTROL FOR ROAD WORKS**

CLAUSE 901 **GENERAL**

Add a new Sub-Clause 901.15 – Site Trial at the end of this Clause as given hereunder.

Clause 901.16 (Additional)

Site Trial

The Contractor shall carry out full-scale site trials on all earthwork and pavement items proposed for the Works using the equipment and methods proposed by the Contractor for constructing the Works. The trials shall be carried out with the agreement and in the presence of the Engineer or his authorised representative. The trials shall be carried out to enable the Contractor to demonstrate the suitability of his mixing and/or compaction equipment to provide the specified material and compact the same to the specified density and to confirm that the other specified requirements of the completed earthworks and pavement courses can be achieved.

Each trial area shall be at least 1000 (approx. 15m x 75m length) square meters and shall be laid to the specified depth for the material. It may form part of the works if so ordered by the Engineer provided it complies with the specification. Any trial areas, which do not comply with the Specification, shall be removed.

The Contractor shall allow in his programme for conducting site trials and for carrying out the appropriate tests on them. The trials on earthworks and each pavement layer shall be undertaken at least 14 days ahead of the Contractor proposing to commence full scale work on earthworks and the pavement layers. The following data shall be ordered at each site trial:

- The composition and grading of the material, including the bitumen content and properties, if appropriate;
- If appropriate, the moisture content at the time of laying;
- If appropriate, the temperature at the time of laying and rolling;
- The type and size of compaction equipment and the number of passes;
- The maximum density or target density as appropriate and the density achieved in the trial;
- The maximum compacted thickness of layer;
- The surface levels and the surface irregularities
- Calibration of machinery for best and efficient results;
- Any other relevant information

Not less than ten sets of tests for each type of test shall be made on each500 square meters of trial area, and provided nine out of ten sets of results meet the specified requirements for the material/work in Clause 903, the site trial shall be deemed successful. The above data recorded in the trial shall become the agreed basis on which the particular material shall be provided and processed to achieve the specified requirements.

If, during execution of the Works, the construction control type of tests indicate that the requirements for a material are not consistently being achieved, then work on that layer shall stop until the cause is investigated. Such investigation may include further laboratory and site trials on the material to determine a revised set of data, as above which, when agreed by Engineer, shall be the basis on which all subsequent material will be provided and processed to achieve the specified requirements.

Approval by the Engineer to a set of data recorded, as above in a site trial shall not relieve the Contractor of responsibility to comply with the requirements of Technical Specifications.

CLAUSE 903 **QUALITY CONTROL TESTS DURING CONSTRUCTION**

Clause 903.4 **Tests on Bituminous Constructions**

Clause 903.4.1 (Addition)

Add at the end of this Clause:

“The density test shall be carried out by 150 mm diameter core cutter machine on Dense Bituminous Macadam and Bituminous Concrete as per the frequency specified”.

In Table 900-4, substitute "Tests for quality of binder as specified in relevant IS Code" under Test column for "Quality of binder".

In Table 900-4, serial No.5 (xviii) for Dense Bituminous Macadam/Bituminous Macadam and for Bituminous Concrete, add the following at the end in the Frequency column:

"10% of the density tests shall be done on edges."

In Table 900-4, Serial No. 5 for Dense Bituminous Macadam/ Semi Dense Bituminous Concrete/Bituminous Concrete, modify the ‘Frequency (Minimum)” values for Item NR. (vi), (viii) and (xvi) as under:

Type of Construction	Test	Frequency (Minimum)
Dense Bituminous Macadam/Semi Dense Bituminous Concrete/ Bituminous Concrete	(vi) Sand Equivalent Test	Three tests on aggregates for each 400 t of mix subject to two tests per plant per day.
	(viii) Polished Stone Value (PSV)	Initially one set of three representative specimens for each source of supply. Subsequently when warranted by changes in the quality of aggregates.
	(xvi) Density	One test per 250 m^2 area subject to the of compacted Layer condition that 10% of density tests shall be done near the edges.

Add the following note at the end of Table 900-4:

Note:

1. The laboratory and field tests shall be performed on materials and works at the frequency values indicated against each. The Supervision Personnel shall ensure that there are no deviations in this regard.
2. Daily, Weekly and Monthly Reports on the testing done, results obtained thereof must be prepared indicating the location of sampling and testing, deviations from the acceptance norms for materials and works and actions taken in respect of removal of defective works must be prepared by the Contractor and authenticated by the Supervision Personnel that these tests were done in their presence and that the testing has been carried out as per the prescribed methodology. The Supervision Personnel should also prepare a summary of all tests carried out the results obtained thereof. The Engineer- in-Charge of the Project should take full responsibility of authenticity of such reports and summary sheets.

Clause 903.4.3 (Addition)

Characteristics to be tested on completed Bituminous Layers

The characteristics to be tested on completed bituminous layers are:

Relative compaction

Layer thickness

For testing the above characteristics, the following sampling criteria shall apply:

(a) Random Sampling

When testing any lot, or an isolated section, which is obviously defective or exhibits abnormal variation of the characteristics under consideration, all samples shall be taken in a random pattern.

(b) Lot Size

The lot size shall normally be a section laid and compacted in one process and for which essentially the same materials had been used. Where production is on a continuous basis, a lot shall normally mean one-day production and shall not exceed two full days production. However, the Engineer for investigating compliance with the specifications may order a lot of any smaller size, if:

- The factors affecting the characteristics under investigation exhibit abnormal variation within the normal lot size;
- The area is obviously defective or of poorer quality that of the rest;
- The rate of production is very high.

Clause 903.5.2.1

(Modification)

1. One sample set to be collected for each 150 Cum of pavement

Concrete or part thereof shall consist of.

3 Nos. of cylinder / cubes	:	28 days Split Tension Test
3 Nos. of cubes	:	7 days testing
3 Nos. of beams	:	7 days testing
3 Nos. of cubes	:	28 days testing
3 Nos. of beams	:	28 days testing
3 Nos. of cubes	:	90 days testing/for other purposes
3 Nos. of beams	:	90 days testing/for other Purposes

2. Additional samples shall be collected if so instructed by the Engineer without extra cost.

3.Except above modification clause 903.5.2.1 will remain unchanged

Clause 903.5.2.2

(Additional)

Add the following sentence at end of this Clause

The samples taken for density measurement shall cover the full depth of layer being tested.

Clause 903.5.2.4

(Modification)

Summary of control tests :- In table 900-6 –5(iii) Add following “compaction factor test IS :1199”

Clause 2702.1

Substitution

Bituminous Wearing Coat

Read the clause with the following:

For the Bituminous Wearing Coat for bridges also refer to relevant specifications given in Section 2 of Volume 5.

2.3 Paver Block

2.3.1. Scope

The paver blocks are proposed to be used for Pedestrian Ways, Paved shoulders and Footpaths. The interlocking paver block of 80 mm thickness to be used for pedestrian ways and footpaths.

2.3.2. Material

Bedding Sand Course: The bedding sand shall consist of a clean well graded sand passing through 4.75mm sieve and suitable for concrete. The bedding .should be from either a single source or blended to achieve the following grading.

Bedding Sand Requirement

In Sieve size	% passing
9.52	100
4.75	95-100
2.38	80-100
1.18	60-100
600 micron	25-60
300 micron	10-30
150micron	5-15
75 micron	0-10

Contractor shall be responsible to ensure that single-sized, gap-graded sands or sands containing an excessive fines or plastic fines are not used. The sand particles should preferably be sharp not rounded as sharp sand possess higher strength and resist the migration of sand from under the block to less frequently areas even though sharp sands are relatively more difficult to compact than rounded sands, the use of sharp sands is preferred for the more heavily trafficked driveways. The sand use for bedding shall be free of any deleterious soluble salts or other contaminants likely to cause efflorescence.

The sand shall be of uniform moisture content and within 4% - 8% when spread and shall be protected against rain when stock piled prior to spreading. Saturated sand shall not be used. The bedding sand shall be spread loose in a uniform layer as per drawing. The compacted uniform thickness shall be of 45mm and within +/- 5mm thickness variation shall not be used to correct irregularities in the base course surface.

The spread sand shall be carefully maintained in a loose dry condition and protected against pre- compaction both prior to and following screening. Any pre- compacted sand or screened sand left overnight shall be loosened before further laying of paving blocks take place.

Sand shall be slightly screened in a loose condition to the predetermined depth only slightly ahead of the laying of paving unit.

Ready Mix Concrete

The concrete mix design should be followed for each batch of materials separately and automatic batching plant is to be used to achieve uniformity in strength and quality.

The concrete pavers should have perpendiculars after release from the mould and the same should be retained until the laying. The surface should be of anti- skid and anti-glare type. The pave should have uniform chamfers to facilitate easy drainage of surface run off. The pavers should have uniform interlocking space of 2mm to 3mm to ensure compacted sand filling after vibration on the paver surface.

2.3.3. Manufacturing & strength

The pavers shall be manufactured in single layer only. Paver block machine should be used for manufacturing the blocks.

The average compressive strength of the 80mm thick paver blocks tested shall be 45 N/Sq. mm. and average compressive strength of the 60mm to 50 mm: thick paver blocks shall be 35 N/Sq. mm.

2.3.4. Laying & Interlocking

Paver blocks shall be laid in herringbone laying pattern throughout the pavement. Once the laying pattern has been established, it shall continue without interruption over the entire pavement surface. Cutting of blocks, the use of infill concrete or discontinuities in laying pattern is not be permitted in other than approved locations.

Paver blocks shall be laced on the un compacted screened sand bed to the nominated laying pattern, care being taken to maintain the specified bond throughout the job. The first row shall be located next to an edge restraint. Specially manufactured edge paving blocks are permitted or edge blocks may be cut using a power saw, a mechanical or hydraulic guillotine, bolster or other approved cutting machine.

Paver blocks shall be placed to achieve gaps nominally 2 to 3 mm wide between adjacent paving joints. No joint shall be less 1.5mm not more than 4mm. Frequent use of string lines shall be used to check alignment. In this regard, the "laying face" shall be checked at least every two metres as the face proceeds. Should the face become out of alignment, it must be corrected prior to initial compaction and before further laying job is proceeded with.

In each row, all full blocked shall be laid first. Closure blocks shall be cut and fitted subsequently. Such closer blocks shall consist of not less than 25% of a full block.

To infill spaced between 25mm and 50mm wide concrete having screened sand, coarse aggregate mix and strength of 45 N/Sq. Mm shall be used. Within such mix the nominal aggregate size shall not exceed one-third the smallest dimension of the infill space. For smaller spaces dry packed mortar shall be used.

Except where it is necessary to correct any minor variations occurring in the laying bond, the paver blocks shall not be hammered into position.

Where adjustment of paver blocks necessary care shall be taken to avoid premature compaction of the sand bedding.

Initial Compaction: After laying the paver blocks, they shall be compacted to achieve consolidation of the sand bedding and brought to design levels and profiles by not less than Two (3) passes of a suitable plate compactor.

The compactor shall be a high-frequency, low amplitude mechanical flat plate vibrator having plate area sufficient to cover a minimum of twelve paving blocks. Prior to compaction all debris shall be removed from the surface Compaction shall proceed as closely as possible following laying and prior to any traffic. Compaction shall not, however, be attempted within one metre of the laying face. Compaction shall continue until lipping has been eliminated between adjoining blocks. Joints shall then be filled and recompacted.

All work further than one metre from the laying face shall be left fully compacted at the completion of each day's laying.

Any blocks that are structurally damaged prior to or during compaction shall be immediately removed and replaced.

Sufficient plate compactors shall be maintained at the paving site for both bedding compaction and joint filling.

Joint Filling and Final Compaction : As soon as possible after compaction and in any case prior to the termination of work on that day and prior to the acceptance of vehicular traffic, sand for joint filling shall be spread over the pavement.

Joint sand shall pass a 2.36mm (No.8) sieve and shall be free of soluble salts or contaminants likely to cause efflorescence. The same shall comply with the following grading limits.

Jointing Sand Requirement

IS Sieve Size	% Passing
2.36 mm	100
1.18mm	90-100
600 Microns	60-90

300 Microns	30-60
150 Microns	15-30
75 Microns	10-20

The Contractor shall supply a sample of the jointing sand to be used in the contract prior to delivering any such materials to site for incorporation into the works. Certificates of test results issued by a recognized testing laboratory confirming that the samples conform to the requirements of these specifications shall accompany the sample.

The jointing sand shall be boomed top fill the joints. Excess sand shall then be removed from the pavement surface and the jointing sand shall be compacted with not less than one (1) Pass by the plate vibrator and joints refilled with sand to full depth. This procedure shall be repeated until all joints are completely filled with sand. No traffic shall be permitted to use the pavement until all joints have been completely filled with sand and compacted.

Both the sand and paver blocks shall be dry when sand is spread and broomed into the joints to prevent premature setting of the sand.

The difference in level (lipping) between adjacent blocks shall not exceed 3mm with not more than 1 % in any 3m x 3mm area exceeding 2mm. pavement which is deformed beyond above limits after final compaction shall be taken out and reconstructed to the satisfaction of the Engineer.

Edge Restraint: Edge restrains need to be sufficiently robust to withstand override by the anticipated traffic, to withstand thermal expansion and to prevent loss of the laying course material from beneath the surface course. The edge restraint should present a vertical face down to the level of the underside of the laying course. The surface course should not be vibrated until the edge restraint, together with any bedding or concrete launching, has gained sufficient strength. It is essential that edge restrains are adequately secured

2.3.5. Sample Size:

Following are the sample sizes:

a) **Internal:** Average of minimum 3 samples per 5000 blocks - for paver block manufacturers

b) **External**: Minimum 9 Blocks per 5000 Blocks. Average of minimum 9 Blocks per site: for captioned contractors.

Sampling for Testing: Sampling for testing of paver blocks shall be done in accordance with clause No. 14.5, 14.6 and 14.7

Compressive Strength: Testing for compressive strength shall be undertaken in accordance with clause 14.7.

Water Absorption: Testing for water absorption shall be in accordance with IS:2185 : 1979 : Part I (Specifications for Concrete Masonry Blocks) Appendix C.

In case of failure of test sample: In case of failure of test sample for above test, the contractor should replace the entire lot of paver blocks representing samples are taken. The samples of replaced lots shall be tested. However, 25% of the payment of the measurement of the lot will be recovered as penalty.

Tensile Splitting Test: (for blocks subject to vehicular traffic) -The mean tensile strength of 8 blocks shall be not less than 3.9 MPa and no individual block shall have tensile strength less than 3.6 MPa when tested as per Annex E of BS6717:2001

Abrasion Resistance (blocks subject to vehicular traffic) : Set of 3 blocs tested as per Annex F of BS 6717 :2001 shall be more than 23mm.

Method for the determination of Water Absorption:

The specimens shall then be weighed, while suspended by a metal wire and completely submerged in water. They shall be removed from the water and allowed to drain for one minute Visible surfaces water being removed with a damp cloth, and weighed.

Subsequent to saturation, all specimens shall be dried in a ventilated oven at 100 to 115°C for not less than 24 hours and until two successive weightings at intervals of 2 hours show an increment of loss not greater, than 0.2 per cent of the last previously determined mass of the specimen for 24 hours.

2.3.6. Sampling & testing of Paver Blocks:

Method of Sampling: Before laying paver blocks, each designated section comprising not more than 50000 blocks, shall be divided into ten approximately equal groups. Nine blocks shall be drawn from each group.

Marking and Identification: All samples shall be clearly marked at the time of sampling in such a way that the designated section part thereof and the consignment represented by the sample are clearly defined. The sampled shall be dispatched to the approve test laboratory taking precaution to avoid damage to the paving in transit. Protect the paving from damage and contamination until they have been tested. The samples shall be stored in water at 20°C + 5°C for 24 hours prior to testing.

Procedure for Testing of Compressive Strength for Paver Blocks:

Testing Machine: The testing machines shall be of suitable capacity for the test and capable of applying the load at the rate specified. It shall comply as regards repeatability and accuracy with the requirements of relevant IS specification.

Procedure : The sample specimens shall be tested in wet condition after being stored for at least 24· hours, in water maintained at a temperature of 20°C + 5°C, before the specimens are submerged in water, the necessary area shall be determined.

The plates of the testing machine shall be wiped clean and any loose grit or other material removed from the contact faces of the specimen. Plywood nominally 4mm thick, shall be used as packing between the upper and lower faces of the specimen and the machine plates, and these boards shall be larger than the specimen by a margin of at least 5mm at all points. Fresh packing shall be used for each specimen tested. The specimen shall be placed in the machine with the wearing surface in a horizontal plane and in such a way that the axes of the specimen are aligned with those of the machine plates. The load shall be applied without shock and increased continuously at the rate of Approximately 15 N/Sq. mm per minute until no greater load can be sustained. The maximum load applied to the specimen shall be recorded.

Calculation of Corrected Strength: The compressive strength of each block specimen shall be calculated by dividing the maximum load by full cross section area and multiplying by an appropriate factors.

Thickness and Chamfer Correction Factors for Compressive Strength

Work Size Thickness in mm	Correction Factors	
	Plain Block	Chamfered Block
60	1.00	1.06
80	1.12	1.18
100	1.18	1.24

Compressive Strength Calculation: The average corrected compressive strength for the designed block section shall be calculated.

2.4 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.

2.5 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.

2.6 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.

2.7 Road Marking:

2.7.1. Road markings shall be of hot applied thermoplastic materials with glass reflectorising beads as per relevant clauses of Section 803 of MoRTH Specifications.

2.7.2. Road markings shall be as per IRC: 35-1997. These markings shall be applied to road centre lines, edge lines, continuity line, stop lines, give-way lines, diagonal/chevron markings, zebra crossing and at parking areas by means of an approved self-propelled machine which has a satisfactory cut-off valves capable of applying broken lines automatically.

2.7.3. Synthetic enamel paints shall be used to display details of structure number, span arrangement etc. on all culverts and bridges with required description as per M.O.S.T. guidelines.

2.7.4. Specifications of Thermo-Plastic Road Marking:

2.7.5. All markings should be strictly in accordance with code of practice for road marking, paints lRC-35 and as specified by the Engineer-In Charge.

2.7.6. The Thermoplastic material shall be homogeneous / composed of aggregate, pigment, resins and glass reflector zing beads and shall conform to 8.S.3262 Part-I / ASTMD36.

2.7.6.1. Requirements

2.7.6.1.1. Composition: The material shall be free from all skins, dirt and foreign objects.

SR NO	Component	White	Yellow
1	Binder	18 Min.	18 Min.
2	Glass Beads	20 Min.	20 Min.
3	Titanium Dioxide	10 Min.	-

2.7.6.1.2. Properties: The properties of thermoplastic material, when tested in accordance with A.S.T.M.D. 361 BS-3262 (Part-I) shall be as below:

(i) Luminance:

(ii) White Day Light - Luminance at 45° - 65% min, as per AASHTO M 249 - Yellow Day Light - Luminance at 45° - 45% as per AASHTO M249

(iii) Drying Time : When applied at a temperature specified by the manufacturer and to the required thickness, the material shall set to beat traffic in not more than 15 min.

(iv) Skid Resistance - not less than 45 as per BS-6044

(v) Cracking Resistance at Low Temperature: The material $hall show no cracks on application to concrete blocks.

(vi) Softening Point: 102.5 as per 9.5c as per ASTMD 36.

(vii) Flow Resistance: Not more than 25% per ASSHTO M249.

(viii) Yellowness Index (for white thermoplastic paint) not more than 0.12 as per AASHTO M249.

2.7.6.2. Reflectorisation shall be achieved by incorporation of beads. The grading and other properties of the beads shall be as under:

2.7.6.3. The glass beads shall be transparent, colourless and free from milkiness, dark particles and excessive air inclusions. The thermoplastic material shall readily get screeded 1 extruded at temperature specified by the manufacturers for respective method of application to produce a line of specified thickness which shall be continuous and uniform in shape having clear and sharp edges.

2.7.6.4. The subject material upto heating to application temperature, shall not exude fumes which are toxic, obnoxious or injurious to persons or property.

2.7.6.5. Properties of finished road marking shall be as under:

(i) The strip shall not be slippery when wet.

(ii) After application and proper drying the strip shall not show appreciable deformation or discolouration under traffic.

(iii) The marking shall· not deteriorate by contact with sodium chloride or oil drippings from traffic.

(iv) The strip of marking shall maintain its original dimensions in position. Cold ductility of the material shall be such as to permit normal movement with the road surface without chopping or cracking.

(v) The colour of yellow marking shall conform to LS. Code No. 356 as given in IS 164.

(vi) Durability: The road markings shall be highly durable in all weather and traffic conditions. It shall last for a period of five years. The markings when tested shall show no sign of cracking, flaking, peeling off or disintegration.

2.7.6.6. The marking shall be done by machine.

2.7.6.7. The thermoplastic material shall be applied hot either by screeding of extrusion machine at a temperature within the range specified by the manufacturer.

2.7.6.8. The surface shall be thoroughly cleaned of all dust, dirt, grease, oil and all other foreign matter before application of the paint.

2.7.6.9. The paint shall be applied in intermittent or continuous lines as directed and specified and of uniform thickness of at least 2.5mm, unless specified otherwise.

2.7.6.10. Where arrows or letters are to be provided, the paint may be hand applied.

2.7.6.11. The tenderer shall furnish a copy of certified test reports from the manufacturer of glass beads obtained from a reputed laboratory showing results of all the tests specified and shall certify that the material meets all the requirements of specifications.

2.7.6.12. The thermoplastic material used should be complying to specifications of B.S.3262 (Part-I) / ASTMD-36.

2.8 Micro –surfacing

2.8.1. Scope

The work shall consist of design, testing and construction of micro-surfacing composed of modified bitumen emulsion, mineral aggregate, water and necessary additives (if needed), proportioned, mixed and uniformly spread over a properly prepared surface for surface treatment of pavements in accordance with these Specifications.

2.8.2. Type of Micro-Surfacing

Micro-surfacing is applied on an existing pavement surface which is structurally sound but the surface shows signs of premature ageing, aggregate loss, cracking,high degree of polishing etc, It may be used as surface sealing treatment to improve skid resistance, surface durability, to seal fine and medium cracks and forpreventive maintenance and periodic renewal treatment on low and medium trafficroads. Types of micro-surfacing and rates of application are given in Table 500- 31.

Types of Micro-Surfacing and Rate of Application Items

Application	Type III (6 to 8 mm)** Preventive and Renewal Treatment for Roads Carrying1500 to 4500 CVPD
2 Quantity of mix* (kg/m)	11.1 to 16.3
Residual binder (percentage by weight of dry aggregate)	5.5 to 10.5

2.8.3. Binder

The bitumen emulsion shall be a modified bitumen emulsion conforming to requirements specified in Table 500-32. The modifier shall be polymer/rubber, preferably synthetic or natural rubber latex.

Requirement of Modified Bitumen Emulsion for Micro-Surfacing

Requirements	Specifications	Method of test
Residue on 600 micron IS sieve (percent by mass), maximum	0.05	IS:8887
Viscosity by Say bolt Furol Viscometre, at 25°C, in second	20-100	IS :8887
Coagulation of emulsion at low temperature	Nil	IS :8887
Storage stability after 24 h (168 h), % maximum	2(4)	IS :8887

Particle charge, + ve/-ve	+ ve	IS :8887
Tests on residue:		
a) Residue by evaporation, % minimum	60	IS :8887
b) Penetration at 25°C/100 g/5 s	40-100	IS :1203
c) Ductility at 27°C, cm, minimum	50	IS :1208
d) Softening point, in °C, minimum	57	IS :1205
e) Elastic recovery*, %, minimum	50	IS :15462
f) Solubility in tri-chloroethylene, % minimum	97	IS :1216

2.8.4. Aggregates

The mineral aggregates shall be crushed stone dust, clean, sharp, hard, durable and uncoated dry particles and shall be free from soft pieces and organic and other deleterious substances. The aggregate shall satisfy the requirement given in Table 500-26. The target grading shall conform to one of the three types given in Table 500-27.

Properties of Aggregates

Properties	Test Method	Specification
Sand Equivalent Value	IS:2720 (Part 37)	Min 50 percent
Water absorption*	IS.-2386 (Part 3)	Max 2 percent
Soundness with- Sodium sulphate Magnesium sulphate	IS:2386 (Part 5)	Max 12 percent Max 18 percent

In case water absorption exceeds 2% but is less than 4%, same may be permitted subject to conformity of soundness test and wet stripping test

Aggregate Grading

Sieve Size (mm)	Percentage by Mass Passing (Minimum Layer Thickness)		
	Type I (2-3 mm)	Type II (4-6 mm)	Type III (6-8 mm)
9.5	-	-	100
6.3	-	100	90-100
4.75	100	90-100	70-90
2.36	90-100	65-90	45-70
1.18	65-90	45-70	28-50
0.600	40-65	30-50	19-34
0.300	25-42	18-30	12-25
0.150	15-30	10-21	7-18
0.075	10-20	5-15	5-15

Tolerances : Percent passing each sieve shall not vary by more than the tolerance limitindicated in Table 500-28 and shall remain within the gradation band.

Tolerances for Slurry Seal

Description	Tolerance
Aggregate passing 4.75 mm	±5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	±5%
Aggregate passing 0.3 mm	±4%
Aggregate passing 0.15 mm	±3%
Aggregate passing 0.075 mm	±2%

If more than one nominal size aggregate is used to produce the required grading,the correct amount of each type of aggregate used shall be proportioned separately to meet the requirements of grading as per Table 500-27, prior to adding other materials inthe mixture. After target gradation has been submitted, the percent passing each sieve shall not vary by more than the tolerance limits given in Table 500-29, and shall remain within the gradation band. The aggregate will be acceptable based on average of five gradation tests at the job location.

2.8.5. Filler

Water

Mineral filler shall be Ordinary Portland Cement. The quantity of filler shall be inthe range of 0.5 to 2 percent by weight of dry aggregate.

Water shall be potable, free from harmful salt and contaminants. The pH of thewater shall be in the range of 6 to 7.

Additives

Chemical additives may be used to accelerate or retard the break-set time of the slurry or to improve the resulting surface finish. The quantity of additive, if used, shall be decided by mix design and to be adjusted as per the site/climate conditions. The specifications for additive shall be supplied by the supplier of the emulsion. The additive and emulsion shall be compatible with each other.

2.8.6. Design and Proportioning of Micro-Surfacing Mix

The design criteria for micro-surfacing mixture is specified in below Table. The mix design report shall clearly show the proportions of aggregate, filler, water and residual bitumen content based on the dry weight of aggregates and additives used (if any). The set time shall be determined by the method given in Appendix-2 of IRC:SP: 81.

Mix Design Criteria for Micro-Surfacing Mix

Requirements	Specifications	Method of Test as givenin IRC:SP:81
Mix time, minimum	**120** s	Appendix-1
Consistency, maximum	**3 cm**	Appendix-3
Wet Cohesion, within 30 min, minimum.	**12 kg cm**	Appendix-4
Wet Cohesion, within 60 min, minimum	**20 kg cm**	Appendix-4
Wet stripping, pass %, minimum	**90**	Appendix-5
Wet track abrasion loss (one hour soak), maximum	**2** **538 g/m**	Appendix-6

Aggregate, modified bitumen emulsion, water and additive (if used), shall be proportioned by weight of aggregate utilizing the mix design approved by the Engineer. If more than one type of aggregates is used, the correct amount of each type of aggregate used to produce the required grading shall be proportioned separately prior to adding other materials of the mixture, in a manner that will result in a uniform and homogenous blend. Final completed mixture, after addition of water and any additive, if used shall be such that the micro-surfacing mixture has proper workability and permit traffic within a short period depending upon the weather conditions without occurrence of ravelling and bleeding. Trial mixes shall be prepared and laid for the designed mix and observed for breaking time and setting time. The wet track abrasion test is used to determine the minimum residual bitumen content. Indicative limits of various ingredients for job mix of micro-surfacing shall be as given in below Table

Indicative ingredients in mix

Ingredients	Limits (Percent Weight of Aggregate)
Residual bitumen	6.5 to 10.5 for type II and 5.5 to 10.5 for Type III
Mineral filler	0.5 to 3.0
Additive	As needed
Water	As needed

2.8.7.Weather and Seasonal Limitations

Laying of slurry seal shall not be undertaken, if either the pavement temperature or air temperature is below 10°C. However during a dry spell , slurry seal may belaid in rainy season also, even if the surface is wet but there is no stagnant wateron the pavement surface.

2.8.8. Surface Preparation

The underlying surface on which the slurry seal is to be applied shall be cleaned of all loose material, mud spots, vegetation and extraneous matter and shall be prepared and shaped to the needed profile. It is essential to pre-treat cracks on the pavement surface with an appropriate crack sealing material prior to application of slurry seal, if it is used for preventive/ renewal treatment. The surface should be swept clean by removing caked earth and other foreign matterwith wire brushes, sweeping with mechanical brooms and finally dusting with air jet or other means approved by the Engineer.

2.8.9. Application of Tack Coat

Tack coat is not required normally for flexible pavements, unless surface is extremely hungry and dry. In case it is needed.

2.8.10. Machine

The machine shall be specially designed and manufactured to lay Microsurfacing.It shall be self-propelled equipment, truck mounted, consisting of following sub- assemblies used to manufacture and simultaneously spread these mixes on the surface

(1) Aggregate bin.
(2) Filler bin.
(3) Water and Emulsion Tanks.
(4) Additive Tanks.
(5) Aggregates and filler conveyors to supply the mixer box.
(6) Pump or compressed air system to supply the emulsion/water.
(7) Mixer Box.
(8) Spreader box to place the mixed slurry on the job.

2.8.11. Calibration of Machine

Microsurfacing laying machine shall be calibrated for flow of all the constituents asper the job mix in presence of Engineer. No machine shall be allowed to work on the project until the calibration has been completed and accepted by the engineer. 2 kg samples of Microsurfacing mix will be taken and verified for proportioning andmix consistency. The verification for application rate shall also be carried out in presence of the Engineer. The procedure for calibration and verification is as given in Appendix 7 of IRC: SP: 81.

2.8.12. Application of Micro-Surfacing

A calibrated micro-surfacing machine as per requirements of job mix shall be usedto spread the material. The surface shall be pre-wetted (if required under extremehot weather conditions) by spraying water ahead of the spreader box. The rate ofapplication of spray shall be adjusted during the day to suit temperature, surface texture and midity. The application of micro-surfacing shall be a calibrated Microsurfacing machine, as per requirements of job mix, shall be used to spread the material. The surface shall be pre-wetted by fogging ahead of the spreader box (if required under hot weather conditions). The rate of application shall be adjusted during the day to suit temperature, surface texture and humidity. The mixture shall be agitated and mixed uniformly in the spreader box by means of twin shafted paddles or spiral augurs fixed in spreader box. A front seal shall be provided to ensure no loss of the mixture at the road contact point. The rear seal shall act as final strike off and shall be adjustable. The spreader box and real strike off shall be so designed and operated that a uniform consistency is achieved to produce free flow of material to the rear strike off. A secondary strikeoff shall have the same adjustment as the spreader box. The spreader box shall have the suitable means provided to side shift the box to compensate for variation in pavement geometry. Sufficient amount of material shall be carried in all parts ofspreader box at all times so that a complete coverage is obtained. Overloading ofthe spreader box shall be avoided. No lumping, balling and unmixed aggregates shall be permitted. No streak, caused by oversized aggregates shall be left on the finished surface. Longitudinal joints shall correspond with the edges of existing traffic lanes. Other patterns of longitudinal joints may be permitted, if pattern will not adversely affect the quality of finished surface. In case streak is formed, it shallbe corrected immediately by fresh material and with use of squeeze. Longitudinaljoints, common to two traffic lanes shall be butt joints with overlap not exceeding an average of 60-100 mm. The mixture shall be uniform and homogeneous after spreading on existing surfaces and shall not show separation of the emulsion andaggregates after setting.

2.8.13. Rate of Application

The micro-surfacing mixture shall be of proper consistency at all times so as to provide the application rate required by the surface condition. The quantities of micro-surfacing mix (by weight of dry aggregate) to be used shall be as given in Table 500-31.

2.8.14. Quality Control and Surface Finish

The surface finish of construction shall conform to the requirements. For control ofthe quality of materials and work carried out, relevant provision of Section 900 shall apply.

Control Tests for Bituminous Works and their Minimum Frequency

Sr No	Type of Construction	Test	Frequency (min.)
1	Micro surfacing	Quality of Aggregate	One per source/ site
		Sand Equivalent Value	
		Water Absorption	
		Soundness Test (Sodium/ Magnesium Sulphate Test)	
		Quality of Emulsion	One per lot of 20 t as per IS:8887

		Aggregate Moisture	Two per day
		Aggregate Gradation	Two per day at site
		Binder Content	Two per lane per Km
		Calibration of Machine	Once per Project
		Quantity of Slurry (By weight of aggregate)	Daily (Travel time of Machine)

2.8.15. Control of Traffic

Micro-surfacing mix requires about 2 hours to set. Traffic may be opened only after2 hours restricting the speed to 20 km/h till 12 hours thereafter.

2.8.16. Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance.

2.8.17. Measurement for Payment

The rate shall be for a unit of Smt.

3 CODES AND STANDARDS

Reference to the Standard Codes of Practice from:

MORTH	Ministry of Road Transport and Highways
IRC	Indian Road Congress
BMC	Brihanmumbai Municipal Corporation

Applicable Codes, Standards & Publications

Code No.	Title
IRC: 6-2017	Standard Specifications and Code Of Practice for Road Bridges, Section –II Loads and Load combinations (Seventh Revision)
IRC:37-2001	Guidelines for the Design of Flexible Pavements
IRC: 38-1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision)
IRC: 58-2015	Guidelines for the Design of Rigid Pavements for Highways (Fourth Revision)
IRC: 92- 2017	Guideline for Design of Interchanges in Urban areas (First Revision)
IRC:106-1990	Guidelines for Capacity of Urban Roads in Plain Areas
IRC:SP-23-1983	Vertical curves for Highways
IRC:SP-41- 1994	Guidelines on Design of At-Grade Intersections in Rural and Urban Areas
IRC:SP-42-2014	Guidelines on Road Drainage (First Revision)
IRC SP 047: 1998	Guidelines on Quality Systems for Road Bridges

IRC:SP-49-2014	Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement
IRC:SP-50- 2013	Guidelines on Urban Drainage
IRC:SP-57-2000.	Guidelines on Quality Systems for Roads
IRC:SP-63-2004	Guidelines for the Use of Interlocking Concrete Block Pavement
IRC:SP-92- 2010	Guidelines For the Design of Interchange in Urban Areas

Volume 5

Outline Construction Specifications

Section- 2

Bridges

Brihanmumbai Municipal Corporation

Mumbai, India

1 Preamble

This Technical Specifications shall be read in conjunction with all other Documents constituting the Contract – viz. Notice of Intimation, Instructions to Tenderers, Conditions of Contract, Outline Specifications, Drawings and other related documents mentioned in these Bidding Documents.

2 Standards

Applicable codes and standards are listed in Section 2 of Volume 4, Outline Design Specification for Bridges.

3 Site Clearance

This work shall consists of cutting, removing and disposing of all materials such as trees, bushes, shrubs, stumps, roots etc. to an average depth of 150 mm in thickness required for construction.

4 Excavation for Structures

4.1 Scope

Excavation shall be carried out after completion of earth improvement works as per the technical specification in Section 4 of this Volume.

Excavation for structures shall consist of the removal of material for the construction of foundations for bridges, culverts, retaining walls, headwalls, cut-off walls, pipe culverts and other similar structures, in accordance with the requirements of these Specifications and the lines and dimensions shown on the drawings or as indicated by the Engineer. The work shall include construction of the necessary cofferdams and cribs and their subsequent removal; all necessary sheeting, shoring, bracing, draining and pumping; the removal of all logs, stumps, grubs and other deleterious matter and obstructions, necessary for placing the foundations; trimming bottoms of excavations; backfilling and clearing up the site and the disposal of all surplus material.

4.2 Classification of Excavation

All materials involved in excavation shall be classified in accordance with Clause 301.2 of Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

4.3 Construction Operations

4.3.1. Setting out:

After the site has been cleared according to Clause 2.4, the limits of excavation shall be set out true to lines, curves and slopes.

4.3.1.1. **Excavation:**

Excavation shall be taken to the width of the lowest step of the footing and the sides shall be left plumb where the nature of soil allows it. Where the nature of soil or the depth of the trench and season of the year do not permit vertical sides, the Contractor at his own expense shall put up necessary shoring, strutting and planking or cut slopes to a safer angle or both with due regard to the safety of personnel and works and to the satisfaction of the Engineer.

The depth to which the excavation is to be carried out shall be as shown on the drawings, unless the type of material encountered is such as to require changes, in which case the depth shall be as ordered by the Engineer. Propping shall be 'undertaken when any foundation or stressed zone from an adjoining structure is within a line of 1 vertical to 2 horizontal from the bottom of the excavation.

Where blasting is to be resorted to, the same shall be carried out in accordance with Clause 302 of Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, and Government of India and published by the Indian Roads Congress and all precautions indicated therein observed. Where blasting is likely to endanger adjoining foundations or other structures, necessary precautions such as controlled blasting, providing rubber mat cover to prevent flying of debris etc. shall be taken to prevent any damage.

4.3.1.2. **Dewatering and protection:**

Normally, open foundations shall be laid dry. Where water is met with in excavation due to stream flow, seepage, springs, rain or other reasons, the Contractor shall take adequate measures such as bailing, pumping, constructing diversion channels, drainage channels, bunds, depression of water level by well point system, cofferdams and other necessary works to keep the foundation trenches dry when so required and to protect the green concrete/masonry against damage by erosion or sudden rising of water level. The methods to be adopted in this regard and other details thereof shall be left to the choice of the Contractor but subject to "Notice to Proceed" by the Engineer. "Notice to Proceed" from the Engineer shall, however, not relieve the Contractor of the responsibility for the adequacy of dewatering and protection arrangements and for the quality and safety of the works.

Where cofferdams are required, these shall be carried to adequate depths and heights, be safely designed and constructed and be made as watertight as is necessary for facilitating construction to be carried out inside them. The interior dimensions of the cofferdams shall be such as to give sufficient clearance for the construction and inspection and to permit installation of pumping equipment, etc., inside the enclosed area.

If it is determined beforehand that the foundations cannot be laid dry or the situation is found that the percolation is too heavy for keeping the foundation dry, the foundation concrete shall be laid under water by tremie pipe only. In case of flowing water or artesian springs, the flow shall be stopped or reduced as far as possible at the time of placing the concrete.

Pumping from the interior of any foundation enclosure shall be done in such a manner as to preclude the possibility .of the movement of water through any fresh concrete. No pumping shall be permitted during the placing of concrete or for any period of at least 24 hours thereafter, unless it is done from a suitable sump separated from the concrete work by a watertight wall or other similar means.

At the discretion of the Contractor, cement grouting or other approved methods may be used to prevent or reduce seepage and to protect the excavation area.

The Contractor shall take all precautions in diverting channels and in discharging the drained water as not to cause damage to the works, crops or any other property.

4.3.1.3. **Preparation of foundation:**

The bottom of the foundation shall be levelled both longitudinally and transversely or stepped as directed by the Engineer. Before footing is laid, the surface shall be slightly watered and rammed. In the event of excavation having been made deeper than that shown on the drawings or as otherwise ordered by the Engineer, the extra depth shall be made up with concrete or masonry of the foundation at the cost of the Contractor as per Clause 2.11.1.4. Ordinary filling shall not be used for the purpose to bring the foundation to level.

When rock or other hard strata is encountered, it shall be freed of all soft and loose material, cleaned and cut to a firm surface either level and stepped as directed by the Engineer. All seams shall be cleaned, out and filled with cement mortar or grout to the satisfaction of the Engineer. In the case of excavation in rock, annular space around footing shall be filled with lean concrete (L3;6 nominal mix) upto the top level of rock.

If the depth of fill required is more than 1.5m above the top of the footing, filling upto 1.5m above top of footing shall be done with lean concrete (1:3:6 nominal mix) followed by boulders grouted with cement.

When foundation piles are used, the excavation of each pit shall be substantially completed before beginning pile driving operations therein. After pile driving operations in a given pit are completed, all loose and displaced materials therein shall be removed to the elevation of the bottom of the footings.

4.3.1.4. **Slips and slip-outs:**

If there are any slips or slip outs in the excavation, these shall be removed by the Contractor at his own cost.

4.3.1.5. **Public safety:**

Near towns, villages and all frequented places, trenches and foundation pits shall be securely fenced, provided with proper caution signs and marked with red lights at night to avoid accidents. The Contractor shall take adequate protective measures to see that the excavation operations do not affect or damage adjoining structures. For safety precautions, guidance may

be taken from IS:
3764.

4.3.1.6. **Backfilling:**

Backfilling shall be done with approved material after concrete or masonry is fully set and carried out in such a way as not to cause undue thrust on any part of the structure. All space between foundation masonry or concrete and the sides of excavation shall be refilled to the original surface in layers not exceeding 150 mm compacted thickness. The compaction shall be done with the help of suitable equipment such as mechanical tamper, rammer, plate vibrator etc., after necessary watering, so as to achieve a density not less than the field density before excavation.

(1) **Removal of temporary works for excavation.**

The coffer dams, cribs shall be removed after the completion of work without disturbing the finished work.

4.3.1.7. **Disposal of surplus excavated materials:**

Clause 301.3.11 of Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress shall apply.

4.4 Form Work

4.3.2. Description

Formwork shall include all temporary or permanent forms required for forming the concrete of the shape, dimensions and surface finish as shown on the drawing or as directed by the Engineer, together with all props, staging, centering, scaffolding and temporary construction required for their support. The design, erection and removal of formwork shall conform to IRC: 87 "Guidelines for Design and Erection of Falsework for Road Bridges" and these specifications.

4.3.3. Materials

All materials shall comply with the requirements of IRC: 87. Materials and components used for formwork shall be examined for damage or excessive deterioration before use / re use and shall be used only if found suitable after necessary repairs. In case of timber formwork, the inspection shall not only cover physical damages but also signs of attacks by decay, rot or insect attack or the development of splits.

Forms shall, be constructed with metal or timber. The metal used for forms shall be of such thickness that the forms remain true to shape. All bolts should be countersunk. The use of approved internal steel ties or steel or plastic spacers shall be permitted. Structural steel tubes used as support for forms shall have a minimum wall thickness of 4 mm. Other materials conforming to the requirements of IRC: 87 may also be used if approved by the Engineer.

4.3.4. Design of formwork

The Contractor shall furnish the design and drawing of complete formwork (i.e. the forms as well as their supports) for Notice of the Engineer before any erection is taken up. If proprietary system of formwork is used, the Contractor shall furnish detailed information as per Appendix 1500/I of "Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress to the Engineer for his Notice.

Notwithstanding any approval or review of drawing and design by the Engineer, the Contractor shall be entirely responsible for the adequacy and safety for formwork.

The design of the formwork shall conform to provisions of IRC: 87. It shall ensure that the forms can be conveniently removed without disturbing the concrete. The design shall facilitate proper safe access to all parts of formwork for inspection.

In the case of pre stressed concrete superstructure, careful consideration shall be given to redistribution of loads on props due to pre stressing.

For distribution of load and load transfer to the ground through staging, an appropriately designed base plate must be provided which shall rest on firm sub-stratum.

4.3.5. Workmanship

1) The formwork shall be robust and strong and the joints shall be leak-proof. Balli shall not be used as staging. Staging must have cross bracings and diagonal bracings in both directions. Staging shall be provided with an appropriately designed base plate resting on firm strata.
2) The number of joints in the formwork shall be kept to a minimum by using large size panels. The design shall provide for proper "soldiers" to facilitate alignment. All joints shall be leak proof and must be properly sealed. Use of PVC JOINT sealing tapes, foam rubber or PVC T-section is essential to prevent leakage of grout.
3) As far as practicable, clamps shall be used to hold the forms together. Where use of nails is unavoidable minimum number of nails shall be used and these shall be left projecting so that they can be withdrawn easily. Use of double headed nails shall be preferred.
4) Use of ties shall be restricted, as far as practicable. Wherever ties are used they shall be used with HDPE sheathing so that the ties can easily be removed. No parts prone to corrosion shall be left projecting or near the surface. The sheathing shall be grouted with cement mortar of the same strength as that of the structure.
5) Unless otherwise specified, or directed, chamfers or fillets of sizes 25 mm x 25 mm shall be provided at all angles of the formwork to avoid sharp comers. The chamfers,

bevelled edges and mouldings shall be made in the formwork itself. Opening for fixtures and other fittings shall be provided in the shuttering as directed by the Engineer.

6) Shuttering for walls, sloping members and thin sections of considerable height shall be provided with temporary openings to permit inspection and cleaning out before placing of concrete.

7) The formwork shall be constructed with pre-camber to the soffit to allow for deflection of the formwork. Pre-camber to allow for deflection of formwork shall be in addition to that indicated for the permanent structure in the drawings.

8) Where centering trusses or launching trusses are adopted for casting of superstructure, the joints of the centering trusses, whether welded, riveted or bolted should be thoroughly checked periodically. Also, various members of the centering trusses should be periodically examined for proper alignment and unintended deformation before proceeding with the concreting. They shall also be periodically checked for any deterioration in quality due to steel corrosion.

9) The formwork shall be so made as to produce a finished concrete true to shape, line and levels and dimensions as shown on the drawings, subject to the tolerances specified in respective sections of these specifications, or as directed by the Engineer.

10) Where metal forms are used, all bolts and rivets shall be countersunk and well ground to provide a smooth, plane surface. Where timber is used it shall be well seasoned, free from loose knots, projecting nails, splits or other defects that may mar the surface of concrete.

11) Forms shall be made sufficiently rigid by the use of ties and bracings to prevent any displacement or sagging between supports. They shall be strong enough to withstand all pressure, ramming and vibration during and after placing the concrete. Screw jacks or hard wood wedges where required shall be provided to make up any settlement in the formwork either before or during the placing of concrete.

12) The formwork shall take due account of the calculated amount of positive or negative camber so as to ensure the correct final shape of the structures, having regard to the deformation of false work, scaffolding or propping and the instantaneous or deferred deformation due to various causes affecting pre stressed structures.

13) Suitable camber shall be provided to horizontal members of structure, especially in long spans to counteract the effects of deflection. The formwork shall be so fixed as to provide for such camber.

14) The formwork shall be coated with an approved release agent that will effectively prevent sticking and will not stain the concrete surface. Lubricating (machine oils) shall be prohibited for use as coating.

4.3.6. Formed & Unformed surface and finishes

The surface finishes for formed and unformed surfaces are classified and defined as below. Surface irregularities permitted for the various classes of finishes are termed either 'abrupt' or 'gradual'. Fins or offsets caused by displaced or misplaced form sheeting, lining or form sections, by loose knots in form lumber or by otherwise defective form lumber are considered abrupt irregularities. All other cases are described as gradual irregularities. Gradual irregularities will be measured with a template consisting of a straight edge for plans surfaces or its equivalent for curved surfaces. The length of template for testing gradual irregularities on formed surfaces shall be 1.5 m in length, the permissible gradual irregularities being measured over this length of the template.

Finish F1, F2 and F3 shall describe formed surfaces. Finish U1, U2 and U3 shall describe unformed surfaces.

(1) **Class F1 Finish**

This class of finish shall apply to all formed surfaces for which class F2 or F3 is not specified. It shall generally be formed by sawn timber formwork/timber frame or steel frame mounted with plywood or steel sheet. It shall be so constructed that there shall be no loss of material from the concrete during placement and compaction. After hardening, the concrete shall be in the required positions and shall have the shape and dimensions called for in the drawings. Any abrupt irregularities shall not exceed 10mm. All fins and drifts in excess of the above limits shall be made good by chipping and grinding if required by the Engineer-in-Charge. Small blemishes caused by entrapped air or water may be expected but the surface shall be free from voids, honeycombing or other large blemishes. Class F1 finish shall be generally specified for all surfaces buried in ground or not visible during service or for surfaces that are to receive further rendering treatment such as plastering etc. Unless otherwise specified in the item of Bill of Quantity the surface finish shall be understood to be Class F1.

(2) **Class F2 Finish**

Class F2 finish shall be obtained by the use of properly designed forms, either close jointed wrought timber forms or with forms having plywood or steel sheet lining. The abrupt irregularities shall not exceed 5mm and gradual irregularities shall be less than 8mm. Small blemishes caused by entrapped air or water may be permitted but the surface shall be generally free from honeycombing, voids and large blemishes. Surface irregularities in excess of those stipulated shall be removed by chipping or rubbing with abrasive stone.

(3) **Class F3 Finish**

Class F3 finish shall be formed by specially designed close jointed rigid forms having lining of high quality form plywood. The surface irregularities shall be limited to nil for abrupt irregularities and 3 mm for gradual irregularities. Class F3 finish may be obtained from class F2 finish by carefully removing all abrupt irregularities including fins and projections by rubbing/grinding. If steel forms are used they shall have steel sheet backing faced with plywood.

In addition, finish F3 shall include filling air holes with mortar and treatment of the entire surface with sack rubbed finish. It shall also include cleanup of loose and adhering debris. For a sack rubbed finish, the surface shall be prepared within two days after of removal of the forms. The surface shall be wetted and allowed to dry slightly before mortar is applied by sack rubbing. The mortar used shall consist of one part cement to one and one half parts by volume of fine (I.S. No. 16 mesh) sand. Only sufficient mixing water to give the mortar a workable consistency shall be used. The mortar shall then be rubbed over the surface with a fine burlap or linen cloth so as to fill all the surface voids. The mortar in the voids shall be allowed to stiffen and solidify after which the whole surface shall be wiped clean with clean burlap such that all air holes etc. are filled and the entire surface presents a uniform appearance without air holes, irregularities etc.

(4) **Class U1 Finish**

This is the screeded finish used on surfaces over which other finishes such as wearing coats etc. are to be placed. It is also the first step in the formation of U2 and U3 finishes. The finishing operation consists of levelling and screeding the concrete to produce an even and uniform surface so that the gradual irregularities are not greater than 5 mm. Surplus concrete should be removed immediately after consolidation by striking it off with a sawing motion of a straight edge or template across a wooden or metal strip that has been set as guide. Unless the drawings specify a horizontal surface or show the slope required, the tops of narrow surfaces, such as stair treads, walls, curbs and parapets shall be sloped approximately 10 mm per 300 mm width. Surfaces to be covered with concrete topping, terrazzo, and similar surfaces shall be smooth screeded and levelled to produce even surfaces, irregularities not exceeding 5mm.

(5) **Class U2 Finish**

This is a floated finish used on all outdoor unformed surfaces not prominently exposed to view such as tops of piers etc. The floating may be done by hand or power driven equipment. It should not however be started until some stiffening has taken place in the surface concrete and the moisture film or 'shine' has disappeared. The floating should work the concrete no more than is necessary to produce a surface that is free from screed marks. All joints and edges should be finished with edging tools. It shall include the repair of gradual irregularities exceeding 5 mm. All abrupt irregularities shall also be repaired unless a roughened texture is specified.

(6) **Class U3 Finish**

This is a trovelled finish used on all surfaces exposed to view at close quarters such as tops of parapets and kerbs etc. Steel trovelling should not be started until after the moisture film and 'shine' have completely disappeared from the floated surface and the concrete has hardened enough to prevent an excess of fine material and water from being worked to the surface. Excessive trovelling, especially if started too soon, tends to produce crazing and lack of durability. Too long a delay will result in a surface too hard for proper finishing. Steel trovelling should be performed with a firm pressure that will flatten and smooth the sandy surface left by floating. Trovelling should produce a dense, uniform surface free of blemishes, ripples and trovel marks. It shall include the repair of all abrupt irregularities and the repair of gradual irregularities exceeding 5 mm. It shall also include finishing the joints and the edges of concrete with edging tools.

4.3.7. Precautions

(1) Special measures in the design of formwork shall be taken to ensure that it does not hinder the shrinkage of concrete. The soffit of the formwork shall be so designed as to ensure that the formwork does not restrain the shortening and/or hogging of beams during prestressing. The forms may be removed at the earliest opportunity subject to the minimum time for removal of forms with props retained in position.

(2) Where necessary, formwork shall be so arranged that the soffit form, properly supported on props only can be retained in position for such period as may be required by maturing conditions.

(3) Any cut-outs or openings provided in any structural member to facilitate erection of formwork shall be closed with the same grade of concrete as the adjoining structure immediately after removal of formwork ensuring watertight joints.

(4) Provision shall be made for safe access on, to and about the formwork at the levels as required.

(5) Close watch shall be maintained to check for settlement of formwork during concreting. Any settlement of formwork during concreting shall be promptly rectified.

(6) Water used for curing should not be allowed to stagnate near the base plates supporting the staging and should be properly drained.

(7) Natural ground shall be checked for bearing capacity and likely settlement before erection of the staging.

4.3.8. Preparation of formwork before concreting

The inside surfaces of forms shall, except in the case of permanent formwork or where otherwise agreed to by the Engineer be coated with a release agent supplied by approved manufacturer or of an approved material to prevent adhesion of concrete to the formwork. Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not be allowed to come into contact with any reinforcement or pre stressing tendons and anchorages. Different release agents shall not be used in formwork for exposed concrete. Before re-use of forms, the following actions shall be taken:

- The contact surfaces of the forms shall be cleaned carefully and dried before applying a release agent.
- It should be ensured that the release agent is appropriate to the surface to be coated.

The same type and make of release agent shall be used throughout on similar formwork materials and different types should not be mixed.

- The form surfaces shall be evenly and thinly coated with release agent The vertical surface shall be treated before horizontal surface and any excess wiped out
- The release agent shall not come in contact with reinforcement or the hardened concrete. All forms shall be thoroughly cleaned immediately before concreting.
- The Contractor shall give the Engineer due notice before placing any concrete in the forms to permit him to inspect and approve the formwork, but such inspection shall not relieve the contractor of his responsibility for safety of formwork, men, machinery, materials and finish or tolerances of concrete.

4.3.9. Removal of formwork

The scheme for removal of formwork (i.e. de-shuttering and de-centering) shall be planned in advance and furnished to the Engineer for scrutiny and approval. No formwork or any part thereof shall be removed without prior Notice of the Engineer.

The formwork shall be so removed as not to cause any damage to concrete. Centering shall be gradually and uniformly lowered in such a manner as to permit the concrete to take stresses due to its own weight uniformly and gradually to avoid any shock or vibration.

Where not specifically approved, the time of removal of formwork (when ordinary Portland Cement is used without any admixtures at an ambient temperatures exceeding 10 degrees Celsius) shall be as under:

Walls, piers, abutments, columns and vertical faces: 12 to 48 hours as may be of structural members decided by the Engineer

Soffits of Slabs (with props left under)	:	3 days
Props (left under slabs)	:	14 days
Soffit of Gilders	:	7 days (with props left under)
Props (left under girders)	:	21 days

Where there are re-entrant angles in the concrete sections, the formwork should be removed at these sections as soon as possible after the concrete has set, in order to avoid cracking due to shrinkage of concrete.

4.3.10. Re-use of formwork

After forms are stripped, all materials shall be examined for any damage and damaged pieces, if any, shall be removed either as rejected or for rectification if possible. The materials found fit to be reused shall be thoroughly cleaned. Holes bored through sheathing for form ties shall be plugged by driving in common corks or foamed plastics. Patching plaster may also be used to fill small holes. After cleaning and before re-fixing, each formwork shall be got approved from the Engineer. All Form work and staging shall be so used as to ensure quality of the exposed surface. If in the opinion of the Engineer, any particular panel/member has become unsatisfactory for use at any stage, the same will be rejected and removed from site.

4.3.11. Specialized formwork

Specialized formwork may be required in the case of slip form work, underwater concreting, segmental construction finishes etc. Such specialized formwork shall be designed and detailed by competent agencies and a set of complete working drawings and installation instructions shall be supplied to the Engineer. The site personnel shall be trained in the erection and dismantling as well as operation of such specialized formwork. In case proprietary equipment is used, the supplier shall supply drawings, details, installation instructions, etc. in the form of manuals along with the formwork. Where specialized formwork is used, close co-ordination with the design of permanent structure is necessary.

For slip form the rate of slipping the formwork shall be designed for each individual case taking into account various parameters including the grade of concrete, concrete strength, concrete temperature, ambient temperature, concrete admixtures, etc. In the case of segmental construction, the concrete mix shall be normally designed for developing high early strength so that the formwork is released as early as possible.

In order to verify the time and sequence of striking/removal of specialised formwork, routine field-tests for the consistency of concrete and strength development are mandatory and shall be carried out before adoption.

For specialised formwork, the form lining material may be either plywood or steel sheet of appropriate thickness. Plywood is preferred where superior quality of surface is desired, whereas steel sheeting is normally used where large numbers of repetitions are involved.

4.3.12. Special architectural finishes

Where special architectural finishes have been specified which require special patterns, grooves, ridges, surface finishes etc., and which are to be obtained by casting concrete against forms, need specially designed forms and special finishing using suitable materials. These forms can be made from materials specified in IRC-87, relevant IS codes with special workmanship/controls. Use of any other material is to be permitted only after specific written “Notice to Proceed” from the Engineer.

5 Steel Reinforcement

5.1 Description

This work shall consist of furnishing and placing of the shape and dimensions shown on the drawings and conforming to these Specifications or as approved by the Engineer

5.2 General

Steel for reinforcement shall meet with the requirements of. IS 1786 (last revision) set by Bureau of Indian Standard (BIS)

Reinforcements shall be high strength deformed bars. The reinforcement steel shall be Corrosion Resistant Steel (CRS), Fe 500 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

5.3 Protection of reinforcement

Fusion bonded epoxy coating shall be provided to any type of reinforcement steel.

5.4 Bending of reinforcement

(1) Bar bending schedule shall be furnished by the Contractor and got Notice by the Engineer before start of work.

(2) Reinforcing steel shall conform to the dimensions and shapes given in the Noticed Bar Bending Schedules.

(3) Bars shall be bent cold to the specified shape and dimensions or as directed by the Engineer using a proper bar bender, operated by hand or power to obtain the correct radii of bends and shape.

(4) Bars shall not be bent or straightened in a manner that will damage rile parent material or the coating.

(5) Bars bent during transport or handling shall be straightened before being used on work and shall not be heated to facilitate straightening.

5.5 Placing of reinforcement

(1) The reinforcement cage should generally be fabricated in the yard at ground level and then shifted and placed in position. The reinforcement shall be placed strictly in accordance with the drawings and shall be assembled in position only when the structure is otherwise ready for placing of concrete. Prolonged time gap between assembling of reinforcements and casting of concrete, which may result in rust formation on the surface, shall not be permitted.

(2) Reinforcement bars shall be placed accurately in position as shown on the drawings- the bars, crossing one another shall be tied together at every intersection with binding wire (annealed), conforming to IS: 280 to make the skeleton of the reinforcement rigid such that the reinforcement does not get displaced during placing of concrete, or any other operation. The diameter of binding wire shall not be less than 1 mm.

(3) Bar shall be kept in position usually by the following methods:

(i) In case of beam and slab construction, industrially produced polymer cover blocks of thickness equal to the specified cover shall be placed between the bars and formwork subject to satisfactory evidence that the polymer composition is not harmful to concrete and reinforcement. Cover blocks made of concrete may be permitted by the Engineer, provided "they have the same strength and specification as those of the member.

(ii) In case of dowels for columns and walls, the vertical reinforcement shall be kept in position by means of timber templates with slots cut in them accurately, or with cover blocks tied to the reinforcement. Timber templates shall be removed after the concreting has progressed upto a level just below their location.

(iii) Layers of reinforcements shall be separated by spacer bars at approximately one meter intervals. The minimum diameter of spacer bars shall be 12 mm or equal to maximum size of main reinforcement or maximum size of coarse aggregate, whichever is greater. Horizontal reinforcement shall not be allowed to sag between supports.

(iv) Necessary stays, blocks, metal chairs, spacers, metal hangers, supporting wires etc. or other subsidiary reinforcement shall be provided to fix the reinforcements firmly in its correct position.

(v) Use of pebbles, broken stone, metal pipe, brick, mortar or wooden blocks etc., as devices for positioning reinforcement shall not be permitted.

(vi) CRS bars shall be placed on supports that do not damage the coating. Supports shall be installed in a manner such that planes of weakness are not created in hardened concrete. The coated reinforcing steel shall be held in place by use of plastic or plastic coated binding wires especially manufactured for the purpose. Reference shall be made to Section 1000 of Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress for other requirements.

(4) Placing and fixing of reinforcement shall be inspected and approved by the Engineer before concrete is deposited.

5.6 Bar splices

(1) **Lapping**

All reinforcement shall be furnished in full lengths as indicated on the drawing. No splicing of bars, except where shown on the drawing, will be permitted without Notice by the Engineer. The lengths of the splice shall be as indicated on drawing or as Noticed by the Engineer.

(2) **Welding**

Splicing by welding of reinforcement will be permitted only if detailed on the drawing or approved by the Engineer. Weld shall develop an ultimate strength equal to or greater than that of the bars connected.

While welding may be permitted for mild steel reinforcing bars conforming to IS: 432, welding of deformed bars conforming to IS: 1786 shall in general be prohibited. Welding may be permitted in case of bars of other than S 240 grade including special welding grade of S 415 grade bars conforming to IS: 1786, for which necessary chemical analysis has been secured and the carbon equivalent (CE) calculated from the chemical composition shall be 0.4 or less

The method of welding shall conform to IS: 2751 and IS: 9417 and to any supplemental specifications to the satisfaction of the Engineer.

Welding may be carried out by metal arc welding process. Oxy-acetylene welding shall not be permissible. Any other process may be used subject to the Notice by the Engineer and necessary additional requirements to ensure satisfactory joint performance. Precautions on overheating, choice of electrode, selection of correct current in arc welding etc., should be strictly observed.

All bars shall be butt welded except for smaller diameter bars (diameter of less than 20 mm), which may be lap, welded. Single-V or Double-V butt joints may generally be used. For vertical bars single bevel or double bevel joints may be used.

Welded joints shall be located well away from bends and not less than twice the bar diameter away from a bend. Generally, shop welding in controlled conditions is to be preferred, where feasible. Site welding where necessary shall, however, be permitted when the facilities, equipment, process, consumables, operators, welding procedure are adequate to produce and maintain uniform quality at par with that attainable in shop welding to the satisfaction of the Engineer.

Joint welding procedures, which are to be employed, shall invariably be established by a procedure specification. All welders and welding operators to be employed shall have to be qualified by tests prescribed in IS: 2751 Inspection of welds shall confer s to IS: 822 and destructive or non destructive testing may be undertaken when deemed necessary. Joints with weld defects detected by visual inspection or dimensional check inspection shall not be accepted. Suitable means shall be provided for holding the bars securely in position during welding. It must be ensured that no voids are left in welding. When welding is done in 2 or 3 stages, previous surface shall be cleaned properly. Bars shall be cleaned of all loose scale, rust, grease, paint and other foreign matter before carrying out welding. Only competent and experienced welders shall be employed on the work with the Notice of the Engineer. No welding shall be done on coated bars. M.S. electrodes used for welding shall conform to IS: 814.

Welded joints shall preferably be located at points where steel will not be subject to more than 75 per cent of the maximum permissible stresses and welds so staggered that at any one section, not more man 20 per cent of the bars are welded.

Welded pieces of reinforcement shall be tested. Specimens shall be taken from the site and the number and frequency of tests shall be as directed by the Engineer.

(3) **Mechanical Coupling of Bars**

Bars may be joined with approved patented mechanical devices as indicated on the drawing or as approved by the Engineer e.g. by special grade steel sleeves swaged on to" bars in end-to-end contact or by screwed couplers. In case such devices are permitted by the Engineer, they shall develop at least 125 per cent of the characteristic strength of the reinforcement bar.

5.7 Testing and Acceptance

The material shall be tested in accordance with relevant IS specifications and necessary test certificates shall be furnished. Additional tests, if required, will be got carried out by the Contractor at his own cost.

The fabrication, furnishing and placing of reinforcement shall be in accordance with these specifications and shall be checked and accepted by the Engineer. The sampling and testing procedure shall be laid down in IS:1786.

Shipping, handling & storage: reinforcement shall be covered and protected at all times during transportation. Reinforcing steel of differing material types shall be stored separately. Bar tags identifying the material type shall be clearly visible and shall be maintained in-place until installation of the material. The Contractor shall store all reinforcing steel on platforms, skids, or other suitable means of support able to keep the material above the ground surface while protecting it from mechanical damage or deterioration.

6 Structural Concrete

6.1 Description

The work shall consist of furnishing and placing structural concrete and incidental construction in accordance with these specifications and in conformity with the lines, grades and dimensions, as shown on the drawings or as directed by the Engineer.

6.2 Materials

All materials shall conform to Section 1000 of Specifications for Road & Bridges Works" (Firth Revision / Latest Revision issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

6.2.1. Grades of Concrete

6.2.1.1. The grades of concrete shall be designated by the characteristic strength as given in below Table, where the characteristic strength is defined as the strength of concrete below which not more than 5 per cent of the test results are expected to fall.

Grade Designation	Specified characteristic Compressive strength of 150 mm cubes at 28 days, in MPa
M 15	15
M 20	20
M 25	25
M 30	30
M 35	35
M 40	40

M 45	45
M 50	50
M 55	55

6.2.1.2. The Minimum grades of concrete in bridges and corresponding minimum cement contents and water-cement ratios shall be maintained as indicated in below Tables

A. Minimum Cement Content and Maximum Water Cement Ratio

Table 2.7.2: For bridges with pre stressed concrete or those with individual span lengths more than 30 m or those that are built with innovative design/construction

Structural Member	**Min. cement content for all exposure conditions (kg/Cum)**	**Max. water cement ratio**
		Exposure conditions- Severe
a) PCC members	360	0.45
b) RCC members	400	0.4
c) PSC members	400	0.4

Minimum Strength of Concrete

Member	**Minimum Concrete Grade**
	Exposure Condition-Serve
a) PCC levelling course	M 15
b) Retaining wall	M 35
c) pile foundation/Pile cap	M35
d) Crash barrier, Approach slab, friction slab	M 40
e) PSC in superstructure	M50
f) Substructure	M50

Notes Applicable to Tables 2.7.2

(i) The minimum cement content is based on 20 mm aggregate (nominal max. size). For 40 mm and larger size aggregates, it may be reduced suitably but the reduction shall not be more than 10 per cent.

(ii) For underwater concreting, the cement content shall be increased by 10 per cent.

(iii) Severe conditions of exposure shall mean alternate wetting and drying due to saline water, alternate wetting and drying combined with freezing and buried in soil having corrosive effect.

(iv) The cement content shall be as low as possible but not less than the quantities specified above. In no case shall it exceed 450 kg/Cum. of concrete.

6.2.1.3. Concrete used in any component or structure shall be specified by designation along with prescribed method of design of mix i.e. "Design Mix" or "Nominal Mix". For all items of concrete, only "Design Mix" shall be used, except where "Nominal Mix" concrete is permitted by the Engineer. "Nominal Mix" may be permitted only for incidental construction where strength requirement are up to M 20 only. “Nominal Mix” may also be permitted for non-structural concrete or for screed below open foundations.

6.2.1.4. If the Contractor so elects, the Engineer may permit the use of higher grade concrete than that specified on the drawing, in which event the higher grade concrete shall meet the specifications applicable thereto without additional compensation.

6.2.2.Proportioning of concrete

Prior to the start of construction, the Contractor shall design the mix in case of "Design Mix Concrete" or propose nominal mix in case of "Nominal Mix Concrete", and submit to the Engineer for approval, the proportions of materials, including admixtures to be used. Water-reducing admixtures (including plasticisers or super-plasticisers) may be used at the Contractor's option, subject to the Notice by the Engineer. Other types of admixtures shall be prohibited, unless specifically permitted by the Engineer.

Pulverized Fly Ash (PFA)/ Ground Granulated Blast Furnace Slag (GGBS) and Ultrafine additives (silica fume/ Ultrafine Slag) must be incorporated in all concretes of Grade 35 and above. Ultrafine additives shall have particle size (d95) less than 11 microns and mean particle size (d50) not more than 6 microns. The minimum cementitious content (including PFA/GGBS and Ultrafine additive) shall be 380kg/m3 for all concrete Grade. Maximum water to binder ratio shall not exceed 0.40 for all concrete Grade.
The ultrafine mineral admixtures shall comply with IRC:SP 70-2005 and IRC:112-2011.

The ultrafine mineral admixtures shall not exceed 10% of total cementitious/binder content.
When PFA is incorporated in the concrete as a separate material, it shall not exceed 35% of the total cementitious content.
When GGBS is incorporated in the concrete as a separate material, it shall not be less than 50% and more than 70% of the total cementitious content.

The Contractor shall propose and conduct a program of trial mixes for all grades of concrete to demonstrate their suitability for use in the Works and to meet the Outline Specifications.

6.2.2.1. Concrete performance

High performance concrete (HPC) shall be used for any type of concrete members. However, the application of the concrete member, its purpose and the mix design to be made of HPC shall require the Engineer’s approval. Applicable specifications for HPC shall be IRC, BS

EN and AASHTO, etc.

6.2.2.2. Durability

Concrete shall be durable to provide satisfactory performance in the anticipated exposure conditions during service. The materials and mix proportions specified and used, and the workmanship employed should be such as to maintain its integrity and to protect embedded metal from corrosion. One of the main characteristics influencing the durability of concrete is its impermeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. Impermeability is governed by the constituents and workmanship employed in making the concrete. A suitably low permeability is achieved by having an adequate cement content, sufficiently low water-cement ratio, dense packing of fine particles, by ensuring thorough compaction of the concrete, and by timely and adequate curing. Total water-soluble sulphate (SO3) content of the concrete mix, expressed as (SO3) shall not exceed 4 per cent by mass of cement used in the mix.

Total chloride content in concrete, expressed as chloride-ion, shall not exceed the following values by mass of cement used:

Type	Amount (percent)
Prestressed concrete	0.10
Reinforced concrete	-
(i) in severe condition of exposure	0.20
(ii) in moderate condition of exposure	0.30

6.2.2.3. Requirements of Consistency

The mix shall have the consistency, which will allow proper placement and consolidation in the required position. Every attempt shall be made to obtain uniform consistency.

The optimum consistency for various types of structures shall be as indicated in Table 2.7.4, or as directed by the Engineer. The slump of concrete shall be checked as per IS: 516.

Consistency Requirements

S. No.	TYPE	SLUMP (mm)
1	Structures with exposed inclined surface requiring low slump concrete to allow proper compaction plain cement concrete	-25
2	RCC structures with widely spaced reinforcements; e.g. solid columns , piers, abutments, footings, well steining	-50
3	RCC structures with fair degree of congestion of reinforcement; e.g. pier and abutment caps, box culverts well curb, well cap, walls with thickness greater than 300mm	-75
4	RCC and PSC structures with highly congested reinforcements e.g. deck slab girders, box girders, walls with thickness less than 300 mm	-125
5	Underwater concreting through tremie e.g. bottom plug, cast-in-situ piling	150-200

6.2.2.4. Requirements for Designed Mixes

(1) Target mean strength

The target mean strength of specimen shall exceed the specified characteristic compressive strength by at least the "current margin".

The current margin for a concrete mix shall be determined by the Contractor and shall be taken as 1.64 times the standard deviation of sample test results taken from at least 40 separate batches of concrete of nominally similar proportions produced at site by the same plant under similar supervision, over a period exceeding 5 days, but not exceeding 6 months.

Where there is insufficient data to satisfy the above, the current margin for the initial design mix shall be taken as given in below Table:

Initial Design Mix Current Margin

Concrete Grade	Current Margin (MPa)	Target Mean Strength (MPa)
M15	10	25
M20	10	30
M25	11	36
M30	12	42
M35	12	47
M40	12	52
M45	13	58
M50	13	63
M55	14	69

The initial current margin given in the Table 2.7.5 shall be used till sufficient data is available to determine the current margin as per sub-clause (i) above.

(2) Trial mixes

The Contractor shall give notice to enable the Engineer to be present at the making of trial mixes and preliminary testing of the cubes. The Contractor shall prepare trial mixes, using samples of approved materials typical of those he proposes to use in the works, for all grades to the Engineer's satisfaction prior to commencement of concreting. The initial trial mixes shall generally be carried out in an established laboratory approved by the Engineer. In exceptional cases, the Engineer may permit the initial trial mixes to be prepared at the site laboratory of the Contractor, if a full-fledged concrete laboratory has been established well before the start of construction, to his entire satisfaction. In all cases complete testing of materials forming the constituents of proposed Design Mix shall have been carried out prior to making trial mixes. Sampling and testing procedures shall be in accordance with these specifications.

When the site laboratory is utilized for preparing initial mix design, the concreting plant and means of transport employed to make the trial mixes shall be similar to that proposed to be used in the works.

Test cubes shall be taken from trial mixes as follows. For each mix, set of six cubes shall be made from each of three consecutive batches. Three cubes from each set of six shall be tested at an age of 28 days and three at an earlier age approved by the Engineer. The cubes shall be made, cured, stored, transported and tested in accordance with these specifications. The average strength of the nine cubes at 28 days shall exceed the specified characteristic strength by the current margin minus 3.5 MPa.

(3) Control of strength of design mixes Adjustment to Mix Proportions

Adjustments to mix proportions arrived at in the trial mixes shall be made subject to the Engineer's approval, in order to minimize the variability of strength and to maintain the target mean strength. Such adjustments shall not be taken to imply any change in the current margin. Change of Current Margin

When required by the Engineer, the Contractor shall recalculate the current margin in accordance with Clause 2.7.4.2 (1). The recalculated value shall be adopted as directed by the

Engineer and it shall become the current margin for concrete produced subsequently.

(4) Additional Trial Mixes

During production, the Contractor shall carry out trial mixes and tests, if required by the Engineer, before substantial changes are made in the material or in the proportions of the materials to be used, except when adjustments to the mix proportions are carried out in accordance with sub-clause (a) above.

6.2.2.5. Requirements of Nominal Mix Concrete

Requirements for nominal mix concrete unless otherwise specified shall be as detailed in below Table

Proportions for Nominal Mix Concrete

Concrete Grade	Total Quantity of dry aggregate by mass per 50 kg of cement to be taken as the sum of individual masses of fine and coarse	Proportion of fine to Coarse aggregate (by mass)
M15	350	Generally 1:2 subject to upper limit 1:1.5 and lower limit of
M20	250	--do--

6.2.2.6. Additional Requirements

Concrete shall meet with any other requirements as specified on the drawing or as directed by the Engineer. Additional requirements shall also consist of the following overall limits of deleterious substances in concrete:

a) The total chloride content of all constituents of concrete as a percentage of mass of cement in mix shall be limited to values given below:

Prestressed Concrete : 0.1 per cent

Reinforced concrete exposed to chlorides in service: 0.2 per cent

Other reinforced concrete construction : 0.3 per cent

b) The total sulphuric anhydride (SO.) content of all the constituents of concrete as a percentage of mass of cement in the mix shall be limited to 4 per cent

6.2.2.7. Suitability of Proposed Mix Proportions

The Contractor shall submit the following information for the Engineer's approval:

a) Nature and source of each material

b) Quantities of each material per cubic metre of fully compacted concrete

c) Either of the following :

(i) appropriate existing data as evidence, of satisfactory previous performance for the target mean strength, current margin, consistency and water/cement ratio and .any other additional requirements) as specified. (ii) full details of tests on trial mixes.

a) Statement giving the proposed mixes proportions for nominal mix concrete.

Any change in the source of material or in the mix proportions shall be subject to the Engineer's prior approval.

6.2.3.Admixtures

Duly tested admixtures/additives conforming to IS: 6925 and IS: 9103 (without replacement of cement) may be used subject to satisfactory proven use, with the Notice by the Engineer. Admixtures generating Hydrogen or Nitrogen and containing chlorides, nitrates, sulphides, sulphates and any other material liable to affect the steel or concrete shall not be permitted. For use of mineral admixtures, refer clauses 1714.1 and 1715.2 of MORTH Specification.

6.2.4.Size of Coarse Aggregate

The size (maximum nominal) of coarse aggregates for concrete to be used in various components shall be given in below Table

Coarse aggregate size

SL No	Components	Maximum Nominal Size of Coarse Aggregate (mm)
i)	RCC works in girders. Slabs, wearing coat, kern, approach slab, hollow piers and abutments, pier/abutment caps, piles	20
ii)	PSC work	20
iii)	Any other item	as specified by Engineer

Maximum nominal size of aggregates shall also be restricted to the smaller of the following values:

10 mm less than the minimum lateral clear distance between main reinforcements 10 mm less than the minimum clear cover to the reinforcements

The proportions of the various individual sizes of aggregates shall be so adjusted that the grading produces densest mix and the grading curve corresponds to the maximum nominal size adopted for the concrete mix.

6.2.5.Equipment

Unless specified otherwise, equipment for production, transportation and compaction of concrete shall be as under:

a) For Production of Concrete:

For all structural concreting work on the Project, the Contractor shall provide automatic weigh-batching plant of suitable capacity. The plant used shall conform to IS: 4925.

The Contractor shall provide Concrete mixers (IS: 1791 – Batch type concrete mixers, IS: 2438 – Roller Pan Mixer) and Vibrators (IS: 2505 – Concrete Vibrators Immersion Type, IS: 2506 – Screed board concrete vibrators, IS: 4656 – Form Vibrators for Concrete) supplied by recognised manufacturers.

All measuring devices of the equipment shall be maintained in a clean and serviceable condition. Its accuracy shall be checked over the range in use, when set up at each site and thereafter periodically as directed by the Engineer.

The accuracy of the measuring devices shall fall within the following limits:

Measurement of Cement ± 3 per cent of the quantity of cement in each batch
Measurement of Water ± 3 per cent of the quantity of water in each batch
Measurement of Aggregate ± 3 per cent of the quantity of aggregate in each batch
Measurement of Admixture ± 5 per cent of the quantity of admixture in each batch

b) For Concrete Transportation :depending upon actual requirement

Concrete dumpers :minimum 2 tonnes capacity Powered hoists

:minimum of 0.5 tonnes capacity Chutes

Buckets handled by cranes Transit truck mixer Concrete pump

Concrete distributor booms

Belt conveyor Cranes with skips Tremies

c) For Compaction of Concrete:

The Contractor shall provide Vibrators (IS: 2505 – Concrete Vibrators Immersion Type, IS: 2506 – Screed board concrete vibrators, IS: 4656 – Form Vibrators for Concrete) supplied by recognised manufacturers.

6.2.6. Mixing Concrete

Concrete shall be mixed either in a concrete mixer or in a batching and mixing plant, as per these specifications. Hand mixing shall not be permitted. The mixer or the plant shall be at an approved location considering the properties of the mixes and the transportation arrangements available with the Contractor. The mixer or the plant shall be approved by the Engineer.

Mixing shall be continued till materials are uniformly distributed and a uniform colour of the entire mass is obtained, and each individual particle of the coarse aggregate shows complete coating of mortar containing its proportionate amount of cement. In no case shall mixing be done for less than 2 minutes.

Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before putting in a new batch. Unless otherwise agreed to by the Engineer, the first batch of concrete from the mixer shall contain only two thirds of the normal quantity of coarse aggregate. Mixing plant shall be thoroughly cleaned before changing from one type of cement to another.

6.2.7. Transporting, Placing and Compaction of Concrete

The method of transporting and placing concrete shall be approved by the Engineer. Concrete shall be transported and placed as near as practicable to its final position, so that no contamination, segregation or loss of its constituent materials takes place. Concrete shall not be freely dropped into place from a height exceeding 1.5m. When concrete is conveyed by chute, the plant shall be of such size and design as to ensure practically continuous flow. Slope of the chute shall be so adjusted that the concrete flows without the use of excessive quantity of water and without any segregation of its ingredients. The delivery -end of the chute shall be as close as possible to the point of deposit. The chute shall be thoroughly flushed with water before and after each working period and the water used for this purpose shall be discharged outside the formwork.

All formwork and reinforcement contained in it shall be cleaned and made free from standing water, dust, snow or ice immediately before placing of concrete.

No concrete shall be placed in any part of the structure until the Notice by the Engineer has been obtained.

If concreting is not started within 24 hours of the approval being given, it shall have to be obtained again from the Engineer. Concreting then shall proceed continuously over the area between the construction joints. Fresh concrete shall not be placed against concrete, which has been in position for more than 30 minutes unless a proper construction joint is formed.

Except where otherwise agreed to by the Engineer, concrete shall be deposited in horizontal layers to a compacted depth of not more than 450 mm when internal vibrators are used and not exceeding 300 mm in all other cases.

Concrete when deposited shall have a temperature of not less than 5 degrees Celsius, and not more than 40 degrees Celsius. It shall be compacted in its final position within 30 minutes of its discharge from the mixer, unless carried in properly designed agitators, operating continuously, when this rime shall be within 1 hour of the addition of cement to the mix and within 30 minutes of its discharge from the agitator. It may be necessary to add retarding admixtures to concrete if trials show that the periods indicated above are unacceptable. In all such matters, the Engineer's decision shall be final.

Concrete shall be thoroughly compacted by vibration or other means during placing and worked around the reinforcement, tendons or duct formers, embedded fixtures and into corners of the formwork to produce a dense homogeneous void-free mass having the required surface finish. When vibrators are used, vibration shall be done continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner that does not promote segregation. Over vibration shall be avoided to minimise the risk of forming a weak surface layer. When external vibrators are used, the design of formwork and disposition of vibrator shall be such as to ensure efficient compaction and to avoid surface blemishes. Vibrations shall not be applied through reinforcement and where vibrators of immersion type are used, contact with reinforcement and all inserts like ducts etc., shall be avoided. The internal vibrators shall be inserted in an orderly manner and the distance between insertions should be about one and a half times the radius of the area visibly affected by vibration. Additional vibrators in serviceable condition shall be kept at site so that they can be used in the event of breakdowns.

Mechanical vibrators used shall comply with IS: 2502, IS: 2506, IS: 2514 and IS: 4656.

6.2.8.Construction Joints

Construction joints shall be avoided as far as possible and in no case the locations of such joints shall be changed or increased from those shown on the drawings, except with express Notice by the Engineer. The joints shall be provided in a direction perpendicular to the member axis.

Location, preparation of surface and concreting of construction joints shall conform to the additional specifications given in Appendix 1700/I of Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

6.2.9.Concreting Under Water

When it is necessary to deposit concrete under water, the methods, equipment, materials and proportions of mix to be used shall be got approved from the Engineer before any work is started. shall contain 10 per cent more cement than that required for the same mix placed in the dry.

Concrete shall not be placed in water having a temperature below 5 degrees Celsius. The temperature of the concrete, when deposited, shall not be less than 16 degrees Celsius, nor more than 40 degrees Celsius.

Coffer dams or forms shall be sufficiently tight to ensure still water conditions, if practicable, and in any case to reduce the flow of water to less than 3m per minute through the space into which concrete is to be deposited. Coffer dams or forms in still water shall be sufficiently tight to prevent loss of mortar through the joints in the walls. Pumping shall not be done while concrete is being placed, or until 24 hours thereafter. To minimize the formation of laitance, great care shall be exercised not to disturb the concrete as far as possible while it is being deposited.

All under water concreting shall be carried out by tremie method only, using tremie of appropriate diameter. The number and spacing of the tremies should be worked out to ensure proper concreting. The tremie concreting when started should continue without interruption for the full height of the member being concreted. The concrete production and placement equipment should be sufficient to enable the underwater concrete to be completed uninterrupted within the stipulated time. Necessary stand-by equipment should be available for emergency situation.

The top section of the tremie shall have a hopper large enough to hold one full batch of the mix or the entire contents of the transporting bucket as the case may be. The tremie pipe shall not be less than 200 mm in diameter and shall be large enough to allow a free flow of concrete and strong enough to withstand the external pressure of the water in which it is suspended, even if a partial vacuum develops inside the pipe. Preferably, flanged steel pipe of adequate strength for the job shall be used. A separate lifting device shall be provided for each tremie pipe with its hopper at the upper end. Unless the lower end of the pipe is equipped with an approved automatic check valve, the upper end of the "pipe shall be plugged with a wadding of gunny sacking or other approved material before delivering the concrete to the tremie pipe through the hopper; so that when the concrete is forced down from the hopper to the pipe, it will force the plug (and along with it any water in the pipe) down the pipe and out of the bottom end, thus establishing a continuous stream of concrete. It will be necessary to raise slowly the tremie in order to allow a uniform flow of concrete, but it shall not be emptied so that water is not allowed to enter above the concrete in the pipe. At all times after placing of concrete is started and until all the required quantity has been placed, the lower end of the tremie pipe shall be kept below the surface of the plastic concrete. This will cause the concrete to build up from below instead of flowing out over the surface and thus avoid formation of layers of laitance. If the charge in the tremie is lost while depositing, the tremie shall be raised above the concrete surface and unless sealed 'by a check valve, it shall be replugged at the top end, as at the beginning, before refilling for depositing further concrete.

6.2.10. Adverse Weather Conditions

6.2.10.1. Cold Weather Concreting

Where concrete is to be deposited at or near freezing temperature, precautions shall be taken to ensure that at the time of placing, it has a temperature of not less than 5 degrees Celsius and that the temperature of the concrete shall be maintained above 4 degrees Celsius until it has thoroughly hardened. When necessary, concrete ingredients shall be heated before mixing but cement shall not be heated artificially other than by the heat transmitted to it from other ingredients of the concrete. Stock-piled aggregate may be heated by the use of dry heat or steam. Aggregates shall not be heated directly by gas or on sheet metal over fire. In general, the temperature of aggregates or water shall not exceed 65 degrees Celsius. Salt or other chemicals shall not be used for the prevention of freezing. No frozen material or materials containing ice shall be used. All concrete damaged by frost shall be removed. It is recommended that concrete exposed to freezing weather shall have entrained air and the water consent of the mix shall not exceed 30 litres per 50 kg of cement.

6.2.10.2. **Hot Weather Conditions**

When depositing concrete in very hot weather, precautions shall be taken so that the temperature of wet concrete does not exceed 40 degrees Celsius while placing. This shall be achieved by stacking aggregate under the shade and keeping them moist, using cold water, reducing the time between mixing and placing to the minimum, cooling formwork by sprinkling water, starting curing before concrete dries out and restricting concreting as far as possible to early mornings and late evenings. When ice is used to cool mixing water, it will be considered a part of the water in design mix. Under no circumstances shall the mixing operation be considered complete until all ice in the mixing drum has melted.

The Contractor will be required to state his methodology for the Engineer's approval when temperatures of concrete are likely to exceed 40 degrees Celsius during the work.

6.2.11. Protection and Curing

Concreting operations shall not commence until adequate arrangements for concrete curing have been made by the Contractor. Curing and protection of concrete shall start immediately after compaction of the concrete to protect it from:

(i) Premature drying out particularly by solar radiation and wind High internal thermal gradients Leaching out by rain and flowing water

(ii) Rapid cooling during the first few days after placing Low temperature or frost

(iii) Vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement

Where members are of considerable size and length, with high cement - content, accelerated curing methods may be applied, as Noticed by the Engineer.

6.2.11.1. **Water Curing**

(1) Water for curing shall be as specified in Section 1000 of “Specifications for Road & Bridges Works” (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

(2) Creek water shall not be used for curing. Creek water shall not come into contact with concrete members unless it has attained adequate strength.

(3) Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacks, canvas, Hessian or similar materials and shall be kept constantly wet for a period of not less than 14 days from the date of placing of concrete.

6.2.11.2. **Steam Curing**

(1) Where steam curing is adopted, it shall be ensured that it is done in a suitable enclosure to contain the live steam in order to minimise moisture and heat losses.

(2) The initial application of the steam shall be after about four hours of placement of concrete to allow the initial set of the concrete to take place.

(3) Where retarders are used, the waiting period before application of the steam shall be increased to about six hours.

(4) The steam shall be at 100 per cent relative humidity to prevent loss of moisture and to provide excess moisture for proper hydration of the cement.

(5) The application of steam shall not be directly on the concrete and the ambient air temperature shall increase at a rate not exceeding 5 degrees Celsius per hour until a maximum temperature of 60 degrees Celsius to 70 degrees Celsius is reached. The maximum temperature shall be maintained until the concrete has reached the desired strength.

(6) When steam curing is discontinued, the ambient air temperature shall not drop at a rate exceeding 5 degrees Celsius per hour until a temperature of about 10 degrees Celsius above the temperature of the air to which the concrete will be exposed, has been reached.

(7) The concrete shall not be exposed to temperatures below freezing for at least six days after curing.

6.2.11.3. **Curing Compounds**

(1) General

Liquid membrane forming compounds are permitted to be used by the Engineer for curing concrete for part or whole of the total curing period as specified in sections dealing with concrete construction. These membranes reduce the loss of water from concrete during early hardening period and some types of compounds also help in reducing the temperature-rise of concrete exposed to the radiation from the sun. These specifications cover the type and use of such compounds. However, the use of the same will need specific “Notice to Proceed” from the Engineer, who may require a number of tests to be carried out for establishing the conformity of the product to these specifications and to establish that the curing compound and its method of use does not have any unacceptable effect on the quality of concrete. The cost of the initial acceptance testing and the quality control testing will be borne by the contractor.

All equipment, material etc., needed for curing and protection of concrete shall be at hand and ready for installing before actual concrete begins. Detailed plans, methods and procedures whereby the various phases of curing and protection shall be firmly established, shall be settled and got Noticed in writing from the Engineer-in-charge sufficiently in advance of the actual concreting. The equipment and method proposed to be utilised shall provide for adequate control and avoid interruption or damage to the work of other agencies.

(i) The curing compound shall be conforming to ASTM-C-309-81, Type-2, white pigmented compound. The solids dissolved in vehicle shall be either Class `A’ (no restrictions) or Class `B’ (resin as defined in ASTM D-883) as approved by the Engineer.

(ii) White pigmented compound (Type-2) shall consist of finely divided white pigments as vehicle solids, ready mixed for immediate use without alteration. The compound shall present a uniform white appearance when applied uniformly to a fresh concrete surface at a specified rate of application. It shall be of such consistency that it can be readily applied by spraying to provide uniform coating at temperatures above 40C. If two coats are to be applied then it should be applied at an interval of approximately one hour. They shall adhere to freshly placed concrete that has stiffened or sufficient to resist marking during the application and to damp hardened concrete and shall form a continuous film when applied at a rate of 5 m2/ liter. When dry, the covering shall be continuous flexible and without visible breaks or pin holes and shall remain as unbroken film at least 28 days after application. It shall not react deleteriously with the concrete.

(iii) The compound shall meet with the requirement of water retention test as per ASTM designation C-156-80. The loss of water in this test shall be restricted to not more than 0.55 kg/m^2 of exposed surface in 72 hours.

(iv) The white pigmented compound (Type 2) when tested as specified in accordance with method E-97 of ASTM shall exhibit a day light reflectance of not less than 60% of that of magnesium oxide.

(v) It shall fulfil the requirement of drying time when tested in accordance with ASTM-C-309- 81. The compound applied shall be dry to touch in not more than 4 hours. After 12 hours it shall not be tacky or tack off (peel off) concrete when walked upon nor it shall impart a slippery surface.

(vi) The liquid compound should be of a spray able consistency. (2) Acceptance Criteria and Testing

Prior to the approval of the brand / trade name of compound and the source of supply and manufacturer acceptance testing shall be carried out to demonstrate the conformance of the compound to this subsection. In addition, testing shall be performed to demonstrate that no adverse / undesirable change in quality of concrete or concrete surface takes place as a result / by-product of the use of the compound. These tests should be designed to check properties such as loss of strength at 28 days of surface layer, or of concrete cube, change in surface texture, change in adhesion to subsequently applied layer like plaster, flooring, tiling etc. The type and number of tests are to be as specified by the Engineer.

(2) Routine Testing

i) The liquid membrane forming curing compound should be brought in the manufacturer's original clear containers. Each container shall be legibly marked with the name of the manufacturer, the trade name of the compound, the type of compound and class of vehicle solids, the nominal percentage of volatile material and batch or lot number. The lot numbers will be assigned to the quantity of compound mixed, sampled and tested as single product. The manufacturer shall exercise the care in filling the container so that all are equally representative of the compound produced.

ii) Curing compound to be used on site shall be got tested at least 14 days in advance so that the result of water retention tests, reflectance test, drying etc, are available before it can be permitted for use. All of the filled containers represented by the approved sample shall then be sealed to prevent leakage, substitution or dilution. The Engineer-in-charge or authorised representative should mark each container represented by the samples with a suitable identification mark for later identification and correlation and shall be kept in store with double lock arrangements. One key shall be kept with the Contractor and the other with Engineer. Random samples shall be collected from every batch of the compound. Frequency of random sampling shall be done as directed by the Engineer. The Contractor shall provide samples and labour for collecting samples free of cost. Testing shall be carried out by agency Notice by the Engineer and in presence of his representative.

(3) Method of application

The compound shall be sprayed using mechanical sprayer of Noticed design to ensure uniform and continuous membrane on the concrete surface. The coverage shall be at the rate specified by the manufacturer or at the rate of 4 m^2 per litter or as specified by the manufacturer and Noticed by the Engineer. Field trials shall be conducted to decide effective coverage rate, which depends upon surface finish. The Engineer after verification of the field trials and based on the actual experience shall order the rate of application as needed for achieving the proper curing. With a view to ensure thorough and complete coverage, approximately one half of the compound for a given areas should be applied by moving the spray gun back and forth in one direction and the remaining half at right angles to this direction. In case the application is still not found uniform, the Contractor shall have to apply the second coat as and when directed by the Engineer. If a second coat is to be applied, it should be applied approximately after an interval of one hour. The curing compound shall generally be applied as soon as the bleeding water or shine disappears, leaving dully appearance.

If surface treatment by roughing, hand brushing etc., is required (e.g. as in case of road pavements) the curing compound should be applied immediately after the same. Equipment for spraying curing compound shall be of pressure tank type (5 to 7 kg/cm^2) with provision of continuous agitation. A curing jumbo with multiple travelling spray fans shall be provided for effective spray. Spraying on concrete lining shall be done in such a way that the green concrete is not disturbed or damaged or any foot impression left. Necessary schemes or spraying by mechanised means shall be got Noticed by the Engineer-in-charge. However, in emergency for very small areas / patches) it can be applied with wire or bristled brush.

6.2.12. Finishing

Immediately after the removal of forms, exposed bars or bolts, if any, shall be cut inside the concrete member to a depth of at least 50 mm below the surface of the concrete and the resulting holes filled with cement mortar. All fins caused by form joints, all cavities produced by the removal of form ties and all other holes and depressions, honeycomb spots, broken edges or corners, and other defects, shall be thoroughly cleaned, saturated with water, and carefully pointed and rendered true with mortar of cement and fine aggregate mixed in the proportions used in the grade of concrete that is being finished and of as dry a consistency as is possible to use. Considerable pressure shall be applied in filling and pointing to ensure thorough filling in all voids. Surfaces, which have been pointed, shall be kept moist for a period of twenty tour hours. Special pre-packaged proprietary mortars shall be used where appropriate or where specified in the drawing.

All construction and expansion joints in the completed work shall be left carefully tooled and free from any mortar and concrete. Expansion joint filler shall be left exposed for its full length with clean and true edges.

Immediately on removal of, forms, the concrete work shall be examined by the Engineer before any defects are made good.

The work that has sagged or contains honeycombing to an extent detrimental to structural safety or architectural appearance shall be rejected.

Surface defect of a minor nature may be accepted. On acceptance of such work by the Engineer, the same shall be rectified as directed by the Engineer.

6.2.13. Tolerances

Tolerances for dimensions/shape of various components shall be as indicated in these specifications or shown on the drawings or as directed by the Engineer.

6.2.14. Tests and Standards of Acceptance

6.2.14.1. **Concrete** shall conform to the surface finish and tolerance as prescribed in these specifications for respective components. Random sampling and lot-by-lot of acceptance inspection shall be made for the 28 days cube strength of concrete.

Concrete under acceptance shall be notionally divided into lots for me purpose of sampling, before commencement of work. The delimitation of lots shall be determined by the following:
No individual lot shall be more than 30 cum. in volume
At least one cube forming an item of the sample representing the lot shall be taken from concrete of the same grade and mix proportions cast on any day.
Different grades of mixes of concrete shall be divided into separate lots. Concrete of a lot shall be used in the same identifiable component of the bridge

6.2.14.2. **Sampling and testing**

(1) Concrete for making 3 test cubes shall be taken from a batch of concrete at point of delivery into construction, according to procedure laid down in IS: 1199.

A random sampling procedure to ensure that each of the concrete batches forming the lot under acceptance inspection has equal chance of being chosen for taking cubes shall be adopted.
150 mm cubes shall be made, cured and tested at the age of 28 days for compressive strength in accordance with IS: 516. The 28-day test strength result for each cube shall form an item of the sample.

(2) Test specimen and sample strength: Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes such as to determine the strength of concrete at 7 days or for any other purpose.
The test strength of the sample shall be the average of the strength of 3 cubes. The individual variation should not be more than ± 15 per cent of the average.

(3) Frequency: The minimum frequency of sampling of concrete of each grade shall be in accordance in below

Frequency of Sampling

Quantity of Concrete in work, m3	No. of samples
0– 5	1
5– 15	2
16 – 30	3
31 – 50	4
51 and above	4 plus one additional sample for each additional 50 m3 or part thereof

At least one sample shall be taken from each shift of work.

6.2.14.3. Acceptance criteria

(1) Compressive Strength

When both the following conditions are met, the concrete complies with the specified compressive strength:

- The mean strength determined from any group of four consecutive samples should exceed the specified characteristic compressive strength.
- Strength of any sample is not less than the specified characteristic compressive strength minus 3 MPa.
- The quantity of concrete represented by the test results include the batches from which the first and last samples were taken, together with all intervening batches.
- The results will be unacceptable if:

  i) the average strength determined from any four consecutive test cubes does not exceed the specified the 28 day Concrete Cube Strength(CCS) by 0.5 times the current margin, or; ii) One or more values in forty is less than 85% specified CCS, or;
  iii) Three or more values in forty are less than specified CCS; In which case any of the following actions may be instructed.

  § Change the mix.

  § Improve quality control.

  § Cut and test cores from placed concrete.

  § Load-test relevant structural units.

  § Carry out non-destructive tests on as=placed concrete.

  § Cut-out and replace defective concrete.

- If the range of individual cube strength made from the same sample exceeds 15% of the mean then the method of making, curing and testing cubes shall be checked.

- In the event of a result having a range exceeding 20% the Contractor shall submit his proposals corrective action for Notice by the Engineer.
- The Contractor shall cut concrete cores from as-built locations as may be required by the Engineer and test them to BS 1881 as modified by Concrete Society Report TR 11. If the values, reduced by 0.69 Mega Pascal per week of age in excess of 28 days, are less than 75% CCS, the concrete shall be cut out and replaced unless otherwise agreed with the Engineer

(2) Density of Fresh Concrete

Where minimum density of fresh concrete is specified, the mean of any four consecutive samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 per cent of the specified value.

(3) Density of Hardened Concrete

Where minimum density of hardened concrete is specified, the mean of any four consecutive samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 per cent of the specified value.

6.2.14.4. Concrete Durability Test

The following test shall be made in order to secure the durability of concrete.

(1) Chloride Migration Coefficient Test Chloride Migration Coefficient Test shall be tested as per NT Build 492

Concrete quality classification based on the migration coefficient

Non-steady state migration coefficient ($\times 10^{-12}$ m^2/s)	Concrete quality
< 2	Very good
2 – 8	Good
8 – 16	Normal
> 16	Poor

For Substructure, Chloride migration coefficient shall be less than 2 x 10-12m2/s. For Superstructure, Chloride migration coefficient shall be 2 to 8 x 10-12m2/s

(2) Water Permeability Test:

Water Permeability Test shall be carried out as per BS EN 12390-8:2000 or DIN 1048 part 5- 1991.

Depth of Water penetration shall not be more than 10 mm.

(3) Initial Surface Absorption Test (ISAT):

Initial surface absorption tests shall be tested as per BS 1881: part 208 – 1996.

For Substructure, ISAT shall not be more than 0.25ml/m2/sec. For Superstructure, ISAT shall be 0.25 to 0.5 ml/m2/sec

(4) Rapid Chloride Penetration Test:

The Charge passed (Coulombs) shall be less than 1000

6.2.14.5. If the concrete is not able to meet the standards of acceptance as prescribed, the effect of such deficiency on the structure shall be investigated by the Contractor as directed by the Engineer. Any additional Tests and work required to verify and accept the concrete by the Engineer shall be carried out by the Contractor at his cost. In case the concrete is not found to be acceptable after investigation, the Contractor shall remove the rejected concrete forthwith.

7 Prestressing

7.1 Description

The work specified in this Section shall also consist of furnishing, Installing, stressing and grouting prestressing strand and HS Bars in accordance with the drawings and the requirements of these specifications or as approved by the Engineer.

It shall also include the furnishing and installing of any appurtenant items necessary for the particular prestressing system used, including but not limited to anchorage assemblies, additional reinforcing bars required to resist stresses caused by anchorage assemblies, ducts, vents, inlets, outlets and grout used for pressure grouting ducts.

Concrete and untensioned steel for the construction of prestressed concrete members shall conform to the requirements of sections 2.5 and 2.6 for Structural Concrete and Steel Reinforcement respectively in so far as the requirements of these Sections apply and are not specifically modified by requirements set forth herein.

7.2 Materials

All materials shall conform to Section 1000 of Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

(1) Sheathing

a) All duct material shall be sufficiently rigid to withstand loads imposed during placing of concrete and internal pressure during grouting while maintaining its shape, remaining in proper alignment and remaining watertight.

The duct system, including splices and joints shall effectively prevent entrance of cement paste or water into the system and shall effectively contain pressurised grout during grouting of the tendon. The duct system shall also be capable of withstanding water pressure during flushing of a duct in the event the grouting operation is aborted.

The interior diameter of ducts for single strand, bar or wire tendons shall be at least 6mm greater than the nominal diameter of the tendon. The interior diameter of ducts for tendons consisting of more than one strand, bar or wire shall be large enough to cause the duct to have an interior area not less than 2.5 times the net area of the prestress steel.

The sheathing shall confirm to the requirements as per tests specified in Appendix 1800/I of MORTH.

The internal area of the sheathing duct shall be in accordance with the recommendations of the system manufacturer and shall be about three times the area of the tendons. In case of 6T13, 12T13 and 19T13 sizes of tendons comprising 12/13 mm dia strands, the inner diameter of the sheathing shall not be less than 50 mm, 75 mm and 85 mm respectively or those shown in the drawing, whichever is greater.

Where prestressing tendons are required to be threaded after concreting the diameter of sheathing shall be about 5 mm larger than that required as above.

In severe environment, cables shall be threaded after concreting. In such cases a temporary tendon shall be inserted in the sheathing or the sheathing shall be stiffened by other suitable method during concreting.

b) Sheathing – Type Designation

The sheathing ducts shall be of the spiral corrugated type either in mild steel or HDPE or in PP for internal tendons. External tendons shall be housed in either HDPE sheaths or metallic steel sheaths which have smooth internal surfaces.

c) Duct Material Properties

- M.S sheathing ducts:

The material shall be cold rolled cold annealed Mild steel conforming to IS: 513 intended for mechanical treatment and surface refining but not for quench hardening or tempering. The material shall be clean and free from rust and normally be bright finished.

- Corrugated HDPE sheathing ducts:

****please refer to 1802.2.3 of MORTH Specifications.

(2) Anchorages

Anchorages shall be procured from authorized manufacturers only. Anchorages shall conform to BS: 4447. Test certificates from a laboratory fully equipped to carry out the tests shall be furnished to the Engineer. Such test certificates shall not be more than 12 months old at the time of making the proposal for adoption of a particular system for the project.

No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times. Threaded parts shall be protected by greased wrappings and tapped holes shall be protected by suitable plugs until used. The anchorage components shall be kept free from mortar and loose rust and any other deleterious coaling.

Swages of pre stressing strand and button-heads of pre stressing wire, where provided shall develop strength of at least 95 per cent of the specified breaking load of the strand or wire as the case may be. Where swaging/button-heading is envisaged, the Contractor shall furnish details of his methodology and obtain Notice by the Engineer, prior to his taking up the work.

Un-tensioned Steel reinforcements, around anchorages shall conform to the details of pre stressing system and as shown on the drawing.

Pre stress anchorage devices shall effectively distribute pre stressing loads to the concrete and shall conform to the requirements of Section 9.21 of the AASHTO Standard Specifications for Highway Bridges.

7.3 Testing of pre stressing steel and anchorages

All pre stressing steel, wire, bar, pre stress anchorages and bar couplers shall be assigned as individual number to each Lot at the time of manufacture. Each reel, coil, bundle or package shipped to the project shall be identified by tag or other acceptable means as to Manufacturer's Lot number. The Contractor shall be responsible for establishing and maintaining a procedure by which all pre stressing materials and devices can be continuously identified with the manufacturer's Lot number. Items which at any time cannot be positively identified as to Lot number shall not be incorporated in the work.

Low relaxation stand shall be clearly identified as required by IS: 14268. Any strand not so identified will not be acceptable.

The Contractor shall furnish manufacturer's certified reports covering the tests required by this Specification. A certified test report stating the guaranteed minimum ultimate tensile yield strength, elongation and composition shall be furnished for each lot of pre stressing steel. When requested typical stress-strain curves for pre stressing steel shall be furnished. A certified test report stating strength when tested using the type pre stressing steel to be used in the work shall be furnished for each Lot of pre stress anchorage devices.

The following samples of materials and devices selected at locations designated by the Engineer shall be furnished by the Contractor at his expense.

i. Three samples of 2m long pre stressing wire or bar for each size from each heat number or production Lot.
ii. Three samples of 1.5m long pre stressing strand for each size from each heat number or production Lot.
iii. If bar couplers are to be used, three samples with two specimens each consisting of 1.5m lengths of the specific pre stressing bar coupled with a bar coupler from the materials to be used on the project.
iv. One unit of each pre stress anchorage to be used on the project.

Samples shall be furnished well in advance of the time they are to be incorporated into the work.

The Engineer reserves the right to reject for use any material or device which is obviously defective or was damaged subsequent to testing.

Testing of anchorage devices shall be performed using samples representing the type of pre stressing steel and concrete strength to be used on the project. The test specimen shall be assembled in an unbounded state and, in testing, the anticipated anchor set shall not be exceeded. Certified copies of test results for the anchorage system shall be supplied to the Engineer. The anchorage system shall be so arranged that the prestressing force in the tendon may be verified prior to the removal of the stressing equipment.

The Contractor shall perform certain testing of prestressing tendons as specified herein.

(i) In-Place Friction Test of Tendons

For the purpose of accurately determining the friction loss in stressing raped tendons, prior to stressing a draped tendon, the Contractor shall test, in place, a draped continuity tendon selected by the Engineer. If deemed necessary by the Engineer to accurately establish friction loss, the Contractor shall perform tests on additional tendons selected by the Engineer. The test procedure shall consist of stressing a tendon at an anchor assembly with the dead end anchor incorporating a calibrated load cell. The results of the tests (loss due to friction and modulus of elasticity) shall be submitted to the Engineer. Apparatus and methods used to perform the tests shall be proposed by the Contractor and be subject to the Notice by the Engineer.

(ii) Dynamic Testing of Unbonded Tendons

Unbonded tendons are defined as tendons which are located essentially external to the concrete. For unbonded superstructure tendons, the Contractor shall perform two dynamic tests on a representative specimen and the tendon shall withstand, without failure, 500,000 cycles from 60 percent to 66 percent of its minimum specified ultimate strength. In the second test the tendon shall withstand without failure 50 cycles from 40 percent to 80 percent of its minimum specified ultimate strength. The period of each cycle involves the change from the lower stress level to the upper stress level and back to the lower. The specimen used for the second dynamic test need not be the same used for the first dynamic test. Systems utilizing multiple strands, wires, or bars shall be tested utilizing a test tendon of full size. The test tendon shall duplicate the behavior for the full size tendon and generally shall not have less than 10 percent of capacity for the full size tendon. In lieu of the dynamic testing, the Contractor may submit data from prior test. Acceptance of data from prior test is subject to the Notice of the Engineer.

7.4 Workmanship

(1) Cleaning

Tendons shall be free from loose rust, oil, grease, tar, paint, mud or any other deleterious substance. Cleaning of the steel may be carried out by immersion in suitable solvent solutions, wire brushing or passing through a pressure box containing carborundum powder. However, the tendons shall not be brought to a polished condition.

(2) Straightening

High tensile steel wire and strand shall be supplied in coils of sufficiently large diameter such that tendons shall retain their physical properties and shall be straight as it unwinds from the coil. Tendons of any type that are damaged, kinked or bent shall not be used.

The packing of pre stressing wire/strand shall be removed only just prior to making of cable for placement. Suitable stands shall be provided to facilitate uncoiling of wires/strands without damage to steel. Care shall be taken to avoid the possibility of steel coming into contact with the ground.

(3) Positioning

(i) Post-tensioning

Pre stressing tendons shall be accurately located and maintained in position, both vertically and horizontally, as per drawings.

Tendons shall be so arranged that they have a smooth profile without sudden bends or kinks.

The positioning of pre stressing cables shall be such as to facilitate easy placement and vibration of concrete in between the tendons. High capacity tendon shall be used to reduce the number of cables thereby eliminating the necessity of grouping. The selected profiles of the tendons shall be such that their anchorages are not located in the top deck surface. Where two or more rows of cables have to be used, the cables shall be vertically in line to enable easy flow of concrete. The clear vertical and horizontal distances between any two cables shall in no case be less than 100mm anywhere along the length of the superstructure. Where precast segments are used, the clear distance shall be at least 150 mm.

Sheathing shall be placed in correct position and profile by providing suitable ladders and spacers. Such ladders may be provided at intervals of approximately 1.0 m. Sheathing shall be tied rigidly with such ladders/spacer bars so that they do not get disturbed during concreting.

The method of supporting and fixing shall be such that profile of cables is not disturbed during vibrations, by pressure of wet concrete, by workmen or by construction traffic. Sheathing in which the permanent tendon will not be in place during concreting shall have a temporary tendon inserted or shall be stiffened by some other method to the Notice by the Engineer. The temporary tendon shall be pulled out before threading the permanent tendon into place by a special threading machine or other contrivance.

Where possible tendons shall not be placed until immediately prior to stressing. Tendons shall be handled with care to avoid damage or contamination, to either the tendon or the sheathing. Any tendons damaged or contaminated shall be cleaned or replaced.

(ii) Pre-Tensioning. Pre stressing steel shall be accurately located and maintained in position, both vertically and horizontally, as per drawings.

Each anchorage device shall be set square to the line of action of the corresponding pre stressing tendon and shall be positioned securely to prevent movement during concreting. The anchorage devices shall be cleaned to the satisfaction of the Engineer prior to the placing of concrete. After concreting, any mortar or concrete, which adheres to bearing or wedging surfaces, shall be removed immediately.

(4) Cutting

Suitable mechanical or flame cutters shall do cutting and trimming of wires or strands. When a flame cutter is used, care shall be taken to ensure that the flame does not come in contact with other stressed steel. The location of flame cutting of wire or strand shall be kept beyond 75 mm of where the tendon will be gripped by the anchorage or jacks.

In post-tensioning the ends of pre stressing steel projecting beyond the anchorages, shall be cut after the grout has set.

(5) Protection of pre stressing steel

All pre stressing steel shall be protected against physical damage at all times from manufacture to grouting or encasing in concrete. Pre stressing steel that has sustained physical damage at any time shall be rejected. Any reel that is found to contain broken wires shall be rejected and the reel replaced.

Pre stressing steel shall be packaged in containers or shipping forms for protection of the steel against physical damage and corrosion during shipping and storage. A corrosion inhibitor, which prevents rust or other results or corrosion, shall be placed in the package or form, or shall be incorporated in a corrosion inhibitor carrier type packaging material, or when permitted by the Engineer, a corrosion inhibitor may be applied directly to the steel. The corrosion inhibitor shall have no deleterious effect on the steel or concrete or bond strength of steel to concrete. Inhibitor carrier type packaging material shall conform to the provisions of U.S. Federal Specifications MIL-P-3420. Packaging or forms damaged from any cause shall be immediately replaced or restored to original condition.

The pre stressing steel shall be stored in a manner which will at all times prevent the packing material from becoming saturated with water and allow a free flow of air around the packages. If the useful life of the corrosion inhibitor in the package expires, it shall immediately be rejuvenated or replaced.

At the time the pre stressing steel is installed in the work, it shall be free from loose rust, loose mill scale, dirt, paint, oil, grease or other deleterious material. Removal of tightly adhering rust or mill scale will not be required. Pre stressing steel which has experienced rusting to the extent that it exhibits pits visible to the naked eye shall not be used in the work.

The shipping package or form shall be clearly marked with the heat number and with a statement that the package contains high-strength pre stressing steel, and care is to be used in handling. The type and amount of corrosion inhibitor used, the date when placed, safety orders and instructions for use shall also be marked on the package or form.

If the period of time between installation of pre stressing steel and grouting of the tendon will exceed 10 calendar days, the pre stressing steel shall be protected from corrosion during the entire period it is in place but ungrouted as provided below:

When the plans provide for pre stressing steel to be installed in one unit with a length of pre stressing steel left projecting to be threaded into another until during erection, all of the pre stressing shall be protected from corrosion from immediately after it is installed in the first unit until the tendon is grouted in the second unit as provided below:

When corrosion protection of in-place pre stressing steel is required, a corrosion inhibitor which prevents rust or other results of corrosion shall be applied directly to the pre stressing steel. The corrosion inhibitor shall have no deleterious effect on the pre stressing steel or grout or bonding of the pre stressing steel to the grout. The inhibitor shall be water soluble. The corrosion inhibitor, the amount and time of initial application, and the frequency of reapplication shall be subject to the Engineer’s Notice to Proceed.

(6) Sheathing Duct Joints

The joints of all sheathings shall be watertight. Special attention shall be paid to the junction at the anchorage end, where the sheathing must tightly fit on the protruding trumpet end of anchorage and thereafter sealed preferably with heat shrink tape, to make it waterproof.

The heat-shrink tape is supplied in the form of bandage rolls, which can be used for all diameters of sheathing ducts. The bandage is coated on the underside with a heat sensitive adhesive so that after healing the bandage material shrinks on the sheathing duct and ensures formation of a leak-proof joint. The heating is affected by means of a soft gas flame.

A sheath-making machine should be positioned at the site of work for large projects so that sheathing can be prepared as and when it is required for construction.

The sheathing and all joints shall be watertight. Any temporary opening in the sheathing shall be satisfactorily plugged and all joints between sheathing and any other part of the pre stressing system shall be effectively sealed to prevent entry of mortar, dust, water or other deleterious matter. Sheathing shall be neatly fitted at joints without internal projection or reduction of diameter.

Enlarged portions of the sheathing at couplings or anchorages shall be of sufficient length to provide for the extension of the tendons.

Special attention shall be paid to the junction at the anchorage end, where the sheathing must be tightly fitted on the protruding trumpet end of anchorage and thereafter sealed preferably with tape, to make it water proof.

Ducts shall be securely tied in position, carefully inspected and repaired, before placing of the concrete is started. Care shall be exercised during placement of the concrete to avoid displacing or damaging the ducts. Internal ducts shall be supported as specified in Section 16.4.1 of the AASHTO “Guide Specification for Design and Construction of Segmental Concrete Bridges”. Any additional mild reinforcing required to support post-tensioning ducts shall be supplied by the Contractor at no expense to the Engineer. The tolerance on the location of the tendons shall be plus or minus 6mm at any point. After installation in the forms, the ends of ducts shall at all times be sealed to prevent entry of water and debris.

Where sheathing duct joints are unavoidable, they shall be made cement slurry tight by the use of corrugated threaded sleeve couplers in case of MS sheathing ducts.

(7) Grout vents

Pipes shall be installed on each duct to serve as injection or grout vent ports during grouting.

For other than vertical ducts, any duct which exceeds 120m in length and has a tendon profile varying in elevation by more than 150mm shall be vented at all high points in the tendon profile. All ducts or anchorage assemblies for permanent post-tensioning shall be provided with vent pipes or other suitable connections at each end and at each side of couplers for the injection of grout after post-tensioning. Ducts shall be vented at the high points of the post-tensioning steel profile when there is more than a 150mm variation in the ventral position of the duct and the tendon length exceeds 120m. Vents shall be 20mm minimum diameter standard pipe or suitable plastic pipe. All connections to ducts shall be made with metallic or plastic structural fasteners. Waterproof tape shall be used at all connections including vent and grouting pipes. Plastic components, if selected and approved, shall not react with the concrete or enhance corrosion, of the post-tensioning steel, and shall be free of water soluble chlorides.

The vents shall be mortar tight, taped as necessary, and shall provide mention for injection of grout through the vents and for scaling the vents. Ends of steel vents shall be removed at least 25 mm below the concrete surface after the grout has set and properly grouted over with an epoxy grout. Ends of plastic vents shall be removed to the surface of the concrete after the grout has set.

All grout injection and cent pipes shall be fitted with positive mechanical shut-off valves. Vents and injection pipes shall be fitted with valves, caps or other devices capable of withstanding a pressure form the pumping pressures or 1.0 Mpa whichever is greater without the loss of water, air pressure or grout.

(8) Anchorages

All bearing surfaces of the anchorages shall be cleaned prior to concreting and tensioning.

Anchor cones, blocks and plates shall be securely positioned and maintained during concreting such that the centre, line of the duct passes axially through the anchorage assembly.

The anchorages shall be recessed from the concrete surface by a minimum cover of 100 mm. After the pre stressing operations are completed and pre stressing wires/strands are cut, the surface shall be painted with two coats of epoxy of suitable formulation having a dry Film thickness of 80 microns per coat and entire recess shall be filled with concrete or non-shrink/pre- packaged mortar or epoxy concrete.

(9) Structural concrete

Structural concrete shall conform to Section 2.6. The formwork shall conform to Section 2.4.

7.5 Supervision

All pre stressing and grouting operations shall be undertaken by trained personnel only. A representative of supplier of the pre stressing system shall be present during all tensioning and grouting operations and shall ensure, monitor and certify their correctness.

7.6 Tensioning equipment

All tensioning equipment shall be procured form authorized manufactures only and be Notice by the Engineer prior to use.

Each jack used to stress tendons shall be equipped with a pressure gauge having an accurate reading dial at least 150 mm in \diameter for determining the jack pressure. The pressure gauge must be installed or neat the stressing ram. Prior to use testing laboratory approved by the Engineer.

Calibrating shall be done with the cylinder extension approximately in the position that it will be when applying the final jacking force and with the jacking assembly in an identical configuration to that which will be used at the job site (i. Same length hydraulic lines) Certified calibration calculations and a calibration chart shall be furnished to the Engineer for each jack. Recalibration of each jack shall be done at six month intervals and at other time when requested by the Engineer. At the option of the Contractor, calibration subsequent to the initial laboratory calibration may be accomplished by the use of master gauge. The master gauge shall be calibrated at the same time as the initial calibration of the jacks, and shall be part of the unit for each jack. The data recorded during the initial calibrations shall be furnished to the Engineer for use in the field. The master gauge shall be supplied by the Contractor in a protective waterproof container capable of protecting the calibration of master gauge during shipment. The contractor shall provide a quick-attach coupler next to the permanent gauge in the hydraulic lines which enable the quick and easy installation of the master gauge to verify the permanent gauge readings. The master gauge shall remain in the possession of the Engineer for the duration of the project. If a jack is repaired or modified, the jack shall be recalibrated by the approved testing laboratory. No extra compensation will be allowed for the initial or subsequent jack calibrations or for the use and required calibration of a master gauge.

7.7 Post tensioning

The design of the structure is based on the assumed friction and wobble coefficient shown in the plants.

The post- tensioning forces shown are theoretical and do not include losses in the system or thermal affects.

All post-tensioning shall be tensioned by means of hydraulic jacks so that the force of the pre stressing steel shall not be less than the value shown on the approved shop drawings. The maximum temporary tensile stress (jacking stress) in pre stressing steel shall not exceed 80 percent of the specific minimum ultimate tensile strength of the pre stressing steel. The pre stressing steel shall be anchored at initial stresses in a way that will result in the ultimate retention of permanent forces of not less than those shown on the approved shop drawings, but in no case shall the initial stress at the anchorage, after anchor set, exceed 70 percent of the specified minimum ultimate tensile strength of the pre stressing steel. Permanent force and permanent stress will be considered as the force and stress remaining in the pre stressing steel after all losses, including creep and shrinkage of concrete, elastic shortening of concrete, relaxation of steel, thermal affect, losses in post-tensioned pre stressing steel due to sequence of stressing friction and take-up of anchorages, and all other losses peculiar to the method or system of pre stressing have taken place or have been provided for in an approved stressing plan.

When friction must be reduced, water soluble oil or graphite with no corrosive agents may be used as a lubricant subject to the Notice by the Engineer. Lubricants shall be flushed from the duct as soon as possible after stressing is completed by use of water pressure. These ducts shall be flushed again just prior to the grouting operations. Each time the ducts are flushed, they shall be immediately blown dry with oil-free air.

Tensioning force shall be applied in gradual and steady steps and carried out in such a manner that the applied tensions and elongations can be measured at all times. The sequence of stressing, applied tensions and elongations shall be in accordance with the Noticed drawing or as directed by the Engineer.

It shall be ensured that in no case, the load applied to the concrete before it attains the strength specified on the drawing or as stipulated by the pre stressing system supplier, whichever is more. The concrete strength shall be measured as evidenced by tests on representative samples of the concrete. These samples shall be stored under the same condition as the concrete in order to accurately represent the curing condition of the concrete in place.

After pre stressing steel has been anchored, the force exerted by the tensioning equipment shall be decreased gradually and steadily so as to avoid shock to the pre stressing steel or anchorage.

The tensioning force applied to any tendon shall be determined by direct reading of the pressure gauges or dynamo-meters and by comparison of the measured elongation with the calculated elongation. The calculated elongation shall be invariably adjusted with respect to the modulus of elasticity of steel for the particular lot as given by the manufacturer.

In the event that more than two percent of the individual strand wires in a tendon break during the tensioning operation, the tendon shall be removed and replaced. Previously tensioned strands shall not be allowed unless Noticed by the Engineer.

Post-tensioning bars used to apply temporary post-tensioning may be refused as temporary bars if they are undamaged.

Pre stressing steel shall be cut by an abrasive saw within 20mm to 40mm away from the anchoring device. Flame cutting of pre stressing steel is not allowed, except for pre-tensioned pre stressing steel.

The difference between calculated and observed tension and elongation during pre stressing operations shall be regulated as follows:

If the calculated elongation is reached before the specified gauge pressure is obtained, continue tensioning till attaining the specified gauge pressure, provided the elongation does not exceed 1.05 times the calculated elongation. If 1.05 limes the calculated elongation is reached before the specified gauge pressure is attained, stop stressing and inform the Engineer.

If the calculated elongation has not been reached at the specified gauge pressure, continue tensioning by intervals of 5 kg/cm^2. until the calculated elongation is reached provided the gauge pressure does not exceed 1.05 times the specified gauge pressure.

If the elongation at 1.05 times the specified gauge pressure is less than 0.95 limes the calculated elongation, the following measures must be taken, in succession, to determine the cause of this lack of discrepancy:

Check the correct functioning of the jack, pump and leads.

De tension the cable. Slide it in its duct to check that it is not blocked by mortar which has entered through holes in the sheath. Re tension the cable if free.

Re -establish the modulus of elasticity of steel for the particular lot from an approved laboratory.

If the required elongation is still not obtained, farther finishing operations such as cutting or sealing, should not be undertaken without the Notice by the Engineer.

When stressing from one end only, the slip at the end remote from the jack shall be accurately measured and an appropriate allowance made in the measured extension at the jacking end.

A complete record of pre stressing operations along with elongation and jack pressure data shall be maintained in the format given in Appendix 1800/II of “Specifications for Road & Bridges Works” (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress. The number of stages of pre stressing and grouting shall be reduced to a minimum, preferably 2 in the case of simply supported girders.

7.8 Grouting of pre stressed tendons

Grouting shall conform to Appendix 1800/III of “Specifications for Road & Bridges Works” (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress. A record of grouting operations shall be maintained in the format given in Appendix 1800/IV of Specifications for Road & Bridges Works” (Fifth Revision / Latest Revision issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

7.8.1. General

The purpose of grouting is to provide permanent protection to post tensioned steel against corrosion and to develop bond between the prestressing steel and surrounding structural concrete. The grout ensures encasement of steel in an alkaline environment for corrosion protection and by filling the duct space, it prevents water collection and freezing.

The grout to be used to fill the voids in tendons shall consist of Portland cement, water and admixtures which import low water content, case of flow, minimum bleeding, expansion or non-shrink and, when necessary, set retarding properties to the grout.

7.8.2. Material

(1) Water

Only clean portable water freefrom impurities conforming to section 1000(MORTH) shall be permitted. No creek water is to be used at all.

Water shall not be of injurious quantities or substances (chlorides, sulphites and nitrates) known to be harmful to Portland cement or pre-stressing steel.

(2) Cement

Ordinary Portland cement shall conform to the requirements Section 1000. The cement shall be fresh and not contain lumps or other indication of hydration or “pack set”. The Contractor shall furnish, for each shipment of cement, a manufacturer’s report stating the results of tests made on samples of the material taken during production or transfer and certifying that the applicable requirements of AASHTO M-85 have been met. No creek water is to be used at all. Pozzolana cement shall be used.

(3) Admixture

Unless specifically noted otherwise on the plans, use of admixtures shall be at the discretion of the Contractor. Admixtures shall consist of chemicals which, when incorporated into the grout mixture, impart the properties of low water content, ease of flow, minimum bleeding (sedimentation of cement, expansion or non-shrink and, when necessary, increase in setting time. Any admixture containing chlorides (As Cl in excess of 0.5 percent by weight of admixture assuming 1 kg of admixture per 94 kg of cement), sulphites, flourides or nitrates shall not be used in the grout. The date of manufacture shall be clearly stamped on each container. No admixture shall be used for which the shelf life recommended by the manufacturer has expired. Only admixtures conforming to IS:9102 may be used and only if test have shown that their use improves the properties of the grout.

For tendons which are essentially horizontal, finely ground Aluminum powder, or other gas evolving material which is well dispersed through the other admixture, may be used to obtain a maximum of five percent unrestrained expansion of the grout.

7.8.3.Properties of the Grout

The Contractor shall determine the kinds of admixtures and proportions of materials to be used to meet the requirements set out above and which, from prior document experience with similar materials, equipment and placing conditions, will result in a grout which does not bleed excessively and can be excessively and can be effectively placed. The quantity of water ground shall be as low as possible, consistent with the fluidity needed for placing.

Prior to beginning grouting operations, the Contractor shall furnish to the Engineer the results of tests performed by a laboratory approved by the Engineer demonstrating that grout mixture he proposes to use meets the requirement of this Specification. The information shall include a graphs relating compressive strength of the grout to age, covering ages from 24 hours to 28 days.

A commercial cement-based grout mixture meeting the requirements of this Specification may be used subject to approval by the Engineer.

Grout shall have the following physical prosperities

Property Test Value Test Method.

Water Cement Ratio	: Max 0.45
Compressive Strength at 7 days	: Min 27 MPa
Compressive Strength at 28 days	
(Average of three Cubes)	: Min 30 MPa
Initial Set of Grout	: Min 180 Minutes
Efflux Time from Flow Cone	: Min 11 Seconds*** ASTMC-939

** The test specimen shall be prepared using the material and the proportions which are to be used in production of grout.

*** The flow cone test shall not apply to grout which contains an admixture imparting a thixotropic consistency to the grout.

Water shall be added to the mixer followed by cement and the admixture. The grout shall be mixed in mechanical mixing equipment of continuous which will produce a grout free of lumps and undispersed cement. Re-tempering the grout will not be permitted. Grout shall be continuously agitated until it is pumped.

The grout shall be placed within 30 minutes following the introduction of the cement to the grout.

7.8.4. Grouting Operations

(1) General:

After post-tensioning and anchoring of a tendon has been completed and accepted, the annular space between the prestressing steel and the duct shall be grouted in accordance with this Specification. In the interval between the post-tensioning and grouting operations, the prestressing steel shall be protected as previously provided in the Construction Requirements Section A. Immediately after post-tensioning, all grout vents of each tendon shall be temporarily sealed with plugs to prevent entrance of air or water and left in place until just prior to tendon grouting.

The grouting equipment shall utilise gravity feed to the pump inlet from a hopper attached to and directly over it. The hopper must be kept at least partially full of grout at all time during the pumping operation to prevent air from being drawn into the post-tensioning duct.

Pipes or other suitable devices shall be provided for injection of grout and to serve as vent holes during grouting. The material for these pipes shall be at least 12mm inside diameter and may be either metal or a suitable plastic which will not react with the concrete or enhance corrosion of the prestressing steel and is free of water soluble chlorides. These pipes shall be fitted with positive mechanical shut off valves capable of withstanding grouting pressures. All connections between a grout pipe and a duct shall be made with metal or plastic structural fasteners and taped with a waterproof tape as necessary so as to assure a watertight connection.

For the vertical tendons which have strands as the prestressing steel, a standpipe shall be provided at the upper end of the tendon to store bleed water and allow it to be reabsorbed by the grout. Thus device shall be designed so that the level of grout can be brought to an elevation which will assure that bleeding will at no time cause the level of the grout to drop below the highest point of the upper anchorage device. Provision shall be made assure that bleed water rises into the standpipe, not into the uppermost part of the tendon and anchorage device.

Grouting shall be carried out as early as possible as but not later than 2 weeks of stressing a tendon.

(2) Equipment

Equipment for batching component materials shall be capable of accurately measuring the materials:

The mixer shall be capable of continuous mechanical mixing of the ingredients to produce a grout which is free of lumps and in which the ingredients are thoroughly dispersed.

The grouting equipment shall contain a screen having clear openings of 3mm maximum size to screen the grout prior to its introduction into the grout pump. If a grout with a thixotropic additive is used, a screen opening of 5mm will be satisfactory. This screen shall be easily assembled for inspection and cleaning.

Grout pumps shall be capable of pumping the grout in a manner which complies with the provisions of this Specification. Pumps shall be a positive displacement type capable of producing an outlet pressure of not less that 23KPa and shall have seals which are adequate to prevent introduction of oil, air or other foreign substance into the grout and to prevent loss of grout or water.

A pressure gauge having a full scale reading or no greater than 45KPa shall be placed at some point in the grout line between the pumping outlet and the duct inlet.

The grouting equipment shall utilise gravity feed to the pump inlet from a hopper attached to and directly over it. The hopper must be kept at least partially full of grout at all time during the pumping operation to prevent air from being drawn into the post-tensioning duct.

Pipes or other suitable devices shall be provided for injection of grout and to serve as vent holes during grouting. The material for these pipes shall be atleast 12mm inside diameter and may be either metal or a suitable plastic which will not react with the concrete or enhance corrosion of the prestressing steel and is free of water soluble chlorides. These pipes shall be fitted with positive mechanical shut off valves capable of withstanding grouting pressures. All connections between a grout pipe and a duct shall be made with metal or plastic structural fasteners and taped with a waterproof tape as necessary so as to assure a watertight connection.

For the vertical tendons which have strands as the prestressing steel, a standpipe shall be provided at the upper end of the tendon to store bleed water and allow it to be reabsorbed by the grout. Thus device shall be designed so that the level of grout can be brought to an elevation which will assure that bleeding will at no time cause the level of the grout to drop below the highest point of the upper anchorage device. Provision shall be made assure that bleed water rises into the standpipe, not into the uppermost part of the tendon and anchorage device.

(3) Mixing Grout

The sequence for charging the mixer shall be add water, start mixer and add cement, when cement and water are reasonably well mixed, admixtures shall be introduced in accordance with the written instructions of the manufacture of each admixture. The mixing procedures prevent admixture for getting caught on the blades or sides of the drum and from forming globules. The mixing procedure may be varied in accordance with the written recommendation of the manufacture of the admixtures.

The grout shall be mixed until a uniformly blended mixture is obtained and shall be continuously agitated until it is introduced into the grout pump. Batches of grout shall be placed within minutes of mixing. No water shall be added to the grout to modify its consistency after initial mixing operation is competed.

(4) Cleaning and Flushing Tendons

If a water soluble lubricant or corrosion inhibitor (other than VPI power) is applied to the pre stressing steel or if an embedded tendon is discontinuous through a joint between segments the tendon shall be flushed as provided below.

Immediately prior to grouting operations. The inside of the tendon shall be furnished with water meeting the requirements of the pervious materials section (under pressure) to remove all traces of the corrosion inhibitors used to protect the pre stressing steel. Flushing operations shall continue until the discharge water is free of any traces of the corrosion inhibitor.

Following the flushing operation, water shall be totally drained from within the tendon and it shall be blown out with compressed oil-free air to the extent and the inside surfaces of the pipe.

(5) Placing Grout

a) Grouting shall start at the lowest injection with all vent holes open. The pumping pressure through the pipe shall be maintained until grout is continuously wasted at the next vent hole and until no visible slugs or other evidence of water or air are ejected and the grout being ejected has the same consistency as the grout being injected. The vent valve shall then be closed, the pumping pressure held momentarily and the valve at the injection port closed.

b) The minimum pumping pressure at the tendon inlet shall be 0.3 Mpa, If the actual pressure exceeds the maximum recommended pumping pressure, grouting may be injected at any vent hole which has been or is ready to be closed as long as a one-way flow of grout is-mentioned. When one-way flow of grout be maintained, the grout shall be immediately flushed out of the duct with water.

c) The shut off valves on the pipes on the serving as injection port or vent ports shall not be opened until the grout has taken its final set.

d) When it is anticipated that the air temperature will fall below 0°C, duets shall be-kept free of water so as to avoid freeze damage to ducts. No grouting shall be done when the temperature of the grout is below 8°C .The temperature of the concrete or air surrounding the tendon shall be maintained at 2° C or above from the time grout is placed until the compressive strength of the grout, as determined from tests on 100mm cubes cured under the same conditions as the in-place grout, exceeds 1 Mpa.

e) Under hot weather conditions, grouting shall place early in the morning when daily temperatures are lowest. No grouting shall be done when the temperature of the grout exceeds 30oC. It may be necessary to chill mixing water or takeout special measures to lower the temperature of the grout.

f) After the grout has set, pipes used as injection or vent ports shall be cut off. Metal pipes shall be cut off 25mm below the surface of the concrete. Plastic pipes shall be cut of flush with the surface of the concrete.

7.8.5. Protection of ends

(1) The exposed ends of the tendons and the concrete surfaces of the ends of the units shall be wire brushed clean of all rust, loose mortar, grease and dirt.

(2) The exposed ends of the tendons and concrete surface within 50 mm of tendons shall be then abraded to provide a clean sound surface. An epoxy tar paint suitably formulated to give a dry film thickness of 80 microns per coat shall then be immediately applied over the ends of the tendons unless otherwise directed.

(3) A second coat of paint shall be applied prior to the drying out of the first coat.

7.8.6. Safety precautions during tensioning

(1) Care shall be taken during tensioning to ensure the safety of all persons in the vicinity.Jacks shall be secured in such a manner that they will be held in position, should they lose their grip on the tendons.

(2) No person shall be allowed to stand behind the jacks or close to the line of the tendons while tensioning is in progress.

(3) The operations of the jacks and the measurement of the elongation and associated operations shall be carried out in such a manner and from such a position that the safety of all concerned is ensured.

(4) A safety barrier shall be provided at both ends to prevent any tendon, which might become loose from recoiling unchecked.

(5) During actual tensioning operation, warning sign shall be displayed at both ends of the tendon.

(6) After prestressing, concrete shall neither be drilled nor any portion cut nor chipped away nor disturbed, without Notice of the Engineer.

(7) No welding shall be permitted on or near tendons nor shall any heat be applied to tendons.

Any tendon, which has been affected by welding, weld spatter or heat, shall be rejected.

7.8.7. Transportation and storage of units

(1) Precast girders shall be transported in an upright position. Points of support and the direction of reactions with respect to the girder shall approximately be the same during transportation, and storage as when the girder is placed in final position.

(2) When members are to be stacked, they shall be firmly supported at such bearing positions as will ensure that the stresses induced in them are always less than the permissible design stresses. Further, inclined side-supports shall be provided at the ends and along the length of a precast girder to prevent lateral movements or instability.

(3) Care shall be taken during storage, hoisting and handling of the precast units to prevent their cracking or being damaged. Units damaged by improper storing or handling shall be replaced by the Contractor at his expense.

7.8.8. Tolerances

Permissible tolerances for positional deviation of Pre stressing tendons shall be limited to the following:

Variation from the specified horizontal profile	:	5 mm
Variation from the specified vertical profile	:	5 mm
Variation from the specified position in member	:	3 mm

7.8.9. Tests and standards of acceptance

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

7.9 Elastomeric Bearings

7.9.1. Elastomeric bearings

The term "bearing" in this case refers to an elastomeric bearing consisting of one or more internal layers of elastomer bonded to internal steel laminates by the process of vulcanisation. The bearing shall cater for translation and/or rotation of the superstructure by elastic deformation.

7.9.1.1. **Raw Material**

Chloroprene (CR) only sh Grades of raw elastomer of proven use in elastomeric bearings, with low crystallization rates and adequate shelf life (e.g. Neoprene WRT, Bayprene 110, Skyprene B-5 and Denka S-40V) shall be used.

No reclaimed rubber or vulcanized wastes or natural rubber shall be used. all be used in the manufacture of bearing.

The raw elastomer content of the compound shall not be lower than 60 per cent by its weight. The ash content shall not exceed 5 per cent. (As per tests conducted in accordance with ASTM D-297, sub- section 10).

EPDM and other similar candidate elastomers for bridge bearing use shall not be permitted.

7.9.1.2. **Properties**

The elastomer shall conform to the properties specified in below Table

Properties of Elastomer

S. No.	Property	Unit	Test Method, IS specification reference		Value of the characteristic specified
1.	Physical Properties				
1.1.	Hardness	IRHD	IS:3400 (Part II)		60+5
1.2.	Minimum Tensile Strength	MPa	IS:3400 (Part I)		17
1.3.	Minimum Elongation at break	Per cent	IS:3400 (Part I)		400
2.	Maximum Compression Set CR	Per cent	IS:3400 (Part X) duration (h) +0 to 24.2	temperature (^{0}C) 100 ± 1	35
3.	Accelerated Ageing CR		IS:3400 (Part IV) Duration (h) 70	Temperature (^{0}C) 100 ± 1	
3.1	Max change in Hardness	IRHD			+ 5

S. No.	Property	Unit	Test Method, IS specification reference		Value of the characteristic specified
3.2	Max change in Tensile Strength	Per cent			- 15
3.3	Max change in Elongation	Per cent			-30

Shear modulus of the elastomer bearing shall neither be less than 0.70 MPa nor greater than 1.15 MPa.

The adhesion strength of elastomer to steel plates determined according to IS: 3400 (Part XIV) method A shall not be less than 7 KN/m.

For elastomeric bearings (CR) used in adverse climatic conditions the following ozone resistance/test shall be satisfied:

The ozone resistance of elastomer shall be proved satisfactory when assessed by test according to IS: 3400 (Part XIV). The strain, temperature, duration and ozone concentration of the test shall be 20 per cent, 40 ± I degree Celsius, 96 h and 50 pphm by volume respectively.
No cracking detected by visual observation at the end of the test shall be considered satisfactory. No specific tests for assessment of low temperature resistance may be deemed necessary.

NOTE: For use of elastomer in extreme cold climates, the Engineer may specify special grade of low temperature resistant elastomer in conformity with operating ambient temperature conditions. The specifications of such special grade elastomer including the tests for low temperature resistance shall be mutually agreed to by the Engineer and the producer supplier and are outside the purview of these specifications.
Laminates of mild steel conforming to IS: 2062 shall only be permitted to be used. Use of any other material like fiber glass or similar fabric, as laminates shall not be permitted.
The manufacturers of elastomeric bearings shall satisfy the Engineer that they have in-house facilities for testing the elastomer for carrying out the following tests in accordance with the relevant provisions of ASTM D-297.

Identification of polymers : to confirm the usage of Chloroprene (Appendix X-2)

Ash content test : to determine the percentage (sub-section 34)

Specific gravity test : (sub-section 15)

Polymer content test : (sub-section 10)

The Engineer shall invariably get the test (a) performed within his presence or in the presence of his authorised representative to satisfy the requirement. In case of any disputes regarding interpretation of results the Engineer may carry out test as per ASTM S-3452-78 (Chromatography test) at the manufacturer's cost in a recognised test house.

The elastomer specimen to conduct the test shall be obtained from the bearings selected at random for destructive test. Remaining part of the test bearing shall be preserved by the Engineer for any test to be done in future, if required.

7.9.1.3. **Fabrication**

(1) Bearing with steel laminates shall be cast as a single unit in a mould and vulcanised under heat and pressure.

(2) Casting of elements in separate units and subsequent bonding shall not be permitted, nor shall cutting from large size cast be permitted.

(3) Bearings of similar size to be used in particular bridge project shall be produced by identical process and in one lot as far as practicable. Phased production may only be resorted to when the total number of bearings is large enough.

(4) The moulds used shall have standard surface finish adequate to produce bearings free from any surface blemishes

(5) Steel plates for laminates shall be sand blasted, clean of all mill scales and shall be free from all contaminants prior to bonding by vulcanisation. Rusted plates with pitting shall not be used. All edges of plates shall be rounded.

(6) Spacers used in mould to ensure cover and location of laminates shall be of maximum size and number practicable. Any hole at surface or in edge cover shall be filled in subsequently.

(7) Care shall be taken to ensure uniform vulcanising conditions and homogeneity of elastomer through the surface and body of bearings.

The bearings shall be fabricated with the tolerances specified in given Table.

S. No.	ITEMS	TOLERANCES
1.	Overall plan dimensions	-0, + 6mm
2.	Total bearing thickness	-0, + 5mm
3.	Parallelism	
a)	Of top surface of bearing with respect to the bottom surface as datum	1 in 200
b)	Of one side surface with respect to the other as datum	1 in 100
4 a)	Thickness of individual internal layer of elastomer	± 20 per cent (max. of 2mm)
b)	Thickness of individual outer layer	-0. + 1 mm
5. a)	Plan dimensions of laminates	-3mm, +0
b)	Thickness of laminates	± 10 per cent
c)	Parallelism of laminate with respect to bearing base as datum	1 in 100

The vulcanising equipment/press shall be such that between the plattens of press the pressure and, temperature are uniform and capable of being maintained at constant values as required for effecting a uniform vulcanisation of the bearing.

The moulding dies utilised for manufacturing the bearings shall be so set inside the platten of the press so that the pressure developed during vulcanisation of the product is evenly distributed and the thickness maintained at all places are within acceptable tolerance limits taking into consideration the shrinkage allowance of vulcanizate.

The raw compound which has been introduced inside the metal dies for vulcanisation shall be accurately weighed each time and it must be ensured that sufficient quantity has been put inside the die for proper flow of material at every place so that a homogeneous and compact bearing is produced without any sign of sponginess or deficiency of material at any place.

Before any vulcanizate of any batch of production is used for producing vulcanised bearings, test pieces in the form of standard slab and buttons shall be prepared in accordance with prescribed standards and salient properties tested and recorded regularly against each batch of production to monitor the quality of the products.

7.9.1.4. **Acceptance specifications**

(1) The manufacturer shall have all the test facilities required for the process and acceptance control tests installed at his plant to the complete satisfaction of the Engineer. Test facilities and their operation shall be open to inspection by the Engineer on demand.

(2) All acceptance and process control tests shall be conducted at the manufacturer's plant. Cost of all materials, equipment and labour shall be borne by the manufacturer unless otherwise specified or specially agreed to between the manufacture and the Engineer. Acceptance testing shall be commenced with the prior submittal of testing programme by the manufacturer to the Engineer and after obtaining his “Notice to Proceed”.

(3) Any acceptance testing delayed beyond 180 days of production shall require special Notice by the Engineer and modified acceptance specification, if deemed necessary by him.

(4) All acceptance testing shall be conducted by the Inspector with aid of the personnel having adequate expertise and experience in rubber testing provided by the manufacturer, working under the supervision of the Inspector and to his complete satisfaction.

Lot by lot inspection and acceptance shall be made.

(5) Acceptance lot: A lot under acceptance shall comprise all bearings, including the pair of extra bearings where applicable of equal or near equal size produced under identical conditions of manufacture to be supplied for a particular project.

The size and composition of acceptance lot shall be got Noticed by the Engineer. For the purpose of grading levels of acceptance, testing lots shall be classified as follows:

(i) A lot size of 24 or larger number of bearings shall be defined as a large lot A lot size of less than 24 bearings shall be defined as a small lot.

(ii) When the number of bearings of equal or near equal size for a single bridge project is large and phased production and acceptance is permitted, the number of bearings supplied in any single phase of supply shall comprise a lot, under acceptance. When such phased supply is made, each such lot shall be considered as a large lot for the purpose of acceptance testing.

(6) Levels of acceptance inspection: The level of acceptance testing shall generally be graded into the following two levels depending on lot size:

Level 1 acceptance testing

Level 2 acceptance testing

(i) Acceptance testing Level 1 is a higher-level inspection and shall be applicable to large lots only, unless otherwise specified. This shall involve manufacture of two extra bearings for each lot to be used, as test bearing and eventually consumed in destructive testing.

(ii) Acceptance testing Level 2 shall be applicable to small lots only, (i.e. less than 24 lots) for which one extra bearing shall be manufactured. Out of the lot one bearing shall be selected at random for carrying out material tests. This bearing shall be excluded from the lot accepted.

Acceptance inspection level 1 may be specified at the sole discretion of the engineer taking into account the special importance of bridge project for small lots also under the purview of special acceptance inspection. The cost of extra bearings, in such cases shall be borne by the user, while the cost of all other materials; equipment and testing shall be borne by the manufacturer.

7.9.1.5. **Testing**: Acceptance testing shall comprise general inspection, test on specially moulded test pieces and test on complete bearings or sections for measurement of various quality characteristics detailed below

7.9.1.5.1. Acceptance testing level 1.

General Inspection

1. All bearings of the lot shall be visually inspected for any defects in surface finish, shape or any other discernible superficial defects.
2. All bearings of the lot shall be checked for tolerances specified in Table 2.8-2

3. All bearings of the lot shall be subjected to axial load to correspond to σ_m (i.e. average compressive stress) = 15 MPa applied in steps and held constant while visual examination is made to check for discernible defects like

a) Misalignment of reinforcing plates

b) Poor bond- at laminate/steel interface

c) Variation in thickness of elastomer layers

d) Any surface defects

e) Low stiffness

Deflection under loads between ơm=5 MPa and ơm=15 MPa shall be measured and recorded for all bearings with sufficient accuracy (+ 5 per cent), Variation in stiffness of any individual bearing from the mean of the measured values for all such bearings of the lot shall not be larger than 20 per cent (of the mean value).

Tests on specially moulded test pieces

1. Test pieces shall be moulded by the manufacturer with identical compound and under identical vulcanising conditions as used in the manufacture of the bearings of the acceptance lot. The process shall be open to inspection by the Engineer.
2. Test pieces offered for inspection shall be identified by suitable markings and duly certified by the manufacturer.
3. The quality characteristics tar be tested am listed below. The specification references in parenthesis shall define the corresponding specification for test piece, test method and criterion for acceptance.

- Composition (see Note I below)
- Hardness (Table 2.8-1, 1.1)
- Tensile strength (Table 2.8-1, 1.2)
- Elongation at Break (Table 2.8-1, 1.3)
- Compression Set (Table 2.8-1, 2)
- Accelerated Ageing (Table 2.8-1, 3)
- Adhesion Strength (Clause 2.8.1.1)
- Ozone Resistance (see Note 2 below)

Note 1: For acceptance testing the properties enumerated in Clause 2005.1 of MORTH's specification and specific gravity of elastomer of test pieces from test bearing shall be compared with those for corresponding specially moulded test pieces furnished by the manufacturer. The following variations shall be deemed maximum acceptable:

- Specific Gravity 0.2
- Ash Content 0.5 per cent
- Hardness (Table 2.8-1, 1.1)
- Tensile strength (Table 2.8-1, 1.2)
- Elongation at Break (Table 2.8-1, 1.3)
- Compression Set (Table 2.8-1, 2)

- Accelerated Ageing (Table 2.8-1, 3)

- Adhesion Strength (Clause 2.8.1.1)

Note 2: Ozone resistance test can be waived by the Engineer for bearings of CR when satisfactory results of ozone resistance tests on similar grade of elastomer may be available from process control records or development test data furnished by the manufacturer.
Where such process control data are not available or the frequency of testing not deemed adequate, ozone resistance test shall be mandatory for acceptance of bearings of CR.
However, such tests may not be insisted for bearings not located under adverse conditions of exposure and where the test on accelerated ageing could be considered as adequate.

Process and acceptance control tests for ozone resistance by an independent testing agency shall be acceptable.

Tests on Complete Bearings or Sections

1. Two bearings shall be selected at random from the lot as test bearings. These bearings shall be excluded from the lot accepted.
2. The following tests shall be conducted on test bearings

- Test for determination of shear modulus

- Test for determination of elastic modulus

- Test for determination of shear modulus (short term loading)

- Test for determination of adhesion strength

- Test for determination of ultimate compressive strength

The test specifications and acceptance criteria shall conform to those given in Appendix 2 of IRC: 83 (Part -II).

7.9.1.5.2. Acceptance testing level 2

General Inspection: This shall conform to the provision in Clause 2.9.3.3.1 in all respects.

Test on specially moulded test pieces. This shall conform to the, provisions in Clause 2.9.3.3.1 in all respects.
Test on complete bearings. Test for determination of shear modulus shall be conducted using two bearings of the lot selected at random and conforming to relevant provisions of Clause 2.9.3.3.1. These bearings shall however be part of the lot accepted. The remaining tests stipulated in aforesaid clause shall be carried out on all bearings selected at random, which shall be excluded from the lot accepted.

7.9.1.6. Special acceptance inspection: Special acceptance inspection may comprise the following Acceptance testing by an independent external agency with separate or supplemental test facilities provided by it.

Acceptance testing on test pieces prepared from the surface or body of the test bearings instead of specially moulded test pieces.

Acceptance tests not covered by these specifications but according to the specifications laid down by the Engineer.

Special acceptance inspection may be specified under the following conditions: Special contract agreement

Unsatisfactory evidence of process or acceptance control

7.9.1.7. Inspection certificate: A lot under inspection shall be accepted by the Inspector and so certified, when no defect is found with respect to any of the quality characteristics tested on samples drawn from the lot according to specifications laid down in Clause 2.9.3.3 covering general inspection tests on specially moulded test pieces and on complete bearings.

In case of any bearing with defect, the lot shall be rejected by the Inspector and so Certified.

In case any bearing is found to be defective with respect to any quality characteristic, discerned by general inspection tests specified in Clauses 2.9.3.3.1 and 2.9.3.3.2, tests on specially moulded test pieces and complete bearings as applicable according to Clauses 2.9.3.3.1 and 2.9.3.3.2 shall nevertheless be completed. If the said lot, rejected by general inspection, satisfies the acceptance criteria in respect of these other tests, the lot and individual bearings found defective shall be clearly identified in the inspection certificate.

The manufacturer shall obtain from the inspector, authorised by the Engineer, immediately on completion of his inspection, an inspection certificate which shall include the details of a lot or lots accepted/rejected by him and records of all test measurements.

7.9.1.8. Quality control certificate -The manufacturer shall certify for each lot of bearing under acceptance: That an adequate system of continuous quality control was operated in his plant.

That the entire process remained in control during the production of the lot of bearings under acceptance as verified from the quality control records/charts which shall be open to inspection of Engineer/ Inspector on demand.

A certified copy of results of process control testing done on samples of elastomer used in the production of the lot shall be appended and shall include at least the following information:

Composition of compound - raw elastomer and ash content, the grade of raw elastomer used (including name, some, age on shelf), test results of hardness, tensile strength, elongation at break, compression set, accelerated ageing, etc.

A higher level certification of the process quality control shall be called for at the sole discretion of the Engineer in special cases e.g. where adequate inspection of bearings similar to those comprising the lot under inspection produced in the same plant is not available with the Engineer or in case of any evidence of process or acceptance control being deemed unsatisfactory. The higher-level certification shall comprise submittal of a complete quality control report as given in Appendix 3 of IRC: 83 (Part II) supplementing the quality control certificate.

7.9.2.Acceptance: The manufacturer shall furnish the following to Engineer for the acceptance judgement:

Quality control certificate as laid down in Clause 2.9.3.6.

Inspection certificate as laid down in Clause 2.9.3.5.

The manufacturer shall famish any supplementary information on the system of quality control and/or process and acceptance control testing as may be deemed necessary by the Engineer. In case of any evidence of process or acceptance control testing being deemed unsatisfactory by him, Engineer at his sole discretion may call for a special acceptance of the lot according to specifications laid down by him, without any prejudice to his right to reject the lot. The entire cost of such supplementary inspection shall be borne by the manufacturer.

The Engineer shall be the sole authority for acceptance of a lot on scrutiny of the certificates along with any supplementary evidence and complete satisfaction therewith.

In case of rejection of a lot, the Engineer shall reserve the right to call for special acceptance inspection for the succeeding lots offered for inspection, according to the specifications laid down by him. The entire cost of such tightened inspection shall be borne by the manufacturer.

7.9.3.Certification and marking

Bearings shall be transported to bridge site after final acceptance by Engineer and shall be accompanied by an authenticated copy of the certificate to that effect.

An information card giving the following details for the bearings, duly certified by the manufacturer shaft also be appended.

Name of manufacturer Date of manufacture Elastomer grade used Bearing dimensions Production batch no. Acceptance lot no Date of testing

Specific bridge location, if any Explanation of markings used on the bearing

All bearings shall have suitable index markings identifying the information. The markings shall be made in indelible ink or flexible paint and if practicable should be visible after installation. The top of the bearing and direction of installation shall be indicated.

7.9.4.Storage and handling

Each elastomeric bearing shall be clearly labelled or marked. The bearing shall be wrapped in a cover. They shall be packed in timber crates with suitable arrangement to prevent movement and to protect comers and edges.

Care shall be taken to avoid mechanical damage, contamination with oil, grease and dirt, undue exposure to sunlight and weather to the bearings during transport and handling prior to and during installation.

7.9.5.Installation

Installation of multiple bearings one behind the other on a single line of support shall be of identical dimensions.

Bearings must be placed between true horizontal surfaces (maximum tolerance 0.2 per cent perpendicular to the load) and at true plan position of their control lines marked on receiving surfaces (maximum tolerance ± 3 mm).

Concrete surfaces shall be free from local irregularities (maximum tolerance ± I min in height).

Design shall be checked for the actual inclination in seating if larger inaccuracies than those specified are permitted.

For cast-in-place concrete construction of superstructure, where bearings are installed prior to it's concreting, the forms around the bearings shall be soft enough for easy removal. Forms shall also fit the bearings snugly and prevent any leakage of mortar grout. Any mortar contaminating the bearings during concreting shall be completely removed before setting.

For precast concrete or steel superstructure elements, fixing of bearing to them may be done by application of epoxy resin adhesive to interface, after specified surface preparation. The specifications for adhesive material, workmanship and control shall be approved by the Engineer. Care shall be taken to guard against faulty application and consequent behavior of the adhesive layer as a lubricant. The bonding by the adhesive shall be deemed effective only as a device for installation and shall not be deemed to secure bearings against displacement for the purpose of design.

As a measure of ample safety against accidental, displacement, the bearings shall be placed mi a recess as shown in Fig. 9 of IRC: 83 (Part II).

7.9.6.Seating of Elastomeric Bearings on A Non-Horizontal Plane

Installation of elastomeric bearings on a Non-Horizontal Plane shall be as follows

Elastomeric bearings shall be delivered with MS backing plate fastened to the bearing from the manufacturer.

Template of 6 mm M.S. plate and of size same as bearing holding base plate with matching holes for the anchor screws shall be used. Anchors shall be fined to the templates with the anchor screws but with MS washers in place of elastomer washers. The above template assembly shall be fitted in the formwork at its proper location and in a vertical plane.

After casting of the pedestal and removal of the formwork, the template is to be removed. A. Installation with faceplate and without template in-situ Casting

i) The sub-assembly of elastomeric bearing with the MS backing plate shall be fitted to the embedded anchors with anchor screws and elastomeric washers replacing the steel washer.

ii) A clearance is required between the stainless steel face of the elastomeric bearing and that of the vertical face of the faceplate with stainless steel top installed on the projection below the soffit. This shall be achieved by inserting removable steel sheeting of thickness as per the drawing, during preparation of the formwork before casting of the superstructure.

iii) The faceplate with stainless steel top and pack plate shall be assembled with the anchors with elastomeric washers and anchor screws. The assembly shall be fitted in the formwork at its proper location and in a vertical plane. The removable steel shims shall be removed at an appropriate time after the casting of the super-structure.

B. Installation with faceplate and with template in-situ casting

i) Template of 6 mm MS plate and of size same as faceplate with stainless steel top and matching holes for the anchor screws shall be used. Anchors shall be fitted to the templates with the anchor screws but with MS washers in place of elastomer washers. Separate screws may be used in case of inconvenience of in the length of original anchor screws. The above template assembly shall be fitted in the formwork for the super-structure at its proper location and in a vertical plane-

ii) After removal of the superstructure formwork, the template shall be removed.

iii) The faceplate with the required thickness of pack plate shall be loosely fitted to the anchors embedded in the projection below the superstructure, with elastomer washers and anchor screws.

iv) The sub-assembly of elastomeric bearing with the MS backing plate shall be fitted to the embedded anchors in die pedestal with anchor screws and elastomeric washers replacing the steel washer this time.

v) The required clearance between the stainless steel face of the elastomeric bearing and that of the vertical faceplate installed on the projection below the soffit shall be checked. After adjustment of the required working clearance the small gap between do vertical face of the projection below the soffit and the back of the faceplate (with pack plates, if any) shall be grouted with epoxy grout.

7.10 Pot Bearings

7.10.1. General

(1) Pot type bearings shall consist of a metal piston Supported by a disc or unreinforced elastomer confined within a metal cylinder to take care of rotation. Horizontal movement, if required, shall - with a system of sealing rings is provided by sliding surfaces of PTFE pads sliding against stainless steel mating surfaces. The pot bearings shall consist of cast steel assemblies or fabricated structural steel assemblies.

(2) Provisions of IRC 83 (Part I) shall be applicable for all metallic elements. Provisions of IRC: 83 (Part II) shall be applicable for all elastomer elements. When any items are not covered by

IRC: 83 (Parts I and II), the same shall be as per guidelines given hereunder and BS: 5400 (Sections 9.1 and 9.2), except that no natural rubber shall be permitted. If there is any conflict between BS on the one hand and IRC on the other, the provisions of IRC will be guiding.

(3) Combination bearings using any judicious combination and sliding element shall be permitted. As for example:

Name	Rotation Element	Sliding Element	Generally for
Pot	Pot	None	Vertical Load
Elastomer	Elastomer	None*	Horizontal Buffer
Pot PTFE Spherical	Pot Spherical	PTFE-SS** PTFE-SS**	Vertical Load and Horizontal Load
Knuckle PTFE	Knuckle		Horizontal Load Horizontal Load
Elastomer PTFE	Elastomer	PTFE-SS**	Transverse Guide
Elastomer SS**	Elastomer	SS-SS**	Transverse Guide

* Elastomer shall permit movement by shear

** Stainless Steel

For special and innovative bridges, new combinations beyond what is shown may be required. The same may be used after approval by the Engineer.

7.10.2. Fabrication

(1) The surface mating with the PIPE in the sliding pair shall be corrosion resistant stainless steel. Normally, the stainless steel shall form the upper component. The stainless steel shall overlap the PIM after full movement on all side A. If stainless steel sheet is used, it should be bonded by continuous welding along the edges. Adhesive or any other bonding can be approved by the Engineer. The surface shall be prepared by thorough cleaning to remove grease, dust or any other foreign substance.

(2) PTFE modular sheets of the sliding pair shall be located by confinement assisted by bonding. Confined PTFE shall be recessed into the metal backing plate. The shoulders of the recess shall be sharp and square to restrict the flow of PTFE.

(3) The thickness of the PTFE shall not be less than 4.5 mm with projection above the recess not exceeding 2.0 mm. When the piston is subjected to tilting the seal must slide along the wall and alter its shape according to the angle of tilt. At the same time, it must be sufficiently rigid to bridge the gap between the piston and the wall of the pot. However, the percentage of plan area of the lubrication cavities to the gross area shall not exceed 25 per cent. The depth of the cavity shall not exceed 2.0 mm.

(4) The diameter to thickness ratio of the confined elastomer shall not exceed 15. The

surface of the confined elastomer shall be smooth.

(5) A seal shall be provided to prevent extrusion of the confined elastomer between the piston and the pot wall. The seal should stay functional under the loads and rotations acting on it. Additional seal shall be provided to prevent entry of dust, into the pot sealing rings for pot bearings shall be fabricated from stainless steel. When the piston is subjected to tilting, the seal must slide along the wall and alter its shape according to the angle of tilt. At the same time, it must be sufficiently rigid to bridge the gap between the piston and die wall of the pot

(6) The hardness of the piston and pot wall at their contact region shall be minimum 350 BHN to reduce wear. The surface finish of the pot base in contact with the confined elastomer shall be very smooth.

(7) All bearings shall be installed with anchor and anchor screws or some similar device such that while replacing, the bearings can be removed with minimum lifting of the super structure.

(8) The external surfaces of the assemblies shall be completely cleaned by sand blasting. After sand blasting, dust shall be removed from the surface using clean and dry compressed air or a clean brush after which suitable coating shall be applied.

(9) Pot bearings including all parts as shown on the drawings shall be fully shop assembled at the manufacturer's works to ensure proper fitting of all parts.

7.10.3. Materials

(1) Steel

vi) Structural steel shall conform to IS: 226 and IS: 2062, as applicable.

vii) Cast steel shall conform to Gr 280-52OW of IS: 1030- 0.3 to 0.5 per cent copper may be added to increase the corrosion resistance properties.

viii) Stainless steel shall conform to AISI: 304 or XO4CrI8NiIO of IS: 6911 for ordinary applications. For applications with adverse/ corrosive environment, the stainless steel shall conform to AISI: 316L or 02Cr17Nil2Mo2 of IS: 6911.

(2) PTFE

PTFE (poly tetra fluoro ethylene) shall be of unfilled pure virgin quality. It shall be free sintered. The mechanical properties of unfilled PTFE shall comply with Grade A of BS: 3784.

(3) Elastomer

The confined elastomer inside pot will have the following properties

a)	Hardness	IRHD	IS: 3400	(Part 11)	50 + 5
b)	Min tensile strength	MPa	IS: 3400	(Part 1)	15.5

c)	Nit elongation at break,)	shall be as per Table 2.21-1
	Max compression set and) Accelerated ageing)	"Properties of Elastomer"

For other details, refer to Clause 2005.1.

7.10.4. Workmanship

(1) Welding

All welding shall conform to IS: 9595 with electrodes of suitable grade as per IS: 814. Preheating and post weld stress relieving shall be done as per IS: 9595.

(2) Cast steel assemblies: Cast steel for pot bearing assemblies shall conform to requirements of relevant IS. Castings shall be true to the forms and dimensions shown on the drawings, and shall be free from pouring faults, sponginess, cracks, blow holes and other defects affecting their appearance or their strength. Warped or distorted castings shall not be accepted. Exposed surfaces shall be smooth and dense.

All irregularities, fins or risers shall be ground off flush with the adjacent surface. Castings with visible Cracks, blow holes, or similar blemishes shall be rejected if the imperfections are located on bearing surfaces or cannot be remedied to the satisfaction of the Engineer. Imperfections which are not located on bearing surfaces shall be cleaned out, filled with weld metal of the appropriate composition and ground flush with adjacent surfaces.

(3) Structural steel assemblies: Defects arising from the fabrication of the steel shall be inspected by the Engineer, who will decide whether the materials may be repaired by the Contractor or will be rejected. The cost of repairs or replacement shall be borne by the Contractor.

All steel whether fabricated or not, shall be stored above the ground on platforms, skids, or other supports, and adequately protected against corrosion. Excessively rusted, bent or damaged steel shall be rejected.

All plates shall be flat and rolled bars and shapes straight before marking out or being worked-.

Straightening shall be done by methods, which shall not damage the material. Sharp kinks and bends shall be the cause for rejection.

Steel may be flame cut to shape and length so -that a regular surface, free from excessive gouges and striations are obtained. Flame cutting by hand shall be done only with the Notice by the Engineer.

Exposed comers shall be machined or ground.

(4) Tolerances

i)	Plan dimensions	:	-0 to +5
ii)	Overall height	:	-0 to +3
iii)	Height of elastomer	:	mm
iv)	Height of any steel component		

a) Machined : -0 to +1 nim

b) Un-machined : Class 2 of IS: 4897

v) Stainless steel sliding surface

a) Flatness : 0.0004 L, where L = length in direction of measurement. b) Surface Finish : Ra ≤ 0.25 pin as per IS: 3073

(5) Painting

i) All non-working surfaces shall be coated with two coats of epoxy primer and one or more coat each of epoxy intermediate and finish, total thickness ≤ 0.150 pin or any other painting scheme as Noticed by the Engineer.

ii) Silicon grease shall be applied at the PTFE/SS interface after testing. iii) Anchor sleeves shall be cement coated at the manufacturer's works.

7.10.5. Test

(1) Raw materials: Necessary test certificates for all raw materials as in Clause 2.22.3 above shall be furnished by manufacturers. Reference, may also be made to Clause2.8.1 for tests on elastomers.

(2) Test on casting: Tests specified in IS: 1030 shall be performed. Castings shall be ultrasonically tested and certificates submitted. Quality level of castings shall be level 3 as per IS: 9565.

(3) Test on welding: All welding shall be tested by Dye Penetration method. But welding shall be tested by Ultrasonic method. The manufacturer shall certify soundness of welding.

(4) Acceptance test on bearing:

All bearings shall be checked for overall dimensions. All bearings shall be load tested to 1.1 times maximum design capacity including seismic force and bearing tested at higher loads cannot be used. A pair of bearings selected at random will undergo testing in order to determine the coefficient of friction μ. The coefficient of friction shall be ≤ 0.05 at the design load.

Two bearings selected at random shall be tested for permissible rotation.

7.10.6. Installation of POT-cum-PTFE -Bearings

(1) General

i) Care shall be taken during installation of the bearings to permit their correct functioning in accordance with the design scheme.

ii) To prevent contamination, dismantling of the bearings at site shall not be done.

iii) The load shall be transferred onto the bearings only when the bedding material has developed sufficient strength. The props for the formwork shall only be removed after lapse of appropriate time. In special cases, suitable devices like jacks, etc. can ensure this.

iv) Temporary damps and shims (introduced to maintain working clearance) shall be removed at an appropriate time, before the bearing is required to permit movement.

v) Permitted installation tolerance of the bearing from plane of sliding shall be maintained.

vi) Cement based non-shrink grout with air releasing additive and epoxy-based grout; whichever is specified shall be first tried at the site. For the proprietary grout mixes, appropriate instructions from the manufacturer shall be followed especially with regard to the following:

a) Preparation-> concrete cleaning, roughening, pre-soaking, etc.
b) Forms-> sturdiness, leak proofing, shape, header funnel vents, etc.
c) Bearing Base-> cleaning, etc.
d) Placement-> mixing, consistency, time period, finishing, etc. e) Protection-> curing, ambient temperature, etc.

(2) In-situ casting of superstructure

(i) Formwork around the bearing shall be carefully sealed to prevent leakage.
(ii) Sliding plates shall be fully supported and care taken to prevent tilting, displacement or distortion of the bearings under the weight of wet concrete.
(iii) Bearings shall be protected during concreting operation. Any mortar contaminating the bearing shall be completely removed before it sets.

(1) Seating of bearing

A. Using Template

i) Template with required rigidity and matching holes corresponding to the base of the bearing shall be used.

ii) All the anchors shall be fitted to the lower face of the template using the anchor screws but with steel washer replacing the elastomer washers. Separate screws may be used in case of inconvenience in the length of original anchor screws.

iii) The template assembly shall be located with regard to level and alignment. It shall be ensured that the top of the anchors lies in a horizontal plane at the required elevation. The anchors shall be tied/welded to reinforcements to avoid displacement during concreting

iv) Concreting of the pedestal/pier cap shall be done to a level leaving a gap of 25-50 min below the template.

v) The template and steel washers shall be removed prior to placement of the bearing assembly with temporary clamps. The bearing assembly shall be fitted to the anchors with the help of anchor screws and elastomer washers. Level at the bearing shall be checked.

vi) The gap below the bearing assembly shall be grouted with cement based grout. Reference may be made to Clause 2.9.6.1 (vi).

B. Without Template with Gap

i) Pockets commensurate with the sizes of the anchors shall be kept in pedestals during concreting of the same. The pedestal shall be cast approximately 25 mm short of the required finished level.

ii) Anchors shall be fitted to the bearing bottom with elastomer washers and anchor screws.

The bearing assembly shall be seated in the location on steel chairs/packs. The anchors fitted below the bearing shall go into Pockets in the bed block. Level and alignment of the bearing shall be checked. It shall be ensured that the bearing sits in a horizontal plane.

iii) The gap below the bearing assembly including anchor pockets shall be grouted with cement based grout. Reference may be made to Clause 2.9.6.1 (vi).

C. Without Template without Gap

Elongated pockets commensurate with the sizes of the anchors shall be kept in pedestals during concreting of the same. The geometry and location of the anchor pockets (with tapered funnel extension, if required) shall be such that after placement of the bearing the pockets can be successfully grouted. The pedestal shall be cast 5 mm - 15 mm short of the required finished level. The required level shall be achieved by chipping before placement of the bearing. Careful control shall be exercised to cast at the exact finished level or 1mm - 3 min down from the required finished level.

D. Seating of bearings shall be as per manufacturer's instructions.

7.10.7. Inspection and Testing

Where any patents are used, the manufacturer's certificate with test proofs shall be submitted along with the design and got approved by the Engineer before their use in work.

7.10.8. Tests and Standards of Acceptance

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria.

The work shall conform to these specifications and shall meet the prescribed standards of acceptance.

7.11 Foundations

7.11.1. Open Foundations

7.11.1.1. Description

The work shall cover furnishing and providing plain or reinforced concrete foundation placed in open excavation, in accordance with the drawings and these specifications or as directed by the Engineer.

7.11.1.2. **Materials**

Materials shall conform to Section 1000 of 'Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

7.11.1.3. **General**

A method statement for construction indicating the following shall be submitted by the Contractor for Notice by the Engineer, well in advance of the commencement of open foundation:

i) Sources of Materials
ii) Design, erection and removal of formwork
iii) Production, transportation, laying and curing of concrete
iv) Personnel employed for execution and supervision
v) Tests and sampling procedures
vi) Equipment details
vii) Any other point

Necessary arrangements for execution under water wherever necessary, shall be included in method statement.

Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent bench mark.

7.11.1.4. **Workmanship**

(1) Preparation of Foundations

Excavation for laying the foundation shall be carried out in accordance with Section 300 of these specifications. The last 300 mm of excavation shall be done just before laying of lean concrete below foundation.

In the event of excavation having been made deeper than that shown on the drawing or as ordered by the Engineer, the extra depth shall be made up with M15 concrete in case of foundation resting on soil and foundation grade concrete for foundations in rock, at the cost of the Contractor and shall be considered as incidental work. Special care shall be taken not to disturb the bearing surface. Open foundations shall be constructed in dry conditions and the Contractor shall provide for adequate dewatering arrangements to the satisfaction of the Engineer.

(2) Setting Out

The plan dimensions of the foundation shall be set out at the bottom of foundation trench and checked with respect to Original reference line and axis. It shall be ensured that at no point the bearing surface is higher am the founding level shown on the drawing or as directed by the Engineer.

(3) Construction

Where the bearing surface is earth, a layer of MIS concrete shall be provided below foundation concrete. The thickness of lean concrete layer shall be 100 mm minimum unless otherwise specified.

No formwork is necessary for the lean concrete layer. For foundation concrete work, side formwork shall be used. Formwork for top of the foundation concrete shall also be provided, if its top has slopes steeper than 1(vertical) to 3 (horizontal). When concrete is laid in slope without top formwork, the slump of the concrete shall be carefully maintained to ensure that compaction is possible without slippage down the slope of freshly placed concrete. In certain cases it may be necessary to build the top formwork progressively as the concreting proceeds up the slope. Reinforcement shall be laid as shown on the drawing.

Before laying of lean concrete layer, the earth surface shall be cleaned of all loose material and wetted. Care shall be taken to avoid muddy surface. If any portion of the surface has been spoiled by over wetting, the same shall be removed. Concrete M15 shall be laid to the thickness as required. No construction joint shall be provided in the lean concrete.

Before laying foundation concrete, the lean concrete or hard rock surface shall be cleaned of all loose material and lightly moistened. Foundation concrete of required dimensions and shape shall be laid continuously upto the location of construction joint shown on the drawing or as directed by the Engineer.

Formwork and concrete shall conform to Sections 2.4 and 2.6 respectively of these specifications. Furnishing and providing steel reinforcement shall conform to Section 2.5.

The concrete surface shall be finished smooth with a trowel. The location of construction joint and its treatment shall be done as per requirements of Section 2.6. Formwork shall be removed not earlier than 24 hours after placing of concrete. Where formwork has been provided for top surface, the same shall be removed as soon as concrete has hardened. Curing of concrete shall be carried out by wetting of formwork before removal. After its removal, curing shall be done by laying not less than 10 cm of loose moistened sand, free from clod or gravel and shall be kept continuously moist for a period of 7 days.

Dewatering, where necessary for laying of concrete, shall be carried out adopting any one of the following procedures or any other method approved by the Engineer:

A pit or trench deeper than the foundation level as necessary may be dug beyond the foundation pit during construction so that the water level is kept below the foundation level.

Water table is depressed by well point system or other methods.

Use of steel/concrete caissons or sheet piling for creating an enclosure for the foundations, which can subsequently be dewatered.

Before backfilling is commenced, loose sand laid on foundation shall be removed and dispersed as directed by the Engineer.

All spaces excavated and not occupied by the foundation or other permanent works shall be refilled with earth upto surface of surrounding ground in accordance with Section 300 of 'Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress. In case of excavation in rock, the annular space around foundation shall be fined with M15 concrete upto the top of rock.

The protective works, where provided shall be completed before the floods so that the foundation does not get undermined.

7.11.1.5. **Tests and Standards of Acceptance**

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

No point of the surface of the lean concrete in the case of foundation on soil or the surface of hard rock in the case of foundation of hard rock, shall be higher than the founding level shown on the drawing or as ordered by the Engineer. Levels of the surface shall be taken at intervals of not more than 3m center to center, subject to a minimum of nine levels on the surface.

7.11.1.6. **Tolerances**

Variation in dimensions	:	+50 mm - 10 mm
Misplacement from specified position in plan	:	15 mm
Surface irregularities measured with 3 in straight edge	:	5 mm
Variation of levels at the top	:	± 25 mm

7.11.2. Bored and Socketed Piles

7.11.2.1. **Description of Work**

Construct bored cast in-place reinforced concrete piles with a design axial compression working load as specified on drawings. Diameter and length of piles are shown on the drawings.

Piles are to extend above cut off level to the working platform.

7.11.2.2. **Submittals**

Submit method statement for pile execution prior to start of construction works, including cavity treatment (if encountered).

Submit two signed copies of installation records of each pile to the Engineer not later than noon on the next working day after pile was installed. Report any unexpected boring conditions and note in the records. Pile records to be submitted to the Engineer shall include but not limited to:

1. Pile reference number, location and position.
2. Equipment used and method of boring.
3. Type of pile, shape and dimensions of cross section.
4. Ground surface elevation.
5. Diameter, working level and level of pile toe.
6. Date and time of boring.
7. Type of excavated material.
8. Depth of ground water level.
9. Date and time of concreting.
10. Length of temporary casing, if any.
11. Volume of excavated materials
12. Volume of concrete poured in the pile at different levels.
13. Concrete mix, slump, number of cube tests
14. Delays to boring or concreting works.
15. Remarks or notes of any unexpected boring conditions.
16. Accidental changes in pile position, dimensions, and inclination, if applicable
17. Cavity treatment record

Inform the Engineer each day of the piling programme for the following day. Give adequate notice of any intention to work outside normal hours and at weekends.

Submit to the Engineer certificates for Bentonite powder and Bentonite Slurry test results from an approved testing laboratory showing properties of each consignment delivered to site.

Submit to the Engineer, before work commences, drawings showing clearly the system of proposed pile protection sleeves and method of attaching sleeve to reinforcement.

Quality Assurance

Installer Qualifications: Firm this has minimum of 5 years successful experience in installation of bored cast in place concrete piles similar to the units required for this project, with sufficient production capacity to produce required units without causing delay in work.

Job Conditions

Site Information: Data on subsurface conditions are not intended as representations or warranties of continuity of such conditions. It is expressly understood that Employer will not be responsible for inter pretations or conclusions drawn therefrom by Contractor. The data are made available for convenience of Contractor.

1. Additional test borings and other exploratory operations may be made by Contractor at no additional cost to Employer.

Protection: Protect structures, underground/subsurface utilities and other construction from damage caused by pile boring operations.

Report immediately to the Engineer any circumstance which indicates that ground conditions differ from those assessed and from those interpreted from the report on site exploration.

When boring through non-cohesive or very soft cohesive strata liable to collapse, temporary casing, drilling fluid or other suitable technique is to be used to stabilize the hole. Temporary casing when used is to extend sufficient depth below strata to adequately seal off caving material.

7.11.2.3. **Products**

(1) Concrete and Reinforcement

Concrete work for piles, aggregates, cement, water, admixtures, design, batching, mixing and testing of concrete and reinforcement for concrete are described in Section 2.6 and 2.5 of the Specification.

(2) Drilling Fluid

Bentonite Powder Properties:

Property	**Acceptable Range**
% retained on ASTM sieve # 200	less than 1%
Humidity	less than 1.5%
liquid limit	higher than 400%

Bentonite Suspension Properties:

Property	Range of Results at 20 deg. C	Acceptable Range
Density	1.034 to 1.1 g/ml:	mud density balance
Viscosity	30-90 s	Marsh cone method
Shear strength	2.5 - 10 N/m^2	Shearometer
pH	9.5 - 12.0	pH indicator paper strips or electric pH meter
Fluid loss	less than 18 cm^2	volume of fluid loss in 30 min of 450 cc of suspension at 6% concentration ratio under pressure of 7 Kg/cm^2
Thickness of filter cake	Less than 25 mm	measure filter cake built up in fluid loss test

(3) Casing and Sleeves

Temporary casings of approved quality or approved alternative method may be used to maintain stability of pile excavation which might otherwise collapse. Temporary casings are to be free from significant distortion and of uniform cross-section throughout each continuous length. During concreting they are to be free from internal projections and encrusted concrete which might prevent proper formation of piles.

7.11.2.4. **Execution**

(1) Nuisance and Damage

Carry out work in a manner and at times to minimize noise and disturbance.

If during execution of work, damage is or is likely to be caused to mains, services or adjacent structures, submit to the Engineer proposals for repair or avoidance of such damage.
Ensure damage does not occur to completed piles. Submit to the Engineer proposed sequence and timing for installing piles having regard to avoidance of damage to adjacent piles.
Ensure piles are temporarily braced or stayed immediately after installation to prevent loosening of piles in ground and to ensure that no damage resulting from oscillation, vibration or movement of any free-standing pile length can occur.

(2) Tolerances

Setting out is to be carried out from main grid lines of proposed structure. Immediately before installation of a pile, mark its position with suitable identifiable pins or markers.
Maximum permitted deviation of pile center from center point shown on setting out drawing is to be 50 mm in any direction. An additional tolerance for pile heads cut off below ground level

will be permitted in accordance with Clauses given below.

Maximum permitted deviation of finished pile from vertical is 1 in 100. Forcible corrections to concrete piles are not to be made.

7.11.2.5. **Pile Construction**

General: Excavate holes for piles to required elevation as shown on Drawings. Excavate holes for closely spaced rock sockets, and those occurring in weak strata, only after adjacent holes are filled with concrete and allowed to set.

The design of rock socket is based on assumed subsurface conditions as revealed by the preliminary subsurface investigations. If different subsurface conditions are encountered during pile execution, the depth or the length of the rock socket will be revised as directed by Engineer.

MS lining with adequate protection shall be used for ensuring stability of the strata near ground level until concrete has been placed in the pile. Liner to pile shall be up to refusals with anticorrosion treatment from outside. A pile excavation shall be backfilled without delay where a rapid loss of drilling fluid occurs and no further excavation at the location of that pile shall be carried out until the Contractor has obtained the Engineer's Notice for the proposed remedial work.

Do not bore piles within a distance of at least five pile diameters from other piles which have recently been cast and which contain workable or unset concrete to cause flow of concrete from or damage to any piles.

When ground water which cannot be sealed off is encountered, water in bore is to be maintained above standing level of subsoil water.

On completion of boring, remove loose, disturbed or remoulded soil from base of pile.

Mix bentonite thoroughly with clean, fresh water to make suspension which will maintain stability of pile excavation for period necessary to place concrete and complete construction. Temperature of water used in mixing bentonite suspension and of suspension itself when supplied to borehole are to be not lower than 5 ^{0}C.

Where saline or chemically contaminated ground water occurs take special precautions to modify bentonite suspension.

Maintain level of drilling fluid in excavation so that fluid pressure always exceeds pressures exerted by soils and external ground water. Use adequate temporary casing in conjunction with this method to ensure stability of strata near ground level until concrete has been placed. Maintain fluid level at not less than 1.5 m above level of external ground water.

In the event of rapid loss of drilling fluid from pile excavation, obtain instructions of the Engineer before excavation at that location is resumed.

Take precautions in design of mix and placing of concrete to avoid arching of concrete in casing.at base of boring. Do not allow spoil, liquid or other foreign matter to contaminate concrete.

Place pile reinforcement as per structural drawings requirement.

For piles selected for ultrasonic logging, and before placing concrete, install necessary testing tubes as per requirement of Specification section 2.10.3 “pile testing”.

PLACING CONCRETE IN DRY BORINGS: take approved measures to avoid segregation and bleeding and to ensure concrete at bottom of pile is not deficient in grout.

PLACING CONCRETE UNDER WATER or drilling fluid is to be by tremie unless otherwise approved. Do not discharge concrete freely into water or drilling fluid. Concrete is to be rich cohesive mix of high workability and placed in such a manner that segregation does not occur. CONCRETE REPLACING BENTONITE: piles are to be concreted without undue delay. Placing is to be complete within 12 hours of completion of boring unless evidence can be shown that longer periods are acceptable as approved by the Engineer.

PLACING CONCRETE BY TREMIE: hopper and pipe of tremie are to be clean and watertight throughout. Pipe is to extend to base of boring. Place sliding plug or barrier in pipe to prevent direct contact between first charge of concrete and water or drilling fluid. Pipe is to penetrate concrete which has previously been placed and is not to be withdrawn until completion of concreting. Pipe is to remain at least 4 m into concrete at all times. Maintain sufficient quantity of concrete within pipe to ensure pressure exceeds that from water or drilling fluid. Internal diameter of pipe is to be not less than 150 mm for concrete made with 20 mm aggregate and not less than 200 mm for concrete made with 40 mm aggregate. Tremie is to be so designed that external projections are minimised allowing it to pass through reinforcing cages without causing damage. Internal face of pipe is to be free of projections.

During and after concreting take care to avoid damage to concrete from pumping and dewatering operations.

Inform the Engineer if the volume of concrete used in a working pile varies by more than +/- 25% from the expected volume obtained from preliminary pile.

The work of this section includes demolition and removal of rock, boulders, concrete, masonry, and other subsurface obstructions which are clearly indicated by contract documents, or by available sub-surface exploration data, and such work will not be considered a change in work. Over-excavation: No payment will be made for extra length, when pile shafts are excavated to a greater depth than required or authorized by Engineer, due to over-drilling by Contractor. Complete the pile and fill extra depth with concrete, if other conditions are satisfactory. Over- excavated shafts will be measured and paid for to original design or authorized depth. Excavated Material: Deposit and spread excavated material on site at locations as directed by the Engineer or shown on drawings.

Extraction of Casing

Extract temporary casings while concrete within them remains sufficiently workable to ensure concrete is not lifted.

When casing is being extracted maintain an adequate head of casing below concrete surface during concrete pouring to prevent ingress of ground water or soil into pile concrete. Do not place concrete in boring once bottom of casing has been lifted above top of concrete. Place continuously as casing is extracted until desired head of concrete is obtained.

Adequate precautions are to be taken where excess heads of water or drilling fluid could be caused as casing is withdrawn due to displacement by concrete as it flows into final position against walls of shaft. Where two or more discontinuous lengths of casing (double casing) are used in onstruction, proposed method of working is to be approved.

Use of vibrating casing extractors will be permitted subject to the requirements of avoidance of nuisance and prevention of damage to adjoining properties.

In the event of ground water level being higher than required pile head casting level submit proposals for approval prior to placing concrete. Do not leave pile head below ground water level unless approved precautions are taken.

After each pile has been cast protect any empty bore remaining and carefully backfill as soon as possible with approved materials.

After completion of piling, heads of piles are to be cut to level and reinforcement bent to shape shown on the Drawings.

7.11.2.6. **Field Quality Control**

Frequency of testing drilling fluid is to be defined by the Engineer. Frequency may subsequently be varied depending upon consistency of results obtained.

Control tests are to be carried out on bentonite suspension to determine density, viscosity, shear strength, fluid loss, and thickness of filter cake and pH value. Carry out tests until consistent working pattern has been established taking into account mixing process, any blending of freshly mixed bentonite suspension and previously used bentonite suspension and any process which may be used to remove impurities from previously used bentonite suspension. Measure density of freshly mixed bentonite suspension daily as a check on quality of suspension being formed. Measuring device is to be calibrated to read within 0.005 g/ml. When results show consistent behavior, tests for shear strength, fluid loss, and thickness of filter cake and pH value may be discontinued and tests to determine density and viscosity carried out as agreed with the Engineer. In the event of a change in established working pattern, tests for shear strength, fluid loss, thickness of filter cake and pH value are to be reintroduced if required.

If on cutting back and/or stripping pile head the sleeve is found to be defective the pile will be rejected.

Inform the Engineer not less than 24 hours before each pour of concrete to allow inspection of reinforcement and surfaces on which concrete is to be placed.

Sample of bentonite suspension is to be taken from base of boring using approved sampling device. If density of suspension exceeds specified limit, placing of concrete is not to proceed.

In this event modify or replace bentonite as approved to meet the Specification.

If concrete strength obtained from the cylinders taken during the construction works is below the required strength, report immediately to the Engineer the corrective measures proposed for his approval. Concrete work will not continue until the Engineer is satisfied that the reasons for the low concrete strength are removed.

7.11.3. Initial and Routine Pile Load Testing

7.11.3.1. Summary and Definitions

This Section describes the field testing of piles as follows:

A. The performing of vertical axial compression load test on a preliminary concrete test pile, bored and socketed in rock and provided with an upper double casing/sleeve to eliminate the friction resistance between the concrete pile and the upper soil layers and eva3luate only the shear resistance of the lower concrete rock socket part.
B. The performing of Horizontal load test on a preliminary concrete test pile, bored and socketed in rock
C. The performing of vertical axial Tension load test on a preliminary concrete test pile, bored and socketed in rock
D. The performing of Horizontal load test on a working concrete pile bored and socketed in rock.
E. The performing of vertical axial compression load test on a working concrete pile bored and socketed in rock.
F. Integrity testing using the sonic logging technique as per ASTM D 6760 on a working concrete pile bored and socketed in rock.
G. Integrity testing by Low Strain Impact technique as per ASTM D5882 on all working piles.

DEFINITIONS:

1. Allowable load: load safely applied to pile after taking into account ultimate bearing capacity, negative friction, pile spacing, overall bearing capacity of ground below and allowable settlement.
2. Compression pile: pile designed to resist axial force that would cause it to penetrate further into ground.
3. Tension Pile: Pile which is designed to resist an axial force such as would cause it to be extracted from the ground.
4. Kentledge: dead weight used in loading test.
5. Maintained load test: load test in which each increment of load is held constant either for defined period or until rate of movement (settlement or uplift) falls to specified value
6. Preliminary pile: pile installed before commencement of main piling works or a specific part of the work to establish suitability of chosen type of pile and for confirming its design, dimensions and bearing capacity.
7. Proof load: load applied to selected working pile to confirm suitability for load at

settlement specified; proof load should not normally exceed 150% of working load on pile.

8. Reaction system: arrangement of kentledge, piles, anchors or rafts to provide resistance against which pile is tested.
9. Tension pile: pile designed to resist axial force that would cause it to be extracted from ground.
10. Test load: maximum load to be applied during load test.
11. Test pile: pile to which test is, or is to be, applied.
12. Ultimate bearing capacity: load at which resistance of soil becomes fully mobilised.
13. Working load: load which pile is designed to carry.
14. Working pile: pile forming foundation of a structure.

7.11.3.2. **Submittals**

- Submit a method statement for the Engineer's approval showing the loading method, the reaction system, the instruments proposed to record the data, and their calibration certificates, the equipment and plant proposed, the location and number of load tests and all other required information by the Engineer.
- Design loading arrangements to transfer safely to test pile the maximum load required in testing. Submit full details to the Engineer prior to work related to the testing process being carried out on site.
- Load-bearing Test Reports: Submit copies of test reports for each load-bearing test within 2 days after completion of tests.
- Equipment specifications, methodology and qualification of the testing agency for performing the integrity testing of piles using sonic logging technique and steady state vibration technique.

7.11.3.3. **Quality Assurance**

- Comply with the requirements of sub section 1.4 in Section 2.10.2: bored and socketed piles.
- Carry out tests under the direction of an experienced and competent supervisor conversant with test equipment and test procedure. Personnel operating test equipment are to be trained in its use.
- When required, an experienced testing agent with minimum 5 years’ experience in sonic and steady state tests is to carry out these tests subject to the Engineer's approval.
- Calibrate load measuring device before and after each series of tests, whenever adjustments are made to device or at intervals appropriate to type of equipment. Calibrate pressure gauge, displacement gauge and hydraulic jack together. Supply certificate of calibration to the Engineer. Obtain agreement in writing before any modification of this procedure is adopted.

7.11.3.4. **Codes and Standards**

IS 2911- 4 Code of Practice for Design and Construction of Pile Foundations- Load Test on Piles

ASTM D1143 Standard Test Method of Testing Piles Under Static Axial Compressive Load
ASTM D5882 Standard Test Method for Low Strain Impact Integrity Testing of Deep Foundations

ASTM D6760 Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing

7.11.3.5. **Safety Precautions**

- When preparing for conducting and dismantling a pile test, carry out requirements of various acts, orders, regulation Crosshole ns and other statutory instruments applicable to the work for provision and maintenance of safe working conditions. In addition, make such other provisions as may be necessary to safeguard against hazards involved in testing or preparations for testing.
- Where kentledge is used, construct foundations for kentledge and any crib work, beams or other supporting structure in such a manner that there will be no differential settlement, bending or deflection of an amount that constitutes a hazard to safety or impairs efficiency of the operation. Kentledge is to be bonded, tied or otherwise held together to prevent it falling apart or becoming unstable due to deflection of supports.
- Weight of kentledge is to be greater than maximum test load. If weight is estimated from density and volume of constituent materials, allow adequate safety factor against error.
- Tension piles and ground anchors where used, the load is to be correctly transmitted to tie rods or bolts. Extension of rods by welding shall not be permitted unless the Contractor can prove that steel will not be reduced in strength by welding. Bond stresses of rods in tension are not to exceed normal permissible bond stresses for type of steel and grade of concrete used.
- When hydraulic jack and load measuring device are mounted on pile head, the whole system shall be stable up to the maximum load to be applied. Provide means to enable dial gauges to be read from a position clear of kentledge stack or test frame and where failure in any part of system due to overloading, buckling, loss of hydraulic pressure etc. will not constitute a hazard to personnel.
- Provide hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure, that can withstand test pressure of 1-1/2 times maximum working pressure without leaking.
- Maximum test load or test pressure expressed as a reading on the gauge in use is to be displayed and operators are to be made aware of this limit.

7.11.3.6. **Job Conditions**

- Site Information: Data on indicated subsurface conditions are not intended as representations or warranties of continuity of such conditions. It is expressly understood that Employer will not be responsible for interpretations or conclusions drawn therefrom by Contractor. The data are made available for convenience of Contractor.

- Protect from the weather equipment for measuring load and movement throughout test period.

7.11.3.7. **Execution**

Construction of Preliminary Test Pile

- The purpose of the Preliminary Test Pile is to investigate the shear interface characteristics between the concrete pile rock socket and the rock. A void shall be left below the base of the concrete pile rock socket. This shall enable the shear interface component of the pile to be separated from the end bearing component. Furthermore, the Preliminary Test Pile shall be sleeved using a double casing in its upper part in contact with upper soil layers to remove the effect of skin friction on the pile from these upper soil layers.
- Give the Engineer at least 48 hours' notice of commencement of construction of preliminary pile to be test loaded.
- Construct each preliminary test pile by use of similar equipment, methods and materials of that used for working piles except as mentioned in clause 2.10.3.7.1.4 here below. Variation will only be permitted with prior approval. Extra reinforcement and concrete of increased strength may be permitted in shafts of preliminary piles at the discretion of the Engineer.
- The upper part of the pile in contact with soil layers and above the rock socket shall be provided with double casings/sleeves. The inner diameter of the internal sleeve shall be the same as the concrete pile diameter, while the outer sleeve shall have an inner diameter larger than the inner sleeve by at least 100 mm.
- Before concreting the rock socket, provide a void former to create a void at the base of the rock socket. The Contractor is to propose the appropriate void former and subject to the Engineer approval.
- For each preliminary pile to be tested, keep a detailed record of soils encountered during boring or of progress during driving and submit to the Engineer daily not later than noon on the next working day.
- Where the Engineer requires soil samples to be taken or in situ tests to be made in pile hole, give samples or results of such tests to the Engineer without delay.

Preparation of Test Pile

- Terminate pile shaft at normal cut-off level or at level required by the Engineer. Extend pile shaft where necessary above cut-off level of working piles so that gauges and other apparatus used in testing will not
- Where pile shaft is extended above cut-off level of working piles in soil which would influence load bearing capacity of pile, install a sleeve and keep in place during testing to eliminate friction which would not arise in working pile. Alternatively, if friction above designed cut-off level can be calculated with reasonable accuracy, with Notice by the Engineer a sleeve need

not be used, but calculated friction must be taken into account in assessing load being applied to pile.

- Pile cap for compression test is to be formed to give plane surface normal to axis of pile, sufficiently large to accommodate loading and settlement measuring equipment and reinforced or protected to prevent damage from concentrated application of load from loading equipment.
- Pile cap for compression test is to be concentric with test pile. Joint between cap and pile is to have strength equivalent to pile. Leave sufficient clear space under any part of cap projecting beyond section of pile so that at maximum expected settlement, load is not transmitted to ground except through pile.
- For piles selected for integrity testing using ultrasonic logging technique, install tubes with size compatible with the logging device. The No. of tubes shall be 3 for 600 mm diameter piles and 800 mm diameter piles and 4 for 1200 mm diameter piles. The tubes shall be equally distributed and tightly fixed to the pile reinforcement.

Compression Tests:

Test to be carried out using kentledge, tension piles or specially constructed anchorages. Do not use kentledge for tests on raking piles. Where used support kentledge on crib work disposed around pile head so that centre of gravity is on axis of pile. Bearing pressure under supporting cribs is to ensure stability of kentledge stack. Kentledge is not to be carried directly on pile head, except when directed by the Engineer.

Working piles: do not use as reaction piles without approval. Where working piles are used as reaction piles measure their movement to within an accuracy of 0.5 mm.

1. Where kentledge is used for loading vertical piles in compression, distance from edge of test pile to nearest part of crib supporting kentledge stack in contact with ground is not to be less than 1.0 m.
2. Centre to centre spacing of vertical reaction piles, including working piles used as reaction piles, from test pile is not to be less than three times diameter of test pile or reaction pile. Where pile to be tested has an enlarged base, the same criterion is to apply with regard to pile shaft, with the additional requirement that surface of reaction pile is not to be closer to base of test pile than half enlarged base diameter.
3. Where ground anchors are used to provide test reaction for loading in compression, no part of section of anchor transferring load to ground is to be closer to test pile than three times diameter of test pile. Where pile to be tested has an enlarged base, the same criterion is to apply with regard to pile shaft, with the additional requirement that no section of anchor transferring load to ground is to be closer to pile base than a distance equal to base diameter.
4. The size, length and number of piles or anchors, or area of rafts are to be adequate to transmit maximum test load to ground in a safe manner without excessive movement or influence on test pile.
5. The method employed in installation of reaction piles, anchors or rafts is to prevent

damage to test pile or working pile.

6. Load Application and Measurement

a) Equipment for applying load is to consist of one or more hydraulic rams or jacks. Total capacity of jacks is to be at least equal to required maximum load. Jacks are to be arranged in conjunction with reaction system to deliver axial load to test pile. Complete system is to transfer maximum load required for test.

b) Measurement of load is to be by load measuring device and calibrated pressure gauge included in the hydraulic system. Record readings of both load measuring device and pressure gauge. In interpreting test data the values given by the load measuring device are normally to be used. Pressure gauge readings are required as a check for gross error.

c) Load measuring device may consist of proving ring, load measuring column, pressure cell or other appropriate system. Spherical seating is to be used in conjunction with devices that are sensitive to eccentric loading. Take care to avoid risk of buckling. Load measuring devices and jacks are to be short in axial length to achieve best possible stability. Ensure axial loading is maintained.

d) Loading equipment is to be adjustable throughout test to obtain smooth increase of load or to maintain each load constant at required stages of maintained load test. Measuring Movement of Head Pile

- Maintained load test: movement of pile head is to be measured by one of the methods described in this sub-section as appropriate for vertical and raking piles and as required.
- CRP and CRU tests: check levelling of reference frame or on pile head is not required.
- Dial gauge is to be graduated in divisions of 0.02 mm or less.
- Optical or other levelling method by reference to external datum may be used. Where level and staff are used, level and scale of staff are to be chosen to enable readings to be made to within an accuracy of 0.5 mm. Scale attached to pile or pile cap may be used instead of levelling staff. Establish at least two datum points on permanent objects or other well-founded structures or install deep datum points. Situate each datum point so that only one setting up of level is needed. No datum point is to be affected by test loading or other operations on site. Other method of levelling, where proposed, is to be approved in writing.
- Independent reference frame may be set up to permit measurement of pile movement.
- Position supports for frame in such a manner and at such a distance from test pile, kentledge support cribs, reaction piles, anchorages and rafts that movements of ground in vicinity of equipment do not cause movement of reference frame during test which will affect required accuracy. Make check observations of movements of reference frame and check movement of pile head relative to external datum during progress of test. In no case are supports to be less than four pile diameters or 2 m,

whichever is greater, from centre of test pile.

- Measure pile movement by two dial gauges rigidly mounted on reference frame and bearing on surfaces normal to pile axis fixed to pile cap or head.
- Alternatively gauges may be fixed to pile and bear on surfaces on reference frame. Place dial gauges in diametrically opposed positions and equidistant from pile axis. Dial gauges are to enable readings to be made to within an accuracy of 0.1 mm. Protect reference frame from sun and wind.
- Wire, Mirror and Scale: two parallel wires, one on each side of the test pile are to be held under constant tension between two foundations positioned as described for independent reference frame. Position wire to pass across a scale mounted parallel to the axis of the pile and attached to a mirror fixed to the test piles. Determine movement of scale relative to the image of the wire at the mirror. Make check observations of movements of wire supports or check movement of pile head as described for independent reference frame. Take readings to within an accuracy of 0.5 mm. Protect reference wire from sun and wind.
- Submit any other method for measuring movement of pile heads for approval.

Test Procedure

- Pile Load Testing: Load and test piles which have been in place not less than 48 hours, to determine the load- settlement relationship of test piles under a vertical compression axial load, complying with IS 2911 Part 4, respectively, unless otherwise mentioned below.
- If test is required on working pile, cut down or otherwise prepare pile for testing as required by the Engineer in accordance with the requirements for preliminary test piles.
- Keep construction equipment and persons not involved in testing process at sufficient distance from test to avoid disturbance to measuring apparatus.
- Give the Engineer at least 24 hours' notice of commencement of test.
- During progress of test, testing equipment and records of test are to be available for inspection by the Engineer.

TEST BY MAINTAINED LOAD: minimum test load to be applied in test on preliminary pile is twice working load unless failure occurs first. Minimum test load in test on working pile is 1.5 times working load. Following each application of increment of load, the load is to be held for not less than period specified provided that the rate of settlement is less than 0.25 mm/h and slowing at the end of this period. Calculate rate of settlement from slope of curve obtained by plotting values of settlement versus time and drawing a smooth curve through the points. For period when load is constant record time and settlement immediately on reaching load and at approximately 15 minute intervals for 1h, at 30 minute intervals between 1h and 4h and at 1h intervals between 4h and 24h after application of increment of load.

LOADING AND UNLOADING PRELIMINARY PILES are to be as follows:

Load Percentage of Working Load	Minimum Time of Holding Load
25	1 h
50	1 h
75	1 h
100	6 h
125	3 h
150	12 h
175	3 h
200	24 h
175	15 min
150	15 min
125	15 min
100	15 min
75	15 min
50	15 min
25	15 min
0	4 h

LOADING AND UNLOADING WORKING PILES are to be as follows:

Load Percentage of Working Load	Minimum Time of Holding Load
25	1 h
50	1 h
75	1 h
100	6 h
125	3 h
150	12 h
125	15 min
100	15 min
75	15 min
50	15 min
25	15 min
0	4 h

The safe load on single pile for the Initial test should be least of the following

a) Two-third of the final load at which the total displacement attains a value of 12mm unless otherwise required in a given case on the basis of nature and type of structure in which case, the safe load should be corresponding to the stated total displacement permissible.
b) 50 percent of the final load at which the total displacement equal to 10 percent of the pile diameter in case of uniform diameter piles and 7.5 percent of bulb diameter in case of under- reamed piles.

However, routine test shall be carried for a test load of at least one and half times the working load; the maximum settlement of test loading in position being not exceeding 12 mm.

7.11.3.8. **Pull out Test**

Load Test shall be performed when concrete has reached its required strength i.e. 28 days strength The axial pull out load test should be done as per IS code 2911 part IV (latest revision).

Testing Procedure

- Pile Loading Test shall be performed in conformity with IS2911 Part IV.(latest revision).

  The contractor shall design the test beams, cross beams, weight, etc. and submit them to engineer for his approval.
- Pile head to be chipped to natural plane till sound concrete is met and a cap to be cast over the pile head for resting of Jack. One rolled steel joist (R.S.J.) to rest over jack which shall be kept on pile cap. The two ends on R.S.J. shall rest either on ground, for good and sound soil or concrete block or two numbers dummy piles to be cast at a minimum distance of 2.5 times the diameter of pile. The jack reacts against the R.S.J. frame attached to the top of pile cap such that when the Jack is operated, the pile gets pulled up and the reactions is transferred to the ground through Soil/ Concrete Blocks/Dummy Piles. The frame work can be attached to the pile top with the reinforcement bars which may be threaded or to which threaded bolt may be welded.
- Load applied by jack shall be measured by a calibrated pressure gauge.
- Movement of the pile shall be measured by dial gauges, fixed to datum bar and having least count of 0.01 mm, a minimum of two dial gauges, placed diametrically opposite shall be used. Datum bars shall be provided with rigid supports.

Test Load

Unless failure occurs first, test pile shall be loaded at a successive incremental load of 20% of the design load.

Unless failure occurs first, test pile shall be loaded up to 200% of the design load (Initial Test). Loading sequence in percentage of working load shall be as follows.

Initial Test
0
20
40
60
80

100
120
140
160
180
200
180
160
120
100
80
60
40
20
0

Duration of Load and Intervals of Measurement.

The pull out load increments and consequent displacement reading shall be read as in the case of vertical load test.

The safe load on single pile for the Initial test should be least of the following

a) Two-third of the final load at which the total displacement attains a value of 12mm or the load corresponding to a specified permissible uplift.

b) Half of the load at which the load displacement curve shows a clear break (downward trend).

7.11.3.9. **Lateral Load Test**

Lateral load Test shall be performed when concrete has reached its required strength i.e. 28 days strength. The Pile head to be chipped off upto 300mm above Cut-offLevel. The test to be conducted at cut-off level. The lateral loads test should be done as per IS2911 Part IV(latest revision).

Testing Procedure

Pile Loading Test shall be performed in conformity with IS 2911 Part IV(latest revision). The test may be carried out by the contractor by introducing a hydraulic jack of adequate capacity with pressure gauge abutting the pile horizontally and reacting against a suitable system. The reaction shall be suitably obtained from the adjacent pile if it is conducted by jack located between two piles. The full load imposed by the jack shall be taken as the lateral resistance of each pile. Lateral load applied on the pile shall be measured by a calibrated pressure gauge mounted on the jack and supported by the datum bar arrangement.

Test Load Unless failure occurs first, test pile shall be loaded at a successive incremental load of 20% of the design load. As explained in clause 8.0, unless failure occurs first, test pile shall be loaded up to 200% of the design load (Initial Test) and 150% of the design load (Routine Test) Loading sequence in percentage of design load shall be as follows.

Routine Test	Initial Test
0	0
20	20
40	40
60	60
80	80
100	100
120	120
140	140
150	160
140	180
120	200
100	180
80	160
60	120
40	100
20	80
0	60
	40
	20
	0

The maximum test load shall be observed to the total displacement increased to 12 mm

Duration of Load and Intervals of Measurement

1. The loading should be applied in increments of about 20 percent of the estimated safe load.
2. The next increment should be applied after the rate of displacement is nearer to 0.1mm per 30 minutes or 0.1mm per hour or 2 hours whichever is later. The deflection is at the cut-off level of the pile.
3. Displacements shall be read by using at least two dial gauges, fixed to datum bars and having least count of 0.01 mm sensitivity spaced at 30 cm and kept horizontally one above the other on the test pile. The datum bars shall be provided with rigid supports of steel sections, embedded well into the ground. The supports shall be located more than 3 times the diameter of pile. The dial gauge to be fitted on the pile surface by chipping off concrete

on the side of pile and fix a piece of glass 25mm square. The dial tips shall rest on the central position of the glass plate.

4. Loading shall be continued till one of the following occurs:
   a) Deflection of the pile head exceeds 12 mm.
   b) The applied load on the pile is twice the assumed lateral load capacity of the pile in case of a separate test pile and 1.5 times the rated capacity in the case of working pile.

The safe lateral load on the pile shall be taken as the least of the following:

a) Fifty percent of the final load at which the total displacement increases to 12 mm;

b) Final load at which the total displacement corresponds to 5 mm Note: The deflection is at cut-off level of the pile.

Field Quality Control

- Make three test cubes from concrete used in preliminary test pile and from concrete used for building up a working pile. If concrete cap is cast separately from preliminary pile or working pile make a further three cubes from this concrete. Make cubes and test in accordance with BS 1881.
- Do not start pile test until strength of cubes taken from pile exceeds twice average direct stress in any pile section under maximum required test load, and strength of cubes taken from cap exceeds twice average stress at any point in cap under the same load. Variation of procedure will be permitted only if approved.
- Concrete in piles is to be at least 7 days old before testing.
- If concrete strength obtained from the cubes taken during the construction works is below the required strength, report immediately to the Engineer the corrective measures proposed for his approval. Concrete work will not continue until the Engineer is satisfied that the reasons for the low concrete strength are removed.
- At least 5% of all piles are to be tested for integrity by crosshole sonic logging steady state methods carried out by an approved testing agent.

Presentation of Results

- Submit a summary in writing to the Engineer, unless otherwise directed within 24 hours of completion of test giving:
  a) For maintained load test, for each stage of loading: period for which load was held, load and maximum settlement or uplift recorded
- Submit a completed schedule of recorded data as described here- after within 7 days of completion of test.
- General Data Schedule is to include:

  1. Site location.

  2. Contract identification.

3. Proposed structure.

4. Main contractor.

5. Piling contractor.

6. Engineer.

7. Client.

8. Date of test.

- PILE DETAILS SCHEDULE is to include:

1. Identification (number and location).

2. Position relative to adjacent piles.

3. Brief description of location.

4. Ground level at pile position.

5. Head level at which test load is applied.

6. Type of pile.

7. Pile inclination if not vertical.

8. Shape and size of cross-section of pile, position of change in cross-section, if applicable.

9. Type of pile loading.

10. Shoe or base details.

11. Head details.

12. Length in ground.

13. Level of toe.

14. Any permanent casing or core.

- Pile Details Schedule for Concrete Piles is to include:

1. Concrete mix.

2. Aggregate type and source.

3. Cement type.

4. Slump.

5. Cube test results for pile and cap.

6. Date of casting precast pile.

7. Reinforcement.

- Installation Details Schedule for All Piles is to include:

1. Dates and times of boring, driving and concreting of test pile and adjacent piles.

2. Unexpected circumstances and difficulties.

3. Date and time of casting concrete pile cap.

4. Start and finish of each operation during driving or installation of pile and subsequent testing.

5. Difficulties in handling, pitching and driving pile.

6. Delays due to weather conditions, if applicable.

- Installation Details Schedule For Bored Piles Is To Include:

1. Type of equipment used and method of boring.

2. Temporary casing, method of installation and extraction.

3. Strata encountered during boring.

4. Water encountered during boring.

5. Method of placing concrete and conditions pertaining.

6. Theoretical volume of concrete placed in pile (based on nominal dimension).

7. Actual volume of concrete used at successive levels.

8. Concrete level before and after extraction of casing.

- Test Procedure Schedule is to include:

1. Weight of kentledge.

2. Tension pile, ground anchor or compression pile details.

3. Plan of test arrangement showing position and distances of kentledge supports, rafts, tension or compression piles and reference frame to test pile.

4. Jack capacity.

5. Method of load measurement.

6. Method(s) of penetration or uplift measurement.

7. Type of test (maintained loading and CRP or CRU).

8. Relevant dates and times.

- Test Results Schedule is to include:

1. Tabular form.

2. Graphical form: load plotted against settlement, load plotted against uplift, with times.

3. Ground heave.

4. Effect on adjacent structure.

- Site Investigation Schedule is to include:

1. Site investigation report number.

2. Borehole references. Completion of Test

- On completion of test dismantle and check equipment and measuring devices and either store to be available for use in further tests or remove from site.
- Remove kentledge and supporting structure from test pile and either store to be available for use in further tests or remove from site.
- Preliminary test pile cap: if formed in concrete, break off and remove resulting material from site. If pile cap is steel either cut off and store to be available for use in further tests or remove from site. Make good or extend pile head to cut off level.
- On completion of test on proof pile, the test pile cap, if in concrete, is to be stripped and left ready for incorporation in the permanent work. Remove resulting material from site. If pile cap is steel either cut off and store to be available for use in further tests or remove from site.
- On completion of preliminary test, cut off below ground level tension piles and ground anchors, remove from site and make good ground with approved material.
- On completion of proof test, temporary piles and ground anchors are to be cut off.
- On completion of proof test, temporary piles and ground anchors are to be incorporated in the permanent works.
- On completion of proof test, temporary piles and ground anchors are to be withdrawn.

7.11.3.10. **Routine Pile Load Test**

- All working piles shall be tested by Low Strain Impact technique as per 2911-part 4. Tests shall be carried out by an independent testing organization approved by the Engineer. Results and their interpretation shall be presented to the Engineer for approval.
- A number of working piles shall be subjected to integrity testing using sonic logging according to 2911-part 4, to detect major faults, necking, discontinuities, and cross sectional areas of the piles. Integrity testing of piles shall be carried out by an independent testing

organisation approved by the Engineer.

- If the results of the tests show that the concrete pile or piles are defective, the pile or piles shall be treated as faulty and shall be rejected unless the Contract or can demonstrate to the Notice by the Engineer effective remedial measures that will be carried out.
- The results of tests shall be printed out immediately during tests with printer facility at site and submitted to the Engineer. The Engineer's interpretations and conclusions based on the test results shall be final.
- For the purpose of carrying out sonic logging, the Contractor shall be required to install the necessary tubing or as directed by the Engineer. The No. of tubes shall be 4 for 600 mm diameter piles and 800 mm diameter piles and 4 for 1200 mm diameter piles. The tubes shall be equally distributed and tightly fixed to the pile reinforcement.
- The tubes shall be of internal diameter not less than 50mm with no internal projections or couplings. They tubes shall of mild steel pipes and connected together as specified by 2911- part 4.
- The tubes shall be fixed to the longitudinal bars with equal spacing on the inside perimeter of the links. The tubes shall be watertight with the bottom of the tube sealed and suitably weighted to prevent floating. The tubes shall be secured to the internal face of the reinforcement cage at equal distance from each other on the circumference.
- The tubes shall extend the full depth of the pile and project 300mm above the top of the concrete. All joints shall be made watertight. The tubes shall be filled with water to provide the necessary acoustic coupling, and then plugged or capped before concreting. The type of tube and condition of sealing shall be checked and approved by the Engineer before installation.
- The rate of logging for increments of depth shall be approved by the Engineer.
- After conducting the tests, all tubes shall be grouted and water in the tubes shall be displaced. The grout shall be dense cement grout with an approved expanding agent and approved strength.
- Prior to testing, the necessary equipment shall be thoroughly checked to ensure that all parts are functioning satisfactorily. During sonic logging testing, where any irregularities are detected, the tests shall be repeated at a smaller scale to allow a ‘close-up view’ of the irregularities.
- The time required to carry out the test for each pile must be recorded along with records of starting time and finishing time.
- The results of the tests shall be presented in report by the testing firm and must be signed by a professional engineer. The report shall include comprehensive engineering analysis of the test results for each pile taking into consideration the soil condition and any other relevant factors. Interim reports of each pile or group of piles tested in one day shall be submitted to the Engineer within 2 days of the completion of the test or tests. A final comprehensive report shall be submitted to the Engineer within 7 days of the completion of the last test or

tests.

PILE CAP

Pile Caps shall be of reinforced concrete. A minimum offset of 150 mm shall be provided beyond the outer faces of the outer most piles in the group. If the pile cap is in contact with earth at the bottom, a levelling course of minimum 100 mm thickness of M 15 nominal mix concrete shall be provided.

The attachment of the pile head to the cap shall be adequate for the transmission of loads and forces. A portion of pile top may be stripped of concrete and the reinforcement anchored into the cap. Manual chipping may be permitted after three days of pile casting, while pneumatic tools for chipping shall not be used before seven days after pile casting. The top of pile after stripping shall project at least 150 mm into the pile cap. A layer of surface reinforcement may be provided with a cover of 25 mm to retain the integrity of concrete below the main cap reinforcement which is to be laid 25 mm above the pile top.

Concreting of the pile cap shall be carried out in dry conditions. The bottom of the pile cap shall be laid preferably as low as possible taking account of the water level prevalent at the time of casting.

The top of concrete in a pile shall be brought above cut-off level to permit removal of all laitance and weak concrete before pile cap is laid. This will ensure good concrete at the cut-off level.

The minimum thickness of pile cap should be at least 1.5 times diameter of pile. Such a cap can be considered as rigid. Casting of pile cap should be at level higher than water level unless functionally it is required to be below water level at which time sufficient precaution should be taken to dewater, the forms to allow concreting in dry condition. In marine condition or in areas exposed to the action of harmful chemicals, the pile cap shall be protected with a suitable anti-corrosive paint. High alumina cement, i.e. quick setting cement shall not be used in marine constructions. (Clause 709.5.4 of IRC:78: 2000 was amended as IRC notification No: 54 dated 28.05.2009).

7.12 Sub Structure

7.12.1. Description

The work shall cover furnishing and providing of masonry or reinforced concrete sub-structure in accordance with the drawings and as per these specifications or as directed by the Engineer.

7.12.2. Materials

Materials shall conform to Section 1000 of Specifications for Road & Bridges Works" (Fifth

Revision / Latest Revision issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

7.12.3. General

A method statement for construction indicating the following shall be submitted by the Contractor for Notice by the Engineer, well in advance of the commencement of sub structure:

- Sources of Materials
- Design, erection and removal of formwork
- Production, transportation, laying and curing of concrete
- Personnel employed for execution and supervision
- Tests and sampling procedures
- Equipment details
- Any other point

Arrangements for execution under water wherever necessary, shall be included in method statement.

Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent bench mark.

7.12.4. Piers and Abutments

Masonry, formwork, concrete and reinforcement for piers and abutments shall conform to relevant sections of these specifications. In case of concrete piers, the number of horizontal construction joints shall be kept minimum. Construction joints shall be avoided in splash zones unless specifically permitted by the Engineer and provided they are treated in accordance with special provisions. No vertical construction joint shall be provided. The work shall conform strictly to the drawings or as directed by the Engineer.

In case of tan piers and abutments, use of slip form shall be preferred. The design, erection and raising of slip form shall be subject to special specifications which will be furnished by, the Contractor. The concrete shall also be subject to additional specifications as necessary. All specifications and arrangements shall be subject to the Notice by the Engineer.

The surface of foundation/well cap pile cap shall be scrapped with wire brush and all loose materials removed. In case reinforcing bars projecting from foundations are coated with cement slurry, the same shall be removed by tapping, hammering or wire brushing. Care shall be taken to remove all loose materials around reinforcements. Just before commencing masonry or concrete work, the surface shall be thoroughly wetted.

In case of solid (non-spill through type) abutments, weep holes as shown on the drawings or as directed by the Engineer, shall be provided in conformity with Section 2.27.9.

The surface finish shall be smooth, except the earth face of abutments, which shall be rough, finished.

In case of abutments likely to experience considerable movement on account of backfill of approaches and settlement of foundations, the construction of the abutment shall be followed by filling up of embankment in layers to the full height to allow for the anticipated movement during construction period before casting of superstructure.

7.12.5. Pier Cap and Abutment Cap

Formwork, reinforcement and concrete shall conform to relevant sections of these specifications. The locations and levels of pier cap/abutment cap/pedestals and bolts for fixing bearings shall be checked carefully to ensure alignment in accordance with the drawings of the bridge.

The surface of cap shall be finished smooth and shall have a slope for draining of water as shown on the drawings or as directed by the Engineer. For short span slab bridges with continuous support on pier caps, the surface shall be cast horizontal. The top surface of the pedestal on which bearings are to be placed shall also be cast horizontal.

The surface on which elastomeric bearings are to be placed shall be wood float finished to a level plane, which shall not vary more than 1.5 min from straight edge placed in any direction across the area. The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25 mm below the bottom level of bearings and as indicated on the drawings.

7.12.6. Dirt/ Ballast Wall, Return Wall and Wing Wall

Masonry, concrete and reinforcement shall conform to relevant sections of these specifications.

In case of cantilever return walls, no construction joint shall generally be permitted. Wherever feasible, the concreting in cantilever return walls shall be carried out in continuation of die ballast wall.

For gravity type masonry and concrete return and wing wall, the surface of foundation shall be prepared in the same manner as prescribed for construction of abutment. No horizontal construction joint shall be provided. If shown on drawing or directed by the Engineer, vertical construction joint may be provided. Vertical expansion gap of 20 mm shall be provided in return wall/wing wall at every 10-metre interval or as by the Engineer. Weep holes shall be provided as prescribed for abutments or as shown on the drawings.

Formwork, reinforcement and concrete in dirt/ballast wall shall conform to relevant sections of these specifications.

The finish of the surface on the earth side shall be rough while the front face shall be smooth finished.

Architectural coping for wing wall/return wall in brick masonry shall conform to section 1300 of Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision issued by the

Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

7.12.7. Tests and Standards of Acceptance

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria.

The work shall conform to these specifications and shall meet the prescribed standards of acceptance.

7.12.8. Tolerances in Concrete Elements

Variation in cross-sectional dimensions	: +10 mm, -5 mm
Misplacement from specified position in plan	: 10 mm
Variation of levels at the top	: ±10 mm
Variations of reduced levels of bearing areas	: ± 5 mm
Variations from plumb over full height	: ±10 mm
Surface irregularities measured with 3 in straight edge	
All surfaces except bearing areas	: 5 mm
Bearing areas	: 3 mm

7.13 Concrete Superstructure

7.13.1. Description

The work shall cover furnishing and providing of concrete superstructure in accordance with the drawings as per these specifications or as directed by the Engineer.

7.13.2. Materials

Materials shall conform to Section 1000 of “Specifications for Road & Bridges Works” (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

7.13.3. General

7.13.3.1. A method statement for construction, indicating the following, shall be submitted by the Contractor for Notice by the Engineer, well in advance of the commencement of the construction of superstructure:

i) Sources of Materials
ii) Design, erection and removal of formwork
iii) Production, transportation, laying and curing of concrete
iv) Pre stressing system if applicable
v) Personnel employed for execution and supervision

vi) Tests and sampling procedure

vii) Equipment details

viii) Any other point

7.13.3.2. Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent bench mark so that the final product is in accordance with the drawings or as directed by the Engineer.

7.13.3.3. The work shall conform to the following sections besides stipulations in this section with regard to specific type of construction:

Formwork	:	Section 2.4
Steel Reinforcement	:	Section 2.5
Structural Concrete	:	Section 2.6
Pre stressing	:	Section 2.7

Additionally, some of the common types of superstructure construction shall have features as discussed in this Section.

7.13.4. Reinforced Concrete Construction

7.13.4.1. Solid Slabs

Where adjacent span of slab has already been cast, the expansion joint and filler board shall be placed abutting the already cast span which shall form the shutter on that side of the new span to be cast. The whole of the slab shall be cast with reinforcement embedded for the road kerb and railings. No other construction joint shall be allowed except with the express permission of the Engineer.

Where wearing -coat is required to be provided, after the deck slab has been cast, the surface of the slab shall be finished rough, but true to lines and levels as shown on the drawings, before the concrete has hardened. The areas of construction joints shall be treated in the prescribed manner. The top of the slab shall be covered with clean moist sand as soon as the top surface has hardened. Curing shall be carried out as per Section 2.6.

Where the slab is resting on bearings, the same shall be placed in position in accordance with the drawings, before casting of deck slab.

7.13.4.2. RCC T-Beam and Slab

Provision of construction joint shall conform to the drawings or as per directions of the Engineer. No construction joint shall be provided between the bottom bulb & the web. If not indicated on the drawing, construction joint may be provided at the junction of the web and the fillet between the web and the deck slab with the permission of the Engineer.

The portions of deck slab near expansion joints shall be cast along with reinforcements and embedment for expansion joints, for this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer.

The surface finish of the deck slab shall be finished rough but true to lines and levels as shown on the drawings before the concrete has hardened. Care shall be taken for setting of bearings as indicated on the drawings.

7.13.5. Pre stressed Concrete Construction

7.13.5.1. . PSC Girder and Composite RCC Slab

PSC Girder may be precast or cast-in-situ as mentioned on the drawing or as directed by the Engineer. Girders may be post-tensioned or pre-tensioned. Where precast construction is required to be adopted, selection of casting yard and details of methodology and of equipment for shifting and launching of girders shall be included in the method statement.

In case of cast-in-situ construction, the sequence of construction including side shifting of girders, if applicable, and placing on bearings shall be in accordance with the drawings.

The PSC girder constituting the top flange, web and the bottom flange shall be concreted in a single operation without any construction joint.

The portions of deck slab near expansion joints shall be cast along with reinforcements and embedment for expansion joints. For this purpose, the portion of deck slab near expansion, joints may be cast in a subsequent stage, if permitted by the Engineer.

The surface finish of the deck slab shall be finished rough but true to lines and levels as shown on the drawings before the concrete has hardened. Care shall be taken for setting of bearings as indicated on the drawings.

7.13.5.2. Box Girder

Box girders may be simply supported or continuous. Simply supported box girders shall have minimum construction joints as approved by the Engineer. In the case of continuous box girders the sequence of construction and location of construction joints shall strictly follow the drawing.

The box section shall be constructed with a maximum of one construction joint located in the web below the fillet between the deck slab and web. If permitted by the Engineer, one additional construction joint may be permitted and this construction joint shall, be located in the web above the fillet between the soffit slab and web.

The portions of deck slab near expansion joints shall be cast along with reinforcements and embedment for expansion joints. For this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer.

The surface finish of the deck slab shall be finished rough but true to lines and levels as shown on the drawings before the concrete has hardened. Care shall be taken for setting of bearings as indicated on the drawings.

7.13.5.3. Cantilever Construction

Continuity of untensioned reinforcement from one segment to the next must be ensured by providing full lap length as necessary.

The design of the superstructure shall take into account the following aspects, which form an integral part of the construction operations

Stability against over-turning for each statical condition, through which the assembly passes, shall be checked.

Stresses at each preceding segment joint with the addition of every segment or change of statical conditions shall be checked. The load of equipment as well as construction live load shall be taken into account.

Precambering of the superstructure during construction shall be done in such a manner that the finally constructed structure under permanent load attains the final profile intended in the drawings.

7.13.5.4. Segmental Construction

7.13.5.4.1. The work specified in this Section shall consist of the manufacture of structural precast concrete segments and the storage, transport and the erection of these segments into the completed structure. The final structure shall conform to the lines and grades and the design dimensions shown on the plans and with the provisions of these Specifications. This work also includes reinforcing steel embedded in the segments and the casting of the closure joints.

Definitions

(i) Segment refers to a modular section of the superstructure. The cross-section, length, and details of the segments are as shown in the Design Drawings.

(ii) Match Cast refers to a precast concrete fabrication procedure whereby a segment is cast against the preceding segment thereby producing a matching interface that will permit reestablishment of the cast geometry at the time of erection. Match casting may be accomplished by either the short-line casting method or the long-line casting method.

(iii) Short-line Casting is the method of casting segments one at a time on a casting bed utilizing a fixed or movable bulkhead. The first segment is cast between bulkheads, and successive segments are cast, one at a time, against the bulkhead on one end and the repositioned, previously cast segment on the other end.

(iv) Balanced Cantilever Erection is a method by which the segments are sequentially placed, in cantilever, alternately on either side of the pier to a point where a closure joint is cast in place.

(v) Camber is the amount by which the concrete profile at the time of casting must differ from the theoretical geometric profile grade in order to compensate for all structural dead-load, post- tensioning, long-term and time-dependent deformations (creep and shrinkage), including the intermediate erection stages and effects.

(vi) Casting Curve: is the curve of casting geometry that is followed at the casting bed to achieve the theoretical profile after final deformations have taken place. The casting curve is developed by integrating theoretical profile and camber.

(vii) Erection Elevations are the elevations to which segment joints should be located at each stage of erection in order for the bridge deck to match the theoretical roadway profile after construction and after all long-term dead load deflections have occurred.

(viii) Shop Drawings are documents prepared from the information shown on the Design Drawings which provide details necessary for the construction of the work. “Shop Drawings” is a general term that includes drawings, diagrams, illustrations, samples, schedules, calculations, and other data. The precast segments shop drawings are drawings that are clearly detailed to show the relationship between reinforcing bars, post-tensioning hardware, and all other embedded items in an attempt to avoid interferences between these elements.

(ix) Casting Manual: is a manual for the casting and the geometry control of the precast segments prepared by the Contractor and/or the Construction Engineer in accordance with the information provided in the Design Drawings, the Shop Drawings and these Special Provisions.

(x) Erection Manual: is a manual for the detailed step-by-step erection of the precast segments including all intermediate procedures relating to any erection equipment, falsework, counterweights, post-tensioning, placement or removal of temporary supports, closure operations. The manual also includes theoretical erection elevations at each stage of erection, and survey monitoring procedures.

(xi) Standard Specifications: Standard material specifications conforming to MoRTH specifications or equivalent Indian Standards, British Standards, AASHTO, ASTM as applicable.

7.13.5.4.2. Contractor Proposed Options

The contractor may propose, for consideration by the Engineer, certain variations from the construction and erection schemes shown in the contract documents.

Options for construction details covered by this section are limited to the following

a) Segment lengths may be reduced or increased for those detailed.

b) Optional post-tensioning systems or layouts provided that optional systems meet the requirements specified hereinafter and the requirements set out in Section 2.10

7.13.5.4.3. Restrictions to Contractor Proposed Options

Any redesign or modification with regard to method of superstructure construction or pre stressing differing in any respect from the structure as designed and detailed on the plans shall comply with the following:

a) The Contractor demonstrates that any proposed option or modification meets the design criteria noted on the plans and in the Specifications.

b) Stressing blocks for any optional or modified permanent pre stressing system's anchorages shall only be located within the slab, within the webs of box girders, within reinforced stressing blocks or within partial depth diaphragms of the box girder. Stressing blocks for any temporary pre stressing system anchorages may be located within the slabs, in partial depth diaphragms within the box girder, in external systems temporarily anchored to the girders and removed after use or a combination of any of the above methods. All construction added outside the box girder for temporary pre stressing shall be subsequently removed to restore the girder to the designed cross section shown on the plans or as approved by the Engineer.

c) Any precast, match-cast proposal shall utilize the multiple shear key concept; single shear keys will not be permitted.

7.13.5.4.4. Shop Drawing Requirements

The contractor shall submit detailing drawings on the following items:

a) Fully and accurately dimensioned views showing the geometry of each segment including projections, recesses, notches, openings and blackouts.
b) Complete details of the fabrication system to be used including the forms, foundation and geometry control.
c) Complete geometric layouts for each post-tensioning tendon. Tendon layout shall be accomplished so as to cause no curvature within the longitudinal limits of the trumpet component of a tendon anchorage device. Integrated shop drawings shall not be submitted until these tendon layouts have been Noticed by the Engineer.
d) Fully integrated drawings showing reinforcing steel, pretensioning strands, post-tensioning duct, post-tensioning hardware, inserts, lifting devices and any other items to be embedded in a segment. Details of mild steel reinforcing shall be clearly shown as to size, spacing and location including any anchorage reinforcing not shown in the plans, which may be required by the post- tensioning anchorage system selected by the contractor. Details of post-tensioning ducts shall clearly indicate the size, type, horizontal and vertical profiles, duct support, grout pipes and concrete covers. Any drawing not showing all items to be embedded in the segment concrete will be returned to the contractor for resubmittal as a part of an integrated drawing. Prior to submittal, the contractor shall review these drawing to determine the absence of reinforcement and tendon or embedment conflicts. Any unresolved conflicts shall be assigned a creation mark indicating its location and order in the creation sequence. The Contractor shall be solely responsible for any and all effects of conflicts fund during fabrication.
e) Casting curves shall be prepared in accordance with the casting and erection methods, schedule, loads, and material properties proposed by the Contractor. The casting curves shall be of sufficient accuracy to allow the determination of control point settings for accurately casting the segments. The preparation of the casting curve shall recognize all deviation

from straight line and deformation due to the final requirement and due to dead load, and future superimposed dead loads, erection loads, post – tensioning stresses including secondary movements, creep and shrinkage. Each casting curve submittal shall be accompanied by all information (loads, casting and erection schedules, material properties, etc.) considered in its development. In developing casting curves, deformations due to creep and shrinkage and the concrete modulus of elasticity shall be computed using the latest recommendations of CEB-FIP Model Code for Concrete structures. CEB-FIB stands for Comite Euro-International De Beton –Federation International De La Preconstrainte. The preparation of casting curves is dependent upon the erection procedure, which has been previously approved, he shall develop a new curve in the same manner as required for the original casting curve. The Engineer may waive submittal of a revised casting curve if he considers the change to erection procedures to be insignificant. The Contractor shall include with submittal of a revised casting curve his proposed method (s) and location (s) for transitioning between the current curve(s) in use and the submitted curve(s) .The preparation of casting curves shall be done at no additional cost and shall be considered incidental to the contract.

The Contractor shall similarly adjust initial bearing elevations and structure geometry for time- dependent displacements.

f) Complete details of handling, storing and transporting segments. These details shall include for each type of segment, the method of lifting (location of any inserts, configuration of lifting devices, etc.) and the method of supporting segments during storage and transportation, the planned route for transporting the segments and the axle loads for the segment hauler. The details shall be accompanied by calculations indicating that the forces imposed on a segment during lifting, storage and transportation will not adversely affect the structural adequacy of the segment

g) If the segments are to be stacked, calculations showing the stresses induced by stacking shall be prepared and submitted for approval

h) A detailed step-by-step procedure for erection of segments, post-tensioning, etc., including the sequence in which these items are to be erected and a table of theoretical elevations and alignment of the geometry control points established during casting of each segment computed at each stage of erection. Stages for which theoretical positions of control points are to be computed shall include the segment in place prior to applying post-tensioning and the segment with post-tensioning applied.

The theoretical position shall be computed taking into consideration:

i) The effect of as-cast geometry established from surveys during casting of segments.

ii) Effects of construction dead and live load.

iii) Effects of post-tensioning.

iv) Effects of creep and shrinkage. Deformation due to creep and shrinkage and the concrete modulus of elasticity shall be computed using the latest recommendations of CEB-FIB Model Code for Concrete Structures.

v) Effect of the final profile of the roadway as shown in the plans.

The procedure shall also include a method for measuring and recording the elevations and alignment of all control points at each stage of erection.

The Contractor shall submit a new erection procedure at any time that he proposes to deviate from the sequence of schedule of erection contained in an approved erection procedure under which he is operating.

i) Complete details covering equipment to be used to handle segments and incorporate them into the structure, erection methods to be used, the sequence of erection, all loads to be imposed on any portion of the permanent structure by the erection equipment and details covering the procedure for load testing of erection equipment.

j) Calculations prepared which show that the loads imposed on the permanent structure by the erection equipment will not adversely affect the structural adequacy of the permanent structure, nor exceed allowed stresses during the construction process.

k) Complete details including dimensions and showing reinforcing steel, post- tensioning ducts and hardware and other embedded items for all cast –in- place concrete which includes reinforcement or prestressing tendons which extend or pass into precast concrete units.

l) A manual for the casting and geometry control of the segments prepared by the contractor or his Engineer in accordance with the information provided in the Contract Plans and Documents or as required by this specification.

m) A manual for the detailed step by step erection of the segments including all intermediate procedures relating to any erection equipment, falsework, movement of equipment, support jacking, stressing of temporary post-tensioning bars, closure operations including any partial stressing across the closure during concrete curing, location and size of shim blocks, main field survey and alignment control methods to be employed for setting the initial and subsequent segments and any other relevant operations.

7.13.5.4.5. Material

(1) Concrete

All concrete shall be Grade M50 conform to Section 2.7 except as specifically modified herein. Gradation for coarse aggregate utilized in the concrete for segments shall be such that 100 percent passed a 25 mm sieve.

(2) Sheathing for Post-Tensioning Tendons

Sheathing to be embedded in the segments shall conform to the requirements of the Section 2.12

7.13.5.4.6. Equipment

(1) General

Design calculation prepared shall be submitted for any erection equipment, falsework, and other temporary construction, which may be required to accomplish the work. In addition, calculations pertaining to the permanent structure showing acceptable stress level and acceptable factor of safety against failure must be submitted when portions or whole of the permanent structure is loaded during construction.

Prior to use of any equipment that is fabricated for the specific purpose of erection any portion of the work included in this construct, the Contractor shall demonstrate by a full-scale load test that this equipment is adequate for its intended use on this project.

Observation of load testing of erection trusses, or erection equipment, or review of design drawing and calculations covering erection trusses, or erection equipment by the Engineer shall not be construed as any assumption by the Engineer of responsibility for means, methods, techniques, sequences or procedures of construction, nor on safety precautions or to a safety program thereto.

(2) Brackets Supporting Truss for Span-by-Span Erection.

If an erection truss is to be supported by any part of a pier, in designing support brackets, a lateral force equal to not less than ten percent of the weight of the truss plus the weight of segments to be placed on the truss shall be applied longitudinally. Also, these brackets must have a secondary means of vertical support, which does not rely on friction between the support and the pier.

If an erection truss is to be supported by any part of a pier via support brackets, the design of the brackets shall conform to the following minimum:

- A lateral force equal to not less than ten percent of the weight of the truss plus the weight of segments to be placed on the truss shall be applied longitudinally.
- Brackets must have vertical support that does not rely on friction between the support and the pier.

(3) Load Testing Truss for Span-by-Span Erection

Prior to using an erection truss on the project, the Contractor shall demonstrate the capability of the truss to perform as intended by a full-scale load test. The load test procedure shall include:

a) Constructing two temporary piers approximately the size and shape of the upper portion of the pier, duplicating the relevant portion of the permanent piers, which are to be constructed on the project. The elevation of these temporary piers shall be such that when the erection truss is assembled on them it will be a sufficient distance above the ground to allow any necessary working space beneath it. The temporary piers may be constructed on foundations for the permanent structure. Alternately, the contractor may use the completed sub structure for the first span to be erected to support the truss during the load test.

b) .Assembling the truss supported on the piers in the same manner and using the same supporting devices (beams, brackets, etc.) as will be used on the project.

c) Test loadings the truss with the heaviest segment it will support during erection of the bridge plus an additional load equal to the 25 percent of the weight of the segment

d) Measurement of vertical displacement at mid span and horizontal movement at support points.

e) The Contractor shall give written notice to the Engineer at least 72 hours in advance of the time at which loading of the truss is to be accomplished.

(4) Load Testing Special Equipment for Cantilever Erection.

Prior to using a launching gantry, a beam and winch or any other equipment specifically fabricated for the purpose of lifting precast segments must be load tested. The contractor shall demonstrate by a full scale load test that the equipment is capable of supporting a load equal to 125 percent of the weight of the heaviest segments to be lifted. The full scale load test shall be conducted with the equipment supported in the most extreme loading condition to be encountered during its use on the project.

The Contractor shall give written notice to the Engineer at Least 72 hours in advance of the time at which the test load is to be supplied.

7.13.5.4.7. Construction Requirements

(1) Casting Concrete

a) General

All material, details, and procedures shall be as specified herein or noted on the plans. Casting of segments shall not begin until review of the shop drawings, required computations, the post- tensioning system and a concrete mix design, including a hot weather mix design, has been completed and approved by the Engineer. The segments shall be match-cast.

b) Design and Maintenance of Forms

The design, engineering, and construction of the forms and falsework shall be the responsibility of the Contractor. Forms shall be inspected and approved by the Engineer prior to authorizing casting operations. Forms which are worn, damaged or otherwise unacceptable to the Engineer shall be repaired to the Engineer’s satisfaction before the casting of any segment will be authorized. Any segment cast in forms unacceptable to the Engineer is subject to rejection. Forms which will not produce segments complying with the specified casting tolerance shall not be used until corrections are made. Segments with unacceptable will be rejected.

Forms show damages due to improper maintenance or handling, shall be discarded or repaired. All repaired forms shall be re-approved by the Engineer to authorizing casting operations.

Forms shall be mortar tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads incidental to the concrete operation, including vibration. Forms shall be capable of casting the segments as shown in the plans.

All exposed surface of each element of the structure shall be formed with material, which will produce a similar surface texture, color and appearance for all concrete surfaces. The form surfaces of casting machines for superstructure shall be made of steel. The metal used for forms shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clams, pins or other connecting devices shall be designed to hold the forms rigidly together and to allow form removal without injury to the concrete.

The inside surfaces of forms shall be cleaned of all dirt, mortar and foreign material. Forms shall be properly coated with form oil prior to each use. The form oil be a commercial quality form oil or other equivalent coating which will permit the ready release of the forms and will not discolor the concrete. Form oil shall be applied such that none is deposited on the reinforcement in the forms where sections of forms are to be joined, a maximum offset of 2 mm for flat surfaces and 4 mm for corners and bends will be permitted.

The Contractor accurately survey forms on a periodic basis for the purpose of monitoring settlements and distortion in shape. If any settlements or distortions are of sufficient magnitude to interfere with achieving the required segment tolerances, casting with these forms shall be discontinued until the problem is corrected.

c) Preparation of Casting

Care shall be exercised in setting up forms for casting segments. All materials to be encased within the concrete of the segment shall be properly positioned and supported. Provisions for all projections, recesses, notches, openings, block-outs and the like shall be made in accordance with the approved shop drawings. Extreme care shall be taken in positioning the match-cast segment in relation to the segment to be poured. The match-cast segment shall not be twisted. The abutting surface of the bulkhead segment shall be covered with a thin film of a bond breaker consisting of flax soap and talc, or other material approved by the Engineer. The soap and talc mixture will be approximately five parts flax soap to one part talc. The mixture may be varied based on job experience and results. The acceptability of a material other than soap and talc shall be determined by demonstration on a large specimen, which has a facial area of at least 0.4 square meters, prior to its use in casting of the segments.

d) Geometry Control

General: Before commencing the casting operation, the Contractor shall submit to the Engineer, for approval, his proposed method of geometry controls for both the casting and erection operation. This submittal shall be in the form of a “Casting Manual” and shall include, but not be limited to, the following information: a detailed narrative of the geometry control theory, a detailed narrative of the step-by-step geometry control procedure, detailed calculation forms, and a set of sample calculations. This submittal shall include all measuring equipment, procedures, the locations of the control points to be established on each segment and the qualifications of personnel who will carry out geometry control. The casting manual shall cover all geometry control operations necessary for casting and shall be in agreement with the Contractor's chosen methods of casting and erection, including erection survey, elevation and alignment control. Casting shall not commence without the Engineer's approval of the geometry control method. Instruments used in the casting yard for horizontal geometry control shall be mounted on a permanent platform independent of any other structure. Instruments used in the casting yard for vertical geometry control of super-structure segments shall be mounted on a sturdy tripod set on top of the segments being surveyed. Provisions shall be made to protect instruments from construction activities and to minimize the effects to wind and temperature variations on the accuracy of readings.

A minimum of two permanent horizontal control points shall be established on line with the instrument mounting point. Permanent bench marks shall be established at locations where they will not be disturbed by construction activities. The horizontal control points and benchmarks shall be located so as to be continuously visible from the instrument's location. Prior to beginning casting operations using the short cell method, horizontal and elevation control points shall be established on the fixed bulkhead. The alignment, elevations, and shape of the fixed bulkhead shall be checked by the readings on these control points each time the geometry of adjoining segments is checked. Immediately after casting of a segment is completed, the length of the segment along the line of each web shall be measured and recorded and references for horizontal and vertical control shall be established as follows:

i. Horizontal Control- A wire stirrup on the horizontal control line at both ends of the segment. A line not more than 0.5 millimeters in width shall be scribed in a permanent manner into each stirrup. Wire stirrups shall be stainless steel.
ii. Vertical Control- A flat head bolt, with a pin hole in the head, approximately flush with the surface of the concrete over each web at both ends of the segment. Bolts shall be stainless steel.

After a segment is cast, and before bond breaking, the positions of the two adjoining segments shall be checked form established control points. If the positions are not as required, corrections to the geometry shall be made in the next segment cast utilizing the established control points.

Special Requirements for Short Cell Casting of Structures with Complex Geometry Control

The following additional requirements shall apply to geometry control for short cell casting of segment, for bridges with horizontal curvature and varying super-elevation, and for bridges, which are to be erected using the cantilever method.

i. The instrument used to measure elevations shall be precision levels equipped with parallel plate micrometers capable of obtaining first order control and one piece Invar with centering point bases.

ii. The instruments used to make horizontal measurements shall be one- second theodolites.

iii. A micrometer on either the theodolite or the foresight target shall be used for horizontal measurement reading on segment control points.

iv. Personnel who directly supervise layout and geometry control measurements shall have a minimum of four years' experience as a party chief.

v. The position of two adjacent segments shall be independently determined by the Contractor and the Engineer. Horizontal readings shall be taken with the theodolite in both direct and inverted mode. Casting shall not begin until these surveys agree within the following tolerance.

Elevation : 0.5 mm on any control point.

Horizontal : 0.5 mm and 2 seconds of are on any control point.

e) Embedded Items

Reinforcing steel shall be fabricated and placed in accordance with the plans and as required herein. No reinforcing steel be cut or removed to permit proper alignment of tendon ducts or other embedded items. Any bar that cannot be fabricated to clear a poet-tensioning tendon shall be replaced by additional bars with adequate lap lengths using a method approved by the Engineer. In the plane of the steel parallel to the nearest surface of concrete bars shall not vary from plan placement by more than 10mm, or 1/12 of the spacing between bars, whichever is less. In the plane of the steel perpendicular to the nearest surface of concrete, bars shall not vary from plan placement by more than 12 mm.

The top and bottom clear cover of reinforcing steel shall be within 5mm of the clear cover limits dimensioned on the plans. The end and edge clear cover of the reinforcing steel shall be within 25 mm of the clear cover limits dimensioned on the plans.

Embedded ducts for tendons shall be positioned accurately (within 5mm) in respect to their vertical, linear and transverse position within each segment. Positive methods shall be utilized to assure that ducts will not be displaced during casting. Ducts which act to change the alignment of tendons shall be marked so that proper positioning is assured prior to casting and can be positioned after casting. The Contractor shall indicate on the shop drawings his method of marking and positioning. The Contractor shall submit to the Engineer, for approval, the method he proposes to use to align ducts passing from cast-in-place concrete into precast units.

Methods and spacing of supports for ducts shall be shown on the shop drawings. After installation in the forms, the end of the ducts shall at all times be sealed to prevent entry of water and debris. Following each pour of concrete, the Contractor will be required to demonstrate that all empty duets are free of water and are unobstructed and undamaged. Immediately prior to installation of the pre stressing steel, the contractor shall again demonstrate, to the satisfaction of the Engineer, that all ducts are unobstructed and that they are free of water and debris. Lifting devices incorporated in superstructure segments shall be adequate to distribute the handling and erection stresses so as not to damage the segment.

The anchoring devices for transverse top slab post-tensioning shall be recessed so that the ends of the pre stressing steel and all parts of anchoring devices will be at least 50 mm inside the end surface of the segment. Following post-tensioning, the recesses shall be filled in accordance with the details noted on the plans.

Transverse post-tensioning anchors shall be placed into the form before the concrete is cast. Temporary block-out for anchors shall not be allowed.

(2) Placing Concrete

Placing concrete shall meet the requirements of hereinafter and Section 2.8. Concrete shall not be deposited into forms until the entire set up of the forms, reinforcement, ducts, and anchorage has been thoroughly inspected and checked. The placing of concrete shall not be permitted until the Engineer is satisfied that the rate of producing and placing concrete will be sufficient to complete the proposed pour and finishing operations within the scheduled task, that experienced concrete finishers are available where required for finish work and all necessary finishing tools and equipment are on hand at the site of work and are in satisfactory condition for use. During conveying, placement, and initial set, the concrete shall be protected against undue drying or rise in temperature and inclement weather. The placing of concrete shall also not be permitted until the Engineer is satisfied that adequate measures, and protection, are available to prevent weather damage during conveying and placement.

Special care shall be taken to plan the sequence of placing concrete so as to assure that voids do not occur within the concrete in areas where air is likely to be entrapped within the forms or in areas where flow of the plastic concrete is constrained by embedded items.

Concrete shall be placed in horizontal layers not more than 450 mm thick except as hereinafter provided. When less than a complete layer is placed in one operation, it shall be terminated in a vertical bulkhead. Each layer shall be placed and compacted before the preceding layer has taken initial set. Each layer shall be so consolidated as to avoid the formation of a construction joint with a preceding layer, which has not taken initial set. Bridge deck concrete on super elevation and / or grade that exceeds 0.02 m per m, shall be placed from the low point upward. Immediately after the work of placing concrete is halted, all accumulations of mortar splashed upon the remaining exposed reinforcement and surfaces of forms shall be removed before the concrete takes its initial set. Care shall be taken when cleaning reinforcing steel to prevent damage to or breakage of the concrete-steel bond.

Placing equipment shall be of a size and design that will permit the placing of concrete within the time limits set in Section 2.8. Placing equipment shall be cleaned as necessary at the end of each operation or work day and, just prior to reuse, shall again be checked and cleaned of hardened concrete and foreign materials.

Belt conveyors shall be horizontal or at a slope which will not cause excessive segregation or loss of ingredients. Concrete shall be protected against undue drying or rise in temperature. An approved device shall be used at the discharge end of a belt conveyor to prevent aggregate segregation. Mortar shall not be allowed to adhere to the return length of the belt. Concrete shall be discharged into a hopper or through a baffle.

No construction joints will be permitted within a segment except as detailed on the plans.

(3) Tolerances

The following tolerances shall apply to the fabrication of precast segments: Width of Web ± 3 mm

Depth of Bottom Slab	± 3 mm
Depth of Top Slab	± 3 mm
Overall Depth of Segment	± 5 mm
Overall Width of Segment	± 5 mm
Length of Segment	± 5 mm
Diaphragm Dimensions	± 10 mm
Ends (deviation from a width of depth)	± 5 mm per 5 m not to exceed 10 mm plane per 5 m

Flat Surface (deviation ± 1 mm per 0.5 m not to exceed a total of 5mm from a plane at any location)

Dimensions from segment to segment shall be adjusted so as to compensate for any deviations within a single segment so that the overall dimensions of the completed structure will conform to the dimensions shown on the plans.

(4) Vibration

All concrete shall be consolidated by means of approved vibrators together with any other equipment necessary to perform the work as specified. Internal vibrators shall have a minimum frequency of 8,000 vibrations per minute and sufficient amplitude to consolidate the concrete effectively. At least two standby vibrators in working condition shall be provided for emergency use in case of malfunction. The use of external vibrators for consolidating concrete will be permitted and may be required when the concrete is inaccessible for adequate consolidation. When external vibration is used, the forms shall be constructed sufficiently rigid to resist displacement or damage. Vibrating of concrete shall be done with care and in such a manner as to avoid displacement of reinforcing, ducts, and other embedded items.

(5) Removal of Forms

Weight supporting forms shall remain in-place until the concrete has reached the characteristics compressive strength specified for form removal. For precast segments, constructed as shown in the plans without design modifications, this strength shall be at least 24 [Corr 3*] MPa unless otherwise designated in the plans.

Care shall be exercised in removing the forms to prevent spalling and chipping of the concrete. Prior to moving a segment from its as-cast position, erection marks identifying its location in the structure and order in the erection sequence shall be affixed to the inside of the segment.

(6) Test Samples

Additional test samples and testing for compressive strength on each precast segment and field closure joint shall be made by the Contractor to control the construction activities and to ensure adequate strength of these components at various stages of their manufacture and assembly. The Contractor shall make test cubes from concrete representative of that used to cast the structural component, in accordance with the applicable portion Section 1700, cured in the same manner as the structural components to ensure adequate compressive strength has been achieved in accordance with the plan requirements for the following conditions.

1. Prior to form release and / or moving the components to storage.

2. Prior to post-tensioning transverse tendons if the component is less than 28 days old.

3. Prior to placing a component into position in the structure and / or stressing of post-tensioning tendons if the component is less than 28 days old.

The test specimens for precast segments shall be stored in or on the segment, in a condition representative of the curing conditions that the segment is exposed to. The specimen shall be tested just prior to form removal. The Contractor shall provide sufficient specimens to allow for additional tests, as required.

(7) Curing Concrete

Curing shall be accomplished by the use of steam curing, such curing shall conform to Section 2.6 as modified by the following:

1) After placement of the concrete, members shall be held for a minimum four hour pre steaming period. If the ambient air temperature is below 100 C, steam shall be applied during the presteaming period to hold the air surrounding the member at a temperature between 100 C and 300 C. When the ambient air temperature is above 100 C, the member shall remain undisturbed in the ambient air for a four-hour pre steaming period.
2) To prevent moisture loss on exposed surfaces during the presteaming period, members shall be covered as soon as finishing is complete or the exposed surfaces shall be kept wet by fog spray or wet blankets.
3) Enclosures for steam curing shall allow free circulation of steam around all surfaces of the segments either formed or exposed and shall be constructed to contain the live steam with a minimum moisture loss. The use of tarpaulins or similar flexible covers will be permitted
4) Provided they are kept in good repair and secured in such a manner to prevent the loss of steam and moisture. These enclosures may also provide the required weather

protection if they are substantial enough to prevent wind and rain damage during pouring operations.

5) Steam at the jets shall be low pressure and in a standard condition. Live steam shall not be directed on the concrete, test cylinders, or forms

6) Such as to cause localized high temperature. During application of the steam the temperature rise within the enclosure shall not exceed 200C per hour. The curing temperature shall at no point within the enclosure exceed 650C and shall be maintained within a temperature range of 500C to 650C until the required strength for segment handling has been obtained. Control cylinders shall be covered to prevent moisture loss and shall be placed in a location where temperature is representative of the average temperature of the enclosure.

7) Temperature recording devices that will provide an accurate continuous permanent record of the curing temperature shall be provided by the Contractor. A minimum of two temperature recording devices per casting machine will be required for checking temperature.

8) The steam curing shall include a gradual cooling period during which the rate of decrease in temperature shall not exceed 200C per hour. The

9) Steam curing cycle shall include the gradual cooling period until the temperature inside the enclosure is within ± 100C of the outside.

10) Ambient temperature.

11) Curing of precast concrete (except match cast surfaces) after termination of the steam cycle shall continue by application of an approved curing compound and meet the requirements of Section 2.7. This membrane shall be applied to all exposed surfaces including segment exterior (once exposed by removal from the form).

12) For match-cast segments, the match-forming segment shall be exposed to the same curing environment (temperature and humidity) as the Segment being steam cured. (8) Finishing Concrete

All surfaces of segments and precast components except the roadway surface of superstructure segments shall meet the finish requirements as defined in Section 2.4. Minor breakage, spalling, or honeycomb (not over 25 mm deep) shall be repaired by a method approved by the Engineer. Major breakage or honeycomb will be subject to review by the Engineer. These areas may be repaired by a method approved by the Engineer if he determines that the structural or other functions of the segment will not be impaired. For cast-in-place construction, breakage, spalling or honeycomb on any mating surface of an in-place segment otherwise found acceptable, shall be repaired prior to casting the next segment. For precast segments, no surface finishing or repairs shall be performed on the matching joint surface until after final erection of the segment.

(9) Finish Roadway Surface of Superstructure Box Girder Segments

As soon as the concrete has been placed and vibrated in a section of sufficient width to permit working, the surface shall be approximately leveled, struck off and screeded such that a slight excess of concrete is carried out ahead of the screed to insure filling of all low spots. The screed shall be designed rigid enough to hold true to shape. A hydraulically driven, bare steel tube rotating in the opposite direction of travel may be used if heavy enough to prevent undue distortion.

The longitudinal screed shall be moved back and forth across the concrete while one end rests on the upper surface of the form (bulkhead) and the other end on the match-cast segment. The surface of the concrete shall be screeded a sufficient number of times, and at such intervals to produce a uniform surface, true to grade and free of voids. The screeded surface shall be worked to a smooth finish with a long handled wood or metal float of the proper size, or hand floated from bridges over the top slab.

After the water sheen has disappeared from the surface of the top slab, but while the concrete is still plastic, the final finish shall be applied to the top slab. The final finish shall consist of a U1 finish as specified in Section 2.4

Only minimum hand finishing will be permitted and when the Engineer deems the slab surface is being overworked all hand finishing will be stopped. Only minimal amounts of water will be allowed to aid in the finishing process when evaporation rates effect the quality of the finish. A fog spray shall be used to help retard surface evaporation, but shall not change the water-cement ratio at the deck surface. During periods of excessive drying, a cover of wet burlap or plastic sheeting will be maintained on the slab at all times until final cure cover is placed.

Monomolecular film coating applied to the surface of the slab to retain moisture may be used, provided they effectively retard surface evaporation and are adequately maintained throughout the finishing operation.

The bridge deck and approach slabs shall be subjected to smoothness tests using the Rainhart Profilograph and a Profile Index Value determined in accordance with test method entitled “Determining Profile Index Value using the Rainhart Profilograph”. Profiles will be obtained by the Engineer to within 2 m of the barrier of curb line. The profile index shall not exceed 12 for each wheel path and individual bumps or depressions shall not exceed 3 mm from the 5 mm blanking band. In addition, the surface shall meet a 5 mm in a 3 m straight edge check made transversely across the deck.

When no other surface treatment is intended, deck and approach slabs not meeting the above requirements shall be corrected at the Contractor’s expense. The Contractor shall provide the Engineer a written plan of corrective action for approval before implementation. Approval of the corrective plan will in no way relieve the Contractor of responsibility for meeting rideability requirements. In all cases a minimum of 40 mm of cover over reinforcing steel will be maintained. After corrective action, all decks and approach slabs will be subject to retesting with profilograph to insure compliance with specifications.

Expansion joint installation shall be delayed and the joint temporarily bridged to facilitate operation of the profilograph and corrective equipment across the joint wherever feasible.

It shall be the Contractor’s responsibility to schedule profilograph testing. Requests for testing shall be made at least five days prior to need. The Contractor shall insure that the area to be tested has been cleaned and cleared of all obstructions.

(10) Precast Segment Handling, Storage, and Shipment

1) General

It is the intent of this Contract that the Contractor shall provide precast segments that are cast and placed into the structure with zero defects.

Care shall be exercised in the handling of segments to prevent damage to them. Handling shall be done only by using the devices shown on the approved shop drawings for this purpose. Lifting devices incorporated into any segment shall be adequate to distribute the handling and erection stresses so as not to damage the segment.

The Contractor shall inspect each segment visually for evidence of damage or defect before, during and after critical operations and as often as necessary to ensure adequate quality control. The Contractor shall immediately bring all such evidence of damage or defect to the attention of the Engineer. The extent and frequency of inspection by the Engineer for quality assurance is the Engineer’s prerogative. Segments may be inspected at any time during construction as deemed necessary by the Engineer to monitor compliance with this specification.

Superstructure segments shall be stored level in the deck upright position and shall be firmly supported on a bearing system under the webs at the locations shown on the shop drawings, unless otherwise noted on the plans. The storage area of the segments shall be of suitable stability to prevent differential settlement of the segment supports, which results in an nstable storage condition during the entire period of storage.

The Contractor may request to vertically stack segments in the deck upright position provided he submits completed details of his stacking procedure and calculations substantiating that the segments will not be damaged or distressed by such stacking. The submittal shall be signed and sealed by the Contractor’s Engineer. In no case will stacking be permitted more than two high in a system, which induces forces in the lower segments. Any evidence of damage or distress, as determined by the Engineer, resulting from stacking of segments shall be cause for immediate discontinuance of this practice.

Prior to shipment, each segment shall be inspected for damage. The faces of all match cast joints shall be thoroughly cleaned of laitance, bond breaking compound and any other foreign material by wire brushing or light sandblasting. During transport, firm support at the bearing locations noted above for support during storage shall be provided and the segments shall be fully secured against shifting. Upon arrival at the erection site, each segment shall again be inspected.

If any damage has occurred during shipment, the Contractor shall immediately notify the Engineer. Erection of such damaged segments into the structure shall not proceed without authorization from the Engineer.

2) Damaged or Defective Segments

Isolated defects are defects or damage, which occur randomly and infrequently, as determined by the Engineer.

Recurring defects are defects or damages of the same general type and nature, which continue to be found in the same general location of the segments at an unacceptable frequency, as determined by the Engineer.

As a minimum, the first five segments cast and the first five segments erected will be jointly inspected by the Engineer, the Contractor and the Contractor's Engineer after casting, after moving to storage from the casting machine, and before and after erection. All segment defects shall be identified and categorized during this inspection. The Contractor and Contractor's Engineer shall examine the defects and propose to the Engineer, in writing:

a. The measures that the contractor shall take to prevent recurring defects in future segments. b. The method of repair of all defects discovered as a result of the inspection as required herein.

If recurring defects continue following implementation of the Contractor's preventive measures, or as detected at any time during the construction, the Engineer will instruct the Contractor, in writing, to cease operations producing such defective segments. The Contractor and Contractor's Engineer shall examine the defects and propose to the Engineer, in writing:

(1) The measures the Contractor shall take to prevent recurring defects in future segments, and (2) the method of repair of all defects discovered as a result of the inspection as required herein.

The Engineer will determine what constitutes damage or defect, whether the damage or defect is isolated or recurring, and will categorize the damage or defects. Three categories of defects are recognized by the Engineer for this purpose:

a. Cosmetic: Cosmetic defects or damages are those which do not affect the ability of the segment to resist construction or service loads or reduce the life expectancy of the structure. This category of defect includes a superficial discontinuity such as cracks, small spalls or honeycombed areas, or any defect that does not extend beyond the centerline of any reinforcing steel, or to any elements of the post tensioning system. Cosmetic defects of other types and causes may also be designated by the Engineer.

Repair of cosmetic defects shall be made in such a manner that the aesthetics and the structural integrity of the segments is restored.

b. Structural: This category of defect shall include any defect which will impair ability of the segment to adequately resist construction or service loads or reduce the life expectancy of the structure. Any defect or damage, which extends beyond the centerline of any reinforcing steel or into any element of the post-tensioning system or occurs in the deck portion of the segment, is considered a structural defect.

Examples of such defects include cracks, large spalls and honeycombed areas, major segregation or breakage of concrete; however, structural defects of other types and causes may be designated by the Engineer.

The Contractor’s Engineer shall be responsible for construction load analysis, service load analyses and life expectancy determinations.

Repair of structural defects shall be such that the aesthetics and structural integrity of the segment shall be completely restored to a condition to be expected hand the defect or damage not occurred.

c. Rejectable: a rejectable defect is any defect or damage, as determined by the Engineer, which will impair the ability of the segment to adequately resist service loads or construction loads, or will reduce the life expectancy of the structure and which cannot be successfully repaired such that the structural integrity is completely restored. Any segment with a rejectable defect will be deemed unacceptable and shall be removed from the work and replaced at no additional cost.

Damaged or defective segments may also be rejected by the Engineer for the following reasons:

i) Failure of the Contractor’s Engineer to approve proposed repair procedures.

ii) Failure of the Contractor to execute the repair according to the Contractor’s Engineer’s approved procedure.

iii) Rejection of the proposed repair procedure on repair by the Engineer.

iv) Failure of the Contractor to provide the required certification or demonstration that the repair was successful and that the defect no longer exists, as required below;

v) Failure of the Contractor to eliminate recurring defects.

d) Determination by the Engineer that the work or materials used in the work does not meet other requirements of the Contract Documents and is not acceptable.

Segments with structural defects will not be paid for until the repair procedure is complete and the segment is certified or demonstrated to be free of structural defect as required.

(11) Repairs

Cosmetic repairs shall only be made following procedures prepared by the Contractor, submitted in writing to and approved by the Engineer. The Contractor’s repair procedure shall identify those areas required to be repaired prior to post tensioning, and those that must be repaired after post- tensioning.

Structural repairs shall be made following procedures prepared by the Contractor. The repair procedure shall be signed and scaled by the Contractor’s Engineer, shall be submitted in writing to the Engineer, and shall include the following minimum information.

1) A detailed description and sketch of the defect.

2) The magnitude and type of the most critical construction loading and service life condition

to which the defective area will be subjected.

3) Detailed reinforcement requirements, material types, surface treatments, curing methods and general repair procedures proposed. The procedure shall clearly indicate those areas required to be repaired before erection, and those areas to be repaired after erection.

4) The specific nondestructive testing method and procedure by which the Contractor shall demonstrate to the Engineer that the defect no longer exists and the segment has been restored to a condition to be expected had the defect or damage not occurred. In lieu of physical demonstration, on a case-by-case basis, the Engineer may allow the Contractor to substitute a written certification by the Contractor's Engineer that the repair has been performed satisfactorily and that the defect no longer exists. This work shall not be the basis for any request for extension of time or additional compensation.

(12)Shear Key Repairs

Repairs to the shear keys along the webs shall be made after the segments have been erected. When 20 percent or more of the shear keys in a web have been damaged such that they cannot effectively transfer the shear across the joint, as determined by the Engineer, then the damaged shear keys shall be repaired after the segments have been erected and initially stressed together with no more than 10 percent of the final prestressing force applied across the joint. After the repair has been completed and obtained a minimum characteristic compressive strength of 32 MPa, the final prestressing force may be applied across the joint.

(13)Erection

1. General

An erection scheme for handling and erecting segments is shown in the plans. The erection scheme is a concept only, consistent with the overall bridge design. It is presented to aid the contractor in developing his method of construction, which is also to be consistent with the Overall bridge design. The Contractor shall be solely responsible for design, fabrication, assembly and operation of all equipment to be used for handling and erecting segments.

Erection of segments shall not begin until the required shop drawings calculations have been reviewed and approved by the Engineer. No extra payment will be made to the Contractor for any cost incurred in modifying the permanent structure due to temporary loadings induced By the Contractor's handling and erection equipment or his erection scheme.

Elevations and alignment of segments shall be carefully measured at each stage of erection with instruments capable of providing the degree Of accuracy necessary to assure that erection tolerances will be met. Any deviation from the table of elevations and alignment prepared by the Contractor shall be corrected so as to prevent accumulation of deviations using a method submitted by the Contractor and approved by the Engineer.

2. Age of Precast Segments at Time of Erection

Precast segments shall not be erected until they have reached the age of 14 days and have obtained the minimum specified strength in the plans.

3. Temperature of Precast Segments with Epoxy Joints

Erection of segments will be permitted only when the substrate temperatures of the mating surfaces are between 50C and 400C. Upon Notice by the Engineer, an artificial environment may be provided to maintain the substrate temperature within the permissible limits by creating an enclosure heated by circulating warm air or by radiant heaters. Localized heating shall be avoided and the heat shall be provided in a manner that prevents surface temperatures greater than 350C during the epoxy hardening period. Direct flame heating of concrete will not be permitted.

(14) Tolerances

The following tolerances shall apply to erection of superstructure segments:

1) The maximum differential between the outside face of adjacent segment in the erected position shall not exceed 5 mm.
2) Transversely, the angular deviation from the theoretical slope difference between two successive segment joints shall not exceed 0.001 Rad.
3) Longitudinally, the angular deviation from the theoretical slope change between two successive segments shall not exceed 0.003 Rad.
4) The difference in roadway elevation at the connection of two adjacent segments (measured perpendicular to the deck surface) and across closure joints shall be no greater than 3mm. If the Contractor fails to meet the tolerance, he shall grind the deck surface to meet the tolerance and re-groove the deck. All corrective work shall be at the Contractor's expense.
5) The horizontal and vertical position of a pier segment (superstructure segment which rests on a pier) shall be within 6mm of the longitudinal alignment, grade and cross-slope required by the approved erection plans. The longitudinal slope shall not vary more than 2mm in 3m from that required by the approved erection plans. These tolerances are for relative location of control point's not absolute location.
6) Dimensions from segment to segment shall be adjusted so as to compensate for any deviations within a single segment so that the overall dimensions of the completed structure will conform to the dimensions shown on the plans such that the accumulated maximum error should not exceed 1/1000 of the span length for either vertical profile and/or horizontal alignment. Deviations exceeding the erection tolerances listed above which are discovered during the match-casting operation shall be identified by after-cast surveys at the casting site before the matched-castings are separated. Corrections for these deviations shall be submitted to the Engineer prior to casting the next match-cast segment or in the cast-in-place closure pours.

(15) Special Requirements – Erection of Precast Segments by Cantilever Method

During erection by the cantilever method, the unbalanced load shall not exceed that shown in the erection drawings scheme included in the plans.

Accurate positioning of the segments comprising the pier table is very important as it will establish the line and grade for cantilevers in each direction. Each pier table must be positioned according to the final longitudinal alignment, grade and cross-slope. Further erection shall not continue until these segments of the pier table are properly tied down to the piers by the means provided. The horizontal and vertical alignment of the pier table shall be within 3mm of that required by the approved erection plans.

The alignment ad elevations of the cantilevers shall be checked by the Contractor and the Engineer, independently, within one hour of sunrise on each day that segments are to be erected. The measurements made by the Engineer and the Contractor shall agree to within 6mm.

If measured elevations deviated from the table of elevations, the Engineer shall have the right to suspend further erection of superstructure segments until the cause of the deviation is discovered and a corrective action plan, submitted by the Contractor, is approved by the Engineer. No additional payment or time will be made to the Contractor as a result of this suspension for unacceptable erection deviation.

(16) Epoxy Jointing of Precast Segments

A. Epoxy material placement, inspection, and testing shall be in accordance with AASHTO Materials Specification M235, AASHTO Standard Specifications for Highway Bridges, Division II, Construction, Sections 8.13.7 and these Special Provisions.

B. Application and Amount of Epoxy: The application shall begin immediately after a batch has been mixed. The epoxy bonding agent shall be applied in accordance with the manufacturer’s recommendations by spatula or gloved hand to completely and uniformly cover one of the faces to be joined to a nominal thickness of 2 mm, except that in the vicinity of internal post-tensioning ducts, it shall be applied to both surfaces to a nominal thickness of 1 mm. Epoxy shall not be applied to either face within 12 mm of post-tensioning ducts, conduits or outside edges except that, regardless of spacing, a bead of epoxy shall be applied between each and all post- tensioning ducts and conduits.

The amount of epoxy may be adjusted providing that a sufficient amount is applied to completely fill the interstitial space in the joint and to extrude a small bead from the joint after application of the compressive contact pressure. If a bead of epoxy is not extruded all around the joint, the joint may have to be pressure injected with epoxy or other remedial measures may have to be taken after all internal post-tensioning tendons have been grouted.

When epoxy is applied in conjunction with layers of woven glass matting and high density plastic or other approved material for the purpose of shimming a joint to correct alignment, then a proposal detailing the areas and layers of matting, amounts of epoxy, and operational procedures shall be submitted to the Engineer for review and approval prior to implementation. Application of epoxy bonding agent to the segment joints after combining the components shall follow the manufacturer's recommendations.

C. Closing Segment Joints: Immediately after the segment joint is covered with epoxy bonding agent, the segments shall be brought together and the specified compressive contact pressure applied in accordance with the approved erection procedures. A discernible bead line of extruded epoxy shall be apparent along the exposed edges of the joint or remedial measures such as epoxy injection may have to be taken as required by the Engineer.

D. Failure to Comply with Time Limits: The Contractor shall plan his post-tensioning operations so that the time elapsing between mixing of the components of the first batch of epoxy bonding agent applied to the segment joint and application of a compressive force averaging not less than

0.28 MPa over the entire joint does not exceed the manufacturer's recommendations. If this time limit is exceeded, the concrete segments shall be moved apart and all epoxy bonding agent shall be removed from both faces of the joint. If solvent is used to remove the epoxy bonding agent, re-application of epoxy to the joint surfaces shall not occur until solvent has dissipated and as approved by the Engineer.

E. Record of Jointing: The Contractor shall keep a record of each joint with the following details:

1. Segment, span, and joint numbers
2. Date and time of jointing
3. Batch number for resin and hardener
4. Maximum temperature of the mix
5. Weather conditions (temperature and humidity recorded at 15 minutes intervals)
6. Details of samples

(17) Closure Joints

Concrete for closure joints shall comply with the same specifications and criteria as the concrete in the segments and shall be included in the quantities and unit cost of precast pre stressed segmental concrete box girder. Concrete shall reach the minimum required strength as shown on the plans or in the Specifications prior to stressing the longitudinal post-tensioning. Formwork shall be adequately supported to take all loads applied and they shall not be removed until the concrete in the joints has reached its required strength and longitudinal tendons have been stressed.

(18) Final Clean Up

Before final acceptance, the Contractor shall clean the interior of the concrete box girders of all rubbish, excess materials, loose concrete, dirt and debris. The interior of the box girders shall then be swept out. The final clean up shall be performed after all work on the interior of the box girders, including grouting of all tendons and electric work, has been completed.

7.14 Expansion Joints

7.14.1. Description

This work shall consist of fabrication and placing of expansion joints as indicated on the drawing and conforming to these specifications, or as directed by the Engineer.

7.14.2. General

The expansion joints shall be designed and duly got approved by the Engineer. It shall cater for expected movement and rotation of the structure at the joints and provide smooth riding surface. It shall also be easy for inspection, maintenance and replacement.

Expansion joints shall be robust, durable, watertight and replaceable. Site fabricated expansion joints shall be prohibited. Expansion joints shall be obtained by the Engineer either directly or through the Contractor from approved manufacturers and be of proven type.

For bridges with prestressed concrete superstructure with individual span length more than 20 m or built with innovative design/construction elastomeric expansion joints of slab seal or strip seal type shall be provided.

For slab type of bridges of spans less than 10m continuous surfacing may be provided across the expansion gaps, supported on a 20 mm thick plate placed and fixed at the level of the deck slab. For bridges other than those mentioned in (c) above with spans above 10m, an alternative specification of sliding steel plate joint or filled joints with copper plates may also be adopted if approved by the Engineer, apart from elastomeric expansion joint of slab seal or strip seal type. Vehicular traffic shall not be allowed over expansion joints after its construction for such period as may be determined by the Engineer.

Proprietary type deck joints offered by the Contractor in lien of the type specified shall comply in all respects with the manufacturer's specifications and meet the required range of movements and rotations and be fit for the purpose of ensuring satisfactory long term performance in the bridge. Where alternative type proprietary deck joints are proposed by the Contractor, the following information shall be provided.

Name and location of the proposed manufacturer.

Dimensions and general details of the joint including material specifications, holding down bolt or anchorage details and installation procedures.

Evidence of satisfactory performance under similar environmental conditions of similar joints being produced by the manufacturer.

Any acceptance of alternative types will be at the sole discretion of the Engineer.

Such deck joints shall be installed in accordance with the manufacturer's recommendations and to the general requirements of this Specification.

No expansion joint shall be provided only for the width of the carriageway. It shall follow the profile including the kerb and the footway and facia, if provided. The type of expansion joint for the latter may be made different from that used for the carriageway expansion joint.

Type of Expansion Joint to be used shall be as shown on approved drawing. Expansion Joints shall be procured by the manufacturers approved by MORT&H.

The MORT&H has issued modified interim specifications for expansion joints vide letter dated 31/03/1997 and revised vide letter dated 17/07/1997. These specifications are also included vide following modifications.

Suitability Criteria For Adoption Of Different Types 0f Expansion Joints

Sr. No	**Type of Expansion**	**Suitability for adoption joint**	**Expected Service Life**	**Special Consideration**
1.	Filler Joint	Fixed end of simply supported spans with insignificant movement or simply supported spans not exceeding 10 meter s.	10 years	The sealant and joint filler would need replacement if found damaged.
.	Asphaltic Plug Joint	Simply supported spans or right or skew (Upto 20 degree), moderately curved or wide deck with maximum horizontal movement not exceeding 25 mm. Ambient temperature should be in the range of 5 degree to 50 degree Celsius.	10 years	Only for decks with bituminous /asphaltic wearing coat. Not suitable for bridge with longitudinal gradient more than 2 % and cross camber / super-elevation exceeding 3%. Not suitable for curved spans and spans resting on yielding supports.
3.	Compression Seal Joint* (Chloroprene Seal & Cell Foam Seal)	Simply supported for continuous spans right or skew (Upto 30 degree), moderately curved with maximum horizontal movement not exceeding 40 mm.	10 years	Chloroprene / Closed Form Seal may need replacement during service.

Sr. No	Type of Expansion	Suitability for adoption joint	Expected Service Life	Special Consideration
4.	Single strip seal joint *	Moderate to large simply supported, cantilever / continuous construction having right, skew or curved deck with maximum horizontal movement Upto 70 mm	25 years	Elastomeric seal may need replacement during service.
5.	Modular Strip / Box Seal Joint	Large to very large continuous / cantilever construction with right, skew or curved deck having maximum horizontal movement in excess of 70 mm.	25 years	Elastomeric seal may need replacement during service.
6.	Special Joints for special conditions	For bridges having wide decks / span length of more than 120 m or / and involving complex movements / rotations in different directions / planes, provision of special type of modular expansion joints such as Swivel joists joints may be made	25 years	Elastomeric seal may need replacement during service. Provision of these joints may be made with prior approval of the Ministry.

* - These are proprietary items for which 10 years warranty shall be insisted upon from the suppliers.

7.14.3. Strip Seal Expansion Joint

7.14.3.1. Components

Strip seal expansion joint shall comprise the following items

a) Edge bums - This special claw leg profiled member shall be of extruded rolled steel section combining good weldability with notch toughness.-

b) Strip seal - This shall be of chloroprene with high tear strength, insensitive to oil, gasoline, and ozone. It shall have high resistance to, aging. This components provided to ensure water tightness, shall have bulbous shape of the pan of the seat which is inserted into the groove, provided in the edge beam. The seal should be vulcanised in single operation for minimum full length of joint.

c) Rigid Anchorage - This shall be welded to the edge beam at staggered distance,

d) Anchor loops - This shall be made of weld able steel connecting the rigid anchorage with deck reinforcement.

7.14.3.2. Material

a) Edge beams of this special section are at present being directly imported in India. The steel shall conform to steel grade Rst 37-2 of German Standard or equivalent.

b) Chloroprene of strip seal shall conform to clause 915.1 of IRC: 83 (Part 1J). The properties of chloroprene conform to Table 2.26-1.

c) Anchorage steel shall conform to IS: 2062.

d) Anchor loop shall conform to IS: 2062.

Sealing element is made of chloroprene and must be an extruded section. The working movement range of the sealing element shall be at least 80 mm with a maximum of 100 min at right angles to the joint and ± 40 mm parallel to the joint.

STRIIP SEAL ELEMENT SPECIFICATION

Swelling behavior in Oil	
(116 h/25 per cent C) ASTM Oil no.	
PROPERTY	SPECIFIED VALUE
Volume Change	Max 5 per cent
Change in hardness	Max 10 Shore A
ASTM Oil no.3	
Volume Change	Max 25 per cent
Change in hardness	Max 20 Shore A
Cold Hardening Point	Min -35 deg C
Hardness	63 ± 5 Shore A
Tensile Strength	Min 11 MPa
Elongation at fracture	Min 350 per cent
Tear Propagation Strength	
Longitudinal	Min 10 N/mm
Transverse	Min 10 N/mm
Shock Elasticity	Min 25 per cent
Abrasion	Min 225 mm3
Residual Compressive Strain	
(22 h\70 C/360 per cent strain)	Max 28 per cent
Ageing in hot air	
(14 days/70 deg C) Change in hardness Change in tensile strength	
Change in elongation at fracture	Max+5 Shore A
	Max -20 per cent
	Max -20 per cent

7.14.3.3. Fabrication (Pre- installation)

a) Rolled steel profiles for edge beams shall be long enough to cater for a 2-lane carriageway. These shall be cut to size of actual requirements by means of a metre box saw. Alignment of the cut-to-size steel profiles shall then be made in accordance with the actual bridge cross-section on worktables. For this purpose, the contour of bridge cross-section shall be sketched onto these tables. After the steel profiles are aligned, they will be chucked to the tables by means of screw clamps and tacked by arc welding.

b) Anchor plates shall be cut to the required size by gas cutting. These shall be welded to the edge beams.

c) Anchor loops shall be bent to the required shape and welded to anchor plates.

d) The finally assembled joints shall then be clamped and transported to the work site.

7.14.3.4. Handling and Storage

a) For transportation and storage, auxiliary brackets shall be provided to hold the joint assembly together.

b) The manufacturer shall supply either directly to the Engineer or to the Bridge Contractor all the materials of strip seal joints including sealants and all other accessories for the effective installation of the/jointing.

c) Expansion joint material shall be handled with care. It shall be stored under cover on suitable lumber padding by the Contractor to prevent damage. Any damage occurring after delivery shall be made good at the Bridge Contractor's expense to the satisfaction of the Engineer.

7.14.3.5. Installation

The width of the gap to cater for movement due to thermal effect, prestress, shrinkage and creep, superstructure deformations (if any) and sub-structure deformations (if any) shall be determined and intimated to the manufacturer. Depending upon the temperature at which the joint is likely to be installed, the gap dimension shall be preset.

Taking the width of gap for movement of the joint into account, the dimensions of the recess in the decking shall be established in accordance with the drawings or design data of the manufacturer.

The surfaces of the recess shall be thoroughly cleaned and all dirt and debris removed. The exposed reinforcement shall be suitably adjusted to permit unobstructed lowering of the joint into the recess.

The recess shall be shuttered in such a way that dimensions in the joint drawing are maintained. The formwork shall be tight.

Immediately prior to placing the joint, the presetting shall be inspected. Should the actual temperature of the structure be different from the temperature provided for presetting, correction of the presetting shall be done. After adjustment, the brackets shall be tightened again.

The joint shall be lowered in a pre-determined position. Following placement of the joint in the prepared recess, the joint shall be levelled and finally aligned and the anchor loops on one side of the joint welded to the exposed reinforcement bars of the structure. Upon completion, the same procedure shall be followed for the other side of the joint. With the expansion joint finally held at both sides, the auxiliary brackets shall be released, allowing the joint to take up the movement of the structure.

High quality concrete shall then be filled into the recess. The packing concrete must feature low shrinkage and have the same strength as that of the superstructure, but in any case not less than M 35 grade, Good compaction and careful curing of concrete is particularly important after the concrete has cured, the movable installation brackets still in place shall be removed.

Rolled up neoprene strip seal shall be cut into the required length and inserted between the edge beams by using a crow bar pushing the bulb of the seal into the steel grooves of the edge beams. A landing to a bead shall be formed in the thickened end of the edges of the seal which would force the thickened end against the steel beam due to wedge effect when the strip seal is buttoned in place.

7.14.3.6. As soon as the concrete in the recess has become initially set, a sturdy ramp shall be placed over the joint to protect the exposed steel beams and neoprene seals from site traffic. Expansion joint shall not be exposed to traffic loading before the carriageway surfacing is placed.

7.14.3.7. The carriageway surfacing shall be finished flush with the top of the steel sections. The actual junction of the surfacing/wearing coat with the steel edge section shall be formed by a wedge shaped joint with a sealing compound. The horizontal leg of the edge beam shall be cleaned beforehand. It is particularly important to ensure thorough and careful compaction of the surfacing in order to prevent any premature depression forming in it.

Acceptance Test

i) All steel elements shall be finished with corrosion protection system.
ii) For neoprene seal, the acceptance test shall conform to the requirements stipulated in Table 2.26-1. It shall also be stretch tested. If a manufacturer is to supply this type of joint they will have to produce a test certificate accordingly conducted in a recognized laboratory, in India or abroad.
iii) In view of the importance of the built up edge beams, special investigation of fatigue strength of this section with anchorages to withstand 2 x 106 load change cycles without showing sips of damage, will be required. The supplier shall have to produce a test certificate in this regard conducted in a recognised laboratory, in India or abroad.
iv) The manufacturer shall produce test certificates indicating that anchorage system had been tested in a recognized laboratory to determine optimum configuration of anchorage assembly under dynamic loading
v) The manufacturer shall satisfy die Engineer that water tightness test for the type of joint has been carried out in a recognized laboratory to check the water tightness under a water pressure of 4 bars.
vi) As strip seal type of joint is specialised in nature, generally of the proprietary type, the manufacturer shall be required to produce evidence of satisfactory performance of this type of joint.

7.14.4. Tests and Standards of Acceptance

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria.

The work shall conform to these specifications and shall meet the prescribed standards of acceptance.

Describe over Modular Strip/Box Seal Joint: As per the "Specification for Road & Bridge works", MoRTH.

7.15 Wearing Coat and Appurtenances

7.15.1. Description

This work shall include wearing coat and bridge appurtenances such as railing, approach slab, drainage spouts, weep holes in conformity with details shown on the drawing and these specifications or as Noticed by the Engineer.

7.15.2. Wearing Coat

7.15.2.1. Bituminous Wearing Coat

(1) Specifications for bituminous concrete/bitumen mastic in wearing coat shall conform to Section 500 of "Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Principles of bituminous wearing coat shall comprise the following:

i) A Layer of mastic asphalt, 6 mm thick after applying a prime coat over the top of the deck before the wearing coat is laid. The prime coat and the Layer of mastic asphalt shall be laid as per Clause 2.12 of these specifications and Clause 515 of Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress respectively.

ii) 50 mm thick asphaltic concrete wearing coat in two layers of 25 mm each as per Clause 512 of "Specifications for Road & Bridges Works" (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

In case of high rainfall intensity areas, the, thickness of mastic asphalt layer may be increased to 12 mm.

(2) For high traffic density, an alternative specification for wearing course comprising 40 mm bituminous concrete overlaid with 25 mm thick bitumen mastic layer can be adopted. The work shall be done in conformity with Section 500.

7.15.2.2. Cement, Concrete Wearing Coat

Cement concrete wearing coat may be provided in case of isolated bridge construction or bridges located in remote areas. It shall not be laid monolithic with the deck.

The thickness of wearing coat shall be 75 mm. The minimum grade of concrete shall be M 30 with water cement ratio as 0.4.

Curing of wearing coat earlier than what is generally required may be resorted to, so as to avoid formation of shrinkage cracks in hot weather.

All carriageway and footpath surfaces shall have non-skid characteristics.

The cross slope in the deck shall be kept as 2.5 per cent for decks, level in longitudinal profile.

7.15.2.3. For providing cross camber no variation in thickness of wearing coat shall be permitted.

7.15.3. Railings

7.15.3.1. General

a) Bridge railing includes the portion of the structure erected on and above the kerb for the protection of pedestrians and traffic,
b) Railings shall not be constructed until the centering false work for the span has been released and the span is self-supporting. For concrete with steel reinforcement, specifications of die items of controlled concrete and reinforcement mentioned under relevant sections of these specifications shall be applicable.
c) The type of railing shall be carefully erected true to line and grade. Posts shall be vertical with a tolerance not to exceed 6 min in 3 meters. Me pockets left for posts shall be filled up with non- shrinkable mortar.
d) The type of railing to be constructed shall be as shown on the drawings.
e) Care shall be exercised in assembling expansion joints in the railings to ensure that they function properly.
f) The bridge railings shall be amenable to quick repairs.
g) Railing materials, particularly metal railings, shall be handled and stored with cam, so that the material and parts are kept clean and free from damage. Railing materials shall be stored above the ground on platforms, skids, or other supports and kept free from grease, dirt and other contaminants.
h) Any material, which is lost, stolen or damaged after delivery, shall be replaced or repaired by the Contractor. Methods of repair shall not damage the material or protective coating.

7.15.3.2. Metal Railings

Materials, fabrication, transportation, erection and painting for bridge railings shall conform to the requirements of section 2.20.

All complete steel rail elements, pipe terminal sections, posts, bolts, nuts, hardware and other steel fittings shall be galvanised or painted with an approved paint.

If galvanised, all elements of the railing shall be free from abrasions, rough or sharp edges, and shall not be kinked, twisted or bent. If straightening is necessary, it shall be done by methods approved by the Engineer.

Damaged galvanised surfaces, edges of holes and ends of steel railing cut after galvanising shall be cleaned and re galvanised.

The railing shall be carefully adjusted prior to fixing in place to ensure proper matching at abutting joints and correct alignment and camber throughout their length. Holes for field connections shall be drilled with the railing in place in the structure at proper grade and alignment.

Unless otherwise specified on the drawings, metal railing shall be given one shop coat of paint and three coats of paint after erection if sections are not galvanised.

Railings shall not follow any irregularity in the alignment of the deck. When shown on the drawings, the rail elements shall be curved before erection.

7.15.3.3. Cast in Situ Concrete Railings

The portion of the railing or parapet, which is to be cast in place, shall be constructed in accordance with the requirements for Structural Concrete in Section 2.18. The reinforcement shall conform to Section 2.6.

Forms shall either be of single width boards or shall be lined with suitable material duly approved by the Engineer. Form joints in plane surfaces will not be permitted.

All mouldings, panel work and bevel strips shall be constructed according to the details shown on the drawings. All comers in the finished work shall be true, sharp and clean cut and shall be free from cracks, spalls or other defects. Casting of posts shall be done in single pour.

7.15.3.4. Precast Concrete Railings

Precast members for railings shall be of reinforced cement concrete and shall conform to the specifications given in Sections 2.17 and 2.18. The maximum size of the aggregate shall be limited to 12 mm and the concrete grade shall be M30. The precast members shall be removed from the moulds as soon as practicable and shall be kept damp for a period of at least 10 days. During this period they shall be protected from sun and wind. Any precast member that becomes chipped, marred or cracked before or during the process of placing shall be rejected. Special care shall be taken to watch the surface of the cast in situ portion of the deck.

7.15.4. Approach Slab

Reinforced concrete approach slab covering the entire width of the roadway shall be provided as per details given on the drawings or as approved by the Engineer. Minimum length of approach slab shall be 3.5 in and minimum thickness 300 mm.

The cement concrete and reinforcement shall conform to Sections 2.18 and 2.17 respectively.

The base for the approach slab shall be as shown on the drawings or as directed by the Engineer.

7.15.5. Drainage Spouts

7.15.5.1. This work shall consist of furnishing and fixing in position of drainage spouts and drainage pipes for bridge decks.

Drainage along longitudinal direction shall be ensured by sufficient number of drainage fixtures embedded in the deck slab. The spouts shall be of not less than 100 mm in diameter and shall be of corrosive resistant material such as galvanized steel with suitable cleanout fixtures. The spacing of drainage spouts shall not exceed 10 in. The discharge from drainage spout shall be kept away from the deck structure. In case of viaducts in urban areas, the drainage spouts should be connected with suitably located pipelines to discharge the surface run off to drains provided at ground level.

7.15.6. Fabrication

The drainage assembly shall be fabricated to the dimensions shown on the drawings; all materials shall be corrosion resistant; steel components shall be of mild steel conforming to IS: 226. The drainage assembly shall be seam welded for water tightness and then hot dip galvanised.

7.15.7. Placement

The galvanised assembly shall be given two coats of bituminous painting before placement. The whole assembly shall be placed in true position, lines and levels as shown in the drawing with necessary cut out in the shuttering for deck slab and held in place firmly. Where the reinforcements of the deck are required to be cut, equivalent reinforcements shall be placed at the comers of the assembly.

7.15.8. Finishing

After setting of the deck slab concrete, the shrinkage cracks around the assembly shall be totally sealed with polysulphide sealant or bituminous sealant as per IS: 1834 and the excess sealant trimmed to receive the wearing coat. After the wearing coat is completed, similar sealant shall be finished to cover at least 50 mm on the wearing coat surface all round the drainage assembly.

7.15.9. Weep Hole

Weep holes shall be provided in solid plain concrete/reinforced concrete, brick/stone masonry, abutment, wing wall and return walls as shown on the drawing or directed by the Engineer to drive moisture from the back filling. Weep holes shall be provided with 100 mm dia AC pipe for structures in plain/reinforced concrete or brick masonry. In case of stone masonry, weep holes shall be 80 mm wide, 150 mm high or circular with 150mm diameter. Weep holes shall extend through the full width of concrete/masonry with slope of about 1 vertical: 20 horizontal towards the draining face. The spacing of weep holes shall generally be 1m in either direction or as shown in the drawing with the lowest at about 150 mm above the low water level or ground level whichever is higher or as directed by the Engineer.

7.15.10. Tests and Standards of Acceptance

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

7.16 REINFORCED EARTH

7.16.1. Scope

The work covers the construction of reinforced earth structures, together with the construction of earthwork in layers, assembly and erection of reinforcing elements and placement of facing panels and all associated components.

7.16.2. Reinforcing Element

7.16.2.1. The reinforcing element shall be of Geotextile, aluminium alloy strip, copper strip, carbon steel strip, mats of metal or synthetic grids, or any other proprietary material which may be approved by the Engineer and indicated on the drawings.

7.16.2.2. Geotextile

The material shall conform to Clause 701.2.6 of “Specifications for Road & Bridges Works” (Fifth Revision / Latest Revision) issued by the Ministry of Shipping, Road Transport & Highways, Government of India and published by the Indian Roads Congress.

7.16.2.3. Aluminium alloy strip shall comply with BS: 1470 quality 5454 in the H 24 condition.

7.16.2.4. Copper strip shall comply with BS: 2870 quality C 101 or C 102 in the 1/2 H condition and shall have 0.2 per cent proof stress of not less than 180 N/mm2.

7.16.2.5. Carbon steel strip which shall be galvanized shall comply with BS: 1449 (Part 1), either quality KHR 34/20 P or quality 50/35 P, each having a silicon content of not less than 0.25 per cent and not more than 0.40 per cent. The fabricated element shall be galvanized in accordance with BS: 729, and the average zinc coating weight for any individual test area shall not be less than 1000 gm/sq.m.

7.16.2.6. Stainless steel strip shall comply with BS: 1449 (Part 2) quality 316 S 31 or 3/6 S 33 except that the Material shall be cold rolled to provide a 0.2 per cent proof stress of not less than 400 N/sq. mm and the tensile strength shall not be less than 540 N/sq. m.

7.16.2.7. All metallic components buried in soil shall be of electrolytically compatible materials.

7.16.2.8. Geogrids

The supply of geogrids shall carry a certification of BIS or ISO 9002 for all works. While the reinforcing element for wall or slope portion shall be with mono oriented Geogrid, there enforcement for the foundation of a reinforced earth wall or slope shall be with bi-directionally oriented Geogrid.

For mono oriented Geogrid, the characteristic design tensile strength at a strain not exceeding

10 per cent in 100 years shall be at least 40 KN/m when measured as per GRI: GG3. The strength for bi directionally oriented Geogrid in the longitudinal direction shall be at least 40 Min at a maximum elongation of 15 per cent. The Geogrid shall be inert to all naturally occurring chemicals, minerals and salts found in soil.

7.16.3. Earth Fill

The fill material for reinforced earth structures shall have an angle of interface friction between the compacted fill and the reinforcing element of not less than 25O C, measured in accordance with IS: 13326 (Part 1). The soil should be predominantly coarse grained; not more than 10 per cent of the particles shall pass 75-micron sieve. The soil should have properties such that the salts in the soil should not react chemically or electrically with the reinforcing elements in an adverse manner.

7.16.4. Facia Material

(1) The facing shall comprise of one of following:

(a) Reinforced concrete (Cast in situ or precast) slabs

(b) Plain cement concrete form fill hollow block (precast) Masonry construction, Rubble facia

(c) Other proprietary and patented proven system

The facing shall be sufficiently flexible to withstand any deformation of the fill.

(2) Facia, unit joint filler should be durable resistant to the effect of air pollution and water/saline water.

(3) Bedding material shall consist of either cement mortar or a durable gasket seating such as resin bonded cork strip.

(4) Connection between the facia and the reinforcing element shall be by using polyethylene strips/rods, fiberglass dowels or any other material shown in the drawing. Any other material used shall be tested to provide 100 per cent joint strength as of parent element in continuity.

Overlapping in principal reinforcement or in the joint shall ensure load transfer through joints, perpendicular to the direction of laying.

7.16.5. Construction Details

The plan area of the reinforced earth structure shall be excavated to provide a nominally level base which may be stepped at the back as required to receive the horizontal reinforcing element grid.

The depth of the foundation below the finished ground level at the foot of the slope or wall shall not be less am 1000 mm.

Additional strip footing, trough guide made of concrete or anchor keypad shall be provided at founding level to receive the facia or the bottom most reinforcement connection. This shall have adequate sod cover against erosion and scour in particular cases.

7.16.5.1. Orientation

The reinforcing elements shall be placed at right angles to the face of the wall, with greater cross sectional dimension in the horizontal plane. The placement of the elements including their vertical/horizontal spacing and length shall be as in the drawing.

7.16.5.2. Facing Batter

It may be necessary to set facing unit at an additional batter than as provided in the drawing as there is a tendency for initially positioned units of facia, to lean outward as the fill material is placed and compacted. Care and caution shall be taken to rectify this phenomenon.

7.16.5.3. Drainage

Drainage shall be provided as per drawing given in detail. The retained fill shall have a suitably designed drainage bay to allow free draining of the reinforced fill.

7.16.5.4. Laying and Compacting

The reinforcing elements shall be laid free from all kinks, damage and displacement during deposition, spreading, levelling and compaction of the fill. The programme of filling shall be such that no construction plant runs directly on the reinforcement.

All construction plant having a mass exceeding 1000 kg shall be kept at least 1.5 in away from the fact of slope or wall. In this area (upto 1.5 in from the face of slope or wall), following compaction plant shall be used:

i) Vibratory roller having a weight per metre width of roll not exceeding 1300kg with total weight not exceeding 10,000 kg.

ii) Vibratory plate compactor of maximum weight 1000 kg Vibro tamper having a weight not exceeding 75 kg

Compaction by any other method like using dozer or back blade compaction by dozer or excavator bucket shall be permitted with due approval from the Engineer after ascertaining the level of compaction so achieved.

During construction of reinforced fill, the retained material beyond the reinforcement at the rear or the structure shall be maintained at the same level as reinforced fill.

The compacted layer shall not be more than 200 mm, to achieve compaction of 95 per cent of maximum laboratory density where measured as per IS: 2720 (Part 8). Temporary formwork shall be used to support the construction as per specified details given in the drawing. The forms, scaffolding and props shall be sufficient in numbers to allow taking up of a sectoral construction schedule specified in the design.

Geotechnical Investigation shall be carried out as per section 2400 of MoRTH Specification.

7.17 PVC Water stops and Expansion Joint

7.17.1. Scope

The work under this Section include all labour, materials and equipment required for the supply, fabrication (if any), storage, handling, placing and splicing of PVC Water stops and other components to be incorporated in the movement joints in concrete structures as shown on the Construction Drawings, or as required by Engineer-in-Charge.

The work shall include all the necessary supports and ties required for placing water stops and other materials.

7.17.2. Submittals

Prior to the commencement of any work being carried out on water stops and joints the Contractor shall submit to the Engineer-in-Charge the detail planning for that part of the works. The Engineer-in-Charge reserves the right to require any additional information deemed necessary to be included in submitted documents.

Notwithstanding the above, the Contractor shall submit to the Engineer-in-Charge the details covering the properties and performance, including the certified copies of reports of all tests made by the manufacturers, along with material samples of the products, of:

- PVC Water stops
- Joint filers
- Joint sealing compounds (asphalt seal)

7.17.3. Codes and Standards

Water stops and joints shall be constructed in accordance with the drawings. The Contractor shall provide a method statement for the installation and protection of the water stops at joints and the placing of concrete around the water stops for the approval of the Employers Representative. Water stops shall comply with the relevant Indian Standards or relevant international standard;

- IS 12200: Provision of water stops at transverse and contraction joints in masonry and concrete dams
- IS 13143: Specification for sealing joints in concrete lining on canals – Sealing compound
- IS 12118 Part 1: Specification for two parts polysulphide based sealants: Part 1

General requirements

- IS 12118 Part 2: Specification for two parts polysulphide based sealants: Part 2 Method of tests
- IS 1838 Part 1: Specification for preformed fillers for expansion joints in concrete pavements and structures (non-extruding and resilient type): Part 1 Bitumen impregnated fibre
- IS 15058 PVC Water-Stops at Transverse Contraction Joints for Use in Masonry and Concrete Dams Specification
- IS 11433 (Part 1) Specification for one part grade polysulphide base joints sealant Part 1 General requirements
- IS 11433 (Part 2) Specification for one part grade polysulphide base joints sealant Part 2 Methods of Test

7.17.4. Movement Joints in General Concrete Structures

- The term movement joint comprises both, the expansion and the contraction joints in concrete structures. Movement joints shall be constructed at such locations and to such dimensions as shown on the Construction Drawings or as directed by the Engineer-in-Charge. The Contractor shall supply and install the various joint components as specified herein, as shown on the Construction Drawings and in accordance with the manufacturer's recommendations.
- No fixed metal embedded in the concrete shall be continuous through a movement joint except where expressly shown on the Construction Drawing.
- Expansion joints may be comprised of the following elements:

- Flexible PVC water stop,
- Joint filler,
- Joint sealing compound (asphalt seal),
- Bituminous coating.
- Contraction joints may be comprised of the following elements:
- Flexible PVC water stop,
- Metal sealing strip,
- Bituminous coating or other approved bond breaker.

7.17.5. Materials

7.17.5.1. PVC Water stops

- Water stops shall be made of extruded polyvinyl chloride (PVC) conforming to IS:

12200-2001.

Material for water stops shall be clean, homogeneous and free from porosity and other imperfections.

- Water stops will have minimum width of 200 mm for joints in general Minimum thickness shall be 10 mm.
- The properties of the PVC water stops shall meet the requirements of IS 15058
- The wings of the PVC water stop shall be provided with corrugations or bulbs to achieve good bond. PVC water stops in expansion joints shall be provided with hollow Centre bulb.
- Water stops must have been tested by the manufacturer as follows:
  - o Tensile strength, Tear resistance and ultimate elongation shall be tested in accordance with IS: 8543, specimens being cut by means of Die "C". Conformity shall be determined on the average of results from test on five specimens.
  - o Modulus of elasticity shall be tested by clamping the specimen on the testing machine in such a manner to form a cantilever beam with the 25 mm dimension as the beam width. The specimen shall be held between the centre line and nearest width on one side of the piece so as to result, with the load applied at the farthest rib from the clamp, in a nominal span of 4 cm in length. Load shall be applied across the full width of the specimen by a rigid, blade type,

    loading head of 1 mm contact edge radius. With load value being that obtained for a deflection rate of 5 mm/min., the modulus of the material shall be calculated from the formula E = PL3/3DI, in which:
  - o E = modulus of elasticity (N/mm2)
  - o P = applied load (N)
  - o L = span length (mm)
  - o D = deflection under applied load (mm)
  - o I = moment of inertia of the specimen section (mm4)
  - o The average thickness of specimen may be used for calculation of moment of inertia.

    Conformity shall be determined on the average of results from test on three specimen. Each specimen shall 25 mm in length and of the full cross section of the finished waterstop.
  - o Cold bend test: Each specimen shall be 25 mm wide and approximately 150 mm long. The specimen shall be cooled to 5°C, then immediately bent through 180° around a 6 mm diameter mandrel. Any cracking shall constitute failure. Conformity shall be determined from the test conducted on three sheet samples in the range of 1.5 to 3.0 mm thick.

- o Effect of alkali :
- o Either a single sample cut from the finished water stop, weighing from 75 and 125 g or
- o Six strips from a sheet of PVC compound, each being 150 mm long and approximately 20 mm wide.
- o For the test on i.), the sample shall be weighed to the nearest milligram. For tests on ii.), the strip shall be weighed together, not singly, also to the nearest milligram. The hardness shall be measured in accordance with IS: 3400 (Part 2).
- o The specimen shall be totally immersed in a solution consisting of 5.0 g C.P. sodium hydroxide and 5.0 g C.P. potassium hydroxide dissolved in 1 litre of distilled water. The solution shall be maintained at 20° C to 25°C and shall be replaced every 7 days with a fresh solution at the same temperature. At 7 and 28 days, the specimen shall be removed, rinsed, surface dried, air-dried for 10 minutes and then checked for changes in weight. At 7 days it shall also be checked for any change in hardness. Weight changes shall be recorded as a percentage of the original weight and hardness change in durometer units.

· Storage of material prior to placement shall be made in such a way as not to alter the properties of the material during storage. Water stops shall be stored so as to permit free circulation of air around them. All materials shall be protected from contact with oil and grease. Water stops shall be stored in a place protected from the direct rays of Sun or to any other heat source.

· Water stops shall be joined and fixed in place in accordance with manufacturer's recommendations to form a continuous watertight barrier. All cross-pieces, T-pieces and corner- pieces shall be factory produced. All joints shall be welded with approved, thermostatically controlled electric heat equipment. The temperature at which the splices are made shall be sufficient to melt but not char the plastic material. All splices shall be neat with the ends of the joined waterstops in true alignment. A mitre-box guide and portable knife shall be provided for cutting the ends to be joined to ensure good contact between joined surfaces.

7.17.5.2. Joint Filler

Bituminous fibre sheet shall be 12 mm thick minimum or as shown on construction drawings and shall conform to IS 1838 (Part 1) for preformed expansion joint filers for concrete paving and structural construction (non-extruding and resilient bituminous types).

7.17.5.3. Joint Sealing Compound (asphalt seal)

Joint treatment shall be performed by asphalt seal as per IS 4461 or IS 11433. The joint sealant shall comply with IS 13143 Specification for sealing joints in concrete lining on canals – Sealing compound

7.17.5.4. Bituminous Coating

Bituminous coating shall consist of two (2) layers of coating as per IS: 290.

7.17.6. Execution

Movement joints in General Concrete Structures

- The Contractor shall supply all necessary supports and ties required for placing the waterstop and shall position it so that its central axis coincides with the joint centre. Care shall be taken that waterstop does not bend or deflect during concreting. Concrete adjacent to the waterstop shall be thoroughly worked to ensure full contact with the waterstop but without damaging it. PVC materials shall be protected from sunlight until installation is completed.
- Before casting the second part of a movement joint, the whole surface shall be covered with bituminous coating, bituminous fibre sheet joint filler, or other approved bond breaker as shown on the Construction Drawings.
- Before applying the joint sealant, the joint shall be raked out to a depth as specified. All laitance, dirt, oil and foreign matter shall be removed from the joint by sandblasting, compressed air, grinding discs, or other effective means, and the concrete surfaces coated with an approved suitable primer. Joint sealant shall be placed after the concrete curing period in accordance with manufacturer's instructions. The concrete surface temperature shall not be higher than 30°C at the time of placing, and the concrete shall be surface dry. After placing, the sealant shall be protected from the effects of water for a period of 10 hours.
- Sealant that becomes unbonded from the concrete, or cracks, or shows any other defects before final acceptance of the work, shall be replaced by the Contractor.

7.18 Additional Technical Specification

7.17.7. Protective coatings for concrete

Description

This work shall consist of the application of protective coating for exposed concrete structures specified on the Drawings or otherwise directed to be protected. The work includes, but not limited to, the preparation of surfaces, application and curing of the primer and coating, protection of the work and furnishing all labour, equipment and materials needed to perform the work.

Materials

a) Coating on external surfaces of Deck / Girder / box.

The protective coating shall comprise of epoxy – phenolic primer and an intermediate coat of epoxy – phenolic interpenetrating polymer network system and a top coat of interpenetrating polymer network compatible polyurethane, the IPN system of CBRI Roorkee know-how. The total dry film thickness shall not be less than 250 microns and the system shall have the following properties.

Bond Strength with concrete, N/mm2 : > 2.5 BS 3900-E-10-9

Tensile Strength, N/mm2 : > 15 ASTM D-2370

Elongation % : > 15 ASTM D-2370

Water Vapour transmission, mg / cm2 / mm / 24 hr < 0.15 ASTM D-1653

UV – Resistance : Excellent b) Coating on sub-structure exposed to atmosphere.

The coating shall comprise of two coats of aliphatic acrylic solvented system having the following properties.

FT : 200 microns in 2 coats

Adhesion (ASTM-D-4541-6.01) : 30 kg / cm2 minimum

Water Vapour Permeants (ASTM-D-1655) : Min 20 g/sq.m / day at 75% RH at 250C.

Water Penetration Test (Immersion Method) : Nil

Resistance to chloride : Negligible Less than 10-7 cm2/sec. c) Coating on sub-structure in contact with earth, Coal tar epoxy.

The coating shall consist of two coats of tar – extended epoxy system of CECRI Karaikudi know- how having 300-350 microns in 2 coats and having following properties.

Base Tar extended epoxy – amine adduct Quick curing two component

Colour : Black

Volume of Solids : 80% (minimum) Drying time (touch dry) : 2 hours

D.F.T. in two coats : 300 – 350 microns

Chemical resistance : Excellent against chlorides, salts, sulphate, alkalies.

Salt spray test : Should pass as per ASTM-B-117 1000 hrs minimum

Adhesion : 3.8 KN minimum as per ASTM-D-4541

Resistance Impedance : 108

Surface preparation : As per manufacturers specification or as per relevant IS codes**.**

d) Coating System

1) Coating on External surfaces of Deck / Girder / Box.

Interpenetrating polymer network system of CBRI Roorkee know-how system consists one coat of Epoxy Phenolic primer of DFT 50 microns and one coat of Epoxy Phenolic interpenetrating polymer network (IPN0 coating of DFT 100 microns and one coat of polyurethane of DFT 100 microns IPN compatible system (Total DFT minimum 250 microns) the IPN system of CBRI Roorkee Know-how or any other epoxy coating system approved by the Engineer. The system shall have minimum 5 years field experience in Indian conditions.

2) Coating on sub-structure exposed to atmosphere.

Two coats each of 100 microns DFT (Total 20 microns) of Aliphatic Acrylate based solvented waterproof, anti-fungal coating system or any other equivalent coating system approved by the Engineer. The system shall have minimum 5 years field experience in Indian conditions.

3) Coating on substructure in contact with earth.

Applying two coats of coal tar epoxy system each coat of DFT 150 microns each (Total minimum DFT 300 microns) as per Central Electrochemical Research Institute Karaikudi system. The system shall have minimum 5 years field experience in Indian conditions.

4) Coating on inside of P.S.C. Box girder

Internal concrete surface of box girder shall be painted with three coats of cement based paint approved by the Engineer.

All surfaces shall be dry and free from contamination such as oil, grease, loose particles, decayed matter, laitance, all traces of mould release oils and curing compounds. Where application over existing coatings is required, trials shall be conducted to ensure compatibility and retention of bond between the underlying coating and the substrate.

It is essential to produce an unbroken coating of the material. Surfaces containing blowholes or similar areas of pitting shall first be filled using a cementitious fairing coat and allowed to cure for 48 hours before application of the coating material. Minimum application rates and over coating times are to be observed: as per manufacturer's recommendations or as Noticed by the Engineer.

The primer shall be allowed to dry for a minimum of 12 hours at 200C or longer at lower temperatures, before application of the coating. Under no circumstances shall the primer be over coated until the surface is properly dry.

All products shall have a shelf life of at least 12 months. It shall be stored in cool, dry conditions, away from sources of heat and flames, in the original unopened packs

Contract Code: 7200037432

Volume 5

Outline Construction Specifications

Section- 3

Civil Structural Works

Brihanmumbai Municipal Corporation

Mumbai, India

1 GENERAL

1.1 Introduction

These Specifications contained herein shall be read in conjunction with other Contract Documents. The Indian and International Standards as scheduled below have been used as base for the specifications. The Outline Construction Technical Specifications are also based on latest edition of "Specifications for Road and Bridge works" of Ministry of Road Transport &Highways (MORTH) as published by Indian Roads Congress. The Contractor shall be responsible for detailing in his specifications submitted to the Engineer, as part of the Definitive Design Submission, the standards on which his materials and workmanship will be based. These shall be of similar or higher standard than those listed below. The Contractor is required to Notice in the first instance the Indian Standards, and base the specifications on Indian Standards to the extent that they are applicable.

Alternative or additional codes and standards proposed by the Contractor shall be internationally recognised codes and shall be equivalent to or better than, Indian Standards issued by the Bureau of Indian Standards or any other Indian professional body or organisation, subject to being, in the opinion of the Engineer, suitable for incorporation or reference into the specifications. The specifications have been divided into different sections / sub-heads for convenience only. They do not restrict any cross-references. The Contractor shall take into account inter-relations between various parts of works/trades. No claim shall be entertained on the basis of compartmental interpretations.

1.1.1. Reference to the Standard Codes of Practice

Legend:

ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
BS	British Standard
CPWD	Central Public Works Department
DIN	Deutsches Institut für Normung e.V.
IRC	Indian Road Congress
IRCEM	Institution de Retraite Complementarie des Employes de Particular
IRS	Indian Railway Standards
IS	Indian Standards
MORTH	Ministry of Road Transport and Highways

BMC Brihanmumbai Municipal Corporation

UIC International Union of Railways

The detailed list of Standards referred to is mentioned in Section 1.1.3

1.1.2. Storing of Materials at site

All materials used in this Design and Build Project shall be stored on racks, supports, in bins, silos, godowns, under cover etc as appropriate to prevent deterioration or damage from any cause whatsoever to the entire satisfaction of the Engineer.

The storage of materials shall be in accordance with IS 4082 “Recommendation on stacking and storage or construction materials on site” and as per IS 7969 “Safety code for handling and storage of building materials”.

The materials shall be stored in a proper manner at places at site agreed by the Enginer Should the place, where material is stored by the Contractor, be required by the Employer for any other purpose, the Contractor shall forthwith remove the material from that place at his own cost and clear the place for the use of the Employer within the time as communicated by the Engineer and at no extra cost to the Employer.

1.1.3. Materials:

All materials shall be of best quality and shall conform to manufacturer’s specification. Wherever, no specific code of practice of IRS/IRC/BIS is applicable, the decision of the Engineer shall be final and binding.

1.1.4. Workmanship

All works shall be true to level, plumb and square and the corners, edges and rises in all cases shall be unbroken and neat.

Any work not to the satisfaction of the Employer or the Engineer will be rejected and at the same shall be rectified, or removed and replaced with work of the required standard of workmanship by the Contractor at no extra cost.

1.1.5. Load testing on Completed Structures

1) During the period of construction or within the defect liability period, the Engineer may at his discretion order the load testing of any completed structure or any part thereof if he has reasonable doubts about the adequacy of the strength of such structure for any of the following reasons.

    a. Results of compressive strength on concrete test cubes falling below the specified strength.

b. Premature removal of formwork.

c. Inadequate curing of concrete.

d. Overloading during the construction of the structure or part thereof.

e. Carrying out concreting of any portion without the prior Noticed by the Engineer.

f. Honey combed or damaged concrete which will affect the stability of the structure to carry the design load, more so in important or critical areas of the structure.

g. Any other circumstances attributable to the Contractor which may result in the structure or any part thereof being of less than the strength or performance required under the Contract.

2) All the loading tests shall be carried out by the Contractor in accordance with the agreed methods and Standards. Such tests shall be carried out only after expiry of minimum 28 days or such longer period The structure shall be subjected to a superimposed load equal to the specified superimposed load assumed in the design. This load shall be maintained for a period of 24 hours before removal. During the test, struts strong enough to take the whole load shall be placed in position leaving a gap under the members. The deflection due to the superimposed load shall be recorded by sufficient number of agreed reflectometers capable of reading to an accuracy of 0.02 millimetres and suitably located under the structure.

The structure shall be deemed to have passed the test if the maximum deflection at the end of 24 hours of loading does not exceed the deflection given by the following expressions:

D = 0.001 L2/25 T, where,

D = max deflection due to imposed load only

L = span of the member under load test (the shorter span in case of slabs). The span is the distance between centres of the supports or the clear distance between the supports plus the depth of the member, whichever is smaller. In case of cantilever, this shall be taken as twice the distance from the support to the end and deflection shall be adjusted for movement of the support.

T = depth of member.

If within 24 hours of the removal of the superimposed load, the structure does not recover at least 75% of the deflection under the superimposed load, the test loading shall be repeated after a lapse of 72 hours. If the recovery after the second test is less than 80% of the maximum deflection shown during the second test, the structure shall be considered to have failed to pass the test and shall be deemed to be unacceptable.

3) In such cases the portion of the work concerned shall be taken down or cut out and reconstructed to comply with the specifications. Other remedial measures may be taken to make the structure secure at the discretion of the Engineer. However such remedial measures shall be carried out to the complete satisfaction of the Engineer.
4) All costs involved in carrying out the tests defined in this section (1.1.1.6), (including load and integrity test for piles) and other incidental expense thereto shall be borne by the Contractor regardless of the result of the tests. In case of failure the Contractor shall take down or cut out and reconstruct the defective work or shall take the remedial measures, as instructed, at his own cost.
5) If the load testing is instructed on any grounds other than mentioned in this section (1.1.1.6), then the cost of the same shall be reimbursed if the test results are found to be satisfactory.
6) In addition to the above load tests, non-destructive tests on various elements (except on piles) such as core test and ultrasonic pulse velocity test shall be carried out by the Contractor at his own expense. Such tests shall be carried out by an agency agreed with the Engineer and. The acceptance criteria for these tests shall be as specified by the testing agency or good Engineering practice subject to the Notice of the Engineer.

1.1.6. Structural Work

1) Unless otherwise specified, only controlled concrete with design mix and weigh batching is to be used for the work.
2) Minimum cement content for various grades/- elements of concrete as specified in Volume 4, Section 3, subsection 2.5, is purely from durability point of view. Larger content of cement shall be provided if demanded by mix design or as per the requirement of relevant codes.
3) Mix design using smaller aggregates of 10 millimetres and below shall also be done in advance for the use at the junctions, where reinforcement is congested.
4) Procedure of mixing the admixtures shall be strictly as per the manufacturer's recommendations.
5) All the water tanks and other liquid retaining concrete structures shall undergo hydro- testing.
6) Special benches shall be provided at site for stacking reinforcement bars of different sizes.
7) Formwork for beams of Reinforced Cement Concrete works shall be designed in such a way that the formwork of the adjacent slabs can be removed without disturbing the props/supports to the beams.
8) Wherever there are tension/suspended concrete members which are suspended

from upper level structural members, the shuttering/scaffolding of such members at lower level shall be kept in place until such time as the upper level supporting members have achieved the required minimum strength.

9) The Contractor shall incorporate seismic considerations of anchoring and isolation in the design and detailing of the finishes. The element to be anchored shall have its motion suitably restrained and isolated so as not to be affected by the deformations/vibrations of the building during Construction.

10) Formwork shall be provided for full height at all locations. Special precautions for such tall formwork shall be taken to ensure its safety and stability.

1.1.7. Applicable Codes, Standards & Publications

Code No	Title
IS:875 (Part 3)	Code of practice for design loads (other than earthquake) for buildings and structures
IS:1322	Bitumen felts for water proofing and damp-proofing
IS:1893- 2016 (Part 1)	Criteria for earthquake resistant design of structures
IS:2572	Code of Practice for construction of hollow concrete block masonry
IS:2974(Part 1)	Code of Practice for Design & Construction of machine Foundation
IS:3414	Code of practice for design and installation of joints in buildings
IS:3764	Excavation Work- Code of Safety
IS:6408 (Parts 1,2)	Recommendations for modular co-ordination in building industry– tolerances
IS:10958	General check list of functions of joints in building
IS:11817	Classification of joints in buildings for accommodation of dimensional deviations during construction
IS:11818	Method of test for laboratory determination of air permeability of joints in buildings
IS:12440	Precast concrete stone masonry blocks
CPWD	Specifications 1996.
BS:476 (Part 7)	Method for classification of the surface spread of flame of products
BS:476 (Part 20)	Method of determination of the fire resistance of elements of construction (general principles)
BS:476 (Part 22)	Methods for determination of the fire resistance of non-load bearing elements of construction
BS:5215	Specification for one-part gun grade polysulphide-based sealants
BS:5606	Guide to accuracy in building
BS:6093	Code of practice for the design of joints and jointing in building construction
BS:8200	Code of practice for the design of non-load bearing external vertical enclosure of building
ASTM C 332	Specification for light weight aggregate for insulating concrete
SP 23 (S&T)	Hand Book on Concrete Mixes
B	**Bitumen**
IS:702	Industrial Bitumen

IS:3384	Specification for bitumen primer for use in waterproofing and damp-proofing
C	**Building Construction Practices**
IS:1838 Parts I and II.	Specifications for preformed fillers for expansion joint in concrete pavements and structures.
IS:1946	Code of Practice for use of fixing devices in walls, ceilings, and floors of solid construction.
IS:6509	Code of Practice for installation of joints in concrete pavements.
IS:11134	Code of Practice for setting out of buildings.
IS:11433	Parts I and II. Specifications for one part Gun grade polysulphide based joint sealant.
IS:12200	Code of Practice for provision of water stops at transverse contraction joints in masonry and concrete dams
D	**Cement**
IS:269	33 grade ordinary Portland cement
IS:455	Portland Slag Cement
IS:650	Specification for standard sand for testing cement.
IS:1489 (Part 1)	Portland pozzolana cement: Flyash based
IS:1489 (Part 2)	Portland pozzolana cement: Calcined clay based
IS:3535	Method of Sampling Hydraulic Cements
IS:4031	(Parts 1 to 13) Methods of physical tests for hydraulic cement.
IS:4032	Method of chemical analysis of hydraulic cement.
IS:6925	Methods of test for determination of water soluble chlorides in concrete admixtures.
IS:8042	White Portland Cement
IS:8112	Specification for 43 grade ordinary Portland cement.
IS:12269	Specification for 53 grade ordinary Portland cement.
IS:12330	Specification for sulphate resistant Portland cement.
E	**Concrete**
IS:456	Code of practice for plain and reinforced concrete.
	Code of practice for general construction of plain and reinforced concrete
IS:460 (Parts I to II)	Specification for Test Sieves
IS:516	Methods of test for strength of concrete.
IS:1199	Methods of sampling & analysis of concrete.
IS:1200	Method of measurement of building and civil Engineering
IS:1343	Code of practice for prestressed concrete
IS:1607	Method of Test Sieving
IS:2386	Parts I-VIII. Methods of tests for aggregates for concrete.
IS:2430	Methods of Sampling of Aggregates of Concrete
IS:2438	Specification for roller pan mixer
IS:2514	Specification for concrete vibrating tables
IS:2571	Code of practice for laying in-situ cement concrete flooring
IS:2645	Specifications for integral cement water proofing compounds
IS:2722	Specifications for portable swing batchers for concrete (double bucket type)
IS:2770	Methods of testing bond in reinforced concrete part I pull out test

IS:3025	Methods of sampling and test (physical and chemical) for water & waste water
IS:3370	Code of practice for concrete structures for storage of liquids
IS:3935.	Code of practice for composite construction
IS:4326	Code of practice for earthquake resistant construction of building
IS:6925.	Methods of test for determination of water soluble chlorides in concrete Admixtures
IS:7242	Specifications for concrete spreaders
IS:7251	Specifications for concrete finishers
IS:7861	Parts I & II. Code of practice for extreme weather concreting.
IS:7969	Safety code for handling and storage of building materials
IS:8989	Safety code for erection of concrete framed structures
IS:8142	Methods of test for determining setting time of concrete by penetration resistance
IS:9103	Specifications for admixtures for concrete
	Method of making, curing and determining compressive strengths of
IS:9284	Method of test for abrasion resistance of concrete
IS:10262	Recommended guidelines for concrete mix design.
	Specifications for Road and Bridge Works, Ministry of Road Transport
IRS	Concrete Bridge Code
ASTM - C - 94	Ready Mix Concrete
IS 4926:2003	Ready Mixed Concrete – Code of Practice
ASTM – C - 1240	Specifications for Silica Fume for use in Hydraulic Cement and Mortar
F	**Construction Plant and Machinery.**
IS:1791	Specification for batch type concrete mixers.
IS:2505	General requirements for concrete vibrators: Immersion type.
IS:2506	General requirements for screed board concrete vibrators.
IS:3366	Specification for pan vibrators.
IS:3558	Code of Practice for use of immersion vibrators for consolidating concrete.
IS:4656	Specifications for form vibrators for concrete.
IS:4925	Specification for concrete batching and mixing plant.
IS:11993	Code of Practice for use of screed board concrete vibrators.
G	**Formwork**
IS:4990	Specifications for plywood for concrete shuttering work.
IRC:87-2011	Guidelines for the design and erection of false work for road bridges.
IS:806	Code of practice for use of steel tubes in general building construction.
IS:1161	Specification of steel tubes for structural purposes.
IS:1239	Specification for mild steel tubes. Tubulars and other wrought steel fittings.
H	**Gypsum and Gypsum Board**
IS:2095	Gypsum plaster boards
IS:2542 (Part 1/Sec	Methods of test for gypsum plaster, concrete and products:

1 to 12)	plaster and concrete
IS:2542 (Part 2/Sec	Methods of test for gypsum plaster, concrete and products:
1 to 8)	Gypsum products
IS:2547 (Part 1)	Gypsum building plaster: Excluding premixed lightweight plaster
IS:2547 (Part 2)	Gypsum building plaster: Premixed lightweight plaster
I	**Handling and Storage**
IS:4082	Recommendation of Stacking and Storage of construction materials
IS:8348	Code of practice for stacking and packing of stone slabs for transportation
J	**Instruments For Testing Cement and Concrete**
IS:5513	Specification for vicat apparatus.
IS:5514	Specification for apparatus used in Le-Chaterlier test.
IS:5515	Specification for compaction factor apparatus.
IS:7320	Specification for concrete slump test apparatus.
IS:7325	Specification for apparatus to determine constituents of fresh concrete.
IS:10080	Specification for vibration machine.
IS:10086	Specification for moulds for use in tests of cement and concrete.
IS:10510	Specification for vee-bee consistometer.
K	**Joint Fillers**
	Preformed fillers for expansion joint in concrete pavements and
IS:1838 (Part 1)	structures (non extruding and resilient type): Bitumen impregnated fibre
L	**Paints and Coatings**
IS:102	Ready mixed paint, brushing, red lead, non-setting, priming
IS:109	Ready mixed paint, brushing, priming, plaster, to Indian Standard
	Colour No. 361 and 631 white and off white.
IS:347	Varnish, shellac, for general purpose.
	Specification for powder organic coatings for application and stoving to aluminum alloy extrusions, sheet and preformed
BS:6496	sections for external architectural purposes, and for the finish on aluminum alloy extrusions, sheet and preformed sections coated with powder organic coatings
BS:EN:10152	Specification for electrolytically zinc coated cold rolled steel flat products. Technical delivery conditions
ASTM A 164-71	Specification for electrodeposited coatings of zinc on steel
M	**Pigment for Cement**
BS:1014	Specification for pigments for Portland cement and Portland cement products
N	Reinforcement & Structural Steel
IS:280	Mild steel wire for general Engineering purposes
IS:432	Part I. Mild steel and medium tensile steel bars. Part II Hard drawn steel wire.
IS:814	Parts I & II. Electrodes for metal arc welding of structural steel.
IS:815	Classification coding of covered electrodes for metal arc welding of structural steels
IS:816	Code of Practice for use of metal arc welding for general construction in mild steel.

IS:1566	(Part I) Specifications for hard-drawn steel wire fabric for concrete reinforcement.
IS:1786	Specification for high strength deformed steel bars and wires for concrete reinforcement.
IS:2502	Code of Practice for bending and fixing of bars for concrete reinforcement.
IS:2629	Recommended practice for hot-dip galvanising of iron and steel.
IS:2751	Code of Practice for welding of mild steel plain and deformed bars for reinforced concrete construction.
IS:4759	Hot-dip zinc coating on structural steel and other allied products.
IS:5525	Recommendations for detailing of reinforcement in reinforced concrete works
IS:9417	Recommendations for welding cold-worked steel bars for reinforced concrete construction.
IS:14268	Uncoated stress relieved low relaxation steel class 2 for Pre- stressed concrete
IS:226	Structural steel (Standard Quality)
IS:800	Code of practice for use of structural steel in general building construction.
IS:813	Scheme of symbols for welding.
IS:814	Covered electrodes for metal arc welding of structural steel. (Part I & Part II)
IS:816	Code of practice for use of metal arc welding for general construction in mild steel.
IS:822	Code of practice for inspection of welds.
IS:961	Structural steel (High Tensile)
IS:1024	Code of practice for use of welding in bridges and structures subject to dynamic loading.
IS:1161	Steel tubes for structural purposes.
IS:1182	Recommended practice for radiographic examination of fusion welded butt joints in steel plates.
IS:2062	Structural steel (Fusion welding quality)
IS:3757	Specification for high tensile friction grip bolts.
IS:5624	Specification for foundation bolts.
IS:3600	Code of practice for testing of fusion welded (Part I) joints and weld metal in steel.
IS:4923	Hollow steel sections for structural use.
IS:6227	Code of practice for use of metal arc welding in tubular structure.
IS:801	Code of practice for use of cold formed light gauge steel structural members in general building construction.
IS:811	Specifications for cold formed light gauge structural steel sections.
IS:8500	Structural Steel Micro alloyed (Medium and high strength qualities)
IS:8910	General requirements of supply of weldable structural steel
IS:9595	Recommendations for metal arc welding of carbon & carbon-Manganese steels
IS:7205	Safety Code for erection of Structural Steel Works
O	**Aggregates**
IS:383	Coarse and fine aggregates from natural sources for concrete.
P	Scaffolding

IS:2750	Specification for steel scaffoldings
IS:3696 (Part 1)	Safety Code of scaffolds and ladders: Scaffolds
IS:3696 (Part 2)	Safety Code of scaffolds and ladders: Ladders
IS:4014 (Part 1)	Code of practice for steel tubular scaffolding: Definition and materials
	Code of practice for steel tubular scaffolding: Safety regulations
IS:4014 (Part 2)	for scaffolding
IRC:87-2011	Guidelines for the design and erection of falsework for road bridges
Q	**Sealants**
IS:10959	Glossary of terms for sealants for building purposes
IS:11433 (Part 1)	One part grade polysulphide base joint sealant: General requirement
IS:11433 (Part 2)	One part grade polysulphide base joint sealant: Methods of test
IS:13055	Methods of sampling and test for anaerobic adhesives and
	sealants
BS:5889	Specification for one part gun grade silicone-based sealants.
R	**Wood**
IS:303	Plywood for General Purposes
IS:848	Synthetic resin adhesives for plywood (phenolic and aminoplastic)
IS:1141	Seasoning of Timber - Code of Practice
IS:1328	Veneered decorative plywood
IS:1659	Block Boards
IS:2046	Decorative thermosetting synthetic resin bonded laminated sheets
IS:2202 (Part 1)	Wooden flush door shutters (solid core type): Plywood face panels
IS:2202 (Part 2)	Wooden flush door shutters (solid core (type): Particle face
	panels and hardboard face panels
S	**Bearings**
IRC:83-2018 Part-II	Standard specifications and code of practice for road bridges Elastomeric Bearings
IRC:83-2018 Part-III	Standard specifications and code of practice for road bridges Pot Bearings
T	**UPVC Pipe For Drainage**
IS 4985	Unplasticized PVC Pipes for portable water supplies
U	**PILING**
IS :2911 PART-I	Bored Cast in-situ Concrete Piles
IRC:78-2014	Standard specifications and code of practice for road bridges
	Section VII- Foundation And Substructure
V	All Indian Railway Standards
W	MORTH Specifications for Road and Bridge works (Fifth Revision / Latest Revision)
X	CPWD Specifications (latest Revision)

1.2 Excavation

1.2.1. Preliminaries

Site Clearance

(1) The Contractor shall clear the Site as required by demolishing all buildings, structures and the like, and removing vegetation, debris, trees along with their roots and the like to locations agreed with the Engineer either on or off Site

(2) Stumps and major roots shall be grubbed up and disposed of off-site. The Contractor shall take precautions to protect all adjacent public and private property during these operations and shall be responsible for all and damage arising from such.

(3) The Contractor shall prevent erosion of all cleared excavation and fill areas by providing suitable protection.

(4) The Contractor shall also prevent siltation of all areas adjacent to the Works as a result of fines being transported from the Works by provision of suitable silt fences.

1.2.1.1. Topsoil Stripping

(1) Topsoil shall be removed as required and deposited in separate heaps at locations agreed with the Engineer.

1.2.1.2. Removal of Unsuitable Material

(1) Unsuitable materials are defined in Volume 5, cl 1.2.2.2

(2) The Contractor shall remove all unsuitable materials and dispose of such on or off Site.

(3) Boulders, stones and other materials of value or usable again on the Works shall be neatly stacked in graded heaps.

(4) Surplus suitable materials shall be deposited in layers of appropriate thickness and well compacted in the designated disposal site subject to the Contract requirements.

1.2.1.3. General Excavation

(1) Excavation shall be carried out to the lines, levels and profiles shown on the Drawings. The work shall be carried out by the Contractor in such a way as to avoid soil erosion, groundwater pollution, accidents in habitational or frequented places, disturbance to the surrounding ground or structures, accident to workmen and any other untoward incident. Particular care shall be taken to maintain stability when excavating in close proximity to existing Works. Fencing, caution signages with red lights and other safety measures shall be employed to avoid accidents. Where necessary, signal men shall be employed to guide the movement of people, vehicles and equipment.

(2) The work shall be carried out in a careful manner to ensure that the exposed surfaces are as sound as the nature of the material permits and that no point shall protrude inside the lines shown on the Drawings except as given Notice by the Engineer. In soft soil excavation which is to remain open permanently, exposed faces shall be formed accurately to the required slopes and profiles and properly protected by turfing or pitching as given Notice by Engineer.

(3) The Contractor shall dispose of all material arising from excavations either off the site or to Noticed heaps on the Site, as required.

(4) The Contractor shall be responsible for keeping all excavations free from water from

whatever cause arising and shall provide such pumping capacity and other measures as may be necessary for this purpose.

(5) The Contractor shall be responsible for the safety and stability of all excavations performed by him or under his control. In case of any slips or blows in the excavation, the same shall be cleared by the Contractor at his own cost.

(6) The Contractor shall notify the Engineer without delay of any permeable strata, joints, faults, fissures or unusual ground conditions encountered during excavation and any excavation instability and/or collapse.

(7) The Contractor shall ensure that no air pollution takes place during excavation, storage and transportation of earth by providing suitable measures such as appropriate cover and the like.

(8) The Contractor shall provide to the Engineer full details of the proposed rock excavation methods for his Notice. Excavation should be carried out by such manual/mechanical means or methods, as to eliminate noise and dust up to the prescribed limits and without using any blasting and/or any expansive chemicals. Similarly, the Contractor shall submit his plans for methods for monitoring ground stability and vibration adjacent to residential area.

(9) The Contractor shall carry out ground stabilisation measures without delay before and/or after excavation, the Contractor may request the Engineer to accompany him when inspecting structures and excavated rock surfaces revealed after excavation operations.

1.2.1.4. Excavation beyond True Lines and Levels

If from any cause whatsoever excavations are carried out beyond their true line and level other than as per the Noticed drawings then the Contractor shall make good at his own cost to the required line and level with the appropriate grade of filling to be contained in the true excavation, or with concrete or other material in such a manner subject to the Notice of the Engineer

1.2.1.5. Notice for Excavation

(1) When excavations have been taken out accurately to the profiles or dimensions required for the Works, the Contractor shall inform the Engineer for his Notice.

(2) The Contractor shall carry out additional excavation to such new profiles or dimensions as the Engineer may give Notice.

1.2.1.6. Excavations for Structures

(1) Open excavation to lay a foundation for a structure shall be carried out to the lines and dimensions necessary to permit the proper construction of that structure.

(2) Where a structure is to be founded on soft ground, the excavation shall be taken down until the required suitable soil formation is exposed and prepared to the Notice of the Engineer.

(3) In the event of excavation having been made deeper than that shown on the drawings or as Noticed by the Engineer, the extra depth shall be made up with concrete or masonry of the foundation grade to the cost of the Contractor. Ordinary filling shall not be used for the purpose to bring the base of foundation to required level.

(4) Prior to any construction within that excavation the bottom of the excavation shall be re- compacted to achieve a dense smooth and level surface longitudinally, transversely or stepped. Subject to the Notice of the Engineer, layers of granular fill not exceeding 200 millimetres loose thickness shall be placed and compacted to 95% maximum dry density.

(5) Where required, filtered under drainage pipes shall be placed within the granular fill layer in accordance with the Noticed designs

(6) Surfaces of excavations or filling on which plain (unreinforced) or reinforced concrete will be formed shall be prepared with a blinding layer of concrete as shown on the Drawings or in such other manner as will provide a suitable surface at the correct lines and levels to the Notice of the Engineer.

1.2.1.7. Trench Excavation for Utilities and Services

(1) Trench excavation shall be performed by the use of suitable equipment, in such manner so as to minimise disturbance to the required finished sides and bottom of the excavation.

(2) Trenches for pipes shall be excavated to a sufficient depth and width to enable the utility or service and the specified joint, bedding, hunching and surrounding to be accommodated and for all loose material placed to be compacted to the required standards.

1.2.1.8. Trenches

(1) The Contractor shall carry out excavation in a safe manner such that the sides of the trench are adequately supported and stable till the completion of this work.

(2) The Contractor shall leave a clear adequate space between the edge of the excavation and the inner toes of the spoil banks.

(3) Trenches shall be excavated to the lines and levels shown on the Drawings.

(4) Trenches shall not be excavated too far in advance of pipe-laying and the like, and shall

be sufficiently wide to allow proper and efficient jointing to be carried out in clean and dry conditions. Due allowance shall be made for bedding and surrounds where these are specified.

(5) The bottoms of all trenches shall be trimmed to grade and level and compacted before any bedding is placed or pipes laid.

(6) The widths of trenches crossing roads, or at other locations as directed shall be as narrow as is practicably possible. The maximum width measured between undisturbed soil in the trench sides shall not exceed the outside diameter of the pipe being laid plus 550 millimetres for pipes up to and including 800 millimetres in diameter and plus 750 millimetres for pipes over
800 millimetres in diameter.

(7) Trenches for pipes carrying water under pressure shall, except where otherwise described in the Contract, be excavated to a sufficient depth to ensure a minimum cover of 900 millimetres to the top of the pipes.

1.2.1.9. Road Crossings

The Contractor shall provide adequate support to all excavations within and across existing roads. Care shall be taken by the Contractor to ensure that existing roads and services are not damaged by road-crossing operations. Excavations in roads shall be backfilled and roads repaired as soon as practicable taking all safety precautions.

1.2.1.10. Channels

(1) Channels shall be excavated by methods which do not endanger the stability of the side- slopes.

(2) Existing channels, which are to be reshaped, cleared and trimmed, shall be cleared of all weeds and growth and the beds graded to the required levels. The sides of channels shall be trimmed to the required safe limits of slope and width.

(3) Side-banks of channels shall be trimmed to provide a neat appearance and even surfaces.

(4) Any channels, streams, drains or pipes conducting water to or from cultivated land shall be diverted so as to maintain their flow before being moved or broken into. All diversions and their subsequent reinstatement shall be carried out to the Notice of the Engineer

(5) The Contractor shall control the rates of filling and drawdown of water in channels so as not to endanger the stability of the Works.

1.2.1.11. Notice for Excavations

(1) The Contractor shall seek the Engineer's Notice for all excavations prior to

placing pavement layers, fill or concrete.

(2) The Contractor shall maintain open excavations in a safe and stable condition, and shall rectify the effects of deterioration due to weather.

1.2.2. Fill

1.2.2.1. Fill - General

(1) Prior to commencement of any filling either as backfill to excavations or in the formation of embankments, the Contractor shall submit in writing to the Engineer for “Notice to Proceed” his proposals for carrying out the work such that the optimum use may be made of excavated material. The proposals shall include details of the compaction plant and methods for adjusting the moisture content of the material.

(2) No filling shall commence until the “Notice to Proceed” to his proposals have been received from the Engineer.

1.2.2.2. Fill Material

(1) Fill material shall be obtained only from a source agreed with the Engineer

(2) Fill material, other than for roadworks, shall be evenly graded granular material. Material with more than 20% passing a 75 micron sieve or more than 10% in excess of 75 millimetres size is unlikely to be suitable for use in the Works.

(3) Before compacting the fill material, clods or hard lumps of earth over 75 millimetres in greatest dimension shall be broken up.

(4) The following types of material are considered unsuitable and shall not be used for filling.

a. Materials from swamps, marshes or bogs.

b. Peat, loam, fine silt, log, stump or organic or perishable materials.

c. Material susceptible to spontaneous combustion.

d. Clay of liquid limit exceeding 80% and plasticity index exceeding 55%.

e. Materials containing salts prone to inducing leaching in the embankment. f. Any contaminated and environmentally unacceptable material.

(5) The Contractor shall carry out the following initial tests on the proposed material. Thereafter, one set of tests shall be carried out for each 2000 cubic metres of fill, supplied to Site or as Noticed by Engineer.

a. Wet sieve analysis.

b. Dry density/moisture content relationship

1.2.2.3. Backfill - General

Except around structures, excavations shall be backfilled with suitable excavated material and/or Noticed material compacted in layers of 300 millimetres maximum loose thickness to achieve a density of at least 95% of the maximum dry density.

1.2.2.4. Backfill to Structures

a) The Contractor shall not backfill around structures until the structural elements have attained adequate strength.

b) The backfill material shall be selected excavated material or sand, thoroughly compacted in layers not exceeding 200 millimetres loose thickness to achieve a density of at least 95% of the maximum dry density.

1.2.2.5. Preparation of Base/Foundation for Embankment

(1) Prior to placing any embankment upon any area all clearing and grubbing operations shall have been completed in accordance with this Contract.

(2) Where the height of embankment is 1 metre or less all sod, grass and vegetable matter shall be removed from the ground surface and the top 150 millimeters shall be processed as necessary and compacted to 90% of the maximum dry density.

(3) Where new embankments are to be constructed against and on existing slopes steeper than 1 vertical to 5 horizontal continuous horizontal benches, each no greater than 500 millimetres in vertical height shall be cut into the existing slope and the embankment built up in successive layers. Material in the existing slope which has been loosened shall be re-compacted simultaneously with the first level of embankment material placed.

(4) Where an embankment is to be placed against sloping ground flatter than 1 vertical to 5 horizontal the existing ground shall first be loosened to a depth not less than 100 millimetres to ensure adequate bond between embankment and existing ground.

(5) Unless otherwise shown on the Drawings, where existing unpaved roads are to be covered with less than 300 millimeters of fill, excluding pavement, the top of the old road- bed shall be scarified and re-compacted with the next layer of the new embankment. The total depth of the scarified and added material shall not exceed the permissible depth of layer.

(6) Granular material (eg, sand or gravel) shall be used as filling in swamps or

waterlogged ground. The Contractor shall submit details of his proposed granular fill material to the Engineer for his Notice. The Contractor shall first remove all unsuitable material from the base of the proposed fill area and backfill with the agreed granular material, placed and compacted in accordance with the requirements of this Contract. Where deemed necessary the Contractor may place a geofabric “separator” fabric to prevent “punching of the fill into the underlying soft material in accordance with Volume 5, cl 1.2.2.6

1.2.2.6. Construction of Embankment

(1) General:

Except as otherwise required all embankments shall be constructed in layers approximately parallel to the finished grade of the road-bed. During construction of embankment, a smooth grade having an adequate crown or super elevation shall be maintained to provide drainage. Embankments shall be constructed to the required grade, and completed embankments shall correspond to the shape of the typical sections as shown on the Drawings.

(2) Earth Embankment:

a) Earth embankments shall be defined as those principally of material other than rock, and shall be constructed of Noticed material brought from designated or other Noticed sources.

b) Except as specified for embankment in swamps, earth embankments shall be constructed in successive layers, for the full width of the cross-section and in such lengths as are suited to the compaction and watering methods used.

(3) Placing in swampy or waterlogged ground:

a) Embankment in or over swamps or in water shall be placed by placing granular material in a uniformly distributed layers of thicknesses greater than that necessary to support the equipment while placing subsequent layers, after which the remainder of the embankment shall be constructed in layers and compacted as specified.

b) Separation layers of either suitable geofabric and/or graded sand shall first be placed in controlled layers to prevent excessive penetration and/or the development of mud-waves.

(4) Preparation of subgrade:

The surface of the finished subgrade shall be neat and workmanlike and shall have the required form, super elevation, levels, grades, and cross-section. The surface shall be constructed to sufficient accuracy to permit the construction of subsequent layers of material to the thickness, surface tolerance, and compaction specified.

1.2.2.7. Compaction of Embankments

(1) When necessary, each layer before being compacted shall be processed as required to bring the moisture content sufficiently close to optimum to make possible its compaction to the required density. The material shall be worked as to have uniform moisture content through the entire layer.

(2) Each layer of material shall be compacted uniformly by use of adequate and appropriate compaction equipment. The compaction shall be done in a longitudinal direction along the embankment and shall generally being at the outer edges and progress towards the center in such a manner that each section receives equal amount of compaction.

(3) Hauling equipment shall be operated over the full width of each layer in so far as practicable. There should be a minimum overlap of 150 millimetres between each run of the rollers.

(4) Embankment or backfill compaction shall be carried out in the following way.

a) The top 200 millimetres of the finished embankment shall be compacted to a dry density equal to or greater than 98% of the maximum dry density.

b) Other embankment layers more than 200 millimetres below finished surface or the underside of the lowest layer of base, subbase and shoulder shall be compacted to a dry density equal to or greater than 95% of the maximum dry density.

1.2.2.8. Inverted Filter

(1) An inverted filter comprising of durable coarse stone aggregates with an appropriate filter layer or geo-fabric between the filter and the subgrade shall be constructed behind earth retaining structures.

(2) The inverted filter shall be constructed simultaneously with the filling work to the retaining structure. Care shall be taken during placing of the filter media to ensure that it does not cause damage to structural members or application of excessive pressure against the retaining structure.

1.2.3. Tests

1.2.3.1. Testing of Fill - General

(1) Classification tests as per relevant Standards to which the Engineer has given his Notice shall be carried out to ensure that true comparisons can be made

between in-situ densities, laboratory compaction densities and field trial densities so that it can be determined that variations in properties of the fill materials are being allowed for.

(2) Tests shall be carried out on fill to determine the degree of compaction achieved, at the rate of one test for either each 1200 cubic metres placed or each layer whichever is the more frequent. Compacted layers shall not be covered without Notice from the Engineer.

(3) The density of individual compacted layers shall be determined by a method given Noticed by the Engineer.

(4) The in-situ dry density of fill shall average 95% of the maximum reached in trials. No single result shall be less than 92% and no more than 25% of the results on any one layer shall fall between 92% and 95%. The average shall be computed from the total number of tests on any one layer where the extent of the layer is defined by the Contractor when submitting same for inspection.

1.2.3.2. Materials for Topmost Layer of Fill

(1) In addition to the general requirements for fill material, the material in the topmost layer shall not exceed the following test values.

Plasticity Index: 6% Liquid Limit : 35%

(2) Total fines content shall not exceed 15% and Uniformity Coefficient (Cu) shall not be less than 4.

(3) The laboratory California Bearing Ratio (CBR) value at 95% maximum dry density achieved after soaking for 96 hours shall not be less than 30%.

1.2.3.3. Testing of Top Layer of Fill

Tests shall be carried out on the top layer of fill as shown in the following table. Tests shall be carried out as required by the accepted test procedures

Test A. Laboratory tests to monitor the consistency of the Noticed material during construction:	**Frequency of test** **(not less than one test per...)**
Maximum dry density	1000 square metres
Optimum moisture content	1000 square metres
Grading	1000 square metres
Plasticity index	1000 square metres
Linear shrinkage	1000 square metres
CBR Value	2000 square metres

B. In situ tests to confirm that the required degree of compaction is being achieved during construction:	
Dry density	250 square metres
CBR Value	1500 square metres

1.3 Piling and Diaphragm Walling

1.3.1. General

1.3.1.1. Piling plant and Methods

(1) Not less than 2 weeks before any piling work is commenced the Contractor shall submit to the Engineer for Notice full details of his proposed piling plant, and detailed method statements for carrying out the Works. Such details shall include where applicable a full description of the piling frame, hammer, helmet and packing, methods of handling, pitching and supporting the piles before and during driving, the proposed driving procedure to obtain the required penetration, or the proposed set and the method of calculation of the specified working load of the piles and such further information as the Engineer may require. Details of casings and concreting methods in respect of any driven or bored cast-in-place concrete piles shall be included in the submission.

(2) The Contractor shall not commence any piling until the plant and methods which he proposes to use have received a “Notice to Proceed” from the Engineer but such a Notice shall not relieve the Contractor from any of his obligations and responsibilities under the Contract. If for any reason the Contractor wishes to make any change in the plant and methods of working, he shall not make any such change without having first obtained the Engineer's „Notice to Proceed‟ for such changes.

(3) Reference shall be made to the following documents regarding matters relating to the safety of piling works

BS8004 Code of Practice for Foundations

BS5573 Code of Practice for Safety Precautions in the Construction of large Diameter Boreholes for Piling and Other Purposes

1.3.1.2. Records

The Contractor shall keep complete records of all data as required by the Engineer covering the fabrication, driving and installation of each pile and shall submit two signed copies of these records to the Engineer not later than 24 hours after installation of the piles.

1.3.1.3. Programme and Progress Report

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

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

1.3.1.4. Setting Out

(1) The Contractor shall establish and maintain permanent datum level points, base lines and grid lines to the Notice of the Engineer and shall set out with a suitable identifiable pin or marker the position of each pile.

(2) The setting out of each pile shall be given Notice by the Engineer at least one day prior to commencing work on a pile and adequate Notice for checking shall be given by the Contractor.

(3) Notwithstanding such Notice, the Contractor shall be responsible for the correct and proper setting out of the piles and for the correctness of the positions, levels, dimensions, and alignment of the piles.

1.3.1.5. Tolerances

(1) Piles

a) Piles shall be driven or bored accurately vertical or to the specified rake and the permitted deviation of the pile centre from the centre-point shown on the setting out plan shall not exceed 50 millimetres measured at the working level of the piling rig, or other level given Noticed by the Engineer.
b) Deviation from specified cut-off level shall be 25 millimetres.
c) The maximum permitted deviation of the finished pile shall be 1 in 75 from the vertical for vertical piles, and for raking piles 1 in 25 from the specified rake.
d) Forcible corrections shall not be made to piles.
e) The manufacturing tolerances for precast concrete piles shall comply with the following requirements.
    i. The external cross-sectional dimensions shall be within 0 millimetres and +5 millimetres of the specified dimensions.
    ii. The wall thickness of hollow spun concrete piles shall be within 0 millimetres and +25 millimetres of the specified thickness.
    iii. There shall be no irregularity exceeding 6 millimetres in a 3 metre length along the face of the pile measured using a 3 metre straight edge.

iv. The centroid of any cross-section of the pile shall not be more than 12 millimetres from the straight line connecting the centroids of the end faces of the piles.

v. The centroid of any cross-section of a hollow pile shall be determined by assuming that the pile has a solid section.

f) The diameter of cast-in-situ piles shall be at least 98% of the specified diameter.

(2) Pile caps

a) Variation in dimensions shall be limited to +50 millimetres and –10 millimetres.

b) Misplacement in plan from specified position shall be limited to 15 millimetres.

c) Surface irregularity measured with 3 metre straight edge shall be limited to 5 millimetres.

d) Variation of levels at the top shall not be beyond 25 millimetres.

1.3.1.6. Disturbances and Noise

(1) The Contractor shall carry out the piling work in such a manner and at such times as to minimize noise and disturbance.

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

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

1.3.1.7. Obstructions

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

1.3.2. Concrete Piles

1.3.2.1. Materials - General

(1) Requirements of concrete and reinforcement for precast and cast in-situ piles shall comply with Section 1.4 of this Volume. Minimum grade of concrete shall be as per Outlined Design Specification (Volume 4, Section 2.5) unless otherwise specified. Minimum cement content for concrete in cast-in-place piles as per IS 2911.

(2) Precast piles shall be marked at the time of concreting with all relevant information – eg, date, reference number, length and the like.

1.3.2.2. Reinforcement

(1) The reinforcement shall be assembled before placing in the moulds and all hoops and links shall be of uniform length firmly wired into position. Ends of helical reinforcement shall be firmly secured. Diagonal fork spacers shall be of an Noticed pattern. The cover to all bars shall be not less than 45 millimetres but increased cover thickness may be provided where piles are exposed to the action of harmful chemicals (as in the case of concrete in contact with earth faces contaminated with such chemicals), acid, vapour, saline atmosphere, sulphurous smoke (as in case of steam operated railways), etc, and such increase of cover may be between 15 millimetres and 50 millimetres beyond 40 millimetres as may be specified by the Contractor subject to the Notice of the Engineer.

(2) Joints in main longitudinal bars will be permitted only where each bar cannot be practically supplied in one complete length. Where permitted, joints shall be provided at agreed centres, designed to develop the full strength of the bar across the joint, provided with adequate links or stirrups and staggered in position from those of adjacent longitudinal bars.

(3) Welding of cold worked high tensile requirement bars at joints in main longitudinal bars will not be permitted without the agreement of the Engineer in which case, the Contractor shall comply with the requirements of IS 9417-1989.

Welding of hot rolled high tensile steel bars shall be permitted provided the method used for the same will not adversely affect the properties of bars.

1.3.3. Precast Concrete Piles

1.3.3.1. Formwork

(1) Formwork shall comply with Section 1.5 below of this Volume of this Contract except as specified below. The head of each pile shall be square to the longitudinal axis. The corners of the head and pile shaft for a distance of 300 millimetres from the head shall be chamfered 25 millimetres by 25 millimetres. The method of forming hollow cores where required shall be such that a continuous core is formed. The use of previously cast piles as side forms will not be permitted. Holes for toggle bolts shall be at right angles to the faces of the pile and lined with steel tubes or other Noticed material. Holes for lifting, handling and pitching shall be formed in accordance with the agreed Drawings.

(2) Details of all pile shoes shall be submitted to the Engineer for Notice prior to fabrication or supply. All shoes shall be fitted to the reinforcement as shown on the agreed Drawings.

1.3.3.2. Protection of Finished Piles

Protection of finished piles against aggressive soil conditions shall be provided by one of the following methods.

a) Using sulphate-resistant cement - ASTM or TIS Type 5 or Equivalent Indian Standards IS 12330-1988.

b) Increasing concrete cover to the reinforcement

1.3.3.3. Lengthening Concrete Piles

(1) Where it becomes necessary to lengthen a pile, the reinforcement at the head of the pile shall be stripped of all surrounding concrete and additional reinforcement added.

(2) The length stripped shall be not less than 40 times the maximum diameter of the longitudinal reinforcement in the case of a spliced joint or at least 300 millimetres for a butt-welded joint. New binders of the same size and spacings as in the original pile head and additional blinders shall be fixed in the extension and the pile extended by concreting between properly formed and supported moulds to the required length. Prior to casting the extension, the existing concrete surface shall be cut to sound concrete square to the pile axis and all loose particles removed by wire brushing. This shall be followed by washing with water and preparing and

coating with an Noticed epoxy bonding agent applied in accordance with the manufacturer's recommendation. Care shall be taken to ensure that the alignment of the extended pile across the joint is exactly maintained.

(3) Prior to carrying out any work for the lengthening of piles, the Contractor shall submit a detailed method statement to the Engineer for his Notice.

(4) After piles have been lengthened, driving shall not be resumed until the specified characteristic strength of the added concrete has been attained. Subject to the “Notice to Proceed” from the Engineer in writing, the Contractor may use rapid hardening Portland cement conforming to IS 8041– 1990 for pile extensions in order to expedite the work.

(5) Driving or redriving of concrete piles extended as described above shall not be resumed until the Notice of the Engineer has been given.

1.3.4. Cast-in-Place Piles

1.3.4.1. Bored Piles

(1) The Contractor shall check and agree with the Engineer the casing position for

each pile during and immediately after placing the lining. Piles shall be constructed in a sequence submitted in advance to the Engineer. Hydraulic rig shall be used. During boring, the Contractor shall where take soil, rock or groundwater samples and transport them to a Noticed testing laboratory or carry out in-place soil tests. A complete record of the construction of each pile shall be kept by the Contractor and made available for inspection by the Engineer.

(2) Minimum diameter of pile shall conform to IRC Code and given Notice by the Engineer.

Where enlarged bases are required, these shall be mechanically formed and concentric with the pile shaft to within a tolerance of two per cent of the shaft diameter and shall not be smaller than the required dimension. The sloping surface of the frustrum forming the enlargement shall make an angle not less than 55 degrees to the horizontal. The diameters of piles shall be verified by Koden method or other methods subject to the Notice of the Engineer.

(3) Where bentonite drilling fluid is used in boring for maintaining stability, the level of the fluid in the excavation shall be kept at not less than 1.5 metres as per IS:2911–1979 above the level of the external groundwater or at such other level as will ensure that the fluid pressure is at all times in excess of pressures exerted by the soils and external groundwater.

(4) MS lining with adequate protection shall be used for ensuring stability of the strata near ground level until concrete has been placed in the pile. Liner to pile shall be upto refusals with anticorrosion treatment from outside. A pile excavation shall be backfilled without delay where a rapid loss of drilling fluid occurs and no further excavation at the location of that pile shall be carried out until the Contractor has obtained the Engineer's Notice for the proposed remedial work.

(5) Pumping from a boring shall not be permitted unless Notice is given by the Engineer.

(6) Piles constructed in a stable cohesive soil with liners shall be bored and concreted without prolonged delay which might allow collapse of any part of the pile boring.

(7) On completion of boring, all loose, disturbed or remoulded soil shall be removed from the base of the pile. Prior to placing concrete, the Contractor shall inspect each and every pile boring and submit his pile boring inspection records for Notice by the Engineer.

1.3.4.2. Concreting

(1) The method of placing and the workability of the concrete shall be such as to ensure that a continuous monolithic concrete shaft of the full cross section is formed.The

method of placing shall be subject to the Notice of the Engineer and shall be carried out after inspection without such interruption as would allow the previously placed batch to have hardened. No contamination of the concrete by spoil, liquid or other foreign matter shall be allowed.

(2) The Contractor shall take all precautions to ensure that the concrete mix and placing of the concrete does not result in arching of concrete in a casing. Slump measured at the time of discharge into the pile boring shall be in accordance with requirements as specified in IS 2911-1979, Part I Section 2. Internal vibrators shall not be used to compact concrete unless the Contractor is satisfied that no segregation or arching of the concrete will result.

(3) Where concrete is placed in dry borings, measures shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in cement.

(4) Concrete placed under water or drilling fluid shall be by means of a tremie and shall satisfy requirements as per IS 2911-1979, Part I Section 2.

(5) Before concreting is commenced, the Contractor shall remove any accumulation of silt or other material at the base of the pile or boring.

(6) The hopper and pipe of the tremie shall be clean and water-tight throughout. The pipe shall extend to the base of the pipe or boring and a sliding plug shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie pipe and the water or drilling fluid. At all times during concreting, the tremie pipe shall penetrate the previously placed concrete and shall not be withdrawn from the concrete until completion of concreting. A sufficient quantity of concrete within the pipe shall be maintained at all times to ensure that the pressure within the tremie pipe always exceeds that from the water or drilling fluid.

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

1.3.4.3. Drilling Fluid

(1) Drilling fluid shall comprise bentonite complying with Specification IS:2720-1965; IS:2911- 1979, Part I Section 2 Appendix A or DFCP 4 of the Oil Companies Materials Association or given Notice by the Engineer and thoroughly mixed with clean fresh water to form a suspension meeting the specification requirements as submitted to and given Notice by the Engineer.

(2) The Contractor shall obtain manufacturers' certificates of the bentonite powder consigned to the site giving properties of each consignment and shall submit them to the Engineer prior to commencing the work and whenever required.

(3) The temperature of the water used in mixing the suspension shall not be lower than 5°C. Where saline or chemically contaminated groundwater occurs, special precautions to the Notice of the Engineer shall be taken to modify the bentonite suspension or prehydrate the bentonite in fresh water so as to make it suitable for pile construction.

(4) The type and frequency of testing drilling fluid and the method and procedure of sampling shall be proposed by the Contractor and subject to Notice by the Engineer prior to commencement of piling work. Such control tests on the bentonite suspension shall be carried out during the course of the piling work.

(5) Before concreting a pile, the Contractor shall remove any heavily contaminated bentonite suspension which could impair the free flow of concrete from the tremie pipe. A sample of the bentonite suspension shall be taken from the base of the boring using an Noticed slurry sampling device and the specific gravity of the suspension should not exceed 1.20 as per standard practice and also as per IS:2911. Consistency of the mud suspension shall be controlled throughout the pouring as well as concreting operations in order to keep the hole stabilized as well as to avoid concrete mixing with the thicker mud suspension.

(6) All reasonable steps shall be taken to prevent the spillage of bentonite suspension on the site in areas outside the immediate vicinity of boring. Discarded bentonite shall be removed from the Site without delay and any disposal thereof shall comply with the regulations of all appropriate relevant authorities.

1.3.5. Pile Testing

1.3.5.1. General

Load testing of Piles shall conform to IS 2911-1985, Part IV.

1.3.5.2. Safety Precautions

(1) General

When preparing for conducting a pile test the Contractor shall comply with the requirements of the various acts, orders, regulations and other statutory instruments that are applicable to the work for the provision and maintenance of safe working conditions, and shall in addition make such other provision as may be necessary to safeguard against any hazards that are involved in the testing or preparations for testing.

(2) Personnel

All tests shall be carried out only under the direction and in presence of an experienced and competent supervisor conversant with the test equipment and test procedure. All personnel operating the test equipment shall have been trained in its use.

(3) Kentledge

a) Where kentledge is used the Contractor shall construct the foundations for the kentledge and any cribwork, beams or other supporting structures in such a manner that there will not be differential settlement, bending or deflection of an amount that constitutes a hazard to safety or impairs the efficiency of the operation.

b) The kentledge shall be adequately bonded, tied or otherwise held together to prevent it collapsing, or becoming unstable due to deflection of the supports.

c) The weight of kentledge shall be greater than the maximum test load and if the weight is estimated from the density and volume of the constituent materials an adequate factor of safety against error shall be allowed.

d) No part of the kentledge support system shall be closer to the pile centre-line than a distance of 2.5 times the shaft diameter of the pile subject to the Notice of the Engineer.

e) The weight of the kentledge shall be transferred in manner so that: (i) the load is transferred symmetrically around the pile head;
(ii) the suitability of the kentledge is maintained at all time, and; (iii) any tendency of the kentledge to tilt or sway is minimized.

f) Loads shall not be allowed to be applied by supporting the kentledge directly on the pile or pile cap.

(4) Tension piles and ground anchors

a) Where tension piles or ground anchors are used the Contractor shall ensure that the load is correctly transmitted to all the tie rods or bolts.

b) The extension of rods by welding shall not be permitted unless it is known that the steel will not be reduced in strength by welding.

c) The bond stresses of the rods in tension shall not exceed normal permissible bond stresses for the type of steel and grade of concrete used.

(5) Testing equipment

a) In all cases the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the pile head the whole system will be stable up to the maximum load to be applied.

b) Means shall be provided to enable dial gauges to be read from a position clear of the kentledge stack or test frame in conditions where failure in any part of the system due to overloading, buckling, loss of hydraulic pressure and so on might constitute a hazard to personnel.

c) The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable of withstanding a test pressure of one and a half times the maximum working pressure without leaking.

d) The maximum test load or test pressure expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

e) General requirements for load test equipments shall be as follows.

i) Load capacity not less than the maximum required load in the schedule of testing.

ii) Adequate enough to accommodate the maximum required pile movement specified in the schedule plus the displacement of the reaction system that occurs during load test.

iii) Fully controlled increase or decrease in test load

iv) Fully capable of sustaining the applied load as constant for specified period of time.

1.3.5.3. Presentation of Results

(1) Results shall be submitted as follows.

a) Unless otherwise directed the Contractor shall submit a summary of the pile test results in writing to the Engineer, within 24 hours after completion of the test. This summary shall include as a minimum the following information.

i) For a proof test with maintained load for each stage of loading, the period for which the load was held, the load and the maximum settlement or uplift recorded.

ii) For Constant Rate of Penetration (CRP) or Constant Rate of Uplift (CRU) test, the maximum load reached and a graph showing applied load versus penetration (movement) or applied load versus uplift - movement.

b) Complete schedule of all recorded data shall be submitted to the Engineer as both hard and soft copy in spreadsheet (Excel) format within seven days of the completion of the pile test.

1.3.5.4. Completion of a Test

(1) Measuring equipment

On completion of a test all equipment and measuring devices shall be dismantled, checked and either stored so that they are available for use in further tests or removed from the site.

(2) Kentledge

Kentledge and its supporting structure shall be removed from the test pile and stored so that they are available for use in further tests or removed from the site.

(3) Ground anchors and temporary piles

On completion of a preliminary test, tension piles and ground anchors shall be cut off below ground level, removed from the site and the ground made good with Noticed material.

(4) Preliminary test pile cap

a) The pile cap, if formed in concrete, shall be broken off and the resulting material disposed of off the Site. If the pile cap is made of steel it shall be cut off and stored so that it is available for use in further tests or removed from the Site.

b) Preliminary test piles shall not be incorporated into the Permanent Works. They shall be broken down to 2 metres below ground level or as required and backfilled to the original ground level with suitable material.

(5) Test pile cap

a) On completion of a test on a working pile, the test pile cap, if in concrete, shall be stripped, the pile left in a state ready for incorporation in the Permanent Works and the resulting material disposed of off the site.

b) If the pile cap is made of steel it shall be cut off and stored so that it is available for use in further tests or removed from the site as specified.

1.3.5.5. High Strain Dynamic **Testing** of Piles

Dynamic pile testing, which mobilizes all or part of the available pile static capacity, shall be used where specified or required and shall be subject to the Notice of the Engineer.

1.3.5.6. Lateral Load Tests

Lateral load tests, where required shall be carried out using temporary plant capable of providing an unyielding reaction of at least 1.5 times the maximum lateral load to which the pile is to be tested. Alternatively, where tension piles of the same size and type as the permanent piles are used for providing the reaction system for vertical load tests these may be used for the lateral load test by jacking apart. In this case the reaction piles shall be provided with sufficient reinforcement to sustain the effects of maximum lateral load.

1.3.5.7. Pile Integrity Tests

(1) General

a) Pile integrity testing shall be used where specified or required as a method of proof-testing a pile as work proceeds with the aim of indirectly assessing one or more of the following.

i. The structural integrity of the pile.
ii. The relative shape of the pile shaft and an estimate of the physical mensions of the pile or both.
iii. The continuity of the pile

b) Pile integrity testing, when specified, shall be performed on a sufficient number of piles.

c) All testing shall be be subject to the Notice of the Engineer.

(2) Test Procedure

Where integrity testing is required, the test to be adopted shall be one of the following.

i)Sonic impact test (SIT)

ii) Sonic vibration test (SVT)

iii) Alternative test, as agreed[

(3) Supervision and recording of results

Pile tests shall be carried out under the direction of a person experienced in the supervision of pile integrity tests who shall record all results in both hard and electronic form in preparation for submission to the Engineer.

1.3.6. Diaphragm Walling

1.3.6.1. General

(1) The recommendations of BS 8004 Code of Practice for Foundation and DIN 4126 Cast-in- situ concrete diaphragm walls; design and construction shall be followed insofar as they are applicable to diaphragm wall construction. Similar Indian Standards for guidance or adoption are; IS 9556, IS 4651 and IS 456.

(2) The Contractor shall take full account of fact that in some locations the walls may be close to existing structures and/or within a location where headroom is limited.

(3) The Contractor shall pay particular attention to safety aspects of the work, employing barriers and covers as necessary.

(4) Where diaphragm walls form permanent structures these shall also comply with all the requirements for reinforced concrete design and construction

1.3.6.2. Method Statement

(1) The Contractor shall submit a method statement giving the full details of materials, plant and operations involved in the construction of diaphragm walls at least 4 weeks prior to the commencement of construction of diaphragm wall. This method statement shall include but not be limited to the following details.

a) Dimension of walls and lengths of panels.
b) Design calculation, dimensions and details of guide walls.
c) Formation of the joints between panels, including sealing the joints and installation of water stop.
d) Sequence of excavation and concreting of panels.
e) Methods of monitoring and checking the stability of adjacent buildings, structures properties, pavements, railways, services, utilities road furniture and the like, all termed EBS.
f) Methods of monitoring and checking the tolerances associated with the diaphragm wall panels.
g) Methods of monitoring and checking the stability of the diaphragm wall trench. h) Mixing, transporting and placing equipment for the bentonite slurry.
i) the cleaning and re-use of bentonite slurry;
j) Method of disposal of contaminated bentonite slurry.
k) Type, source, chemical and physical properties of the bentonite to be used.

l) Calculations to show that the density of the bentonite and lowest head of slurry are sufficient to maintain the stability of the trench, in the ground conditions envisaged, to its entire length.

m) Methods of protection of any adjacent structure and utilities existing close to the trench.

(2) Construction of diaphragm walls shall not commence until the Contractor's proposals have received a "Notice to Proceed" from the Engineer

(3) Unless otherwise given Notice by the Engineer, the construction of panels shall be continuous once excavation has commenced. Excavated panels or part panels shall not be left open at night or during weekends.

1.3.6.3. Levels of Work

(1) Diaphragm walls shall be concreted to the levels shown on the Noticed-to drawings.

(2) The effective trimmed final wall levels shall normally be taken as 250 millimetres below top of guide wall when concrete is cast-up to top of trench. If the groundwater table is high and if required cut-off is low and the groundwater table is also at depth, concreting can be stopped at lower level subject to the Notice of Engineer.

(3) Any remaining bentonite within the trench shall be displaced off using lean mix concrete, which shall be poured to the top of the guide walls.

1.3.6.4. Length of Panels

The length of the panels to be concreted shall be defined in the Contractor's method statement and shall be subject to a "Notice to Proceed" from the Engineer.

1.3.6.5. Tolerances

(1) Construction shall be carried out in accordance with the following normal tolerances, unless otherwise defined by the Contractor's drawings or procedures.

a) For straight or other specified profile panels, the minimum clear distance between the faces of the guide walls shall be the specified diaphragm wall thickness plus 25 millimetres, and the maximum distance shall be the specified diaphragm wall thickness plus 50 millimetres. The guide walls shall be propped as necessary, to maintain these tolerances, and the inner guide wall shall be constructed to the line as shown on the drawings.

b) The trench face of the guide wall on the side of the trench nearest to the subsequent main excavation shall be vertical to within 1:200. The wall face shall not vary from a straight line or the specified profile by more than +15 millimetres in 3 metres and shall be without ridges or abrupt irregularities.

c) The plane of the diaphragm wall face to be exposed shall be vertical to within a tolerance of 1:200, relative to a vertical line projected from the base of the guide wall. In addition to this tolerance, 75 millimetres shall be allowed for protuberances resulting from irregularities in the ground excavated beyond the general face of the wall.

d) The ends of panels shall be vertical to within a tolerance of 1:80.

e) Where recesses are to be formed by inserts in the wall, they shall be positioned within a vertical tolerance of ±75 millimetres, a horizontal tolerance measured along the face of the wall of ±75 millimetres, and a horizontal tolerance at right angles to the face of the wall as constructed of ±25 millimetres measured to the reinforcement cage.

f) The tolerance in positioning reinforcement shall be as follows.

   i) Longitudinal tolerance of cage head at the top of the guide wall and measured along the trench: ±75 millimetres.
   ii) Vertical tolerance at cage head in relation to the top of the guide wall: ±50 millimetres.
   iii) Lateral tolerance of reinforcement position in the direction across the width of the wall; ±25 millimetres.

g) The tolerance in positioning couplers and starter bars for subsequent structural connections shall be as follows.

   i) Longitudinal tolerance measured along the trench, ±75 millimetres. ii) Vertical tolerance,: ±50 millimetres.
   iii) Lateral tolerance in the direction across the width of panel, ±25 millimetres.

h) A minimum cover to main reinforcement shall be 75 millimetres . Minimum clear distance between reinforcement bars shall be 100 millimetres.

i) Notwithstanding the requirements of this subsection the tolerances may be aggregated only to the extent that they do not exceed 250 millimetres.

(2) If, during the general excavation, it is detected that the above-stated tolerances have been exceeded, the Contractor shall draw up proposals for remedying or compensating for the defects.

1.3.6.6. Access

The Contractor shall note the restricted access to portions of the Works and shall satisfy himself that his method of excavation, positioning of equipment, spoil handling, placement of reinforcement cages, stop ends, and concreting can be accommodated within these restrictions.

1.3.6.7. Adjacent EBS

(1) The Contractor shall be responsible for any movement, distortion or damage resulting from his work to adjacent EBS.

(2) The Contractor shall be deemed to have made due allowance in his rates and prices for all ancillary treatment and all work necessary to ensure the stability of all EBS that may be affected by his work.

1.3.6.8. Reinforcement

(1) Reinforcement shall comply with the requirements of Section 2 of this Volume.

(2) High strength deformed steel bars and wires for concrete reinforcement conforming to IS 1786-1985 and structural steel sections conforming to IS 800-1984 shall be used.

(3) Structural steel sections shall be inserted into the cage where openings shall be made at subsequent stages.

(4) All reinforcement bars and other structural steel section used shall be clean and free from loose mill scales, dust, rust, oils, grease, paint or other coatings which may reduce the bond with concrete.

(5) Front and rear of cages shall be marked on Site to identify them during placement, and lifting points and design of lifting lugs shall not cause distortion of the cage.

(6) Distance spacers shall be of an agreed type, capable of resisting displacement during cage placement within the trench and shall not entrap slurry during cage placement or concreting.

(7) The reinforcement shall be adequately fixed to avoid displacement and to maintain the minimum specified cover during concreting.

1.3.6.9. Concrete

(1) Concrete shall comply with the requirements of Volume 5, Section 1.4 below. Structural concrete shall have a minimum cement content as per the Volume 4, Section 2.5 Outline Design Specification Civil Structures.

(2) Minimum slump of the concrete shall be 150 millimetres and the mix shall flow easily within the tremie pipe and be designed to produce a dense impervious concrete. Such structural concrete shall have a minimum compressive cube strength of 35 MPa at 28 days and the water: cement ratio of the mix shall not exceed 0.40 or as required by the design.

(3) Lean mix concrete as per IS 456-2000 clauses 5 to 8 shall be used as backfill above

any cut-off level for structural concrete and be taken to the top level of the guide walls.

1.3.6.10. Test Cubes

(1) Test cubes shall be made and tested in accordance with Clause 1.4.2.3 below

(2) Test cubes shall be taken for each panel constructed. Cubes shall be marked with the wall panel numbers and shall be sub-marked within each panel set to indicate a location within the panel.

1.3.6.11. Bentonite

(1) Bentonite for use in the wall support slurry shall be in accordance with the requirements of this Contract.

(2) The Contractor shall institute a programme of regular sampling and testing to ensure that the bentonite fluid properties are suitable for use in the Works. In this regard IS: 9556-1980 shall be used for guidance.

1.3.6.12. Storage of Bentonite

(1) Bentonite shall be stored in dry cool conditions. Particular care shall be taken with bulk storage to prevent balling of bentonite powder due to damp, or deterioration of properties due to damp and heat.

(2) A suitable design of hopper cone and bentonite feeding device shall be adopted.

IS 4082-1996 shall be used for guidance regarding stacking and storage of construction materials and components at site.

1.3.6.13. Alternative Materials

(1) The Contractor may, subject to the requirements of the Contract, consider and adopt suitable additional or alternative ingredients and additives for the wall support slurry to that of the bentonite specified above. Samples and full details shall be obtained from the supplier and manufacturer of such ingredients.

(2) Any such materials shall have no detrimental effect upon the stability of the excavation or concreting, or formed concrete immediate as well as long term.

(3) Ingredients to counteract the loss of slurry to the surrounding strata shall be deemed covered by this Section.

1.3.6.14. Placing Concrete by Tremie

(1) Tremie pipes shall be clean, water-tight and with a minimum internal diameter of 200 millimetres.

(2) The tremie tube shall extend to the bottom of the trench excavation prior to concreting and care shall be taken to ensure that all bentonite slurry is expelled from

the pipe during the initial charging operation. The tremie pipe shall be maintained with a minimum embedment of 2 metres into the concrete to prevent the re-entry of slurry into the pipe.

(3) The Contractor shall ensure that an adequate supply of concrete to the tremie is available at all times so that placement is continuous until completion of the panel.

(4) The number of tremie pipes per panel shall be in accordance with the method statement.

Where more than one tremie pipe is employed during concrete pouring to any one panel, the charging of concrete into the pipes shall be arranged so that it is evenly distributed between the pipes and so that no differential head exists at the concrete/slurry interface over the length of the panel. This level shall be confirmed by soundings taken during the concrete pour.

1.3.6.15. Stop Ends

(1) Stop-ends, inserted before placement of concrete in the panel, shall be clean and have a smooth regular surface. Any shutter release agent shall have no detrimental effect on the finished works. Where stop-ends are inserted in sections, adequate joint connections must be provided to ensure verticality over the whole length.

(2) Extraction of stop-ends shall be carried out at such a time and in such a manner that no damage is caused to the concrete placed against them, or to the adjacent soil and structures.

(3) Stop-ends shall be adequately restrained to prevent movement during concreting and not be permanently encased in the diaphragm wall

1.3.6.16. Inserts

Inserts shall be formed at the locations shown in the Contractor's drawings and in accordance with his method statements and procedures.

1.3.6.17. Checking and Monitoring

The Contractor shall provide all necessary monitoring instrumentation necessary for the close and continuous checking of the movements and distortions of adjacent ground and EBS.

1.3.6.18. Safety and Emergency Procedures

The Contractor shall take all necessary precautions to ensure stability of his excavations and guide walls and shall take all necessary precautions and be responsible for the safety of personnel in the area of operation.

The Contractor shall maintain, available for immediate use, a sufficient quantity of slurry to allow for any sudden loss. The loss continue despite the addition of the slurry and the stability of the trench be placed at risk, the Contractor shall backfill with lean mix concrete to preserve the stability of the trench and ensure the safety of adjacent ground and EBS. The cause of the loss of slurry shall be investigated and works shall not recommence until remedial measures have been implemented.

1.3.6.19. Site Cleanliness

The Contractor shall ensure that the site is cleared of slurry and that surplus or displaced slurry is disposed of safely and without nuisance. All operations shall be conducted in such a manner as to minimise any spillage of slurry over the Site, or accesses thereto.

1.3.6.20. Obstructions

(1) An obstruction is defined as material, the excavation of which hinders normal progress and the existence of which could not have been foreseen.

(2) Upon encountering an obstruction, the Contractor shall determine the method to be employed in removing the obstruction and such method shall be subject to the Notice of the Engineer

1.3.6.21. Disposal of Spoil

(1) Spoil removed from the excavation shall be separated from the slurry employed in the excavation process. It shall be disposed of as quickly as possible to locations subject to the Notice of the Engineer and in such a manner that spillage and annoyance be minimised.

(2) Contaminated slurry, not suitable for re-use, shall be removed from the site and disposed off.

1.3.6.22. Joints

(1) All joints shall be fitted with a water-stop covering the full height of the wall.

(2) Where concrete is cast against previously completed wall panels, the previously formed concrete shall be cleaned so that solid substances are removed before the joint is formed.

(3) When the joint is exposed upon subsequent excavation, the Contractor shall immediately repair any joints which permit jetting or spraying of water or within which

solid foreign substances greater than 3 millimetres separate the concrete in adjacent panels.

(4) The walls and joints formed shall satisfy the water-tightness requirements of this Contract.

1.3.6.23. Records

The following records shall be maintained and kept for each wall panel and such records shall be available for inspection by the Engineer.

a) Name of work.
b) Panel No and reference drawing number.
c) Date and time of start and finish of panel excavation.
d) Details of any obstructions encountered; time spent and construction method adopted in overcoming such obstructions.
e) Date and time of completion of cage placement.
f) Date and time of start and completion of panel concreting;
g) Length of panel and width and depth of panel from top of guide wall
h) Top of guide wall level and densities;
i) Top level of wall as cast, in relation to top of guidewall at the edges and at the centre.
j) A log of soil type encountered from start to finish of excavation, and of slurry levels and densities.
k) Volume of concrete used and time of any interruptions in concrete supply where these exceed 15 minutes.
l) Volumes of normal and lean mix concrete.
m) Cut-off level of concrete below top of guide wall level.
n) Date, place and time of slurry control tests and results recorded.
o) Concrete test cubes, w/c ratio, slump markings, date and results obtained on testing.
p) Details of reinforcement and cage type.
q) Quantity of slurry removed from site and spoil removed from Site recorded by date.
r) A graph of theoretical and placed concrete volumes with depth.

1.3.6.24. Disposal of Slurry

Used bentonite or contaminated slurry not suitable for re-use shall be disposed of in water-tight containers. The Contractor may propose alternative means of disposal which shall be subject to the Notice of the Engineer.

1.4 Structural Concrete

1.4.1. Concrete Materials

1.4.1.1. General

(1) This work shall comprise the construction of all or portions of structures with

cement (OPC) concrete, of the required class or classes, with or without reinforcement, with or without admixtures, constructed in accordance with the Contract and the relevant Standards to the lines, levels, grades and dimensions shown on the Drawings.

(2) Constituent materials for the concrete mix shall comply with the requirements of IS: 456 or BS 5328, unless otherwise given Notice by the Engineer.

(3) Ordinary Portland cement (OPC) of 43 grade and 53 grade conforming to IS 8112-1989 and IS 12269-1987 respectively shall be used. Portland pozzolana cement (PPC) conforming to IS 1486 can also be used. The Engineer may direct the usage of sulphate resistant Portland cement conforming to IS 12330 for structural elements exposed to soil. In all cases the cement shall meet the 28 day strength requirement of IS 8112-1989 or IS 12269-1987.

(4) Testing and non-conformances affecting the standard of the concrete shall be notified to the Engineer in-line with the Quality Assurance (QA) procedure such that mitigation may be effected expeditiously within the critically defined timeframes.

1.4.1.2. Cement

(1) General

If soil has soluble salts in excess of 0.5%, sulphate-resistant cement shall be used conforming to IS12330 (or BS 4027), or total chloride content in cement shall in no case exceed 0.05 percent by mass of cement. Also, total sulphur content calculated as sulphuric anhydride (SO_3), shall in no case exceed 2.5%and 3.0% when tri-calcium aluminate per cent by mass is up to 5% or greater than 5% respectively

(2) Testing

a) Cement shall be certified by the manufacturer as complying with the requirements of the relevant Standard. The Contractor shall submit to the Engineer the manufacturer's QA forms to demonstrate that the cement complies with relevant standards.

b) Before ordering cement, the Contractor shall submit relevant QA details on the proposed supplier and methods of transport, storage and certification to the Engineers for Notice to proceed (HOLD POINT). It must be proven that the quantity and quality required can be attained and maintained throughout the construction period.

c) Representative samples of the proposed cement may be required to be taken and forwarded to an independent laboratory for analyses before the source is Noticed. If cement is imported, fresh tests as per the relevant

Standards shall be conducted in an Noticed laboratory. Subsequent to obtaining the Engineer's Notice. The Contractor shall not change the agreed arrangements without the prior Notice by the Engineer. Each consignment of cement shall be accompanied by a certificate which shall be submitted to the Engineer immediately on delivery, substantiating the place of manufacture and the results of required testing carried out on the batch.

d) The Contractor may be required to sample cement and test such samples in accordance with the relevant or equivalent Indian Standards. The Contractor shall store the cement so that separate consignments can be identified and used in order of delivery to site (first-in, first-out process). In no circumstances shall cement that has exceeded its "use-by" date be allowed as part of the concrete mix.

(3) Cement Delivery and Storage

a) Cement shall be delivered in bulk or in the original manufacturer's sealed and marked bags, and shall be protected from the weather by enclosed transfer systems or other Noticed coverings. The Contractor shall provide silos to store sufficient bulk cement for continuity of work, and cement shall be placed therein upon delivery.

b) All necessary precautions shall be taken to prevent cement dust causing a nuisance.

c) On receipt of Notice from Engineer cement that has been damaged or does not comply with the Contract requirements shall not be used in the Works and be removed from the Site within 3 days of the Contractor's receipt of such Notice.

1.4.1.3. Aggregate

(1) Aggregate Sources

Prior to commencing any concrete work, the Contractor shall obtain the Engineer's Notice for the proposed types and sources of aggregate. Sampling of aggregates shall be as per IS 2430.

(2) Coarse Aggregates

a) Coarse aggregate for all classes of concrete shall conform to the requirements of IS 383. It shall be furnished in two separate sizes; either the 20 millimetres down and or the 38 millimetres down to No. 4 as required by the Standard.

b) Physical tests for suitability shall be carried out in accordance with IS 2386 or Parts I to VIII.

c) Coarse aggregate shall be clean, free from dust and other deleterious material. For reinforced and pre-stressed concrete aggregate shall be well-graded and durable with nominal 20 millimetre sized stones.

d) Hand-broken stone may be used providing such complies with the Contract requirements.

e) Water absorption shall be less than 3% by weight (ASTM C 117) (3) Fine Aggregate

a) Fine aggregate shall conform to the requirements of IS 383 or as required to meet the design requirements.

b) Water absorption shall be less than 3% by weight

(4) Alkali-Silica Reactivity (ASR)

a) If aggregates contain materials which have been tested to show chemical reactivity with alkalis found in any of the constituents of the concrete mix, or in water which will be in contact with the finished work, then the Contractor shall take samples of these materials every week.

b) The Contractor shall ensure that the concrete mix complies with the requirements of this Contract regarding "Minimising Risk of Alkali-Silica Reaction in Concrete",(Section 1.4.1.7)

c) The results of the Contractor's weekly ASR monitoring tests shall be submitted in writing to the Engineer for his Notice

(5) Chloride Content

a) The chloride content of aggregates shall be within the recommended limits stated in IS 383 or BS 882.

b) The chloride content of the concrete mix shall be within the recommended limit of IS 456 or BS 8110.

c) Chloride levels shall be determined daily in accordance with the methods described in BS 812.

(6) Sulphate Content

The total acid soluble sulphate content of the concrete mix, expressed as SO_3, shall not exceed the recommended limits in IS 456 or BS 8110.

(7) Storage

a) All aggregates shall be stored in such a way that they shall be kept free from contact with deleterious matter.

b) All aggregate shall be shaded from direct sunlight by means of a roof of sufficient height to enable unimpeded access to plant. Spraying of aggregate stockpiles with water shall be undertaken as necessary.

c) Aggregate of different sizes shall be stored separately shall be stored in masonry or concrete-based bins or on stages to prevent intermixing, segregation and the inclusion of dirt and foreign materials. . Storage bins shall be emptied and cleaned regularly. All aggregate hoppers shall be painted white.

1.4.1.4. Reinforcement

(1) Steel for Reinforcement

a) Only thermo-mechanically treated reinforcing bars of grade Fe 415/500 with minimum total elongation of 14.5% conforming to IS 1786-1986 shall be supplied and used as steel for reinforcement.

b) All reinforcement bars shall be procured from main steel suppliers and re-rolled steel shall not be used under any circumstances.

(2) Binding/Tying Wire

Tying wire shall be finally annealed mild steel of core diameter approximately 1.25 millimetres or as specified by the Contractor.

(3) Testing & Inspection

a) The Contractor shall provide copies of the manufacturer's certificates of tests results relating to the steel reinforcement to be supplied, and independent test results obtained from a Noticed laboratory in respect of samples taken from reinforcement delivered to the Site.

b) Every bar shall be inspected before before assembling and any defective, brittle excessive rusted or burnt bar shall be removed. Cracked end of bars shall be cut-out.

(4) Storage

Steel reinforcement shall be stored above ground, on timber supports or on a concrete slab, under cover and racked as necessary for protection. b)Stored steel shall not be at any time in direct contract with the ground, floor, slab or racks.

1.4.1.5. Water

(1) General

The Contractor shall make his own arrangements and procure fresh potable water for the mixing and curing of concrete. Testing of such water shall be in accordance with IS 3025.

(2) Quality

a) Water to be used for mixing and curing concrete and mortar shall be fresh and free from dissolved or suspended matter which may be harmful and shall comply with the requirements of IS 456.

b) Water samples from the intended source of supply shall be taken for analysis before any concrete work is commenced, and at intervals throughout the duration of the works.

c) Where potable water supply is not available the Contractor shall obtain confirmation of quality and reliability of a proposed source from the appropriate Water Authority and shall test the water for its chemical and other impurities before its use in the Works. Cost of all such tests shall be borne by the Contractor.

1.4.1.6. Admixtures

(1) General

a) The Engineer's Notice shall be obtained prior to using any admixture in any concrete mix. The minimum cement content specified shall not be shall not be reduced on account of use of admixtures.

b) Admixtures shall conform to IS: 9103 or BS 5075 and BS 1014.

c) Admixtures containing chlorides or other potential corrosive agents shall not be used.

(2) Quality

a) If admixtures are permitted these shall be used in the correct quantities. Noticed equipment and methods shall be used for dispensing and incorporating the admixture in the concrete; the dispensing unit shall be designed so that the discharge of the admixture is visible.

b) The concrete tests described herein shall be conducted with the admixture incorporated to establish that specified strengths are achieved, and that densities are not reduced. If air-entraining agents are used the density shall not be reduced by more than 5%.

c) Set-retarding and water-reducing admixtures shall comprise ligno-sulphonate.

d) Air-entraining agents shall comprise neutralized vinsol resin.

e) The manufacturer's declared equivalent acid soluble alkali content and the dosage rate of any admixture or pigment to be incorporated shall be included with details of all concrete mixes

f) The alkali content of admixtures shall be taken into account when determining the total equivalent alkali content of the concrete mix.

1.4.1.7. Minimising the Risk of Alkali-Silica Reaction (ASR) in Concrete

(1) Concrete mixes for use in the Permanent Works shall comply with the Contract. The Contractor shall notify the Engineer of his proposals for complying with this requirement.

(2) The materials shall satisfy one of the following requirements.

a) The reactive alkali content shall not exceed a maximum value of 0.6% by mass when defined and tested in accordance with this Contract.

b) The total mass of reactive alkali in the concrete mix shall not exceed 3 kg/m3 of concrete when defined, tested and calculated in accordance with this Contract.

c) The aggregate shall be classed as non-reactive in accordance with this Contract.

(3) Cementitious Material (Hydraulic and Latent Hydraulic Binders):

a) The term alkali refers to the alkali metals sodium and potassium expressed as their oxides. The reactive alkali content of Portland cements shall be defined as the percentage by mass of equivalent sodium oxide (Na_2O) calculated from the following relationship.

b) % equivalent Na_2O = % acid soluble Na_2O + 0.658 x (% acid soluble K_2O)

c) The method used in determining the acid soluble alkali content of the materials shall be in accordance with BS 4550: Part 2: Subsection 16.2.

d) The Contractor shall make available the certified average acid soluble alkali content of Portland cements on a weekly basis.

e) The Contractor shall give immediate Notice of any change which may increase the certified average acid soluble alkali content above the level used in the mix design for the concrete. A revised mix design for any concrete which would be affected by the increased alkali content shall be submitted to the Engineer's Representative for his Notice with notification of the change.

(4) Minimising risk by use of cementitous material containing less than 0.6% of reactive

alkali.

a) These requirement shall be met provided the contribution of alkalier from other source does not exceed 0.2 kg/m3.

b) The cementitous material shall be Ordinary Portland Cement (OPC) complying with Indian Standards and shall have additionally a certified maximum acid soluble alkali content not exceeding 0.6%. The Contractor shall provide on request weekly certificates which name the source of the cement and confirm compliance with the Contract.

c) Minimising risk by limiting the reactive alkali content of the concrete to 3 kg/m3.

d) The reactive alkali content of the concrete contributed by OPC to the concrete shall be calculated from:

$$A = \frac{C \times a}{100},$$

Where,

A = reactive alkali content of the concrete to the nearest 0.1 (kg/m^3) C = target mean Portland cement content of the concrete (kg/m^3)

a = certified average acid soluble alkali content of OPC (%).

e) Where reactive alkalis in excess of 0.2 kg/m3 are contributed to the concrete from sources other than the cementetious material, the limit of 3 kg/m3 from the cementetious material shall be reduced by the total amount so contributed. The reactive alkali contributed by sodium chloride contamination of aggregates shall be calculated from:

$$H = 0.76 \times \frac{(NF \times MF)+(NC \times MC)}{100} \text{ kg/m}^3$$

Where,

H = equivalent alkali contribution made to the concrete by the sodium chloride

NF = chloride ion content of the fine aggregate as a percentage by mass of dry aggregates and measured according to BS 812: Part 4

MF = fine aggregate content (kg/m3)

NC = chloride ion content of the coarse aggregate as a percentage by mass of dry aggregate and measured according to BS 812: Part 4: 1976 (now in draft as Part 117)

MC = coarse aggregate content (kg/m^3).The factor 0.76 is obtained from a consideration of the composition of saline / creek water.

The chloride ion content of aggregate sources containing 0.01% of chloride ion by mass or more shall be determined weekly in accordance with BS 812 or another Noticed method. When the chloride ion level is less than 0.01% it shall be regarded as nil.

(5) The Contractor shall provide certificates on request confirming compliance with the Contract which state the following.

a) The target mean cementitious material content of the concrete.
b) The names of the works manufacturing the cement.
c) A weekly report of the cement alkali determinations.
d) The certified average acid soluble alkali content of OPC.

(6) Minimising the Risk by Using Selected Aggregates

Fine and coarse aggregate material shall comply with the requirements of IS 383 and/or AASHTO Standard Specifications (M6 and M80 respectively) to be taken out to conform to 512(2).

(7) Water

a) Water for use in the manufacture of concrete shall be obtained from a public utility supply or from a source Noticed by Engineer.

b) Water shall be potable and comply with the requirement of IS 456 and or BS 3148

c) Where potable water supply is not available the Contractor shall obtain confirmation of quality and reliability of a proposed source from the appropriate water authority test the water for its chemical and other impurities before using. Cost of all such tests shall be borne by the contractor.

1.4.2. Concrete Workmanship

1.4.2.1. Grade

(1) Mixes General

Concrete shall be provided in accordance with IS 456 or BS 5328 except where required otherwise by this Contract.

(2) Concrete Mixes

The concrete mixes to be used in the Permanent Works shall be tabulated in the form in a typical “Table of Concrete Mixes” as given below.

TABLE OF CONCRETE MIXES

(to be completed by the Contractor)

Description used on Drawings

Type of Mix

Type of Cement.

Type of Aggregate Coarse: Fine:

Nominal Aggregate maximum size (mm) Grade

Minimum cement content (kg/m^3)

Sampling rate (cubic metres) -28 day normal curing

-7 day normal curing

Workability - Slump (millimetres)

- VB(s) Compacting

Maximum free water/cement ratio Maximum cement content (kg/m^3) Special cement

Special aggregate. Coarse: Fine:

Fine aggregate (%)

Admixtures Specified: Prohibited:

Amount: Air content

Temperature of Fresh concrete (^oC) Maximum:

Minimum:

Density of Concrete (kg/m^3) Maximum:

Minimum: (3) Chlorides

The total chloride content of the concrete mix shall be in accordance with the limitations given in

IS 456 or BS 8110 (4) Sulphates

The total water soluble sulphate content of the concrete mix shall not exceed the limitations given in IS 456 or BS 8110.

1.4.2.2. Trial Mixes

(1) Laboratory Trials

a) Concrete shall be proportioned to provide an average compressive strength; namely a specified characteristic strength plus a standard deviation factor; in accordance with acceptance criteria given in IS: 456 or relevant British Standard.

b) Not less than 35 days before commencement of concreting, the Contractor shall carry out trials to determine the concrete mixes which will satisfy the requirements of the Contract. The materials and conditions used shall reflect those intended to be used for the Works. A minimum six test cubes shall be made from each of three consecutive batches with three cubes from each batch to be tested at 7 days and three cubes at 28 days.

c) If the average 28 day strength (being defined as the measured stress when the cube fails) exceeds the specified characteristic strength by 20% or more, and the other requirements of IS 456 and IS 10262 or BS 5328 are met, then the trial mix proportions may be used to commence the Permanent Works. Otherwise further trials shall be carried out using re- designed mixes until the minimum required strength is achieved.

d) Additional Requirements of trial mixes shall be tested to determine the following properties of mixes proposed for initial field tests.

i. Bleeding in accordance with ASTM C232.
ii. Drying shrinkage in accordance with BS 1881.
iii. Air content, if applicable.
iv. Free water/cement ratio.
v. Workability.
vi. Wet and dry densities.
vii. Indirect tensile strength in accordance with BS 1881 including cylinder - splitting and beam tests.

e) If the test results obtained do not satisfy the Contract or the design requirements, the mixes shall be re-designed.

(1) Initial field tests

a) Trial mixes shall be prepared under full-scale site conditions and tested in accordance with IS 10262 or BS 1881.

b) Samples of concrete incorporating the reinforcing details to be used shall be cast and examined, before hardening using hand tools, and after hardening by coring to assess the mixes. Cores shall be 150 mm diameter. by 200 mm long.

1.4.2.3. Quality Control

(1) Test Cubes

a) Cubes shall be manufactured in an on-site laboratory, specially equipped for the purpose, in controlled conditions. They shall be made, cured, stored, transported and tested in accordance with IS 516 and BS 1881.

b) The cube-testing machine shall be housed in a laboratory and calibrated to BS 1610 when delivered. The machine calibration shall be verified at 3- monthly minimum intervals by a testing authority having National Accreditation Board for Testing and Calibration Laboratories (NABL) Certification.

(2) Cubes Samples

a) A sample of concrete shall be taken at random on eight separate occasions during each of the first five days of using a mix. The standard deviation shall be calculated from at least 25 individual cube results each representing separate batches of similar concrete produced by the same batching plant under the same supervision. The margin for the concrete batching plant shall be 1.64 times the standard deviation.

b) Thereafter one sample shall be taken at random for each class of concrete from every group of 25 batches made by each concrete batching plant, and at least one sample shall be taken each day that concrete of a particular grade is made. Samples shall also be taken and two cylinders cast to determine the indirect tensile strength of the concrete at 7 days and 28 days, as specified in relevant IS code or BS 1881.

c) These samples shall be taken from every 100 batches, but at least once a week during concreting operations, and shall coincide with samples taken for test cubes. The frequency of sampling may be required to be varied.

d) In addition to the above requirements, at least one sample shall be taken from each individual structural unit, or part of a unit, when the latter is the product of a single pour.

e) From each sample two cubes shall be made for testing at 28 days and one for testing at 7 days for control purposes. The 28 day Concrete Cube Strength (CCS) shall be the mean of two cubes. The procedures shall be repeated when materials or design mixes are changed.

(3) Cube Strength Results

a) The results will be unacceptable if:

i. the average strength determined from any four consecutive test cubes does not exceed the specified CCS by 0.5 times the current margin, or;

ii. one or more values in forty is less than 85% specified CCS, or;

iii. three or more values in forty are less than specified CCS; In which case any of the following actions may be instructed.

§ Change the mix.

§ Improve quality control.

§ Cut and test cores from placed concrete.

§ Load-test relevant structural units.

§ Carry out non-destructive tests on as placed concrete. Cut-out and replace defective concrete.

b) If the range of individual cube strength made from the same sample exceeds 15% of the mean then the method of making, curing and testing cubes shall be checked.

c) In the event of a result having a range exceeding 20% the Contractor shall submit his proposals corrective action for Notice by the Engineer.

d) The Contractor shall cut concrete cores from as-built locations as may be required by the Engineer and test them to BS 1881 as modified by Concrete Society Report TR 11. If the values, reduced by 0.69 Mega Pascal per week of age in excess of 28 days, are less than

75% CCS, the concrete shall be cut out and replaced unless otherwise agreed with the Engineer

(4) Concrete Durability and Other Tests

a) Concrete shall be tested for drying shrinkage, water absorption and moisture movement as directed for which 102 mm cubes and 76 mm by 76 mm prisms shall be prepared and tested in accordance with BS 1881.

b) The concrete shall be tested for permeability according to DIN 1048 and ability to resist chloride ion penetration according to ASTM C-1202.

c) The acceptance limits are as follows.

i. Drying shrinkage: 0.05%

ii. Moisture movement 0.03%

iii. Water absorption refer to item (5) below.

d) Cubes may be required and trials carried out to determine stripping times for formwork, the duration of curing and to check-testing and sampling errors. The air content of air-entrained concrete shall be determined for each batch produced until consistency has been achieved, when fewer batches may be tested.

e) During concreting of the Permanent Works six 150 mm diameter by 200 mm long cores shall be cut through horizontal reinforcement to assess plastic qualities. The qualities shall be equal to those obtained in the initial field tests.

f) Compaction factor, slump, or other workability tests shall be carried out as required during concreting of Permanent Works to control workability at the batching plant at the site of the pour. The degree of workability shall be as for the trial mixes; permitted tolerances shall be in accordance with IS 1199 or BS 5320.

g) Tests shall be carried out at least daily for the moisture content and weekly for absorption value of the aggregate. The values for the aggregate at the mixer shall be determined and changes made to the mix to compensate for variations.

(5) Concrete Durability Tests: Acceptance Criteria

Concrete Durability Tests	**Acceptable Values**	***References***
RCPT(Coulombs)	<1000 (28 days)	*ASTM C1202*
Water Absorption	1.50%	*ASTM C642 & BS1881-122*
Chloride Content	0.2 to 0.3% by wt of cement	*ACI 301 & ASTM C1218, EN 206-1*
Sulphate Content	3%	*BS1881-124*
Water Permeability	<10mm	*DIN 1048 & BS EN 12390*
Initial Surface Absorption Test (ISAT)	0.25ml/m^2/sec	*BS 1881- 208*

Concrete of permanent structures shall fulfil the above mentioned minimum values. (6) Scheme for monitoring

a) Monitoring shall be carried out in accordance with the relevant Standards, as implemented under the requirements of ISO 9002.

b) Compliance of the concrete and associated work to required levels of performance shall be captured in the monitoring regime.

c) The scheme implemented shall be subject to the Notice of the Engineer and undergo regulatory QA checks to ensure the levels of competence in monitoring are being consistently adopted and undertaken in the Works.

1.4.2.4. Batching

(1) Machinery

Batching shall be by weigh-batching machines equipped with accuracy checks for the weighing mechanism. The machines shall be cleaned, checked and adjusted regularly. The water supply to the concrete mixers shall have a metering system to control and record the amount.

(2) Accuracy of Batching

Batched materials shall be measured to the following tolerances and discharged into the mixer without loss.

Cement ± 2% of the weight of the cement in the batch.

Aggregate	± 2% of the weight of each aggregate in the batch.
Water	± 2% of the weight of water added to the batch.
Admixture	± 5% of the amount to be added to the batch.

(3) Calibration of Measuring Equipment

a) Measuring equipment shall be checked and calibrated at the start of preliminary concrete tests and at weekly intervals. The necessary test weights and the like shall be kept available on site. Scales shall be checked over their complete range by a specialist every three months.

b) A calibrated container shall be used to check the accuracy of admixtures dispensers once each month. The results of these checks shall be notified.

(4) Mixing

Concrete constituents shall be thoroughly mixed in batches. The machines shall be capable of discharging while running.

(5) Ready-Mixed Concrete

a) Ready-mixed concrete shall not be used unless Noticed, and shall comply with the requirements specified herein and those of IS: 4826 and BS 5328.

b) The supply and use of ready-mixed concrete shall be subject to the Contractor's QA procedures.

c) Ready-mixed concrete shall be obtained from a depot subject to the Notice of the Engineer. and transported to the Site in truck type mixers which shall continuously agitate the concrete mix.

d) The concrete shall be placed in its final position and compacted within 2 hours of the introduction of cement to the aggregates.

e) The ready-mixed concrete delivered to the Works shall comply with this Specification. One cubic metre of each mix shall be supplied to Site before it is required in the Works to allow the Contractor to carry out workability tests.

f) For plant-mixed concrete the delivery note for each batch shall state the time at which the concrete was mixed and the weight of the constituents of each mix.

g) When truck-mixed concrete is used, water shall only be added under the Contractor’s direct supervision either at the Site or at the central batching plant in accordance with the standard Quality Procedures. In no circumstances shall extra water be added to the concrete after the original mixing is complete.

h) Samples for testing shall be taken as the concrete is placed in its final position.

i) The Contractor shall arrange for the ready-mix concrete supplier to provide the facilities stated in BS 5328, cl 7.1 or 13.1.

(6) Records

a) Daily returns shall be provided showing the quantities of cement and the total volume batched of each class of concrete for each section of the Works.

b) The Contractor shall submit detailed records and test results for all test cubes and specimens taken without delay to the Engineer for his Notice.

1.4.2.5. Control of Chlorides and Sulphates

(1) Chlorides in Concrete

a) The levels of equivalent acid-soluble chlorides as NaCl (Cl x 1.65 = NaCl) in the constituents of concrete as stated elsewhere are indicative and are subject to the over-riding limits for the mixes. The total estimated content as a percentage by weight of the cement in the mix shall not exceed the following limits.

i. For reinforced concrete
0.5% if made with Ordinary Portland Cement (OPC)
0.1% if made with Sulphate-Resistant Portland Cement (SRPC)

ii. For mass concrete
with OPC 0.2% if made with SRPC
0.2% if made with SRPC

b) The Contractor shall test the constituents of the concrete to establish these contents as provided for elsewhere in this Contract.

c) In addition, regular tests to BS 1881: Part 6 for chloride content shall be made on the hardened concrete. The following values are considered tolerable but shall be be subject to Notice by the Engineer.

i. For reinforced concrete made with OPC
95% of the test results less than 0.4% NaCl by weight of cement and no result greater than 0.5% NaCl by weight of cement.

ii. For reinforced concrete made with SRPC
95% of the test results less than 0.1% NaCl by weight of cement and no result greater than 0.14% NaCl by weight of cement.

iii. For mass concrete made with OPC
95% of the test results less than 1% NaCl by weight of cement, and no result greater than 1.3% NaCl by weight of cement.

iv. For mass concrete made with SRPC
95% of the test results less than 0.2% NaCl by weight of cement and no result greater than 0.25% NaCl by weight of cement.

d) In the event that the SRPC used contains a proportion by weight of tri-calcium aluminate which approaches 4% to 8%, then Notice shall be sought from the Engineer for an appropriate adjustment of the relevant chloride content limits.

(2) Sulphates in Concrete

a) The level of acid-soluble sulphates (SO_3) in the mix shall satisfy all of the following requirements.

Coarse aggregate ≤ 0.4% by weight.

Fine aggregate ≤ 0.4% by weight.

Water ≤ 500 mg/l.

b) The total estimated sulphate content (SO_3) of the mix including that present in the cement shall not exceed 3.7% by weight of cement in the mix.

c) In addition, regular tests in accordance with BS 1881: Part 6 shall be carried out on the hardened concrete to determine the total sulphate content, which shall not exceed 4% by weight of cement in the mix.

(3) Permissible Level of Chloride and Sulphates

The permissible level of chlorides and sulphates stated in this Contract shall not be considered as mean values for the whole of the Works, but shall apply to any concrete used in the Works.

(4) Concrete for water-retaining structures shall comply with IS 3370.

1.4.2.6. Placing

(1) General

a) Concrete shall be transported by means which prevent contamination (by dust, rain and the like) segregation or loss of ingredients, and shall be transported from the batching plant and placed without delay.

b) Concrete shall be placed in the positions and in sequences indicated on the Drawings. Placing shall not commence until the fixing and condition of reinforcement and items to be embedded and the condition of the containing surfaces or formwork have been Noticed by the Engineer. The Contractor shall provide the Engineer with written notification not less than 24 hours prior to his intention to place concrete in the Works.

c) Concrete shall be placed directly in its final position without segregation or displacement of the reinforcement, embedded items and formwork. Where necessary concrete may be placed in water in accordance with the Contract requirements.

d) Concrete shall not be dropped through a height greater than 1 meter.

(2) Extent of Pours

a) The limit of individual pours and the height of lifts shall be as Noticed.

b) For walls, the length of panel placed at one time shall not exceed 6m; adjacent panels shall not be placed within 2 days, but shall be placed as soon as practicable thereafter. Subsequent vertical lifts shall not be poured within 2 days.

c) Floors, roofs and ground slabs shall be placed in a sequence of pours to the approval of the Designer and the Notice of the Engineer.

d) If the use of slip-forms or paving trains is permitted, the above pour limits may be revised

e) The sequence of pours shall be arranged to minimise thermal and shrinkage strains.

(3) Placing Equipment

Concrete shall generally be placed without segregation by pumping or bottom-opening skips. If chutes are used their slopes shall not cause segregation and spouts or baffles shall be provided.

(4) Time for Placing

Concrete and mortar must be placed and compacted within 30 minutes of water being added to the mix or otherwise included via damp aggregates, unless admixtures are in use. Partially-set concrete shall not be used in the Works.

(5) Compaction

a) Concrete shall be compacted during placing by Noticed internal vibrators. The vibrators shall operate at a frequency of not less than 10,000 cycles per minute, and shall be designed for continuous operation.

b) The performance of vibrators shall suit the working conditions, and depending on the thickness of layer to be compacted; 25 mm, 40 mm, 60 mm and 75 mm diameter internal vibrators may be used. The radius of influence of the vibrator used shall ensure that the concrete mass being vibrated is compacted at a speed commensurate with the rate of supply of concrete.

(6) Vibrators

a) Vibrators shall penetrate the full depth of the layer of concrete placed and just into the layer below, and be withdrawn slowly to avoid the formation of voids.

b) Vibration shall not be applied directly or indirectly to concrete after the initial set has taken place, nor shall it be used to make concrete flow in formwork.

c) The Contractor shall have a minimum of two spare vibrators available during each concrete pour in case of mechanical breakdowns.

(7) Continuity of Placing

a) Placing in each section of work shall be continuous between construction joints. The Contractor shall make provision for standby equipment.

b) If the placing of concrete is delayed due to breakdown then the Contractor shall erect vertical stop-ends and form a construction joint or remove the concrete already placed and restart after repair of the breakdown.

(8) Placing in Inclement Weather

a) Placing shall not take place in the open during rain or inclement weather. If such conditions are likely to occur the Contractor shall provide protection for the materials, plant and formwork so that placing of concrete may proceed.

b) If strong winds are prevalent protection from driving rain and dust shall be provided for.

c) During storms and heavy rain periods only underground or enclosed concrete pours shall be permitted and this shall also be subject to where there is a reasonable level of protection to the concreting work.

(9) Placing in High or Low Temperatures

a) The temperature of fresh concrete shall not exceed 32 oC, nor drop below 5oC, nor exceed the temperatures stated in the table of mixes. The lowest of these shall be used at the time of placing concrete.

b) The maximum concrete temperature after placement shall not exceed 50oC nor be 30oC above the temperature at the time of placement, whichever is the lower.

c) The Contractor shall comply with the document entitled "Concrete in Hot Countries" published by the FIP congress at New Delhi 1986. The procedures the Contractor wishes to employ in this regard shall be subject to Notice by the Engineer's.

d) The Contractor shall supply suitable maximum and minimum temperature thermometers and record the shade and open-air temperatures at locations where concrete is being placed. A recommendation for cold weather concreting is provided in IS: 7861 (Part 2).

(10) Placement at Night

If Notice has been given for placing concrete at night or in dark interiors, adequate lighting, ventilation and access shall be provided when mixing, transportation and placing are in progress.

(11) Placement Underwater

a) Underwater concreting shall be carried out with minimum disturbance of the water. Running water and wave wash shall be controlled.
b) The specified concrete grade shall be used and the mix design shall provide for good flowing ability.
c) Tremie pipes, bottom-dump skips or other Noticed placing equipment shall be used.
d) Segregation shall be avoided.
e) Placing shall commence in sections and continue to completion subject to Notice by the Engineer.
f) The tremie pipe shall be buried in the concrete for at least 1.5m and the tremie pipe

must not be emptied until the pour is complete.

g) If a bottom-dump skip is used, the contents shall be covered by canvas or similar before lowering into the water. The doors shall be opened when the skip is resting on the bottom with no tension in the support cable, and the skip shall be lifted gradually so that the concrete flows out steadily.

(12) Preparation before Placing

a) Before placing concrete for reinforced work on the ground, the formation shall be compacted as specified and a screed of blinding concrete shall be applied to form a surface for construction.

b) Before placing concrete on or against rock, masonry, brickwork or old concrete, loose material shall be removed and the surface washed down; water seepage shall be stopped or channelled away from the work.

c) For mass concrete placed against masonry or brickwork the following shall apply.

§ The mortar joints in the face work shall have fully hardened.

§ The water-cement ratio of the concrete shall be increased to compensate for absorption of moisture by the existing work.

§ The surface shall be soaked prior to placing.

§ The concrete shall be worked around ties and bond stones and into open joints.

1.4.2.7. Reinforcement

(1) Reinforcement General

a) Steel rod reinforcement shall be cut, bent and fixed in accordance with IS 456 or BS 8110: Part 1.

b) Cold bending shall be used which does not damage the material.

c) Bending hot at a cherry-red heat not exceeding 840oC may be Noticed except for bars dependent on cold-working for strength.

d) Bars shall not be cooled by quenching.

(2) Fixing

a) The number, size, form and position of pieces of reinforcement shall be as shown on the Drawings. They shall be held in position in the formwork during the placing of concrete by use of distance pieces and spacer bars.

b) Links shall be taut so that bars are braced and the inside of their curved parts shall be in contact with the bars being connected. Binding wire shall be twisted tight with pliers and the free ends shall be bent inwards.

c) Reinforcement shall be grit-blasted before use if instructed by the Employer’s

d) Representative to remove rust, oil, grease, salt and other deleterious matter, and where pitting has occurred the causes and products thereof. Repeated blasting may be required when the reinforcement is in position, or partially cast in. Partially-set concrete adhering to exposed bars during concreting operations shall be removed.

e) Reinforcement temporarily projecting from the concrete at joints shall not be bent out of position without Notice of Engineer, in which event the reinforcement shall be bent over a suitably sized former to prevent any damage or over-stressing.

(3) Bending Schedules

The Contractor will provide drawings detailing the reinforcement required and shall prepare bending schedules in accordance with SP 34 of BIS and IS 5525 BS 4466. Laps and anchorages shall be as stated in IS 456 or BS 5400, Part 4.

(1) Welding

a) Electric arc welding may be used, if Noticed, for joining bars. Covered-alloy or shielded-arc electrodes shall conform to IS 814 and/or BS 639.

b) Workmanship shall be to IS 2251 or BS 5135.

c) Joints shall be butt-welded with standard double-V or double-U welds.

(4) Cover to Reinforcement

a) Control of the minimum thickness of concrete cover to reinforcement shall be achieved by the use of Noticed concrete or plastic spacers. Minimum cover shall be as specified in the Contract or IS 456.

b) If concrete spacers are used they shall be of similar concrete grade to the main concrete, and shall have non-metallic ties or Galvanized Iron protected ties. For 30 MegaPascal or more concrete, the spacers shall comply with the requirements of this Contract for water absorption.

c) Cover blocks used also should be same mix as the concrete of member and be with roughened faces

1.4.2.8. Joints

(1) Construction Joints

a) Construction joints shall be located and the sequence of placing arranged as Noticed, to minimise shrinkage and thermal strains in the concrete.

b) Concrete placing shall not be interrupted except where joints occur, and shall continue after normal hours if necessary to achieve this.

c) Joints shall be formed square to the work with keyways included.

d) Before placing is resumed at a joint the set surface shall be roughened to remove laitance and expose the aggregate; the aggregate shall not be damaged. If damaging materials have come into contact with the surface of the joint the concrete shall be cut back and the roughened surface cleaned by compressed air or water jets and brushed and watered immediately before placing. If required the surface shall be coated with a layer of stiff cement grout prior to placing the new concrete.

e) Chemical surface-retarding agents shall not be used.

f) Construction joints shall be sealed with a Noticed sealant at external and liquid-contact faces.

g) Construction joints in water-retaining structures shall incorporate a Noticed water-stop.

(2) Expansion, Contraction and Movement Joints

a) Expansion, contraction and other movement joints shall be incorporated in the Works as shown on the Drawings.

b) Where shown on the Drawings, expansion joint fillers shall be supplied and installed. Filler material shall be stored flat on a dry surface adequately protected from rain or moisture in such a way that the material does not deteriorate. Filler material which has been damaged or has started to deteriorate shall not be incorporated in the works.

c) Movement joints shall be sealed with a Noticed sealant applied in strict accordance with the manufacturer's instructions to the dimensions shown on the Drawings. The surface of the concrete to which the sealant is to adhere shall be straight and cleaned of all filler material, dirt, oil, grease and other matter. The sealant shall be applied by methods recommended by the manufacturer so that the sealant is brought flush to the surface of structure and a smooth surface is achieved. Excess material and spillage shall be properly cleaned off and removed.

d) Dowel bars shall be installed and cast-in across the movement joint where shown on the Drawings. The bars shall be straight with clean cut ends of the diameters and lengths as shown on the Drawings or in the Schedules. Cutting and cleaning of the dowel bars shall comply with the requirements of the Contract

e) The bars shall be firmly supported in the positions shown on the Drawings so that they remain accurately parallel and are not displaced during the casting of the concrete in the first part of the structure. After the concrete has hardened and the formwork removed, the projecting ends shall be cleaned of all concrete spillage and painted with two coats of an Noticed bituminous paint and caps shall be fitted to the free ends of the bars. Dowel bar end caps shall be of cardboard or other material, of correct diameter for the dowel bar and of sufficient length to allow the specified movement of the two adjacent concrete structures. They shall be manufactured expressly for this purpose by a Noticed manufacturer.

f) The Contractor shall take care to protect the projecting ends of dowel bars from bending or other damage prior to concreting the succeeding bay. The bituminous paint shall be applied as soon as practicable, but end caps shall not be fitted until immediately prior to the succeeding concreting operations.

(3) Water-stops

The layout and installation of the water-stops shall be in accordance with the manufacturer's recommendation and shall be subject to the Notice of the Engineer.

(4) Bolts, Inserts and Openings

a) All fixing blocks, brackets, built in bolts, holes, chases, etc., shall be accurately set out and formed and carefully sealed prior to the concrete being placed. No cutting away of concrete for any of these items shall be done.

b) Bolts and other inserts to be cast into the concrete shall be securely fixed to the formwork in such a way that they are not displaced during the concreting operations, and that there is no loss of materials from the wet concrete through holes in the formwork.

c) Unless shown otherwise on the Drawings reinforcement shall be locally moved so that the minimum specified cover is maintained at the locations of inserts, holes, chases, and the like.

d) Temporary plugs shall be removed and the threads of cast-in bolts shall be proved to be free and shall be greased before handing over any part of the Works.

1.4.2.9. Curing and Protection

(1) Curing and Protection

Concrete shall be protected from sunshine and drying winds by Noticed shading and wind-breaks, and from cold, rain or running water, for a period of at least 7 days after placing. During this period or for any extended period the following measures shall be taken to prevent the loss of moisture and to minimise thermal stresses caused by the difference in temperature between the surface of the concrete and the core of the concrete mass.

a) Horizontal surfaces.

§ Polythene sheeting shall be placed immediately after finishing.

§ After final set has taken place, the polythene shall be replaced by wet Hessian covered with polythene. The Hessian shall be kept permanently damp.

- § After 7 days the Hessian and polythene shall be removed and Noticed aluminised or white resin-based curing compound applied unless an alternative method is used. The method of application shall be as recommended by the manufacturer.

Alternative methods of curing shall be subject to the Notice of the Engineer before use in the Works.

b) Vertical surfaces.

- § Polythene over wet Hessian shall be secured to the surfaces immediately after removal of the formwork. The Hessian shall be kept permanently damp.
- § After 7 days the Hessian and polythene shall be removed and an Noticed aluminised or white resin based curing compound applied.
- § Alternatively, the Hessian and polythene to stay for a further 7 days.

Water used during curing operations shall be fresh water. Curing membranes shall be compatible with waterproofing or other materials that may subsequently be applied to the surface of the concrete.

In case of steam curing method the period of curing shall be as required.

(2) Contamination

Concrete shall be protected from contamination by Creek or Saline or brackish water, oil, fuel and other deleterious materials for a minimum period of 30 days after placing.

(3) Insulating Formwork

Insulating formwork shall be left in place for 72 hours after placing the concrete or until the temperature peak of the concrete is reached. The initial curing period defined above may then be reduced in proportion subject to the Notice of the Engineer.

(4) Protection of Joints

Rebates formed to receive sealant and the surfaces of construction joints shall be protected from curing compound by wet Hessian to ensure proper curing of the joint surface and adjacent concrete. The protection shall remain in place until the joint surface is sealed.

1.4.2.10. Finishes

(1) General

a) The finished faces of concrete shall be sound, even-coloured, even-textured and free from defects. Arises shall have a 20mm by 20mm chamfer. Concrete faces shall not be rendered and defective concrete shall be cut out and replaced or made good. A fine finish shall be provided unless otherwise detailed on the Drawings.

b) The Contractor shall carry out timely interfacing to ensure that appropriate finish of concrete surface is rendered to accommodate the Employer's Requirements.

(2) Fine Finish

Surfaces defined as having a fine finish shall be rubbed smooth by carborundum stone; small holes shall be stopped with Noticed mortar of the same final colour as adjacent concrete.

(1) Concrete Surfaces without Formwork

a) On upward-facing surfaces which do not require formwork or special finish the finish shall be produced by proper placing and compacting operations alone.

b) For a fair-finish screeding, this shall be carried out by sliding and tamping a screed board running on the top edges of the formwork, or on screeding guides, to give a dense concrete skin.

c) For a fine finish screeding as described, the surface shall be left until the concrete has stiffened and the film of surface moisture has disappeared. A steel or wooden float shall then be used for a glossy or sandpaper surface as required. Working shall be the minimum compatible with a good finish. The surface shall be protected from water drops.

(3) Wire-Brushed Finish

After removal of the formwork the surface of the concrete shall be abraded by stiff wire brushes and water to remove the cement laitance and expose the aggregate.

(2) Bush-Hammered Finish

a) The surface shall be abraded by carborundum stones to remove irregularities. Within 3 weeks, the surface shall be bush-hammered to remove the cement laitance and expose the aggregate. Noticed bush hammers shall be worked to within 12 millimetres of corners and arrisses; the remaining 12 millimetres shall be hand-chiselled to match.

b) Bush hammers shall be operated perpendicularly to the surface, and the remaining exposed aggregates shall not be loose or fractured. The treated surface shall be washed with water and stiffly brushed. The exposed aggregate shall be clean and free from film.

(4) Chemical Retarders

Chemical surface retarders, may be used to produce an exposed aggregate finish, and the Contractor shall demonstrate that the durability of the concrete surface is not reduced.

(5) Carborundum Finish

a) Carborundum finish shall be achieved by sprinkling carborundum grit on the unset surface and working-in by wooden float.

b) The carborundum grit shall vary in size between BS 1.18 millimetres mesh and BS 0.6 millimetres mesh and shall be distributed from a BS 1.18mm hand-screen at the rate of 2.15 kilograms per square metre.

(6) Specimen Panels of Concrete

If required, the Contractor shall produce specimen panels of finished concrete for the Notice of the Engineer.

1.4.2.11. Special Concrete

(1) No-Fines Concrete

a) The aggregate for no-fines concrete shall be coarse-graded from 10mm to 20mm. A small percentage of fines from 10mm to 5mm may be added to improve the strength if Noticed.

b) Cement shall be mixed with the aggregate in the proportion of 1 to 8 by volume.

c) Segregation of the cement grout shall be prevented.

(2) Granolithic Concrete

a) Granolithic concrete shall consist of one part by weight cement to three parts of combined coarse and fine aggregate.

b) Granolithic concrete shall preferably be laid on top of the unset base concrete, and compacted and worked to the correct levels. The surface shall be floated with a steel float after hardening until water sheen has disappeared. Cement or cement-sand shall not be sprinkled onto the surface. The layer shall be 12mm to 18mm thick.

c) If a granolithic layer is required to be placed on set concrete, the latter shall be scrabbled and cleaned to expose the aggregate, and an Noticed bonding agent applied. The layer shall not be less than 50mm thick.

d) If required, compounds shall be added or applied to give a concrete with improved dust-proof and oil-proof qualities of any desired colouring. The compounds shall be used in accordance with the manufacturer's instructions.

e) Granolithic concrete paving shall be placed in panels not exceeding 3 metre square. Contraction joints shall be provided around the perimeter of each panel.

(3) Cement - Mortar, Grout, and Rendering

a) Cement-mortar shall consist of one part cement and four parts fine sand by volume with just enough water to achieve work-ability.

b) Cement-lime-mortar shall consist of three parts of sand to one part of mixture comprising one part of cement to one part of hydrated lime.

c) Grout shall consist of cement mixed with water in designed proportions. Fine sand may be included in Noticed quantities.

d) Rendering shall consist of three parts fine, sharp sand to one part cement applied in two 10mm thick coats and one 5 mm thick finishing coat. The colour of the finishing coat shall be subject to the Notice of the Engineer.

e) Acid-resistant epoxy mortar shall be obtained from a Noticed manufacturer and applied in accordance with the manufacturer's instructions.

f) Mortar, render and grout shall be used freshly mixed.

1.4.2.12. Protective Coatings

(1) External Sheet Tanking Membrane

a) External protection to concrete substructures where required shall be as Notice by the Engineerand fixed to the surface in accordance with the manufacturer's instructions.

b) Materials and workmanship shall be in accordance with the Contract waterproofing.

(1) External Brush-Applied Tanking Membrane

a) Substructures shall be protected externally, where required with an Noticed membrane applied to the top of the blinding concrete and to the outside surfaces of all buried concrete, and continued where appropriate to 300mm above finished ground level.

b) The surfaces shall be cleaned and brought to a fine finish before coating. Each coat shall be applied at the rate specified by the manufacturer. Coatings shall be protected by hardboard or similar materials during backfilling.

(2) Internal Protection to Concrete

Protection to internal concrete faces shall be provided as required. (2) Protection of Concrete Above Ground Level

a) All exposed concrete surfaces above tanking membrane tuck-in level shall be coated with an Noticed two-coat protection level system, subsequently over-coated with an Noticed compatible two-coat Epoxy based paint..

b) Sample panels of minimum area 10 square metres shall be made on finished concrete to prove the finish quality and enable the colour to be selected. Only those panels finally Noticed may be included in the Works.

1.4.2.13. Tolerances

The tolerances of concrete surfaces shall be in accordance with the following. Precast

Concrete	BS 8110 Members Subsection 6.11.3
Foundations and other	BS 5606 in-situ buried concrete
Exposed concrete	BS 5606 (including internal surfaces of sewer culverts)
Other concrete surfaces:	As shown on drawings/schedule of finishes

1.4.3. Precast Concrete

1.4.3.1. Manufacture Off-Site

(1) Casting of members shall not begin until Notice has been given by Engineer to the shop drawings, required computation, pre-stressing system (if required) and method of manufacture.

(2) When the drawings and method of manufacture have been Noticed, no changes shall be made without the Notice of the Engineer

(3) The Contractor shall inform the Engineer in advance of the date of commencement of manufacture and casting of each type of member. Concrete reinforcement and workmanship shall be as per IS 456.

(4) A copy of all cube test results for the precast concrete works shall be sent to the Engineer as soon as these are available.

(5) No members to which the tests relate shall be dispatched to the Site until the tests have been satisfactorily completed and Noticed by the Engineer.

(6) All members shall be indelibly marked to show the “member mark” as described in the Contract, the production line on which they were manufactured, the date on which the concrete was cast and, if they are of symmetrical section, the face that will be uppermost when the member is in its correct position in the works. The markings shall be so located that they are not exposed to view when the member is in its permanent position.

1.4.3.2. Forms

The design and engineering of the forms and false work as well as their construction shall be the responsibility of the Contractor.

All exposed surfaces of each element of the structure shall be formed with similar material to produce similar concrete surface textures, colour, and appearance.

Forms shall be inspected prior to authorizing casting operations. Details shown on the

Drawings shall be built into the forms. Worn, damaged, or otherwise unacceptable forms shall be repaired before casting of any member will be authorised.

The forms may be made either of steel or of plywood. If the Contractor elects to use plywood forms, it shall be high quality plywood, 19mm minimum thickness marine grade subject to the Notice of the Engineer.

Forms shall be structurally adequate to support the members within permissible tolerances. The form design shall incorporate the method and the necessary hardware to adjust and maintain grade and alignment. Details of the hardware and adjustment procedure shall be included in the required plans.

Forms shall be coated with Noticed form-release agent prior to use. Form release agents shall be of commercial quality, of oil or other equivalent substances which permit the ready release of forms and will not discolour the concrete. Excess form release agents shall not be allowed to stand in puddles in the forms nor shall coating be allowed to come in contact with reinforcing steel or hardened concrete.

Anchor devices may be cast into the concrete for later use in supporting forms provided the arrangement shall be to the Notice of the Engineer.

The use of driven or drilled types of anchorages for fastening forms or form supports to concrete shall not be permitted.

1.4.3.3. Curing

(1) The steam curing shall be at 100% relative humidity to prevent loss of moisture and to provide moisture for proper hydration of the cement. Application of the steam shall not be directly on the concrete. During application of the steam, the ambient air temperature shall increase at a rate not exceeding 22 degrees Celsius per hour (oC/h) until the maximum temperature has been reached. Curing shall comply with the requirements of the Contract.

(2) Steam curing process may be used as an alternative to water curing. The casting bed for any unit cured with steam shall be completely enclosed to prevent steam escaping and exclude outside atmosphere. 2 to 4 hours after placing concrete and after the concrete has undergone initial set, the first application of steam shall be made, unless retarders are used, in which case the waiting period before application of the steam shall be increased to from 4 to 6 hours. Water curing methods to be used from the time concrete is placed until steam is first applied.

(3) Where the steam has been raised the maximum temperature shall be held until the concrete has reached the desired strength. In discontinuing the steam application, the

ambient air temperature shall not decrease at a rate to exceed 22oC/h until a temperature has been reached 10 oC above the temperature of the air to which the concrete shall be exposed. The maximum curing temperature shall be from 60oC degrees to 67oC .

(4) If the Contractor elects to cure by any other special method, the method and its details shall be subject to the Notice by Engineer.

1.4.3.4. Storage

When members are stored, they shall be firmly supported only at the points specified.

(1) The accumulation of trapped water and deleterious matter in the units shall be prevented.

(2) Care shall be taken to avoid rust staining and efflorescence.

1.4.3.5. Handling and Transport

(1) Members shall be lifted or supported only at points specified or otherwise given Notice by the Engineer and shall be handled and placed without impact.

(2) The Contractor shall define the method of lifting, the type of equipment and transport to be used, and the minimum age of the members to be handled and shall be subject to the Notice of the Engineer.

1.4.3.6. Assembly and Erection

(1) The method of assembly and erection described in the Contract shall be as practicable and be strictly adhered to on site.

(2) Immediately after a unit is in position, and before the lifting equipment is removed, temporary supports or connections between members, as necessary, shall be provided.

(3) The final structural connections shall be completed as soon as possible.

1.4.3.7. Forming Structural Connections

(1) No structural connections shall be made until the Engineer's Notice has been received.

(2) Unless otherwise Noticed by the Engineer, the composition and water: cement ratio of the in- situ concrete or mortar used in any connection and the packing of joints shall be in accordance with the assembly instructions.

(3) Levelling devices shall only be released or removed subject to the Notice of the Engineer.

1.4.3.8. Epoxy Grout for Structural Connections (if required)

(1) Description

Epoxy shall be furnished as two components mixed together at the Site.

(2) Sampling and Testing

All tests will be conducted in accordance with the latest test methods of the American Society for Testing and Materials, Federal Test Method Standard No. 141 or equivalent British Standard.

(3) Packaging, Labelling and Storing

a) Each component shall be packaged in steel containers not larger than 20 litres in volume. When the components are to be mixed at a ratio of 2 parts A to one part B, by volume, the container containing component B shall be one half the volume of the container containing component A.

b) The containers shall have lug type crimp lids with ring seals, shall be new, not less than 0.6mm nominal thickness and shall be of such character as to resist any action by the components.

c) Each container shall be clearly labelled with the designation (Component A or B), type (Standard or Rapid) if applicable, manufacturer's name, date of manufacture, batch number (a batch shall consist of a single charge of all components in a mixing chamber), lot number, all directions for use specified elsewhere and the following warning in Hindi, Marati and English:

"CAUTION" or Equivalent in Hindi/Marati

"This material will cause severe dermatitis if it is allowed to come in contact with the skin or eyes. Use gloves and protective creams on the hands. Should this material contact the skin, wash thoroughly with soap and water. Do not attempt to remove this material from the skin with solvents. If any gets in the eyes, flush for 10 minutes with water and secure immediate medical attention."

d) Attention is directed to the characteristic of some epoxy components to crystallize or thicken excessively prior to use when stored at temperatures below 2^{o}C. Any material which shows evidence of crystallization or a permanent increase in viscosity or settling of pigments which cannot be readily re-dispersed with a paddle shall not be used.

(4) Directions for Use

a) At the time of mixing, components A and B shall be at a temperature between 16 degrees and 29^{o}Cunless otherwise specified. Any heating of the adhesive components shall be done by application of indirect heat. Immediately prior to mixing, each component shall be thoroughly mixed with a paddle. Separate paddles shall be used to stir each component. Immediately prior to use, the two components shall be thoroughly mixed together in the specified ratios. When mixed, all adhesives shall have a uniformly grey colour without black or white streaks. No solvent shall be added to any epoxy.

b) After mixing, all epoxies shall be placed in the work and any overlaying or inserted be cleaned and it shall have moisture content of not more than 0.5% when tested. The maximum size of the aggregate shall not exceed that of material which is to be bonded to the work by the epoxy. It shall also be placed before thickening of the epoxy has begun. Surfaces upon which epoxy is to be placed shall be free of rust, paint, grease, asphalt, moisture and loose and deleterious material. When epoxy is used as a binder to make epoxy concrete or grout, the two components of epoxy shall be thoroughly mixed together before the aggregate is added and, unless otherwise specified, the mix proportions shall consist of one part of binder to approximately 4 parts of aggregate, by volume. Aggregate for use in epoxy concrete and grout shall one-fourth of the thickness of the joint to be grouted. All surfaces against which epoxy concrete and grout are to be placed shall be primed with a coat of the epoxy used just prior to placing the grout.

c) No more material shall be mixed than can be used within 20 minutes from the time mixing operations are started. Pot life of the epoxy mixture shall be 45 minutes.

(5) Epoxy Grout Strength Requirements

The compressive strength of 38mm cubes of epoxy grout tested in accordance with ASTM C39 after 10 hours of curing at 20^{o}Cshall be not less than the design strength of the pre-cast member.

1.4.3.9. Protection

At all stages of construction, pre-cast concrete units and other concrete associated therewith shall be properly protected to prevent damage to permanently exposed concrete surfaces, especially arises and decorative features.

1.5 Formwork

1.5.1. General

These specifications shall be read in conjunction with the MORTH specifications and BMC specifications with correction slips/amendments up to date, and other relevant specifications described in Section 1of this Volume 5.

1.5.2. Materials

Formwork shall be of timber, plywood (including marine plywood), steel or any other suitable material capable of resisting damage to the contact faces under normal conditions of erecting forms, fixing steel and placing concrete. The selection of materials suitable for formwork shall be made by the Contractor based on the quality consistent with the specified finishes and safety.. The entire responsibility of planning, designing, erecting, dismantling, shifting and safety of false work lies with the Contractor.

All formwork and formwork supports (centering, props, scaffolds, ladders etc.) shall be in structural steel only and preferably of pipes conforming to IS:806, IS:1161, IS:1239, IS:2750. Wooden ballies shall not be permitted as props/formwork supports. All props shall be properly braced using x & k bracings. Ladders to be used at site should have treads and shall be fabricated from structural steel. Wooden/ bamboo/aluminium/pipe ladders shall not be permitted.

1.5.2.1. Timber

Timber used for formwork shall be easily workable with nails without splitting. It shall be stable and not liable to warp when exposed to sun and rain or wetted during concreting.

1.5.2.2. Plywood

Plywood used for formwork shall be minimum 12mm thick. Shuttering quality plywood complying with IS:4990. Suitable stiffeners and walers shall be provided depending on the shuttering design.

1.5.2.3. Steel

Steel formwork shall be made of minimum 4mm thick black sheets stiffened with angle iron frame made out of M.S. angles 40mm x 6 mm supported at suitable spacing.

1.5.3. Design & Drawings

The permissible stresses in materials in all Temporary Works such as formwork, falsework, staging, launching and the like. shall be the same as for the Permanent Works. The Contractor’s checked and verified calculations and drawings of the same including construction sequence (along with soft copy in CD ROM) shall be submitted to Engineer for his Notice well in advance of work.

All constructed Temporary Works shall be also inspected by the Design Checker and an inspection report shall be submitted to Engineer. All Temporary Works shall be robust, safe and constructed such a way that the concrete can be properly placed and thoroughly compacted to obtain the required shape, position and level subject to specified tolerances.

It is the responsibility of the Contractor to obtain the results required by the Engineer, whether or not some of the work is sub- contracted. Agreement of the temporary works by the Engineer shall not diminish the Contractor's responsibility for the satisfactory performance of the same, nor for the safety and co-ordination of all operations.

The design of false work should be such as to facilitate easy and safe access to all parts for proper inspection.

Methodology for removal of form should be planned as a part of total formwork design process.

In case of pre-stressed concrete work, careful consideration shall be given to re-distribution of loads due to pre-stressing.

1.5.4. Formwork for Exposed Concrete Surfaces

The facing formwork, unless indicated otherwise in drawings, shall generally be made with materials not less than the thickness mentioned below for different elements of the structure:

(1) Plain slab soffit, and sides of beams, joists and ribs and side of walls, , parapets, etc shall be made with:

a) Steel plates not less than 4mm thick of specified sizes stiffened with a suitable structural framework and fabricated true to plane

b) Timber planks of 20mm actual thickness and of specified surface finish, width and reasonable length,

c) Plywood not less than 12mm thick (IS:4990 - Specification for Plywood for Concrete Shuttering Work) stiffened with a suitable timber frame work or 3mm thick plywood with a 20mm timber plank backing, of specified sizes stiffened with a suitable timber framework and bracing. At joints 6mm/10mm sponge to be provided.

(2) Bottoms of beams, sides of columns shall be formed using the following materials.

a) Steel plates not less than 5mm thick of specified sizes stiffened with a suitable structural framework, and fabricated true to plane

b) Timber planks of 35mm actual thickness and of specified surface finish, width and reasonable length,

c) Plywood not less than 12mm thick (IS:4990), of specified sizes stiffened with a suitable timber framework.

(3) For precast segments, portals, and the like suitable steel formwork shall be used.

1.5.5. Formwork for Sloped Surfaces

(1) Forms for sloped surfaces shall be built so that the formwork can be placed board-by-board immediately ahead of concrete placement so as to enable ready access for placement, vibration, inspection and finishing of the concrete.

(2) The formwork shall be built in such a way so that the boards can be removed one by one from the bottom up as soon as the concrete has attained sufficient stiffness to prevent sagging. Surfaces of construction joints and finished surfaces with slopes steeper than 2 horizontal: 1 vertical shall be formed as required herein.

1.5.6. Formwork for Curved Surfaces

(1) The Contractor shall interpolate intermediate sections as necessary and shall construct the forms so that the curvature will be continuous between sections. Where necessary to meet requirements for curvature, the form lumber shall be built up of laminated splices cut to make tight, smooth form surfaces.

(2) After the forms have been constructed, all surface imperfections shall be corrected and all surface irregularities at matching faces of form material shall be dressed to the specified curvature.

1.5.7. Erection of Formwork

The following shall apply to all formwork:

(1) Before fabricating the forms the Contractor shall submit for the Engineer’s Notice the design of forms and the types of material to be used. (Ref. ACI 347 Formwork for Concrete or equivalent I.S. Code).

(2) All shuttering planks and plates shall be adequately backed by a sufficient number and size of walers or framework to ensure rigidity during concreting. All shutters shall be adequately strutted, braced and propped to prevent deflection under deadweight of concrete and superimposed live load of workmen, materials and plant, and to withstand pouring rate and vibration.

(3) Vertical props shall be supported on wedges or other measures shall be taken so that the props can be gently lowered vertically during removal of the formwork. Props for an upper level shall be placed directly over those in the level immediately below, and the lowest props shall bear on a sufficiently strong area. Care shall be taken that all formwork is set plumb and true to line and level or camber or better where required.

(4) Provision shall be made for adjustment of supporting struts where necessary. When reinforcement passes through the formwork care should be taken to ensure close fitting joints against the steel bars so as to avoid loss of fines during the compaction of concrete.

(5) If the formwork is held together by bolts, these shall be so fixed that no iron will be exposed on surfaces against which concrete is to be laid and within the concrete cover to the steel reinforcement. In any case wires shall not be used with exposed concrete formwork. If the Contractor elects to use tie-bolts running through the concrete then the Contractor shall define the location and size of such tie-bolts and submit his proposals for Notice by the Engineer. The tie-bolts shall be so designed that their removal on de-shuttering does not leave any embedment with in the concrete cover to steel reinforcement. Holes left in the concrete by these tie-bolts shall be filled by the concrete repair material and the methodology set out in the Contractor's Noticed proposal.

(6) Provision shall be made in the shuttering for beams, columns, and walls for a port hole of convenient size so that all extraneous materials that may be collected could be removed just prior to concreting.

(7) Formwork shall be so arranged as to permit removal of forms without jarring the concrete. Wedges, clamps and bolts shall be used wherever practicable instead of nails. The formwork for beams and slabs shall be so erected that forms on the sides of the beams and the soffit of slabs can be removed without disturbing the beam bottoms or props under beams.

(8) Surfaces of forms in contact with concrete shall be oiled with a mould oil of Noticed quality form releasing agent. The use of mould oil which results in blemishes of the surface of the concrete including diesel, burnt oil and any other lubricating oil shall not be allowed. Mould oil shall be applied before reinforcement has been placed and care shall be taken that no oil comes in contact with the reinforcement while it is being placed in position. The formwork shall be kept thoroughly wet during concreting and the whole time that is left in place. Nothing extra shall be paid to Contractor for oiling the moulds.

(9) Immediately before concreting is commenced, the formwork and other related arrangements shall be carefully examined to ensure the following.

a) Removal of all dirt, shavings, sawdust and other refuse by brushing, washing and compressed air/vacuum cleaning.
b) The tightness of joints between panels of sheathing and between these and any hardened core.
c) The correct location of tie bars, bracing and spacers, and especially connections of bracing.
d) Adequate cover blocks are in place
e) Straightness and plumbness of the form work
f) Side supports/restraints for the form work are enough and robust
g) Construction joint (wherever applicable) is properly prepared

h) That all wedges are secured and firm in position.

i) That provision is made for traffic on formwork not to bear directly on reinforcing steel.

j) Pouring platform along with its approach from ground is robust and safe for workers movement.

k) Arrangement for vibrators for compaction of concrete

l) Sequence of concrete pouring is well defined and is agreed upon by the Engineer and is explained to concrete pouring team

m) The Pouring area is well lit.

n) Curing arrangements are well planned and agreed upon by the Engineer.

o) The concrete protection measures in accordance with the Contract are in place.

(10) The Contractor shall ensure dimensional accuracies of the work and for the general arrangement of propping and bracing. (IS:3696 - Safety Code of Scaffolds and Ladders, IS:4014 Steel Tubular Scaffolding I & II). All scaffolding and staging shall be either of steel tubes or built up section of rolled steel with adequate bracing at several levels in each perpendicular direction connecting each prop. In addition to this diagonal bracing should be provided in elevation ideally at 45 degrees or between 30 degrees and 60 degrees. The Contractor shall be entirely responsible for the adequacy of propping, and for keeping the wedges and other locking arrangements undisturbed through the de-centering period. (IS:8989 Safety code for erection of concrete framed structures)

(11) Formwork shall be continuously watched during the process of concreting. If during concreting any weakness develops and formwork shows any distress the work shall be stopped and remedial action shall be taken.

1.5.8. Concrete Finishes

This section deals with the surface of concrete on which forms had been fixed while concreting.

1.5.8.1. Formed Surface

Allowable deviation from plumb or level and from the alignment profile, grades and dimensions shown on the drawings is defined as "tolerance" and is to be distinguished from irregularities in finishes as described herein. Tolerances in concrete construction are specified elsewhere.

The classes of finish and requirements for finishing of concrete surface shall be as shown on the drawings or as hereinafter specified.

Completed concrete surface shall be tested, where necessary to determine whether surface irregularities are within the limits specified hereinafter.

Surface irregularities are classified as "Abrupt" or "Gradual". Offsets caused by displaced or misplaced form sheathing, or form sections or by loose knots or otherwise defective timber form will be considered as abrupt irregularities, and shall be tested by direct measurements. All other irregularities shall be considered as gradual irregularities and will be tested by use of template, consisting of a straight edge or the equivalent thereof for curved surfaces. The length of the template shall be 150 cm for testing of formed surfaces and 300 cm for testing of unformed surfaces.

The classes of finish for formed concrete surfaces are designated by one of the symbols F1, F2, F3 and F4. Unless otherwise specified or indicated on drawings, these classes of finish shall apply as follows:

Finish F1: This finish applies to surfaces where roughness is not objectionable, or surface that will otherwise be permanently concealed. Surface treatment shall be the repair of defective concrete, correction of surface depressions deeper than 25 mm and filling of tie rod holes. Form sheathing will not leak mortar when concrete is vibrated. Forms may be manufactured with a minimum of refinement.

Finish F2: This finish is required on surfaces permanently but not prominently exposed to public view for which other finishes are not specified except F1. Forms shall be manufactured in a workmanlike manner to the required offsets or bulges. Surface irregularities shall not exceed 5mm for abrupt and 8mm for gradual irregularities measured with a 1.5 m template.

Finish F3: This finish is required for coarse textured concrete surfaces intended to receive plaster, stucco or wainscoting. Surface irregularities shall not exceed 5mm for both abrupt and gradual irregularities.

Finish F4: This finish is designated for surfaces prominently exposed to public view where appearance is also of special importance.. To meet with requirements for F4 finish, forms shall be manufactured in a skilful, workmanlike manner, accurately to dimensions. There should be no visible offsets, bulges or misalignment of concrete. At construction joints, the forms shall be rightly set and securely anchored close to the joint. Abrupt and gradual irregularities shall not exceed 3mm. Irregularities exceeding this limit shall be reduced by grinding to a level of 1:20 ratio of height to length. Jute bag subbing or sand blasting shall not be used.

1.5.8.2. Unformed Surfaces

The classes of finish for unformed surfaces are designated by symbols U1, U2, U3 and U4. Unless otherwise specified or indicated on drawings, these classes of finish shall apply as follows:

Finish U1: This finish applies to unformed surfaces that will be concealed permanently or otherwise where a screeded surface finish meets the functional requirements. Finish U1 is also used as the stage of finishes for U2 and U3. Finishing operations shall consist of sufficient levelling and screeding to produce an even uniform surface. Surface irregularities shall not exceed 10mm.

Finish U2: This is floated finish, and used on all outdoor, unformed surfaces. Finish U2 is also used as the second stage of finish for U3. Floating to be performed manually or mechanically on stiffened screed surface shall be minimum to produce textured surface. If finish U3 is to be applied, floating shall be continued till a small amount of mortar without excess water is brought to the surfaces so as to permit effective trowelling. Surface irregularities shall be removed

Finish U3: This is a trowelled finish and shall be used for tops of parapets, etc prominently exposed to view. When the floated surface has hardened sufficiently, steel trowelling shall be started. Steel trowelling on hardened, floated surface shall be performed with firm pressure to produce a dense uniform surface free from blemishes and trowel marks and having slightly glossy appearance. Surface irregularities shall not exceed 5mm.

Finish U4: This is a steel-trowelled finish, similar to finish U3, except that light surface pitting and light trowel marks such as obtained from the use of machine trowelling will be acceptable, provided that surface irregularities do not exceed the limits specified for finish U3.

Unformed surfaces which are nominally level shall be sloped for drainage as shown on drawings unless the use of other slopes or level surface is indicated on drawings. Narrow surface such as tops of parapets, walls and kerbs shall be sloped approximately 10mm per 300mm of width. Broader surface such as roadways platform shall be sloped approximately 5mm per 300mm of width. Finishes of floor and roof slabs shall be sloped Exposed Concrete Work

Exposed concrete surfaces shall be smooth and even, originally as stripped without any finishing or rendering. The surface shall be rubbed with carborundum stone immediately on striking the forms. The Contractor shall exercise special care and supervision of formwork and concreting to ensure that the cast members are made true to their sizes, shapes and positions and to produce the surface patterns desired. No honeycombing shall be allowed. Honeycombed parts of the concrete including the other surface defects in the concrete shall be removed by the Contractor as per the methods, which do not affect the strength of adjoining concrete.

Part of defective concrete thus removed shall be re-cast using fresh concrete of same grade or Noticed quality concrete repair material depending upon the size, location, thickness of the defective concrete and structural behavior of the member having defective concrete at no additional cost. Contractor shall ensure that no air bubbles are formed on the exposed surface. Concrete pouring sequence, vibration methodology etc shall be planned to avoid air bubbles.

1.5.9. Age of Concrete at Removal of Formwork

In accordance with IS: 456. Immediately after the forms are removed, they shall be cleaned with a jet of water and a soft brush.

1.5.10. Stripping of Formwork

The work of form work removal should be planned and a definite scheme of operation worked out. Formwork shall be removed carefully without jarring the concrete, and curing of the concrete shall be commenced immediately. Concrete surfaces to be exposed shall be rubbed down with carborundum stone or bush-hammer to obtain a smooth and even finish. Where the concrete requires plastering or other finish later the concrete surface shall be immediately hacked lightly all over using Noticed methods. No extra payment will be due to the Contractor for such work on concrete surfaces after removal of forms.

1.5.11. Reuse of Forms

The Contractor shall not be permitted reuse of timber facing formwork brought new on the works for more than 5 times for exposed concrete formwork and 8 times for ordinary formwork. 5 or 8 uses shall be permitted only if forms are properly cared for, stored and repaired after each use. Use of different quality boards or the use of old and new boards in the same formwork shall not be allowed. If any other type of special or proprietary form work is used, the number. of times they can be used shall be given a Notice by the Engineer.

1.5.12. Formwork for Precast / Prestressed Concrete

(1) The provisions in this section shall be considered supplementary to the general provisions stated above and additional Technical Specifications for pre-cast segments. Pre-cast concrete members and panels shall be made in accurately constructed moulds, on a properly prepared casting bed.

The Contractor shall submit detailed drawings of formwork to the Engineer for his Notice.

Finishing with cement mortar shall not be allowed.

(2) The formwork should be so designed that it does not restrain the shrinkage movements and possible shortening due to pre-stress of the concrete. The formwork shall be of sturdy construction with special considerations to shutter vibrators when used. All edges and joints of the formwork should be designed and sealed so that no cement grout can escape and there is no wedging or keying to the concrete. The effect of curing on the formwork should be given special consideration. Depending on care, curing, erection and maintenance of the formwork after stripping, the following number of uses can be made with different types of formwork.

(3) Stripping

As soon as the pre-cast units have attained sufficient strength, the formwork shall be stripped. The pre-cast unit shall be lifted uniformly out of the formwork without being subjected to tilting or restraint effects.

1.5.13. Special Architectural Finishes

Special Noticed architectural finishes like grooves, logos, engravings/projections in inset and out set as per the Noticed design shall be provided by fixing monolithic rubber forms or any other Noticed material fixed on the entire surface of the form work. The shore hardness of the rubber shall be 600 5A to ensure strength, flexibility and elasticity. The rubber shall be cold cured (preferably polyurethane based) and fixed to the formwork under controlled conditions in shade and air temperature not exceeding 280^{o}C.

The form liners should be shrinkage free, solvent free and should be impervious to abrasion by Concrete, resistant to concrete pressure and heat resistant up to 700^{o}C dry heat. Formwork liner fixation should be factory made under close tolerances and stage inspections.

If proprietary system of formwork is used, detailed information as given in Appendix A herein shall be furnished to Engineer for his Notice before use.

1.5.14. M.S. Liner

Any liner or bore-hole which is improperly located or shows partial collapse that would affect the load carrying capacity of the pile, shall be rejected or repaired as directed by the Engineer at the cost of the Contractor. The minimum thickness of liner shall be 6mm. (Clause 709.1.4 of IRC:78: 2000 was amended as IRC notification No: 54 dated 28.05.2009) Wherever practicable, concrete should be placed in a clean dry hole.

Where concrete is placed in dry and there is casing present, the top 3 m of the pile shall be compacted using internal vibrators. The concrete should invariably be poured through a tremie with a funnel so that the flow is directed and concrete can be deposited in the hole without segregation.

Where the casing is withdrawn from cohesive soils for the formation of cast-insitu pile, the concreting should be done with necessary precautions to minimize the softening of the soil by excess water. Where mud flow conditions exist, the casing of cast-In-situ piles shall not be allowed to be withdrawn.

Care shall be taken during concreting to prevent as far as possible the segregation of the ingredients. The displacement or distortion of reinforcement during concreting and also while extracting the tube shall be avoided.

If the concrete is placed inside precast concrete 'tubes or consists of precast sections, these shall be free from cracks or other damage before being installed.

The concrete shall be properly graded, shall be self-compacting and shall not get mixed with soil, excess water, or other extraneous matter. Special care shall be taken in silty clays and other soils with the tendency to squeeze into the newly deposited concrete and cause necking. Sufficient head of green concrete shall be maintained to prevent inflow of soil or water into the concrete.

1.5.15. Anti – Crash Barrier:

1.5.15.1. Definition:

Crash barriers are designed to withstand the impact of vehicles of certain weights at certain angle while traveling at the specified speed. They are expected to guide the vehicle back on the road while keeping the level of damage to vehicle as well as to the barriers within acceptable limits. Ideally a crash barrier should present a continuous smooth face to an impacting vehicle, so that the vehicle is redirected, without overturning, to a course that is nearly parallel to the barrier face and with a lateral deceleration, which is tolerable to the motorist. To achieve these aims the vehicle must be redirected without rotation about both its horizontal or vertical axis (that is, without 'spinning out' or overturning), and the rate of lateral deceleration must be such as to cause the minimum risk of injury to the passengers.

1.5.15.2. Objectives:

i. Reducing the likelihood of a vehicle crossing the central reserve and reaching the opposite carriageway.
ii. Minimising the damage to a barrier and vehicle, following vehicle strike and also reducing the risk to the workforce and work related congestion.
iii. Being maintenance-free and having a life of 25 to 50 years.

1.5.15.3. Types of Crash Barriers:

In view of the above factors, various options should be considered in evolving the need, location and design of the crash barriers, central railings and dividers.

No provision, vehicular carriageway raised for pedestrian walkway at grade.

i. 15 cm to 25 cm high curb stone.
ii. Flexible/ removable/ sinking divider or railing.
iii. Water filled plastic jerry can safety barrier.
iv. Reinforced Glass/ Plastic/ Rubber railing.
v. Jersey Barriers (concrete) and its variations (constant slope, F shape, Jali, etc).
vi. Steel concrete barriers, Railings, Fencing etc.

vii. Hybrid combining two or more options

According to IRC, following are the categories of crash barriers:

Category	Application	Containment for
P-1: Normal Containment	Bridges carrying expressway, or equivalent	15 kN vehicle at 110 km/h, and 20 degree angle of impact
P-2: Low Containment	All other bridges except bridge over railways	15 kN vehicle at 80 km/h, and 20 degree angle of impact
P-3: High Containment	At hazardous and high risk locations, over busy railway lines, complex interchanges, etc.	30 kN vehicle at 60 km/h, and 20 degree angle of impact

According to the IRC (6-2000) the crash barriers shall be provided at the following locations:

i. For bridges without foot paths, concrete crash barriers shall be provided at the edge of the carriageway.

ii. The type design for the crash barriers may be adopted as per IRC:5. The design loading for the barriers shall be as per Clause 209.7 of IRC:6.

iii. For bridges with foot paths, pedestrian railing shall be provided on the outer side of footpath.

iv. The railings of existing bridges shall be replaced by crash barriers, where specified in Schedule-B of the Concession Agreement.

v. Parapets/ Railings of the existing bridges/ culverts to be repaired/ replaced shall be specified in Schedule-B of the Concession Agreement.

In the urban environment traffic barriers are needed on urban motorways and primary distributors, where speeds are high and dangerous.

Traffic barriers should be erected on both sides of roads on embankments 6m high or more and on the outer edge of the roads where the radius is 850m or less and the embankment height 3m or more.

Barriers may also be needed on an embankment where there is road, railway or river at the foot, on bridges with lightly built parapets or to protect bridge piers or other obstruction on the central reserve or verges.

This is recommended on embankment, ramps to flyovers and interchanges and high speed corridors in open area. (Not recommended for highly built up area with pedestrian and cycle traffic).

1.5.15.4. End **Treatment**: It is important to provide suitable and treatment for such type of barrier in view of safety. The ends of this barrier must either be embedded into ground by tapering down or these must be embedded into the rigid parapet wall of a culvert or specially prepared rigid parapet fir the purpose of imbedding Crash barriers can be rigid type, using cast-in-situ precast reinforced concrete panels, or of flexible type constructed using metallic cold-rolled and/ or hot-rolled sections, the metallic type, called semi-rigid type, suffer large dynamic deflection of the order of 0.9 to 1.2m, or on impact, whereas, the 'rigid' concrete type suffer comparatively negligible deflection . The efficacy of the two types of barriers is established on the basis of full size tests carried out by the laboratories specializing in such testing. Due to the complexities of the structural action the value of impact force cannot be quantified.

A certificate from such laboratory can be the only basis of acceptance of the semi-rigid type, in which case all the design details and construction details tested by the laboratory are to be followed in to without modifications, and without changing relative strengths and positions of any of the connections and elements. For rigid barrier, at the end compulsory left out and right out signage be placed as per IRC 67:2001. The end of these rigid barriers may be treated with retro reflective tape or paint for night visibility and distant visibility.

1.5.15.5. Crash Barriers need to be provided at the following locations: Crash/ Safety barrier of rigid, flexible or semi rigid type, in accordance with MOSRT&H guidelines/ circular shall be provided at following locations: i. Where height of embankment is 3m or more, ii. Where height of embankment is retained by a retaining structure, iii. Between main carriageway and cycle track (if any) in bridges. iv. At hazardous location identified through safety audit or at the edge of the flyovers/ bridges.

1.5.15.6. Design Requirements

According to IRC 6-2000, the below table states the minimum requirement for design of the crash barriers:

Item	**Requirement**	**Parapet Type**		
		P1 In-situ/ Precas	P2 In-situ/ Precast	P3 In-situ
1	Shape	Shape on traffic side to be as per IRC:5, or New Jersey (NJ) Type of 'F' Shape designated thus by AASTHO		
2	Minimum grade of concrete	M-40	M-40	M-40
3	Minimum thickness of RCC wall (at top)	175mm	175mm	250mm
4	Minimum moment of resistance at base of the wall [see note (i)] for bending in vertical plane	15 kNm/m	7.5 kNm/m	100 kNm/m for end section and 75 kNm/m for intermediate

Item	Requirement	Parapet Type		
	with reinforcement adjacent to the traffic face [see note (ii)].			section [see note (iii)]
5	Minimum moment of resistance for bending in horizontal plane with reinforcement adjacent to outer face [see note (ii)]	7.5 kNm/m	3.75 kNm/m	40 kNm/m
6	Minimum moment of resistance of anchorage at the base of a pre-cast reinforced concrete panel	22.5 kNm/m	11.25 kNm/m	Not Applicable
7	Minimum transverse shear resistance at vertical joints between precast panels or at vertical joints made between lengths or in-situ parapet	44 kNm/m	22.5 kNm/m	Not Applicable
8	Minimum height	900 mm	900 mm	1550 mm

Notes:

i. The base of wall refers to horizontal sections of the parapet within 300 mm above the adjoining paved surface level. The minimum moments of resistance shall reduce linearly from the base of wall value to zero at top of the parapet.

ii. ii. In addition to the main reinforcement, in items 4 and 5 above, distribution steel equal to 50 per cent of the main reinforcement shall be provided in the respective faces.

iii. iii. For design purpose the parapet Type P3 shall be divided into end sections extending a distance not greater than 3.0 m from ends of the parapet and intermediate sections extending along remainder of the parapet.

iv. iv. If concrete barrier is used as a median divider, the steel is required to be placed on the both sides.

v. v. In case of P3, In-situ type, a minimum horizontal transverse shear resistance of 135 kNm/m shall be provided.

1.6 Structural Steelwork

1.6.1. General

Workmanship and materials shall be generally in accordance with relevant Indian Standards or where alternatively Noticed by the Engineer, in accordance with BS-EN or ASTM standards.

1.6.2. Material Properties

1) Steel for rolled sections, plates and bars shall normally comply with IS 226/ IS 2062 or BS 5950, Part 2 Grade 43, or special steel as per design requirement.
2) Dimensional properties, tolerances and rolling margins shall comply with the relevant Standards.
3) The condition of steel for fabrication shall be to IS 2062 or Swedish Standard 05 5900, Grade C unless otherwise detailed.
4) Bolts and nuts shall comply with design requirement.
5) Washers shall comply with BS 4320.
6) Stainless steel shall be grade 316 S31 to BS 970: Part 1, unless detailed otherwise.

1.6.3. Testing

(1) The Contractor shall perform tests and submit test certificates for the materials to be used in the work. The tests shall include the following in accordance with IS: 226/IS: 2062 or BS- EN 1993:2006 or applicable Indian Standard.

a) Chemical analysis
b) Tensile tests
c) Bend tests
d) Flattening tests

(2) The tests shall be carried out by a Noticed testing authority and Notice shall be given of the intended execution of any such test. The specimens for testing shall be a random sampling of steelwork to be used for the project.

(3) If any sample fails a test, the consignment it represents may be rejected in part or in whole. Alternatively it may be possible to either:

a) retest the consignment using another sampling set or;
b) Notice the criteria for acceptance of this particular consignment, should the Engineer allow an acceptance for a particular use justified by the design requirements

(4) In no way do these specific qualifications provide a precedent for future acceptance of any failed consignment.

1.6.4. Fabrication

(1) The work of fabrication shall comply with the requirements of IS: 800 or other relevant codes of practice Noticed to the Engineer, in accordance with BS-EN 1993 : 2006 or ASTM. Fabrication accuracy shall be within the limits detailed in BS-EN 1993: 2006.

(2) All parts assembled for bolting shall be in close contact over the whole surface and all bearing stiffeners shall bear tightly at top and bottom without being drawn or caulked. The component parts shall be so assembled that they are neither twisted not otherwise damaged as specified cambers if any shall be provided. Drilling done during assembling shall not distort the metal or enlarge holes. The butting surfaces at all joints shall be so cut and milled so as to butt in close contact throughout the finished joints.

(3) Cutting shall be done automatically. Hand flame cutting will not be permitted.

(4) The edges and ends of all cut/sheared flange plates, web plates of plate girders, and all cover plates, and the ends of all angles, tees, channels and other sections forming the flanges of plate girders, shall be planed/ground.

(5) Holes for bolts shall be drilled to conform to clause 10 of IS:7215 (1974). Punching of holes will not be permitted. All drilling shall be free from burrs. No holes shall be made by gas cutting process.

(6) All welding for the works shall be carried out by first class welders and shall be in accordance with IS:816, IS:819, IS:1024, IS:1261, IS:1323 and IS:9595. The Engineer may at his discretion order periodic tests of the welder and/or of the welds produced by them. All such tests shall be carried out by the Contractor at his cost.

(7) Safety requirements should conform to IS : 7205, IS : 7273 and IS : 7269 as applicable and should conform to safety, economy and rapidity.

(8) As much work as possible shall be welded in shops. The pieces shall be manipulated to ensure down hand welding for all shop joints as far as possible. All parts to be welded shall be arranged so as to fit properly on assembly. After assembly and before the general welding is to commence the parts are to be tack welded with small fillet or butt welds as the case may be. The tack welding must be strong enough to hold the parts together but small enough to be covered by the general welding. The welding procedure shall be so arranged that the distortion and shrinkage stresses are reduce to a minimum.

(9) All joints required in structure to facilitate transport or erection shall be shown on the drawings. The lengths of structural shall be the maximum normally available in the market and the jointing of shorter length in order to make up lengths required shall not be permitted.

(10) Each piece of steel work shall be marked distinctly before delivery, indicating the position and direction in which it is to be fixed. Three copies of a complete marking plan shall be supplied to the Engineer before erection commences.

(11) In the case of welded fabrication any distortion remaining in the member after welding operations are completed shall be rectified by and/or at the expense of the Contractor.

(12) All members of trusses and lattice girders shall be straight throughout their length, unless shown otherwise on the drawings, and shall be accurately set to the lines shown on the drawings. Sheared edges of gussets or other members to be straightened and dressed where necessary.

(13) Templates and jigs used throughout the work shall be all steel. In cases where actual materials have been used as templates for drilling similar pieces, the Engineer's Notice shall be obtained to use as parts of the finished structure.

(14) Apart from the requirements of welding specified under the above sub clauses, sections above, the Contractor shall ensure the following requirements in the welded joints.

(15) Strength-quality with parent metal. (16) Absence of defects

(17) Corrosion resistance of the weld shall not be less than that of parent material in an aggressive environment.

(18) No gasket or other flexible material shall be placed between the holes. The holes in parts to be joined shall be sufficiently well aligned to permit bolts to be freely placed in position. Driving of bolts is not permitted. The nuts shall be placed so that the identification marks are clearly visible after tightening. Nuts and bolts shall always be tightened in a staggered pattern and, where there are more than four bolts in any one joint, they shall be tightened from the centre of the joint outwards

1.6.5.Detailing of Connections

(1) Detailing of connections shall ensure that inaccessible pockets/gaps are avoided. In this respect, back-to-back angles with spacers and similar details which would prevent full accessibility for painting are not acceptable.

(2) Where cope holes are required to allow completion of butt welding they shall be of adequate size to allow fillet welding to seal the connection, while still allowing full accessibility for subsequent painting.

(3) Snipping of stiffeners at the root radii of rolled members is not acceptable. Stiffeners shall be cut to the required profile to fit closely into all such radii, and seal welded.

(4) High-strength friction grip (HSFG) bolts shall be used only on mating surfaces as specified herein.

(5) HSFG bolted connections, slip-bolted connections and welded connections shall not be used interchangeably or in tandem with each other. The use of each of these types of connections shall be separate and distinct.

1.6.6. Submissions

(1) The Contractor shall submit to the Engineer two initial copies of each shop drawing and subsequently four copies of the final shop drawings for retention by the Engineer.

(2) The Contractor shall submit for Notice details of erection procedures. The procedure should contain details of safety precautions to be taken during erection - refer IS 7205.

1.6.7. Welding

(1) Metal-arc welding of steel shall be in accordance with the requirements of relevant IS, BS- EN or ASCI standards.

(2) Run-on/run-off plates shall be used during butt welding.

(3) Fillet welds shall be continuous to form a complete seal where two members join or abut.

1.6.8. Electrodes

Welding consumables shall be suitable for the type of steel and position of welding, and shall give a weld deposit with mechanical properties not less than the minimum specified in the relevant welding standards. Hydrogen-controlled electrodes shall be used for butt welding of steel over 25 millimetres thick.

1.6.9. Welders

Welders employed on the work shall be tested to BS 4871 and BS 4872 : Part 1. Welding shall be carried out under the supervision of a competent welding technologist and the test pieces shall be tested to BS 4870.

1.6.10. Testing

(1) The Contractor shall make radiographic examination of butt welds in accordance with Section 8 of American Petroleum Industry (API) Standard 1104 and shall carry out dye- penetrant tests in accordance with BS 6443.

(2) Not less than 10% of the length of each butt weld shall be radiographically inspected and 10% shall be tested using the dye-penetrant method.

(3) Not less than 5% of the length of each fillet weld shall be tested using dye-penetrant testing.

1.6.11. Site Welding

(1) The Contractor may, subject to prior Notice, use site welding as an alternative to bolted connections.

(2) Site-welded joints shall be inspected by radiography in accordance with Section 8 of API Standard 1104 or by ultrasonic means when given Notice by the Engineer. Initially 100% of each butt weld shall be inspected. At the Notice of the Engineer, the number of inspections may subsequently be reduced.

(3) Finished welds shall comply with Section 6 of API Standard 1104. Defective welds shall be cut out, remade and retested as Noticed.

1.6.12. Erection of Steelwork

Erection of steelwork shall comply with the requirements of BS-EN 1993: 2006, Stanchions shall be plumbed using steel packs and wedges and restrained while the spaces beneath the base- plates are filled with a Noticed non-shrink cementations grout. Packs and wedges shall be protected by grout to a minimum thickness of 50mm.

The Contractor shall be responsible for checking the alignment and level of foundation and correctness of foundation bolt centres, well in advance of starting erection work, and shall be responsible for any consequences for non-compliance thereof. Discrepancies if any shall immediately be brought to the Notice of the Engineer.

The structure should be divided into erectable modules as per the total scheme. This should be pre-assembled in a suitable yard/platform and its matching with members of the adjacent module checked by trial assembly before erection.

Immediately prior to erection any rust in the paint area shall be removed by power wire brushing to a standard equivalent to SA3.

During erection the rough handling of fabricated materials such as bending, straining or pounding with sledges shall be avoided. Any damage to the structure during transportation or erection shall be immediately rectified by the Contractor at his own cost. The straightening of bend edges of plates, angles and other sections shall be done by methods which will not cause fracture.

Following the completion of the straightening, the surface of the member shall carefully be inspected for damage before further use.

The Contractor shall be responsible for accurately positioning, levelling and plumbing of all steelwork and placing of every part of the structure in accordance with the Noticed drawings and to the satisfaction of the Engineer. All stanchion base, beam and girder bearings etc. shall be securely supported on suitable steel packs. All reference and datum points shall be fixed near the work site for facilitating the erection work.

All equipment used by the Contractor shall be sufficient for the purpose and for the erection of the steel work, in the time specified in the contract. Any lifting or erecting machinery shall be Noticed to be removed from the site if the Engineer considers such appliances dangerous or unsuitable for their functions. The Notice of the Engineer shall not relieve the Contractor of the responsibilities for the loads to which the erection equipment shall be called upon to carry. Adequate arrangement shall be made to resist wind loads and lateral forces arising at the time of erection.

The Contractor is entirely responsible for the stability of the structure during erection and shall arrange that sufficient tack bolts, braces or guy ropes are used to ensure that work will remain rigid until final bolting, rivetting or welding is completed. The Contractor shall supply and fix, without extra charge, any temporary bracing which may be necessary.

All steelwork shall be erected in the exact position as shown on the Drawings. All vertical members shall be truly vertical throughout and all horizontal members truly horizontal, fabrication being such that all parts can be accurately assembled and erected. No permanent bolting, welding or grouting shall be done until proper alignment has been obtained and checked.

At stanchion splices and at other positions where concrete cover to the steel is liable to be restricted, bolts will be placed with their heads on the outside of the members.

All field assembly bolting and welding shall be executed in accordance with the requirements for shop fabrication excepting such as manifestly apply to shop conditions only. Where steel has been delivered painted the paint shall be removed before field welding for a distance of at least 50mm on either side of the joints. The number of washers on permanent bolts shall not be more than two for the nut and one for the bolt head.

1.6.13. Tolerances

The tolerances for erected steelwork shall be as shown on the Drawings. In-lieu of other information the tolerances from BS-EN 1993:2006 shall be adopted.

1.6.14. Bolted Connections

(1) Bolts shall be threaded only over the length of shank which is outside the parts bolted together. The bolt shall protrude by at least two complete threads and not

more than four complete threads beyond the outer face of the tightened nut.

(2) Holes shall not be distorted or enlarged by the use of drifts.

(3) High strength friction grip bolts shall be fitted in accordance with BS 4604, Part 2.

(4) Load-indicating washers shall be installed in accordance with the manufacturer's recommendations.

1.6.15. Transportation and Storage

Steelwork and protective coatings shall be protected from damage during packing, handling, transportation and storage. The Contractor shall ensure that members are not subjected to greater stresses than those allowed in BS 5950, Part 2 during fabrication, transportation, storage and erection. Stored items shall not be in contact with each other and shall be clear of the ground.

1.6.16. Damaged Material

Steelwork deemed to be damaged during the Contract period shall be replaced. The Contractor shall provide Notice by the Engineer for remedial work to damaged material if repairable. The method of repair and final repaired condition shall be obtained a Notice by the Engineer.

1.6.17. Galvanising

(1) Galvanising of steelwork, if required, shall be carried out after fabrication is complete.

Steelwork required to be galvanised shall be pickled in dilute hydrochloric acid, washed, fluxed and stoved, and then coated with zinc by dipping in a bath of molten zinc. Components shall be immersed in the bath only for the period sufficient to attain the temperature of the bath and shall be withdrawn at a speed which ensures that a coating of 610 grams per square metre of surface is achieved – ie, 85 microns minimum Dry Film Thickness (DFT). Components shall be covered evenly on all surfaces. Items shall not be galvanised in more than one dip event due to potential warping or additional stresses that may be induced in the metal.

(2) Items described as heavily galvanised shall be grit or sand blasted prior to galvanising and shall receive a minimum coating of 1000 grams per square metre of surface – ie,140 microns minimum DFT.

(3) Lightweight gauge metalwork shall be galvanised by the hot-dip process as specified in BS 3083 or BS 2989.

(4) Contact between galvanised steel members and aluminium surfaces or between galvanised and ungalvanised steel members shall be prevented by means of Noticed insulating washers and grommets.

(5) Galvanised steelwork shall be cleaned, degreased and etch primed before application of the specified paint treatment.

1.6.18. Preparation of Steelwork for Protective Treatment

(1) Surfaces shall be cleaned to BS 7079 before any protective treatment is commenced.

(2) Steelwork shall be degreased and shot or grit blasted to Sa 2.5 quality standard with surface amplitude of 50 to 75 microns to remove rust and mill scale. Dust and debris shall be removed by vacuum cleaner, compressed air or brush. Site welds and adjacent steelwork shall be blast cleaned and similarly prepared. Surface defects shall be removed in accordance with BS 5950..

(3) Regular mill scale detection tests shall be made using the Copper Sulphate method.

(4) Blasting operations and painting processes shall be segregated.

1.6.19. Painting Generally

(1) Paint shall be applied by brushing or spraying in accordance with the manufacturer's instructions. When permitted, thinners shall be added to paint in strict accordance with the manufacturer's permitted percentages.

(2) Brushes stored in thinners shall be worked to remove thinners before re-use.

(3) Painting shall not be carried out when the steelwork temperature is below 4oC, above 50^{o}C, less than 3^{o}C above the dew point, or when the relative humidity is above 80%.

(4) Stripe coats shall be applied to welds and steel edges before painting.

(5) Strong paint films shall be achieved on all cleats, arisses, bolt holes, bolt heads and the like.

(6) Protective treatment, other than the site-applied coatings, shall be applied under factory conditions in an enclosed shop. Completed coats shall be checked for continuity by a low-voltage wet sponge holiday detector and for thickness by an Elcometer. The colour of each coat shall be sufficiently different to permit detection of incomplete application.

(7) If a required film thickness is specified, it shall be the minimum dry film thickness (DFT) as measured by a Noticed gauge. The gauge shall be calibrated for each coating by the use of a shim placed on the shot blasted blank or on the underlying coat. The shim shall correspond to the theoretical film thickness of the coating to be measured. Otherwise, a full coating shall be applied in accordance with the rate of coverage recommended by the manufacturer, having regard to the surface profile of the steel and the conditions of application.

(8) Sample plates shall be prepared for approval and shall thereafter be adopted as the standard to be achieved in the finished work.

(9) The Contractor shall prevent dust and dirt coming into contact with freshly painted surfaces.

(10) Before the site painting coats are applied, the surfaces shall be lightly abraded, if required by the manufacturer's instructions, and washed with clean water to

remove salt and other impurities.

(11) Paint shall not be applied to the embedded portions of metal items except those within 75 millimetres of the finished concrete surface.

1.6.20. Application of Protective Layers

Blast-cleaned surfaces shall be kept dry and shall receive the first coat within 4 hours of the start of cleaning – ie, 2 hours for outdoor blast-cleaning. They shall be treated in accordance with the protective treatment schedule, except the faying surfaces for high strength friction grip bolt connections.

1.6.21. Protection of Bolts etc.

Bolts, including high strength friction grip bolts, nuts and washers shall be hot-dip spun-galvanised or as Noticed by the Engineer. The threads of nuts may be re-tapped as provided for in BS 729.

1.6.22. High Strength Friction Grip Connections

(1) Faying surfaces for high strength friction grip connectivity shall be blast-cleaned to Sa 2.5 quality standard, masked within two hours to exclude air and exposed just before bolting-up. Paint and other contaminants shall not be allowed on faying surfaces.

(2) Each consecutive coat of paint shall be stepped back from the edge of the faying surface by 15 millimetres.

1.6.23. Protective Treatment

(1) Damaged paintwork shall be blast-cleaned if bare metal is exposed or corrosion is present.

If the first coat is intact the surface shall be prepared by power wire brushing. The prepared surface shall be protected with a nominated full paint protection system.

(2) Submerged steelwork shall, in addition, be coated with a compatible chlorinated rubber-based anti-fouling paint to a DFT of 75 microns.

1.6.24. Paintwork Executed on Site

(1) Following erection, the exposed parts of galvanised nuts, washers and bolts (except chain fixing bolts) shall be degreased, etch-primed and painted to the specification for adjacent steelwork. Freshly galvanised surfaces shall be abraded and washed before application of the etch-primer.

(2) After the preceding operations, and prior to the erection of cladding, if any, the Contractor shall apply to the superstructure steelwork the finish coat(s) as specified. .Any damage to shop-coats will be made good on site prior to application of the Site coats. If steel has been exposed then the area shall be blast-cleaned primed and receive all shop-coats or Site- coats to the required standard.

(3) Before the Site-coats are applied, the surfaces shall be lightly abraded, if required by the manufacturer's instructions, and washed with clean water to remove salt and other impurities. Paint shall not be applied to the embedded portions of metal items except those within 75 millimetres of the finished concrete surface.

1.7 Cut and Cover Construction

1.7.1. General

(1) Cut and cover construction shall comply with the relevant requirements of the Contract for temporary ground support including elements to be incorporated into Permanent Works.

(2) Temporary ground support including elements to be incorporated into the Permanent Works are described in Volume 5, Section 3,subsections 1.2, 1.4 & 1.5.

(3) Support by bracing, ties or anchors: are described in Volume 5, Section 3, subsections 1.4 & 1.7.

(4) Excavation and backfilling: are described in Volume 5, Section 3, and subsection 1.2.

(5) Reinforced concrete construction is described in Volume 5, sub sections 1.5 of the Contract.

(6) Vibration recording devices shall be provided to monitor for vibrations which may cause damage to the proposed constructions and EBS. These devices shall be installed at intervals and locations to provide comprehensive coverage of the Works. Unless otherwise directed by the Fire/Life Safety Committee, these devices shall record ground accelerations generated by the Works to ensure that these accelerations do not exceed the values set by the relevant Authorities or those determined by the Contractor for the stability and safety of the Temporary and Permanent Works and adjacent EBS.

1.7.2. Waterproofing

1.7.2.1. General

(1) Submission, Requirements, Method Statements and Working Drawings

a) The Contractor shall include details of his intended waterproofing methods in his design submissions for Notice by the Engineer.

b) Manufacturer's literature shall be provided where necessary to confirm the suitability of the proposed details.

c) The Contractor shall produce and submit comprehensive Working Drawings showing all details and procedures for waterproofing of the Works.

d) The proposed waterproofing material shall be suitably resistant to all chemicals with which they are likely to come into contact.

1.7.2.2. Waterproofing Application

a) Waterproofing material shall be installed only by the manufacturer of the products or his Noticed applicator. The Contractor shall submit a method statement, prepared in conjunction with the applicator and endorsed by the manufacturer of the material, describing the details of the waterproofing works including protective measures at all stages.

b) Waterproofing material shall be stored in a cool place. The material which are subsequently exposed to sunlight shall not be affected by atmospheric conditions or ultra violet light.

c) No material shall be used which is beyond its manufacturer’s expiry date.

1.7.2.3. Structural Concrete Works

(1) Concrete Joints

a) Notwithstanding the provision of waterproofing membranes, the Contractor shall construct his concrete works so as to minimise the likelihood of water penetration. Before placing new concrete against concrete that has already hardened, the face of the old concrete shall be treated in accordance with Subsection 1.4.2.6 of this section.

b) Concrete shall be cast water-tight between construction joints. Should such concrete be found to leak or to have moist patches, the affected concrete shall be rectified by injection of resin material, breaking out and recasting, or other methods of sealing within the concrete. Inside rendering will not be accepted as a method of making watertight.

(2) Water-stops

All water-stops used in the Works shall be of PVC material and of a type appropriate to the location. All joints shall be made with moulded or prefabricated intersection pieces properly jointed in accordance with the manufacturer's instructions. The water-stops shall be installed so that they are securely held in their correct positions whilst the concrete is being placed. No holes shall be made through any water-stop except where provided for by the manufacturer.

(3) Piles and Pilecaps

Where the waterproofing membrane is discontinuous to permit structural connections to piles and pile caps, water tightness shall be achieved by use of a concrete additive or bituminous material in accordance with the manufacturer's recommendations.

(4) Fillers and Sealants to Expansion Joints

a) All materials used to fill expansion joints shall be such that they will accept the calculated movements of the joints without extrusion and shall not shrink away from either surface of the joints. Backing strips and fillers agreed with the Engineer shall be used in accordance with the manufacturer's recommendation.

b) Where joints are required to be filled with polysulphide or polyurethane sealants, the material shall comply with BS 4254 or BS 5212.

c) The appropriate sealant grades shall be used for horizontal and vertical joints, and the joints shall be thoroughly cleaned and primed with the appropriate primer before applying the sealant. The sealant shall be of a colour to match as nearly as possible the colour of the adjoining surfaces where it is to be permanently exposed. The sealing material shall be used and applied strictly in accordance with the manufacturer's instructions. The Contractor's attention is drawn to the undesirability of the sealant being smeared over the adjacent surfaces, and appropriate precautionary measures, including the use of masking tape, shall be taken to avoid this.

1.7.2.4. Cleaning and Preparation of Surfaces

No laying shall be commenced until all rough edges and excrescencies have been removed from the surfaces to receive the membrane. Surface depressions shall be filled in accordance with the Noticed procedures and the filling allowed to set. The surface to be waterproofed shall be thoroughly cleaned, dried and swept, and kept clean and dry at all stages until the work is completed.

1.7.2.5. Waterproofing Sub-surface Structures

The following requirements are applicable to all sub-surface structures built by cut and cover methods. A complete method statement for the Works together with relevant shop drawings and details shall be submitted to the Engineer for Notice prior to application of the system. The method statement shall include all QA/QC procedures required to ensure the integrity of the system. Proposed manufacturers and applicators should have similar experience on previous metro projects in India.

(1) Base Slabs

a) Waterproofing shall consist of a fully-bonded membrane system applied to a blinding concrete layer, or other similar system Noticed by the Engineer.

b) Binding concrete shall be a minimum of 75 millimetres thick. Where ground conditions are such that there would be risk of localised settlement of this blind layer during or after subsequent construction operations, the concrete thickness shall be increased and reinforced as necessary to avoid such localised settlement. A drainage layer shall be provided beneath the blinding concrete where necessary to ensure that the blinding concrete is not damaged by hydrostatic pressures prior to casting of the structural slab.

c) The waterproofing membrane shall be laid by the manufacturer's applicators strictly in accordance with the recommendations of the manufacturer and with accepted good practice in the trade. Proper accessories such as anchor strips, pipe collars, outside and inside corners, steel laminated plates etc. shall be used for the correct and secure application of the waterproofing system.

d) When laying the membrane, no other works shall be carried out in the vicinity which may cause personnel or equipment to intentionally or accident ally come into contact with the membrane before it has been protected. Expanded polystyrene boards or similar shall be used by the persons laying the membrane to avoid stepping directly on to the laid membrane.

e) The membrane may be laid across changes in the plane of the concrete surface where the material is sufficiently pliable to enable the adhesive to remain in continuous contact with the primed concrete. Where this cannot be achieved, preformed angles or similar features shall be provided and bonded to the concrete surface.

f) Where openings must be left in the membrane for structural continuity of piles or for other items projecting below the soffit of the base slab, the size of opening in the membrane must be kept to a minimum. The opening shall be sealed all round by a bituminous liquid.

g) Where external wall above the base slab are to be constructed in open cut, the membrane laid beneath the base slap shall extend 300 millimetres beyond the limits of the structural slab in order that waterproofing to the wall may be lapped on to it. Blinding concrete beneath the membrane shall extend 500 millimetres beyond the limits of the structural slab.

h) Where the structural base slap will be cast against diaphragm walls, piled walls, or rock faces, the membrane shall be turned up against the face of the wall by a minimum of 100 millimetres and then turned horizontally into a 20 millimetres by 20 millimetres chase cut into the wall face, and sealed with a bituminous compound. The wall surface shall first be leveled by the application of a steel trawled mortar coat where there is any risk that its roughness may cause the membrane to be punctured. The construction joints shall form a sealed compartment for which general arrangement is indicated in the drawings.

(2) External Walls to Structures Built in Open Excavation

a) Waterproofing shall be provided and shall conform to the requirements of this Contract. Concrete surfaces to be waterproofed shall be prepared where necessary by grinding and local filling with mortar having a steel toweled finish to provide a smooth surface free from voids, loose aggregate and sharp protrusions. A brickwork protection layer shall be provided to the membrane system to ensure that no damage is suffered to the membrane during backfilling operations.

b) Where pipe penetrations are required through the wall, these shall be formed as sections of galvanized steel pipe of the required diameter, with 36 millimetre welded flange plates having outside diameter 300 millimetres greater than the diameter of the pipe. The waterproofing membrane shall be fitted into the pipe penetration to maintain the integrity of the waterproofing system as per a recommended detail which shall be proposed by the waterproofing manufacture and Noticed by the Engineer.

(3) External walls Built against Diaphragm Walls

a) Where in-situ concrete lining walls are cast against diaphragm walls having water- bars at panel joints, no waterproofing membrane is required at the interface between the diaphragm and in-situ walls. At base and roof slab levels, water bar shall be provided or allowance for caulking by grout injection.

c) In all cases where slabs are cast against diaphragm walls an injection grouting system shall be provided in each diaphragm wall panel joint at the base and roof slab level, sufficient to enable the joint to be grouted between the inner face of the diaphragm wall and the innermost water bar across the panel joint. After completion of the base slab but before concreting of the in-situ lining wall, if any, the base slab level grout injection shall be carried out.

c) After the grout has set the groundwater level beneath the joint shall be allowed to rise to 1 meter above slab level and left for 7 days. The panel joint shall be inspected for water leakage or dampness and if present the joint shall be re-grouted and re- tested. Grout injection at roof slab level shall be carried out after completion of the roof slab.

(4) External Walls Built Against Pile Walls or Rock or Soil Faces

a) Where in-situ concrete walls are cast against temporary pile walls, rock or soil faces, or any other material, a fully bonded membrane system shall be provided. The face against which the in-situ wall is to be cast shall be built up by with a steel-trowelled finish, to provide a smooth surface free from voids, loose aggregating and sharp protrusions. Where the thickness of mortar would be excessive, concrete shall be cast as primary filler.

b) Material and application requirement for the waterproofing membrane shall be in accordance with this Contract for base slabs. The membrane shall be lapped to the base slab membrane and continued upwards to 300 millimetres above roof slab level, or to the limit of the face against which the in-situ wall is to be cast if this is lower. In such cases suitable provision shall be made for continuity of the membrane with the water-tightness provisions to the wall above. Unless it is to be bonded to the structural wall the membrane shall be protected by suitable geofabric (fleece) sheeting hung from above and left in place

(5) Roof/Top Slab

a) Waterproofing shall be provided by fully bonded membrane system and shall conform to the requirements of this Contract.

b) Where external walls above the base slab are to be constructed in open cut or cast directly against diaphragm walls, piled walls and the like, the roof/top slab membrane shall be extended and turned down the wall and welded to the external water-bar across the roof slab/wall construction joint to form the sealed compartment as per the Contract requirements.

c) A 75 millimetre thick concrete protection layer shall be applied over the membrane system for protection during backfilling operations.

(6) Waterproofing of Below Grade Construction Joints

All below-grade construction joints shall incorporate a re-injectable hose which shall be capable of performance in the following manner:

a) The hose should be of a re-injectable nature and be capable of re-injection several times over the life of the structure.

b) Installation should be seamless and without cuts and joints when installed at multiple bends/corners/circular paths in congested heavily reinforced concrete.

c) The hose shall be capable of following infinite changes in direction and turn corners with ease without impeding the path of grout injected through the hose.

d) Valves shall be enclosed in a retaining mesh to avoid displacement of these during pressure testing and injection.

e) The injection resin should be of a re-sealable type made of an acrylate hydrogel, capable of being vacuumed out of the hose with water (not flushed), before it gels.

f) The injection resin should be of a low viscosity (<50 Centipoises) to enable maximum penetration of very narrow fissures.

The system shall be placed in 10 to 12 metre lengths with entry port and vent ends terminating in a junction box and shall offer the user the option of vacuuming and re-injection should this be necessary. The junction box shall be placed in vertical elements adjacent to the joint. Should this not be possible the junction box and its cover should be installed flush with the floor level and should be able to tolerate vehicular traffic.

The system should be used to seal off the construction joints permanently thus providing protection to the steel reinforcement.

Where indicated, all construction joints (vertical and horizontal) shall have the re-injectable hose installed. The re-injectable hose system shall be injected at least once, prior to switching off the dewatering with a vinyl ester methacrylate based injection resin of viscosity < 40milli Pascal (mPas).

1.7.2.6. Waterproofing to Surface and Partially Sub-surface Structures

(1) Ground Slabs

Waterproofing to ground slabs shall be the same as for all underground structures defined in this Contract

(2) External Walls Below Ground Level

The requirements of this Contract shall apply to all external walls at greater depth than 500 millimetres below ground level

1.7.2.7. Stray current collectors

These shall be provided as per the Contract.

1.7.2.8. Warranty

(1) All waterproofing systems shall be warranted against all defects for a minimum period of 10 years from the date of completion of the Works.

(2) The warranties shall cover the whole of the waterproofing systems and shall be provided jointly and severally by the Contractor.

1.8 Prestressed Members

1.8.1. Pre-stressing Tendons

1.8.1.1. Materials

(1) Steel Wire

Steel wire shall comply with BS 5896.

(2) Cold worked high tensile alloy bar

Cold worked high tensile alloy steel bars for prestressing shall comply with the requirements of BS 4486.

(3) Stress-relieved seven-wire strand

Stress relieved seven-wire strand shall comply with the requirements in TIS 420, Grade

1860, nominal diameter 12.7 millimetres or 15.2 millimetres, or have properties that are not inferior. The characteristic breaking load shall not be less than that specified by the Contractor.

(4) Sampling and Testing

(a) When it is proposed to use super strand complying with BS 5896 Table 6 or other than the lowest strength 3,4,5,6 or 7 mm diameter wire complying with BS 5896 Tables 4 or 5 the following shall apply:

(i) A sample shall be taken from each reel of material proposed for use in the Works

(ii) A reel shall only be accepted if both the breaking load and the 0.1% proof load of the sample exceeds the specified characteristic loads given in Tables 4 or 6 of B5 5896. In the case of Table 5 this requirement shall apply to the breaking load and the load at 1% elongation.

(iii) These requirements shall be additional to any other requirements of the Contract.

(b) The Contractor shall arrange for samples of the steel intended for use in the Works to be tested at a noticed laboratory.

1.8.1.2. Handling and Storage

(1) Care shall be taken to avoid mechanically damaging, work-hardening or heating pre- stressing tendons while handling. All pre-stressing tendons shall be stored clear of the ground and protected from the weather, from splashes from any other materials, and from splashes from the cutting operation of an oxy-acetylene torch, or arc-welding processes in the vicinity.

(2) In no circumstances shall pre-stressing tendons after manufacture be subjected to any welding operation, or 'on-site' heat treatment or metallic coating such as galvanising. This does not preclude cutting as specified in this Contract.

(3) All wires, strands or bars stressed in one operation shall be taken, where possible, from the same parcel. Each cable shall be tagged with its number from which the coil numbers of the steel used can be identified. Cables shall not be kinked or twisted. Individual wires and strands for which extensions are to be measured shall be readily identifiable at each end of the member. No strand that has become unraveled shall be used.

1.8.1.3. Surface Condition

Pre-stressing tendons anchorages, blocking devices and internal and external surfaces of ducts shall be clean and free from pitting, loose rust, loose scale and chloride contamination at the time of incorporation in the work. If any surface cleaning is required it shall not heat, damage or polish the surface, or coat it with oil, grease or any other material.

1.8.1.4. Straightness

(1) Prestressing Wire

Unless otherwise agreed with the Engineer, low relaxation and normal relaxation wire shall be in coils of sufficiently large diameter to ensure that wire pays off straight.

(2) Strand

Pre-stressing strand, however manufactured, shall be in coils of sufficiently large diameter to ensure that the strand pays off reasonably straight.

(3) Bars

Pre-stressing bars as delivered shall be straight.Bars bent in the threaded portion shall be rejected. Any straightening of bars shall be carried out cold but at a temperature of not less than 5^{o}C. Any necessary heating shall be by means of steam or hot water.

(4) Reinforcement mesh or wire

Mesh or wire shall be delivered in sheets or coils. Any straightening of bars shall be carried out cold but at a temperature of not less than 5^{o}C. Any necessary heating shall be by means of steam or hot water.

(5) Cutting

All cutting of wire, strand or bar shall be carried out using either:

(a) a high-speed abrasive cutting wheel, friction saw at not less than one diameter from the anchor or any other mechanical method noticed by the Engineer, or

(b) an oxy-acetylene cutting flame, using excess oxygen to ensure a cutting rather than a melting action not less than 75 millimetres from the anchor whilst the temperature of the tendon adjacent to the anchor shall not be greater than 200^{o}C. Care shall be taken that neither the flame nor splashes come into contact with either the anchorage or other tendons or reinforcement.

1.8.2. Pre-cast Construction

Care shall be exercised in the set-up of each member. All materials to be encased within the concrete of the member shall be properly positioned and supported. Provisions for all projections, recesses, notches, openings, blackouts and the like shall be made in accordance with the Drawings.

1.8.3. Stressing Tendons

1.8.3.1. General

(1) It shall be the obligation of the Contractor to provide a technician skilled in pre-stressing systems to supervise or provide appropriate surveillance of the work and give the Engineer such pertinent information as he may require for inspecting the work. Such a representative shall be available full-time on all days during which the stressing and grouting of tendons is in progress.

(2) All post-tensioning steel shall be tensioned by means of hydraulic jacks so that the force of the pre-stressing steel shall not be less than the value shown on the noticed working drawings. The maximum temporary tensile stress (stressing stress) in pre-stressing steel shall not exceed 80% of the specified minimum ultimate tensile strength of the pre- stressing steel.

1.8.3.2. Tensioning Apparatus

The tensioning apparatus shall meet the following general requirements:-

(a) The means of attachment of the tendon to the jack or tensioning device shall be safe and secure.

(b) Where two or more wires or strands are stressed simultaneously, they shall be approximately of equal length between anchorage points at the datum of load and extension measurement. The degree of variation shall be small compared with the expected extension.

(c) The tensioning apparatus shall be such that a controlled total force is imposed gradually and not dangerous secondary stresses are induced in the tendons, anchorage or concrete.

(d) The force in the tendons during tensioning shall be measured by direct-reading load cells or obtained indirectly from gauges fitted in the hydraulic system to determine the pressure in the jacks. Facilities shall be provided for the measurement of the extension of the tendon and of any movement of the tendon in the gripping devices. The load-measuring device shall be calibrated to accuracy within ± 2% and checked at intervals Elongation of the tendon shall be measured to accuracy within 2% or ±2 millimetres, whichever is the more accurate.

(e) The tensioning equipment shall be calibrated before the tensioning operation and at intervals of months or as noticed by the Engineer.

(f) Any indication in the loss of strength in tendons during the tensioning operation shall be brought to the attention of the Engineer. Any corrective measures which may be required in procedures and/or material shall be noticed by the Engineer.

(g) When friction must be reduced, water-soluble oil may be used to the notice of the Engineer. This oil may be flushed from the duct as soon as possible after stressing is completed by use of water pressure. These ducts shall be flushed again just prior to the grouting operations. Each time the ducts are flushed, they shall be immediately blown dry with oil-free air.

(h) Loss in strength of tendons may occur from wedge pull-in, bond failure tendon slippage or concrete elastic shortening, and these shall be separately identified by methods agreed with the Engineer. Immediate loss in strength must also be identified from relaxation loss for the purposes of design and testing.

1.8.4. Testing by Contractor

(1) For the purpose of accurately determining the tendon elongations while stressing, the Contractor shall bench-test two samples of each size and type of strand tendon to determine the modulus of elasticity prior to stressing the initial tendon. The

bench should be at least 6 metres long, with concrete anchorage blocks having a constant area end section of at least four times that of the anchorage assembly area. The tendon shall be straight and centered on the cross-sectional area of the bench.

(2) The test procedure shall consist of stressing the tendon at an anchor assembly with the dead end consisting of a load cell. The test specimen shall be tensioned to 80% of ultimate in a minimum of 10 increments.

(3) For each increment, the gauge pressure, elongation and load cell force shall be recorded. The data shall be furnished to the Engineer. The theoretical elongations shown on the post-tensioning working drawings shall be re-evaluated by the Contractor using the results of the tests and corrected as necessary.

(4) Revisions to the theoretical elongations shall be noticed to the Engineer. Apparatus and methods used to perform the tests shall be proposed by the Contractor. After the initial testing, five (5) more tests shall be performed. These tests shall be spaced evenly throughout the duration of the Contract.

1.8.5. Pre-tensioning

Where pre-tensioning methods are used, the tension shall be fully maintained by some positive means during the period between tensioning and transfer. The transfer of stress shall take place slowly to minimize shock. It is important to identify the different modes of stress transfer between and ungrouted tendons and allow for the test system to behave in the appropriate manner for each setup.

1.8.5.1. Straight Tendons

(1) In the long-line method of pre-tensioning, sufficient locator plates shall be distributed throughout the length of the bed to ensure that the wires or strands are maintained in their proper position during concreting.

(2) Where a number of units are made in the line, they shall be free to slide in the direction of their length and thus permit transfer of the pre-stressing force to the concrete along the whole line for grouted tendons. In the individual mould system the moulds shall be sufficiently rigid to provide the reaction to the pre-stressing force without distortion. In ungrouted tendons the locator plates must be fashioned so that load transfer is not incorrectly carried out at these plate locations but only at the external concrete faces by bearing.

1.8.5.2. Deflected Tendons

(1) Where possible the mechanisms for holding down or holding up tendons shall ensure that the part in contact with the tendon is free to move in the line of the tendon so that frictional losses are nullified. If, however, a system is used that develops a frictional force, this force shall be determined by test and due allowance made as agreed with the Engineer.

(2) For single tendons the deflector in contact with the tendon shall have a radius of not less than 5 times the tendon diameter for wire or 10 times the tendon diameter for a strand, and the total angle of deflection shall not exceed 15 degrees. Where the radius is less than 5 times the diameter of the tendon and the angle of deflection exceeds 15 degrees, the loss of strength of the tendon shall be determined by test and due allowance made.

(3) The transfer of the pre-stressing force to the concrete shall be effected in conjunction with the release of hold-down and hold-up forces as noticed by the Engineer.

1.8.6. Post-tensioning

(1) Arrangement of Tendons

Where wires, strands or bars in a tendon are not stressed simultaneously, the use of spacers shall be in accordance with the recommendations of the system manufacturer.

(2) Anchorages

(a) Anchorages shall be tested in accordance with the requirements of BS 4447

(b) For each anchorage system used in the Works, the characteristic value for anchorage efficiency shall be not less than 90%.

(c) Proprietary anchorages shall be handled and used strictly in accordance with the manufacturer's instructions and recommendations.

(3) Deflected Tendons

The deflector in contact with the tendon shall, have a radius of not less than 50 times the diameter of the tendon, and the total angle of deflection shall not exceed 15 degrees unless otherwise agreed with the Engineer.

(4) Tendoning Procedure

a. Before tensioning, the Contractor shall demonstrate that all tendons are free to move in the ducts unless the geometry of the ducts makes this impracticable as agreed with the Engineer. Tensioning shall be carried out in such a manner that the stress in the tendons increases at a gradual and steady rate.

b. Unless otherwise described in the Contract, concrete shall not be stressed until it has reached at least the age at which 2 test cubes taken from it attain the specified transfer strength. The test cubes shall be made and tested as described in BS 1881. They shall be cured in similar conditions to the concrete to which they relate in a manner noticed by the Engineer.

c. The Contractor shall cast sufficient cubes to demonstrate that the required strength of the concrete at transfer has been reached.

d. The Contractor shall ensure that those carrying out the stressing are provided with particulars of the required tendon loads, order of stressing and extensions. Allowance shall be made during stressing for the friction in the jack and in the anchorage, although the former is not necessary when using load cells.

e. Any allowance for draw-in of the tendon during anchoring shall be noticed to the Engineer.

f. Stressing shall continue until the required extension and tendon load are reached or are noticed by the Engineer.

g. The extension shall allow for any draw-in of the tendon occurring at the non- jacking end, but measurement shall not commence until any slack in the tendon has been taken up.

h. Immediately after anchoring, the forces in the pre-stressing tendons shall not exceed 70% of their characteristic strength. During stressing the value may exceed 70% of their characteristic strength, with notice to the Engineer, but shall not exceed 80%.

i. After the tendons have been anchored, the force exerted by the tensioning apparatus shall be decreased gradually and steadily so as to avoid shock to the tendon or the anchorage. Full records shall be kept of all tensioning operations, including the measured extensions, pressure-gauge or load-cell readings, and the amount of draw-in at each anchorage. Copies of these records shall be supplied to the Engineer within 24 hours of each tensioning operation.

j. Unless otherwise agreed with the Engineer tendons shall not be cut less than 3 days after grouting.

1.8.7. Pre-stressing Tendons - Protection and Bond

(1) The pre-stressing tendons shall be protected in their permanent positions from both mechanical damage shall be applied to all unbonded pre-stressing tendons within 28 days of installation of the tendon in the duct. The tendon protection compound shall be applied to the ends to avoid corrosion as described in the Contract and the following sub- clauses.

(2) The exposed tendons at the anchorages and the anchorages themselves shall be sealed within a closed box and protected from both mechanical damage and corrosion. Suitable access shall be left for jacking equipment for the later removal of the strands of unbonded tendons. The means of protection shall be designed by the pre-stressed steel supplier and noticed by the Engineer.

(3) A tendon protection compound shall be a micro-crystalline wax (petrolatum) base material containing additives to enhance the corrosion inhibiting, wetting, and moisture displacing properties, as well as the ability to form a polar bond with the tendon steel.

(4) The compound manufacturer shall provide test data verifying that the following properties are met for the service life of 120 years and temperature range of $0^{o}C$ to $50^{o}C$

(a) Freedom from cracking and brittleness;
(b) Continuous self-healing film over the coated surfaces;
(c) Chemical and physical stability;
(d) Non reactivity with the surrounding and adjacent materials such as concrete, tendons, and ducts;
(e) Moisture displacing characteristics.

(5) Additionally it shall remain flexible to allow removal and replacement of the tendons. The tendon protection compound and its method of installation shall be Noticed by the Engineer.

(6) Provision shall be made for expansion of the tendon protection compound during the lifetime of the structure.

(7) Before installing the tendon protection compound it shall be demonstrated that the ducts, U-bend anchorage and anchorages are clean and free of water and chlorides.

(8) The tendons, internal face of the steel u-bend anchorage, stressing anchorages and any other metallic components of the pre-stressing system shall additionally be pre-treated with a protection compound before delivery to site. The protection compound shall be applied to each strand of the tendon and shall be compatible with the tendon

protection compound injected into the ducts. The protection compound shall be noticed by the Engineer.

(9) The Contractor shall notice the Engineer on tendon protection compound suppliers proposals which shall describe how the tendon protection compound can be removed and re-injected into ducts, including buried ducts, within the permanent works.

(10) All materials used in the pre-stressing systems shall not give off toxic fumes at temperatures below 50oCand shall not support combustion.

1.8.8. Ducts for Bonded Tendons

1.8.8.1. Ducts

(1) Ducts for longitudinal, transverse or vertical tendons embedded into the concrete may be of flexible, semi-rigid, or rigid galvanized, ferrous metal capable of withstanding concrete pressures without deforming or permitting the entrance of cement paste during casting of the member.

(2) Ducts shall retain their shape and be capable of transferring bond stresses. The semi- rigid duct must be rigid enough to remain straight when supported at 1200 millimetres maximum intervals but flexible enough to allow 3600 millimetres radius curves. Flexible duct shall be secured or supported at not more than 300 millimetres intervals.

1.8.8.2. Grouting of Pre-stressing Tendons

(1) General

The Contractor shall undertake grouting trials when required by the Engineer.

(2) Materials

a) Unless otherwise directed or agreed by the Engineer as a result of grouting trials, the grout shall consist only of Ordinary Portland Cement.

b) Cement and water. The water/cement ratio shall be as low as possible consistent with the necessary workability, and under no circumstances shall the water: cement ratio exceed 0.45 by weight.

c) The grout shall not be subject to bleeding in excess of 2% after 3 hours or 4% maximum when measured at 25oCor such other temperature as may be noticed by the Engineer, in a covered cylinder approximately 100 millimetres diameter with a height of grout of approximately 100 millimetres and the water shall be reabsorbed by the grout during the 24 hours after mixing.

d) Admixtures may be used with the written permission of the Engineer and shall be applied strictly in accordance with the manufacturer's instructions. Admixtures shall not contain chloride ions in excess of 0.25 % by weight.

e) Dry materials shall be measured by weight.

(3) Ducts

a) Air vents shall be provided at any crests in the duct profile and elsewhere as specified.

b) All ducts shall be thoroughly clean before grouting. Ducts formed without metal sheathing shall be provided with effective drainage and, unless otherwise directed by the Employer"s Representative, shall be flushed with water before grouting.

c) All surplus water shall be removed by compressed air injection.

d) All anchorages shall be sealed or fitted with grouting connections.

(4) Grouting Equipment

a) The mixing equipment shall produce a grout of homogeneous consistency and shall be capable of providing a continuous supply to the injection equipment.

b) The injection equipment shall be capable of continuous operation with little variation of pressure and shall include a system for recirculating the grout while actual grouting is not in progress. Compressed air shall not be used.

c) The equipment shall have a sensibly constant delivery pressure not exceeding 1 MegaPascal. All piping to the grout pumps shall have a minimum of bends, valves and changes in diameter. All baffles to the pump shall be fitted with 1.18 millimetre sieve strainers. All equipment, especially piping, shall be thoroughly washed through with clean water after every series of operations and at the end of use for each day. The interval between washing shall not exceed 3 hours.

(d) The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a valve that can be locked off without loss of pressure in the duct.

(5) Mixing

Water shall be added to the mixer first, then the cement. When these are thoroughly mixed, the admixture, if any, shall be added. Mixing shall continue until a uniform consistency is obtained. Mixing shall not be by hand.

(6) Injecting Grout

(a) Grouting shall be carried out as soon as is practicable after the tendons in them have been stressed and anchors trimmed and the Engineer's permission to commence has been obtained.

(b) Injection of grout shall be continuous, and it shall be slow enough to avoid producing segregation of the grout. The method of injecting grout shall ensure complete filling of the ducts and complete surrounding of the steel. Grout shall be allowed to flow from the free end of the duct until its consistency is equivalent to that of the grout injected. The opening shall then be firmly closed. Any vents or bleed holes shall be closed in a similar manner one after another in the direction of the flow. After an appropriate time, further injections shall be carried out to fill any possible cavities.

(c) The injection tubes shall then be sealed off under pressure until the grout has set.

(d) The filled ducts shall not be subjected to shock or vibration within 1 day of grouting.

(e) Not less than 2 days after grouting, the level of grout in the injection and vent tubes shall be inspected and made good as necessary.

(f) The Contractor shall keep full records of grouting including the date each duct was grouted, the proportion of the grout and any admixtures used, the pressure, details of any interruptions and topping up required. Copies of these records shall be supplied to the Engineer within 3 days of grouting.

(g) The Contractor shall provide facilities and attendance for the radiographic testing of the grouted duct.

(7) Strength of Grout

The compressive strength of 100 millimetres cubes made of the grout shall exceed 17 Mega Pascals at 7 days. Cubes shall be cured in a moist atmosphere for the first 24 hours and subsequently in water.

1.8.9. Ducts for Unbonded Tendons

(1) Unless shown otherwise on the Drawings, ducts and injection tubes in the superstructure and substructure shall be formed from high density polyethylene (HDPE) which shall incorporate a stabilizing agent to prevent Ultra Violet Light (UVL) degradation.

(2) The minimum wall thickness of the ducts shall be such that the ducts are capable of resisting the pressures developed during installation of the protection compound. The ducts shall be smooth bore.

(3) Ducts with external diameters greater than 70 millimetres shall be transported and stored in straight lengths without stacking. The distance between supports shall be limited to 3 metres and the height of storage to 1.5 metres. Alternatively ducts may be transported and stored in coils provided that they are fixed to the designed tolerances. Damaged ducts shall not be used in the Works.

(4) No boring of any holes in the ducts shall be permitted once the tendons are installed.

(5) U-bend anchorages shall be formed from smooth-bore unwelded steel tubes and shall comply with the requirements of BS 4360.

(6) Joints between ducts, ducts and anchorages and ducts and U-bend anchorages shall be formed by a coupling device using thermo-fusion techniques which shall provide a water- tight seal to the ducts and shall be capable of resisting the pressure developed during installation of the tendon protection compound. The inner surfaces of the joints shall form a smooth transition between ducts and U-bend anchorages to allow satisfactory installation of the tendons. All coupling devices shall be noticed by the Engineer.

(7) Injection tubes shall be provided at the U-bend anchorages, the stressing anchorages and at any other positions on the length of the ducts which are required to achieve satisfactory installation of the tendon protection compound. The injection tubes at the U- bend anchorages shall also be used as drainage points for the U-bend. The connection between the ducts and the injection tubes shall be water-tight and capable of resisting the pressure developed during installation of the tendon protection compound.

(8) All injection tubes shall be sealed after use to prevent the ingress of water

(9) After completion of all duct joints and before completion of the in-situ joints between pre- cast segments and before installation of the tendons, all ducts shall be air tested to an equivalent 100 millimetres water gauge. The test shall be performed in accordance with BS 8301 Section 5.

(10) Any ducts which do not contain tendons shall remain empty and shall be sealed at each end to prevent the ingress of water.

1.8.10. Pre-stressing Tendons - Trial Construction-Unbonded Tendons

(1) Before commencing construction of the pre-cast segments a trial shall be carried out which shall demonstrate the satisfactory installation, removal and replacement of a pre-stressing strand together with the proposed techniques for duct jointing, duct testing and installation of the tendon protection compound.

(2) The tendons shall be stressed in accordance with this Contract.

(3) The ducts shall be filled with a tendon protection compound in accordance with this Contract and the tendon extension and anchorage shall be protected as if they were to be included in the permanent works.

(4) The trial shall demonstrate that any one strand may be destressed, removed, inspected, replaced and restressed and that no voids are created within the tendon protection compound.

(5) The trial shall also demonstrate that all of the strands in a duct may be removed and that the tendon protection compound can be removed from the ducts and U-bend anchorage

(6) The trial shall be undertaken using the pre-stressing system to be used in the Permanent Works and shall be noticed by the Engineer.

1.8.11. Pre-stressing Tendons - Temporary Tendons

(1) Temporary tendons may be re-used as temporary tendons elsewhere provided special precautions are incorporated at the anchorages to ensure tendons are not damaged. These precautions shall be Noticed by the Engineer.

(2) The tendons shall be enclosed within a duct throughout their length.

(3) The tendons shall be pre-treated in accordance with the Contract and the protection compound shall be applied to the outer surfaces of the tendon after each use.

(4) The maximum jacking force for the re-usable temporary tendons shall not exceed 70% of their guaranteed minimum breaking load.

(5) After removal of the tendons the ducts shall be sealed at each end to prevent the ingress of water.

1.8.12. Preparation for Casting

(1) The Contractor shall submit for notice, in accordance with the provisions of the Employer's Requirements, working drawings of the pre-stressing system proposed for use. For initial notice, 3 sets of such drawings shall be submitted.

(2) After notice, between 6 and 12 sets, shall be submitted The working drawings of the pre- stressing system shall show complete details and be accompanied by substantiating calculations of the method and materials the Contractor proposes to use in the pre- stressing operations, including any additions or rearrangement of reinforcing steel from that shown on the Drawings. Such details shall outline the method and sequence of stressing and shall include complete specifications and details of the pre-stressing steel and anchoring devices, working stresses, anchoring stresses, type of ducts, and all other data pertaining to the pre-stressing operation, including the proposed arrangement of the pre-stressing steel in the members.

(3) Working drawings shall be A1 size and each drawing and calculation sheet shall include the job site, name of the structure as shown on the Contract Drawings and Contract name.

(4) Working drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for notice by the Employer’s Representative and correction by the

Contractor of the drawings without delaying the work. Such time shall be proportional to the complexity of the work but in no case shall such time be less than eight (8) weeks.

(5) At the completion of each structure, one set of reproducible Mylar of the corrected original tracing of all working drawings for said structure shall be furnished to the Engineer. Drawings which are common to more than one structure shall be provided for each structure. An index prepared specifically for the working drawings for each structure containing sheet numbers and titles shall be included.

(6) Reinforcing steel shall be fabricated and placed in accordance with the Drawings and as required herein. No reinforcing steel shall be cut and removed to permit proper alignment of stressing ducts. Any bar that cannot be fabricated to clear the conduits shall be replaced by additional bars with adequate lap lengths and shall be submitted to the Engineer. In the plane of the steel parallel to the nearest surface of concrete, bars shall not vary from plan placement by more than 12 millimetres or one-tenth (1/10) of the spacing between bars, whichever is less.

(7) All pre-stressing steel shall be protected against physical damage and rust or other results of corrosion at all times from manufacture to grouting or encasing in concrete. Pre-stressing steel that has sustained physical damage at any time shall be rejected. The development of visible rust or other results of corrosion shall be cause for rejection, Pre- stressing steel shall be packaged in containers or shipping forms for the protection of the steel against physical damage and corrosion during shipping and storage. A corrosion inhibitor which prevents rust or other results of corrosion shall be placed in the package or form, or shall be incorporated in a corrosion inhibitor carrier type packaging material, may be applied directly to the steel, with notice to the Engineer. The corrosion inhibitor shall have no deleterious effect on the steel or concrete or bond strength of steel to concrete. Packaging or forms damaged from any cause shall be immediately replaced or restored to original condition.

(8) The shipping package or form shall be clearly marked with a statement that the package contains high-strength pre-stressing steel, and the care to be used in handling; and the type, kind and amount of corrosion inhibitor used, including the date when placed, safety orders and instructions for use.

(9) Pre-stressing steel for post-tensioning which is installed in members prior to placing and curing of the concrete, shall be continuously protected against rust or other corrosion, until grouted, by means of a corrosion inhibitor placed in the ducts or applied to the steel in the duct. The corrosion inhibitor shall conform to the requirements specified herein.

(10) When steam curing is used, pre-stressing steel for post-tensioning shall not be installed until the steam curing is completed.

(11) All water used for flushing ducts shall contain either quick lime (calcium oxide) or slaked lime (calcium hydroxide) in the amount of 13 grams per litre. All compressed air used to blow out ducts shall be oil free.

(12) When acceptable pre-stressing steel for post-tensioning is installed in the ducts after completion of concrete curing, and if stressing and grouting are completed within 10 calendar days after the installation of the pre-stressing steel, rust which may form during said 10 days will not be cause for rejection of the steel. Pre-stressing steel installed, tensioned and grouted in this manner, all within 10 calendar days, will not require the use of a corrosion inhibitor in the duct following installation of the pre-stressing steel. Pre- stressing steel installed as above but not grouted within 10 calendar days shall be subject to all the requirements in this section pertaining to corrosion protection and rejection because of rust.

(13) Any time acceptable pre-stressing steel for pre-tensioning is placed in the stressing bed and is exposed to the elements for more than 36 hours prior to encasement in concrete, adequate measures shall be taken by the Contractor, as noticed by the Engineer, to protect said steel from contamination or corrosion.

(14) All ducts shall be located within 5 millimetres of the locations given on noticed fabrication plans. Method and spacing of supports for ducts shall be shown on the working drawings. After installation in the forms, the end of the ducts shall at all times be sealed to prevent entry of water and debris. Following each pour of concrete, the Contractor will be required to demonstrate that all empty ducts are free of water and are unobstructed and undamaged. Immediately prior to installation of the pre-stressing steel, the Contractor shall again demonstrate that all ducts are unobstructed and that they are free of water and debris.

(15) Where tendons are described in the Contract as debonded from the concrete they shall be covered with sleeves noticed by the Engineer. The ends of the sleeves shall be taped to the tendon to prevent the ingress of grout.

(16) Concrete shall not be deposited into forms until the entire set-up of the forms, reinforcement, ducts, and anchorage has been thoroughly inspected and checked. The Contractor shall submit a proposal to the effect that the rate of producing and placing concrete will be sufficient to complete the proposed pour and finishing operations within the scheduled time, that experienced concrete finishers are available where required for finish work and all necessary finishing tools and equipment are on hand at the site of the work and are in satisfactory condition for use.

(17) Concrete on sloped forms shall be placed on the lowest end or edge and worked to the

higher end or edge to avoid loss of water and compaction. Self-levelling concrete may be used where access is limited, however vibration is still necessary.

(18) Conveying equipment shall be of a size and design that will permit the placing of concrete within the time limits specified. Conveying equipment shall be cleaned at the end of each operation or work day and just prior to reuse shall again be checked and cleaned of hardened concrete and foreign materials.

(19) Belt conveyors shall be horizontal or at a slope which will not cause excessive segregation of loss of ingredients. Concrete shall be protected against undue drying or rise in temperature. An noticed arrangement shall be used at the discharge end to prevent aggregate segregation. Mortar shall not be allowed to adhere to the return length of the belt. Concrete shall be discharged into a hopper or through a baffle.

(20) The concrete shall be first placed in the web forms followed by placement at the bottom slab and then in the top form. Any alternate sequence shall be submitted noticed to the Engineer.

(21) For pours conducted in stages, the concrete from the first stage interfacing with the newer pour should be clean and moistened. Older concrete surfaces should be scabbled to allow aggregates to be partially visible or else scarified and roughened if the first pour is fairly recent.

(22) All concrete shall be consolidated by means of noticed vibrators together with any other equipment necessary to perform the work as specified. Internal vibrators shall have a minimum frequency of 8,000 vibrations per minute and sufficient amplitude to consolidate the concrete effectively.

(23) Vibrators should be of sufficient size but not oversized for the particular pour – eg, the vibrators should be able to fit between reinforcement cages, rebar spacing and into corners. Vibration time shall be controlled such that segregation is not caused by keeping the vibrator in one place for prolonged periods. Typical diameters range from ½” to ¾” (12 to 18 millimetres) for standard pours and to be determined by trial pours prior to use on actual works. Honeycombing from air-entrainment is also reduced by proper vibration, especially between the reinforcement and form faces.

(24) At least two (2) stand-by vibrators in working condition shall be provided for emergency use in case of malfunction. The use of external vibrators or vibrating forms for consolidating concrete will be permitted and may be required when the concrete is inaccessible for adequate consolidation. When external vibration is used, the forms shall be constructed sufficiently rigid to resist displacement or damage. Vibrating of concrete shall be done with care and in such a manner as to avoid displacement of reinforcing, conduits, and other items to be fixed in place.

Appendix A

Information to be supplied by Manufacturers of Proprietary Systems of form Work

1. General

1.1. The information which the manufacturer is required to supply shall be in such detail as to obviate unsafe erection and use of equipment due to the intention of the manufacturer not having been made clear or due to wrong assumptions on the part of the user.

1.2. The user shall refer unusual problems of erection/assembly not in keeping with intended use of equipment, to the manufacturer of the equipment.

2. Information Required

2.1. The manufacturers of proprietary systems shall supply the following information;

a) Description of basic functions of equipment.
b) List of items of equipment available, giving range of sizes, spans and such like, with manufacturer's identification number or other references.
c) The basis on which safe working loads have been determined and whether the factor of safety given applies to collapse or yield.
d) Whether the supplier's data are based on calculations or tests. This shall be clearly stated as there may be wide variations between results obtained by either method.
e) Instructions for use and maintenance, including any points which require special attention during erection, especially where safety is concerned.
f) Detailed dimensional information, as follows :
    i. Overall dimensions, depths and widths of members.
    ii. Line drawings including perspectives and photographs showing normal uses.
    iii. Self weight.
    iv. Full dimensions of connections and any special positioning and supporting arrangements.
    v. Sizes of members, including tube diameters and thicknesses of material.
    vi. Any permanent camber built into the equipment.
    vii. Sizes of holes and dimensions giving their positions.
    viii. Manner of fixing including arrangements for sealing joints.
    ix. Method of de-stripping, storing & shifting.
g) Data relating to strength of equipment as follows:
    i. Average failure loads as determined by tests.
    ii. Recommended maximum working loads for various conditions of use.
    iii. Working resistance moments derived from tests.
    iv. Working shear capacities derived from tests.

v. Recommended factors of safety used in assessing recommended loads and deflections based on test results.

vi. Deflections under load together with recommended pre-camber and limiting deflections.

vii. If working loads depend on calculations, working stresses should be tested. If deflections depend on theoretical moments of inertia or equivalent moments of inertia rather than tests, this should be noted.

viii. Information on the design of sway bracing against wind and other horizontal loadings.

ix. Allowable loading relating maximum extension of bases and/or heads.

x. Any restrictions regarding usage of any component or full assembly with regard to spans, heights and loading conditions.

Volume 5

Outline Construction Specifications

Section- 4

Geotechnical, Geotextile & Ground Improvement

Brihanmumbai Municipal Corporation

Mumbai, India

2.1 Geotextile Material

All geotextiles shall be manufactured by and purchased/obtained from a reputable manufacturer(s) and ISO 9001: Compliant. The manufacturer(s) shall have ample experience in the fabrication of the type of geotextile specified.

Before ordering any quantity of geotextile, the Contractor shall submit samples, and test reports from an Noticed independent testing laboratory accredited in accordance to ISO 17025 and certified by GAI-LAP certification. The test reports from laboratories without accreditation are not acceptable.

The Geotextile is supplied in Roll. Each Roll shall be wrapped using good quality wrapper. A packing label is pasted on the roll and also at the inner face of the core of the roll. The packing label shall necessarily indicate:

a) Manufacturer's name,
b) Type of geotextile (Product code and Product grade)
c) Manufacturing date.
d) Roll No. & Lot no.

No geotextiles shall be used in the Works which were manufactured more than one year prior to arrival on Site. The geotextile shall not be exposed more than 6 weeks to Sun-light. In case of higher exposures are needed, it should be covered temporarily with a 90gsm tarpaulin cloth till it is permanently covered.

The contractor shall design the geotextile properties required for this project and submit to engineer for approval.

2.1.1. Laying of Geotextile

The surface on which geotextiles are placed shall be relatively smooth, free of obstructions, depressions and soft pockets. Depressions shall be filled with compacted material as directed by the Engineer. Placing of the geotextile shall not start until underlying slope has been Noticed by the Engineer.

The geotextile shall be placed loosely without wrinkles or folds with the warp running normal to the coastline. The geotextile will be laid in one piece over the required depth. Lapped joints will not be permitted. Joining of geotextile strips shall be achieved by stitching.

No joints in the geotextile are allowed perpendicular to the coast. All seams (if used) must face upwards from the creek bottom to allow for inspection and repair. A surplus of minimum 10 mm of geotextile shall be provided at the seams to allow movement.

Holding the geotextile in position shall be by ballasting with the filter rock. Pinning with steel pins or wooden pegs will not be allowed. No cover layer shall be placed on top of the geotextile without approval by the Engineer.

From the time the textile is removed from storage for incorporation into the works, until it is placed and covered by the first gravel layer shown on the drawing, the total period shall not exceed 7 days. No geotextiles shall be placed in the Works which cannot be covered with protective elements the same day.

2.2 Ground Improvement

The Contractor shall undertake all design, construction and ground improvement performance verification as necessary to the satisfaction of the Engineer to ensure that the ground improvement works satisfy the performance requirements stipulated in the Employer's Requirements.

Engineering requirements to be addressed by the Contractor in his selection of the most appropriate methods of and equipment for any ground improvement to be undertaken at the Site, in order to meet the Employer's Requirements, shall include but shall not be limited to the need to control lateral earth and water pressures on the Earthen Bunds & structures, under normal condition.

Where the adoption of more than one form of ground improvement has been Noticed by the Engineer, the areas within which each form of ground improvement are to be used shall be carefully delineated by the Contractor having due regard to the soil conditions to be expected in each part of the Site.

2.2.1. Method of Improvement

Ground improvement shall be carried out for earth fill up to the depth of recent fill (existing creek bed to ground level) and also in the soils below earth improvement as per the design and drawings Noticed by the engineer.
The choice of a particular method of ground improvement shall be decided by considering the degree of improvement required, the depth of fill to be treated, the proximity to existing structures or facilities, and the relative cost benefits.

Filling for earth improvement above Mean High Water Spring Tidal level, shall be compacted to achieve maximum dry density of 95% by means of mechanical vibratory roller or tendon roller. The required number of passes roller weight, roller speed, frequency, amplitude of vibration shall be decided based on the trial compaction and to meet the required MDD as per this specification. If the required compaction is not achieved with the above mentioned number of passes then number of passes shall be increased till the final compaction is achieved. Care shall be taken to see that the compaction equipment does not hit or come too close to any structural member so as to cause any damage to them or excessive pressure against the structure.

The fill material place below Mean High Water Spring Tide level shall be improved by means any suitable ground improvement methods as specified in latest IS13094 and as per the design/site conditions noticed by the engineer.

The soft soil below the filled Ground shall be treated using any of the ground improvement technique to achieve the Relative Density of minimum 70% for frictional sandy soil and 90% consolidation for cohesive soil, as necessary, to provide adequate stability, and bearing capacity and settlements to withstand the applied loadings defined in the Specifications and to provide a firm foundation for construction of costal road structures and to achieve the specified settlement criteria.

Acceptable methods of in situ soil improvement works are likely to include:

a) Replacement of unsuitable soft soils

b) Adequate methods of improvement to ensure compliance, including but not limited to preloading, wick drains, vibro-compaction, sand compaction piles and stone columns etc.

The contractor is required to plan and perform the ground improvement under water as well as on the land side.

The Contractor shall submit the construction sequence and methodology for ground improvement works to the Engineer a minimum of two weeks before the commencement of the works.

The scope of the ground improvement works includes, but is not limited to, the following major work elements:

a) Seek the Engineer's approval to undertake the ground improvement works as designed and proposed

b) Install monitoring instrumentation such as surface settlement markers, multi-level pyrometers, standpipes and observation wells, inclinometers, and other suitable instruments. The contractor shall submit the instrumentation plan and schedule to Engineer for approval prior to start of work.

c) Closely monitor the behaviour of the earth improved areas during the ground improvement phase.

d) Submit regular instrumentation monitoring reports to Engineer.

e) Carry out quality control field tests on ground improvement elements during and after installation.

f) Carry out pre and post-ground investigations to confirm that the earth improvement works and natural ground under consideration has been improved to required MDD of 95% above Mean High Water Spring Tide Level, Relative Density of 70% below Mean High Water Spring Tide level and 90% consolidation if clayey soil encounter as natural ground below Mean High Water Spring Tide Level.

g) Prepare pre-ground improvement, and post-ground improvement assessment report to confirm that the design objectives have been met, for the review of the Engineer. Demonstration of the effectiveness of the ground improvement works in accordance with the test procedures set out hereunder or subject to the Engineer's instructions otherwise stated. The acceptance by the Engineer of such test results shall not relieve the Contractor of the responsibility that the fill material in the earth improved area shall comply with the Specification.

h) Details of sequencing of filling with construction of the perimeter and internal dividing bunds, so that stability of the bunds is maintained.

i) Methods for working within bund areas to achieve the required soil Specifications and levels.

j) Ground settlement after improvement shall be brought to final finish level and compacted using vibratory roller to meet the minimum required density criteria as specified in this specifications.

2.2.2. Performance Criteria

The Contractor shall be responsible for the construction, performance verification (including pre and post treatment testing, instrumentation and monitoring) and rectification of any defects in and upon completion, of any and all of the ground improvement works adopted for the development

The Contractor shall provide such technical expertise, plant, materials, standards, workmanship etc. that may be necessary or desirable to meet the performance requirements as specified in the specifications.

Following completion of the cutting and filling of the ground surface, after to the commencement of compaction, the Contractor shall undertake CBR testing at the final grade level to ensure that the material can satisfy the relevant design CBR requirements specified by Engineer.

The field CBR testing shall be carried out in accordance with IS: 2720 Part 16 on the compacted in-situ soil to the same relative density specified above. The Contractor shall submit the test results to the Engineer for approval prior to the commencement of any subsequent compaction or filling activities.

2.2.3. Compaction Acceptance Criteria

The degree of compaction shall be sufficient to achieve a dry density of not less than 95% of modified proctor's dry density at optimum moisture content as per IS-2720 (Part – VIII) for fill above Mean High Water Spring Tide level and 70% Relative Density for fill below Mean High Water Spring Tide level as per IS-2720 (Part-XIV) as applicable depending on the nature of filling material. The work of filling will be accepted after the Engineer is satisfied with the degree of compaction achieved.

Test	Frequency
Field density test by sand replacement method	· 1 test for every 1000 Sq.m. of each compacted area. · In areas where the degree of compaction is doubtful.
Field CBR test	· 1 test for every 3000 cum. on the top 500 mm of the compacted layer · The bulk sample shall be collected preferably from the road area.

2.2.4. Acceptance of Settlement Criteria

The Contractor shall be responsible for reviewing the instrumentation monitoring data, estimating the long-term residual settlements based on the monitoring data, preparation of settlement report, and ensuring that the settlement criteria as given in the Engineer's Requirements and under section 3.7.2 of specification volume-4 are achieved.

In case failed in achieving the Engineer's Requirements, the Contractor shall investigate the cause of the non-achievement and propose remedial measures with detailed calculations to the engineer and re-improve the ground without any additional cost. The Contractor's proposed remedial measures shall not in any way delay the prescribed dates for handover of the Site and affect the stability and structural integrity of all features including but not limited to age earthen bunds, slopes and utilities and the existing buildings and other features under any other proposed remedial measures.

2.2.5. Acceptance of Ground Improvement

The uppermost zone of fill shall be placed and treated to ensure that the earth improvement above Mean High Water Spring Tidal level has an in-situ density not less than 95% of the maximum dry density. The relative density of fill below Mean High Water Spring Tide level shall not be less than 70%. The values of maximum dry density shall be obtained in accordance with IS 2720 Part (VIII).

The soft in-situ soil below Mean High Water Spring Tide and bunds after ground improvement shall be tested by undertaking cone penetration test (CPT) at least full depth of soft zone, to demonstrate compliance with both the engineer's requirements and contractor's design requirements. Where CPT (SCPT/DCPT) cannot be carried out due to obstructions, SPTs shall be carried out within drill holes at every 1.5m interval till the final improvement level reached. The test frequency for cone penetration test/SPT shall be kept 1 number per 1000sqm of improved area along with the locations where improvement is doubtful. The contractor shall not claim any variation to change in the test methods.

2.2.6. Field Trials and Monitoring

Prior to ground improvement works adopted the Contractor shall carry out trials to demonstrate the adequacy of the proposed improvement methods to achieve the requirements of the Contractor's design, and to examine the sequence of operations.

The trials shall take place at a location as specified in the Contractor's Noticed drawing with adequate monitoring instrumentation and pre and post treatment testing as agreed by the Engineer. The results obtained from the trials shall be used to assess the acceptability of the initial design.

The Contractor shall submit detailed report of trail tests for approval of Engineer. In case, based on the field trials, if any variation in the Ground Improvement design is required to meet the specification requirements, than the Contractor shall suggest the revised ground improvement design to meet the requirement of the specifications. The Contractor shall not claim any additional cost by any means of any change in the design.

2.2.7. AAA Monitoring System

Any existing and newly constructed structures or utilities within or adjacent to the Site, which may be subjected to undue movement and/or settlement by the adjacent Contractor's construction activities, including but not limited to excavation, ground improvement, and temporary works, shall be monitored regularly during the construction activities.

Movement control levels for the monitored elements shall be defined in accordance with the following criteria.

a) Alert Level - Remedial measures agreed.
b) Action Level - Remedial measures instituted and revised Alert and Action levels set.
c) Alarm Level - Serviceability limit, stop work.

Alarm level value is defined as the highest or lowest (as appropriate) reading anticipated based on the design. In no case the readings are not to be exceeded beyond this level during the work.

Action level value will be established as approximately 90% of the Design Values. Allowable level reading is considered to be failing to comply with the maximum or minimum (as appropriate) levels consistent with the requirements of the contract.

Alert level will be established as approximately 70% of the Design Values. Remedial measures become effective when alert values are exceeded.

2.2.8. Failure to Comply

Where an area(s) of ground subject to ground improvement verification has (have) failed to comply with the performance requirements of the Specification, the area(s) of non-compliance shall be re-treated by means of the final Noticed method of ground treatment so that compliance with the Specification is achieved to the satisfaction of the Engineer. The Contractor shall promptly submit alternative ground improvement proposals to be undertaken at a nearby area for the Engineer's consideration. Such alternative ground improvement proposals shall not differ significantly from those already noticed and subjected to verification without good reason and all changes shall be discussed in detail with the Engineer and his approval sought to their implementation.

Following approval of the Contractor's revised proposals for ground improvement, ground improvement of the newly designated area shall be completed to the satisfaction of the Engineer incorporating such amendments in methodology as agreed. The new area of ground improvement shall then be subject to ground improvement performance verification. Only when performance verification of the Contractor's chosen ground improvement method has been completed to the entire satisfaction of the Engineer, shall permission be given for the verified ground improvement techniques to be adopted in the Permanent Works.

The Contractor shall closely monitor the progress of and maintain adequate resources to ensure the completion to the satisfaction of the Engineer of his ground improvement performance verification works within the time-frame allocated in his programme. The Engineer shall be immediately notified should it at any time appear that programme slippage is likely to occur and the Contractor shall take such steps as necessary to remedy the situation.

2.3 Materials Not Specified

Any materials not fully specified in these specification and which may be offered for use in the works shall be subject to approval of Engineer, without which it shall not be used anywhere in the construction works.

Volume 5

Outline Construction Specifications

Annexure – 1

Brihanmumbai Municipal Corporation

Mumbai, India

EXISTING BUILDING STRUCTURES (EBS) PROTECTION

(1) The Contractor shall minimise the induced loads, and total and differential deflections (angular distortion) of the ground surface and EBS above or below the ground surface that may result from the Works. The impacts of construction shall be so limited as to not affect the operation of the EBS, road and pavement.

(2) "green-field" condition shall be considered in determining the total and differential deflections of the ground and EBS.

2.4 Ground Assessment

1.2.1. General Ground Conditions

(1) The Contractor shall be responsible for determining the geology, ground conditions, and hydrogeology and geotechnical design parameters for his proposed construction area.

(2) The regional geology for the area of the alignment is generally documented by the Geological Survey of India.

(3) The Employer will make available to the Contractor, for information only, geotechnical information he has collated. The Contractor shall supplement this information to the extent necessary to ensure that all his construction will satisfy the Employer's requirements, specifications and conditions as set out in the Contract.

(4) The geotechnical investigation undertaken by the Employer shall not be relied upon to provide adequate information concerning the nature of the ground and it shall not should it be relied upon by the Contractor to fully develop comprehensive method statements for geotechnical and cut and cover works, or other related activities .In preparing his designs and method statements, the Contractor shall carry out additional investigations as necessary and make his own assessment on the adequacy of the available geotechnical information, and shall indicate where he considers such information to be deficient having regard to the particular works or activities to which the design or method statement relates.

(5) The Contractor shall at his own expense, conduct additional geotechnical investigations and present to the Engineer for information a geotechnical factual and interpretive report for any additional geotechnical investigations conducted by the contractor. This additional geotechnical investigation shall be in sufficient to enable the Contractor to identify all reasonably foreseeable ground conditions which may affect the safe and effective execution of the Works and ensure that there is no likelihood of encountering any unexpected or unforeseen ground conditions which may impact on the delivery of the works. The Contractor shall continuously assess the requirements for any supplemental site investigation and implement the

requirements prior to design or if necessary promptly during construction and as conditions demand.

(6) The Contractor shall before commencement of any construction works submit full details of his proposed additional ground investigation programme, name and qualifications of investigation subcontractors including field engineers and engineering geologists, work plans, equipment, methods and procedures etc. to the Engineer for information.

(7) Prior to commencing any works, the Contractor shall compile a list of geotechnical risks and include these in a ground assessment Risk Register. This ground assessment risk register and proposed mitigation measures will be submitted as part of his design submission when seeking a Notice to Proceed from the Engineer.

(8) The risk register shall include design, construction, environmental and safety related risk together with mitigation measures and responsible person for the management of the risk during execution of the work. This risk register shall form part of the Risk management plan and be included within the overall project risk register.

(9) If the Contractor intends to carry out additional ground investigations from the surface, beyond the limits of the contract boundary, he shall make his own arrangements with landowners and occupiers for the necessary access. He shall not assume that such access will necessarily be granted. The Engineer will when appropriate provide assistance where such additional investigation if he deems it to be to the benefit of the Works.

(10) If surface access for additional ground investigations is not available, or if for any other reason the contractor believes there is a significant likelihood of encountering a geological hazards whose extent and location is unknown, the Contractor shall submit notice to the Engineer. During execution of the works in areas where additional ground investigation has been denied or is deemed inaccessible the contractor shall highlight this in his design submission and include for such provision when submit a construction method statement. Additionally the contractor shall clearly identify in his design submissions means by which such geological hazards will be identified as the construction proceeds.

(11) Furthermore, the Contractor shall also identify how cut- and-cover structure design and construction activities will be modified to recognise any deficiency in the ground information prior to commencement of construction.

(12) Detailed seismic loading and ground-acceleration criteria are referenced under Loads and Requirements of these Outline Design Specifications. Consideration of design-level seismic forces in the design of temporary structures is generally not required, except at locations, to be agreed by the Engineer or where public safety and loss/ damage to adjacent properties/Structures might be involved. At such locations, the contractor shall consider effects of the design seismic event on the stability of excavations, the performance of the proposed structures and on the

potential for liquefaction of soils during design and construction of the Works.

2.5 Site Investigation Requirements

(1) The intent and objectives of the additional site investigations shall be for the Contractor to collect all pertinent and reliable geotechnical related data and information required to produce a safe, accurate and durable design and to meet all the Contract requirements.

(2) For the purpose of these Outline Design Specifications, site investigation shall be considered to include, but not be limited to, the following.

a) Compiling and reviewing pertinent existing geological data.

b) Compiling and reviewing pertinent existing geotechnical data supplied from the vicinity projects.

c) Compiling and reviewing pertinent existing foundation, structure, substructure, utilities and other related data from projects in the vicinity.

d) Performing a detailed field reconnaissance along the complete alignment

e) Performing additional geophysical surveys/investigations.

f) Performing additional ground investigations that include, but are not limited to drilling, soil sampling, rock coring, groundwater sampling, in-situ field installations and testing, trial pits, soil stripping, rock mapping and cored holes.

g) Performing laboratory testing on soil, rock, and groundwater samples collected from the ground investigations, including chemical testing to identify potentially corrosive conditions and/or contamination that may be a threat to public and durability of the Works.

(3) As a minimum, the additional site investigation programme shall consider the locations together with lateral and vertical extent of the following.

a) Major existing structures such as viaducts, bridges, flyovers, underpasses/sub- ways and crossing structures, underground water and sewer lines, portal structures, retaining structures, commercial developments, ancillary structures and any future works to be undertaken by others in the foreseeable future.

b) Earthworks such as soil and rock excavations, embankment fills, earth improvement, areas requiring ground improvement, borrow pits and disposal areas and the like.

c) All existing structures adjacent to the alignment that may be influenced by the proposed construction Works. That includes, structures adjacent to, above, or below excavations that may be affected by construction works such as dewatering, excavation or blasting; structures deemed to have poor structural integrity or foundations; structures containing sensitive equipment or materials, structures with heritage/historic/cultural significance and the like.

d) Significant engineering geological features that may influence the proposed construction Works. That is, major/principal faults, shear zones, persistent jointing; mass wasting, old landslips and the like.

e) Electrical earthing.

f) All other utilities including but not limited to water supply, communication cables, gas lines and electrical networks and sub-stations

(4) All EBS, including private water supply wells/tube wells.

(5) Ground investigations (GI) as part of a comprehensive site investigation programme, shall be conducted in accordance with IS1892 and BS 5930. The extent of such GI shall be consistent with the form, type and extent of the proposed construction works unless otherwise agreed with the Engineer.

(6) All aspects of the Work shall be conducted under the direction of qualified geotechnical personnel.

(7) Detailed plans and Methods statements including technical specifications, together with standard forms, proposed staffing, reporting indicating the types, locations, and proposed depths of ground investigations relative to the proposed Works shall be prepared and submitted to the Engineer for his Notice to Proceed prior to commencement of any such work.

(8) Any and all revisions to the initial site investigations and GI programmes shall be submitted to the Engineer for his Notice to Proceed.

(9) All GI data shall be prepared in accordance with IS/BIS or internationally accepted standards using Association of Geotechnical and Geo-environmental Specialists (AGS) format or equivalent and Geotechnical Integrator (GINT) software, latest versions. All data shall be provided in both printed and electronic file formats to the satisfaction of the Engineer.

(10) Prior to commencement of any additional GI investigation the Contractor shall obtain all necessary approvals from relevant Agencies/Authorities and determine the locations of any services or utilities that may be damaged by his proposed GI. The Contractor shall comply with all necessary requirements of all pertinent Agencies/Authorities.

(11) Additional GI Investigations including drill-holes, tests and the like shall extend

to a minimum depth of 5 metres below the underside of the proposed structures.

(12) The additional GI spacing along the alignment shall be no greater than 250 metre along the alignment or at distances agreed with the Engineer. Furthermore, additional GI should also be carried out where unusual features have been identified such as deep weathering of rock, location of geological features, high piezometric pressures, loss of drilling fluid or very weak ground or where data obtained from other site investigations gives the Contractor or Engineer cause for concern.

2.6 Investigation Methods

(1) Geological studies

a) Geological studies shall include, but not be limited to, a review of pertinent and existing literature, aerial photographs, remote-sensing data, detailed field reconnaissance of the site and review of project-specific maps and cross-sections.

b) Project-specific geological plans and cross-sections shall be prepared to 1:2000 scale, for both horizontal and vertical directions. The geological plans shall be overlain on suitable base plans which show relevant features such as survey grid, roads, selected EBS and the like.

(2) Geophysical surveys/Investigations

a) Geophysical surveys/investigations shall be carried out where appropriate to provide additional site-specific information on depths and characteristics of overburden soils, bedrock, water table and hydrostatic pressure which may impact on the design considerations.

b) Geophysical (e.g., seismic refraction, reflection, Side acting shear wave, resistivity, magnetometer, gravity, and other such surveys/investigations may be used to obtain subsurface information for planning other detailed GI studies, and for extending information between other investigation positions.

(3) All such geophysical surveys/investigations shall be calibrated by appropriate absolute GI methods such as drilling, Cone Penetration Tests (CPT), test pits and the like.

(4) Exploratory drill-holes; Exploratory drilling in soil and rock, disturbed and undisturbed soil sampling, and rock coring shall be performed according to procedures outlined in IS 1892 and BS 5930. Full-time monitoring by qualified geotechnical personnel is required to direct the drilling, sampling, and coring, and also to prepare field records for these drill-holes.

(5) Other ground investigation methods Other GI methods to be employed during ground investigations shall include, but not limited to, the following.

a. Field testing: Standard Penetration Tests (SPT), Cone Penetration Tests(CPT) with pore pressure measurement (CPTu) or with seismic cone (CPTz), in-situ vane shear, pressure meter, permeability tests, water absorption tests, impression packer or/and discontinuity surveys, acoustic borehole imaging, in- situ density, plate load testing, point load tests, “cover meter” and the like.

b. Field instrumentation: standpipes, piezometers, inclinometers, extensometers and the like.

c. Test pits with and without the recovery of “disturbed” and “undisturbed” samples.

d. Inspection pits

e. Hand-auger bores.

f. Coring through rock, earth retaining structures or other manmade features Vibrocoring.

g. In-situ (constant or falling head) permeability tests.

h. Packer tests for rock permeability and/or rock jointing.

i. Pumping tests.

j. Groundwater sampling for chemical testing.

(6) Groundwater

a. Standpipes and piezometers shall be installed during ground investigations to measure current and seasonal fluctuations in groundwater levels. The GI programme shall incorporate the details of a groundwater observation plan, including locations and details of standpipe/piezometer installations together with frequency and duration of observations. The GI programme shall also include chemical analysis of groundwater.

b. Where necessary, full-scale groundwater pumping tests deemed shall be conducted to develop design parameters for construction dewatering schemes.

c. Groundwater information shall be interpreted, and recommendations for design groundwater levels, including variation of levels that may develop across structures during Construction and subsequent Rail Operations shall be provided by the Contractor.

(7) Environmental Testing for Soil and Groundwater Contamination

a. Areas with potential land contamination concerns or suspected historical contamination, once identified in the assessment, shall be investigated for contamination.

b. Soil/rock samples shall be collected at different depths using ground investigation methods such as trial pits, auger bores or other soil/rock boring methods. Groundwater monitoring wells shall be provided for monitoring fluctuation in the water table and the collection of groundwater samples.

c. Care shall be taken to avoid cross-contamination and degradation of samples.

All samples shall be, sealed in properly labelled air-tight containers and stored in a shaded, air- and moisture-tight store, the storage area of which shall be maintained at constant temperature and humidity in accordance with the appropriate standards.

d. Unless otherwise permitted all such samples shall be tested within one week of having been obtained

2.7 Laboratory Testing Methods

(1) **General;** The Contractor shall develop a laboratory testing programme which allows for the particular site conditions, project/contract requirements and the applicable design standards, codes, regulations, and related publications as identified in the Employers Requirements.

(2) Preparation and submission of information, all laboratory test data shall be prepared using the latest version of AGS format. All data shall be provided in both printed and electronic file formats. All testing shall be conducted by laboratories holding current accreditation under International Standards Organisation/Bureau of Indian Standards

(3) Soil testing

a. Index/classification soil tests shall comprise; natural moisture content, specific gravity, particle size distribution (with and without hydrometer grading), Atterberg limits, bulk and dry density, dry density and moisture content relationships, and shrink-swell limits, where applicable.

b. Strength testing shall include: single- and/or multi-stage, consolidated drained and consolidated-undrained (with pore pressure measurement) tri-axial tests; unconsolidated undrained tri-axial tests; on “undisturbed” samples of diameter not less than 70 millimetres: vane shear tests on retrieved undisturbed samples.

c. Consolidation testing shall include one-dimensional, consolidation or Rowe cell tests on undisturbed 60 to 100 millimetre diameter specimens.

d. Soil permeability tests shall include constant-head and variable-head permeability tests performed using either a permeameter or tri-axial cell.

e. Chemical tests for soil and groundwater shall include determinations of resistivity, redox potential, acidity (pH), chloride ion content, sulphate ion content, total sulphate content, total sulphide content, organic content, and carbonate content and identification of other potentially corrosive conditions.

(4) Rock testing; Rock testing shall include water content, porosity, density, water absorption uniaxial compressive strength testing of intact rock core, tri-axial strength testing of discontinuities (using Hoek cell or appropriate shear box), Brazilian tensile test, abrasiveness (Cherchar tests) and any other type testing required by the standards referenced in the Employers requirements or deemed necessary by the Engineer. Any additional testing required by the Engineer will be at no additional cost to the contract.

(5) Environmental testing; Environmental testing of soil and groundwater samples shall test for potential contaminants such as; heavy metals, volatile organics, semi-volatile organics, pesticides, petroleum hydrocarbons, polychlorinated biphenyls, cyanide and other chemicals of concern.

1 INSTRUMENTATION, MONITORING & REPORTING

1.1 General

(1) The Contractor shall instrument, monitor and report on ground and EBS movements and distortions, groundwater levels, stresses and displacements in the excavation and lateral support systems, structural movements during construction to validate and check his predictions.

(2) Monitoring shall be carried out at such frequencies agreed with the Engineer and reflects the importance of the EBS and/or the risk of damage to the EBS or other structures or utilities coming under the zone of influence of the works. Special attention shall be paid to any heritage/historical buildings, sensitive structures and wells located along the alignment.

(3) Monitoring shall begin prior to commencement of the Works to enable instrument base- line values to be determined accurately, and shall continue until all movements, settlements and distortions to the ground and EBS, and changes to the groundwater have effectively ceased for a period of three months.

(4) The Contractor shall submit a complete comprehensive instrumentation, monitoring and reporting scheme to the Engineer for his Non-objection prior to any construction. The scheme shall include the following.

a. To establish typical background movement, distortion, groundwater fluctuation, noise and vibration limits for the ground, groundwater and EBS prior to commencement of the Works.

b. Protection to all parties and stakeholders during and after the construction by providing early adjacent ground and EBS.

c. To provide movement and deformation information for design verification of the Temporary and Permanent Works.

d. To ensure that the maximum allowable tolerances associated with various structures/elements within the zone of influence of the Works are not exceeded.

e. To confirm that groundwater drawdown outside of the excavations does not exceed the expected fluctuation limits

(5) Vibration recording devices shall be provided to monitor for vibrations which may cause damage to the proposed construction and EBS. These devices shall be installed at such intervals and locations to provide comprehensive coverage of the Works.

(6) Unless otherwise directed by the Relevant Fire/Life Safety/any other Agencies/Authorities or the Engineer, these devices shall record ground accelerations generated by the Works to ensure that these accelerations do not exceed the values set by the Relevant Authorities or those determined by the Contractor for the stability and safety of the Temporary and Permanent Works and adjacent EBS.

Building Damage Classification

Building Damage Classification1 (after Burland et al, 1977 and Boscardin and Cording, 1989)				
1	2	3	4	5
Risk Category	Description of Degree of Damage	Description of Typical Damage and Likely Form of Repair for Typical Masonry Building	Approx Crack Width	Max Tensile Strain %
0	Negligible	Hairline cracks		Less than 0.05
1	Very Slight	Fine cracks easily treated during normal redecorations. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection	0.1 to 1	0.05 to 0.075
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible: some repointing may be required for weather tightness. Doors and windows may stick slightly.	1 to 5	0.075 to 0.15
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Tack-pointing and possibly replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Water tightness often impaired.	5 to 15 a number of cracks greater than 3	0.15 to 0.3
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams.	15 to 25 but also depends on number of cracks	Greater than 0.3
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams, loadbearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability.	Usually greater than 25 but depends on number of cracks	

Notes:

1. The table is based on the work of Burland et al (1977) and includes typical maximum tensile strains for the various damage categories (column 5) used in the stage 2 settlement analyses

2. Crack width is only one aspect of damage & should not be used on its own as its direct measure.

1.2 Limiting Construction-Induced Vibrations at Adjacent EBS

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

Peak Particle Velocities in mm/sec (Max. Allowable) at Adjacent EBS

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

Above limits are maximum permissible, however this may have to be restricted further if required to avoid damage to the adjacent EBS or causing discomfort to the occupants.

Along the proposed alignment, other limitations may be imposed at adjacent EBS, such as hospitals, school buildings, telephone-exchange structures, special water-supply structures and Heritage structures etc. In addition working hours for such equipment’s causing vibrations may have to restricted, keeping the convenience and comfort of the occupants in mind.

1.3 Submissions

(1) The Contractor shall submit his designed instrumentation, monitoring and reporting scheme to the Engineer for seeking his Notice to Proceed. This scheme shall be designed to achieve the objectives stated in this document.

(2) In order to complete the above scheme the Contractor shall refer to the information provided with the Contract documents and supplement this with his own GI as required by the Contract. This scheme should give due emphasis to the information provided with the Contract documents and as a minimum shall include following,

a) Ground conditions including the geotechnical properties of the different soil and rock layers.

b) Adjacent EBS within the zone of influence including their existing condition and foundations as available.

c) Proposed method of construction, and the type of equipment proposed.

d) Assumptions and calculations for the basic design including the installation of appropriate instrumentation for monitoring and recording ground and groundwater movements, settlements & displacements, deflections, tilts, rotations, distortions, cracks, pressures, loads/stresses & strains and the like.

e) Proposed types of instrumentation, locations of and programs for establishing the base readings and continuous observations.

f) Proposed methodology for installation (including proposed installation programme & procedures, Quality Assurance Plan along with proposed tests for quality control, Site organization plan for deployment of Contractor's personnel), calibration (including function testing and acceptance tests), maintenance and operation/running (including Data Collection/ Data transfer systems; type and presentation of output to be produced by the Contractor) of the instrumentation system, including location of gauge houses, proposals for de-airing of piezometers and any other special requirements.

g) Frequency of the monitoring/data recording

h) Trigger (Alert, Action & Alarm) levels for each and every instrument and each and every parameter to be monitored.

i) Frequency of reporting monitoring records to Contractor's construction site staff and to the Engineer.

j) Possible preventive and remedial measures to be adopted to ensure that the trigger levels are maintained within acceptable limits.

1.4 Types of Instrumentation

(1) The types and quantities of geotechnical instrumentation shall be proposed by the Contractor, and non-objected by the Engineer. Instruments of robust nature shall be used which are capable of giving reliable data to within the manufacture's tolerances over long periods of measurement.

(2) The Contractor shall establish suitable temporary bench marks for the purposes of monitoring vertical movements. Such bench marks shall be outside the zone of influence of construction.

(3) Precise levelling points shall be provided on monuments at ground level to extend throughout the area where predicted settlement is expected to exceed 5 millimetres.

(4) Precise levelling studs (road nails) shall be installed on highway (on Roads) and pavement areas in array at 90 degrees to the alignment. These arrays shall extend to the outer edges of the 5 millimetres predicted settlement contour lines. Suitable monitoring points which cannot be readily disturbed shall be installed over open/park areas.

(5) Precise levelling shall be carried out of survey monuments and of settlement

monitoring points on EBS sufficient to determine the imposed strain. Where the structures are subjected to protective works, electro-level beam systems shall be employed, with a back-up system relying on the use of precise levelling pins also installed.

(6) Piezometers (vibrating wire, pneumatic, Casagrande standpipe) are to be provided in the ground for measuring changes in piezometric pressure at different depths. The type of piezometer required will be determined by the anticipated response times.

(7) Inclinometers, strain gauges and extensometers in the ground and within diaphragm walls (or retaining structures) are to be provided for measuring lateral displacements. The depth of the instrumentation in the ground shall extend beyond the influence zone (to be proposed by the Contractor for the non-objection of the Engineer) of the Works with respect to ground movement and excavations and shall be fixed at least 1 metre below the bottom of the diaphragm wall (or retaining structure) and/or into a hard stratum.

(8) Borehole extensometers shall be provided in soft grounds to monitor heave and vertical deformations with depth.

(9) Load cells shall be installed at selected struts and anchors in excavations to enable design predictions to be verified and to monitor performance.

(10) Targets (Reflectors) shall be provided for determining 3D-coordinates and monitoring 3D- absolute displacements to track the target movements in space which shall allow a realistic assessment of deformation behaviour.

(11) Strain meters shall be used for determining the stress development in the shotcrete lining by measuring strains. They shall be installed in pairs to allow determination of sectional forces such as normal thrust and bending moments. Strain meters shall be temperature compensated to compensate for temperature increase of the shotcrete during the hardening process.

(12) Shotcrete Creep Test Equipment: An in-situ shotcrete creep test stand shall be installed in the vicinity of the excavation. It shall consist of a hydraulic piston with precise automatic load control, strain measurement installation on one specimen (200x200x400mm), temperature measurement installation within the specimen as well as shrinkage monitoring on two, non stressed specimens.

(13) The specimen shall be produced by means of the shotcreting equipment and shotcrete used for regular support. Time dependent stress levels shall be applied to the specimen and by means of the resulting stress-strain-time relation necessary parameters for the shotcrete material law shall be generated.

(14) Tangential Pressure cells shall be used for determination of shotcrete lining stress.

They shall be installed in areas of special interest such as intersections etc. They shall have a dimension of 100 × 200 mm. Readings shall be taken in a remote controlled manner with electrical transducers.

(15) Rock bolt axial force meter shall be used to determine the load development along the anchor. This will provide information on increase in load from the anchor tip to the anchor plate. Measuring anchors shall be installed together with rock bolt load cell and extensometers.

(16) Rock bolt load cell shall be installed at the anchor plate to get information on the maximum anchor load and the degree of utilization of the anchor.

(17) Tilt meters shall be provided on walls of adjacent EBS where tilt has been identified as being critical.

(18) Crack meters shall be installed to monitor existing and new cracks on applicable EBS.

1.5 Monitoring and Reporting

(1) The Contractor shall propose details of the performance monitoring of the Works and shall define appropriate trigger (Alert, Alarm and Action) levels for each.

a) EBS,

b) Proposed instrument,

c) Parameter to be monitored for Geotechnical works

d) These trigger levels shall be defined by the Contractor and submitted to the Engineer for Non-objection. Any changes to these trigger levels during the Works shall also be subject to the Notice to Proceed from the Engineer.

(2) The general definitions for the trigger (Alert, Action & Alarm) levels are given below.

a) "Alert Level" shall initially be set as 0.5 times the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical.

b) "Action Level" shall be set at 0.8 times the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical.

c) "Alarm Level" shall initially be set at the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical.

(3) The serviceability limit value for a monitored element/parameter shall be taken as the lesser of:

a) Calculated design value for the serviceability limit, including stresses and displacement/movement of geotechnical.

b) Monitored element movement/distortion which would theoretically cause service disruption.

c) For utilities, the values of settlement/rotation those are acceptable to the Relevant Agencies/Authorities and/or the Engineer.

d) Allowable structure or ground limits corresponding to “Slight” Damage Classification – refer Table 2.1

e) Groundwater drawdown (a drop of water table during construction) by one metre below the lowest recorded groundwater table

Note: The lowest recorded groundwater table shall be considered as the lowest level of groundwater table as recorded by the Contractor prior to the construction.

(4) If any of the trigger levels is reached, the Contractor’s Response shall comprise of emergency actions which could include the following and other necessary measures.

a) On reaching an “Alert Level’ at any location, the Contractor shall immediately submit a written report to the Engineer, reviewing all total and differential movements/distortions (or the relevant parameters) to date, assessing the effects of the movements/distortions (or of the relevant parameters) on the monitored elements and predicting further movement (or further deterioration of the parameter) and their effect on monitored elements based on the trend to date.

b) Where it is considered and non-objected by the Engineer that movement (or the relevant parameter) trends indicate that “Action Level” may be reached during the course of the Works, the Contractor shall be required to submit proposals for remedial measures to limit further movement (or further deterioration of the parameter) for seeking the Notice to Proceed from the Engineer. The remedial proposals shall include the details of the remedial measures and their likely efficiency.

c) Notwithstanding the above, a change between consecutive readings greater than 5 millimetres (movement) shall necessitate the imposition of “Alert Level” status regardless of the global movements.

d) On reaching an “Action Level” at any location, the Contractor shall submit an updated report reviewing the movements including differential movements and distortion (or the relevant parameters). The report shall assess the effects on monitored elements and predict further movement (or further deterioration of the parameter) and their subsequent effect on monitored elements. The report shall allow for remedial works that have been implemented and shown to be effective.

e) Where it is considered and non-objected by the Engineer that movement (or relevant parameter) trends indicate that “Alarm Level” may be reached or exceeded during the course of the Works, the Contractor shall reassess the design and propose remedial measures(including design modifications) for seeking the Notice to Proceed from the Engineer. The Contractor shall propose a Contingency Plan that shall be implemented in the event “Alarm Level” is reached or exceeded and obtain Notice to Proceed from the Engineer.

f) The Contractor shall also develop an Emergency Plan that shall be implemented in the event the applied contingency measures cannot control the situation and obtain Notice to Proceed from the Engineer. In addition, a new set of “Alert Level” and “Action Level” values which take into account the implementation of the proposed remedial works shall be proposed by the Contractor for seeking the Notice to Proceed from the Engineer before work may be allowed to continue. The Contractor shall also provide a report after the remedial measures (including the design modifications) have been implemented, detailing the full history of movements (or other relevant parameters) and effects of implemented remedial measures in relation to the actual construction work. The report shall also contain the review and interpretation of events along with a justification to proceed with the Work for seeking the Notice to proceed from the Engineer.

g) Work shall only be resumed after a Notice to Proceed has been received from the Engineer.

h) In case an “Alarm Level” is reached or likely to be reached, all work shall be suspended within 30 metres (or as required) of the instrument/or affected portion of the Works. The Contractor shall immediately implement the measures as defined in the Contingency/Emergency plans to make the related part of the Works safe and control the situation. The Contractor shall provide a report detailing the full history of movements (or other relevant parameters) and an interpretation of events to the Engineer.

i) To resume the suspended work, the Contractor shall demonstrate to the satisfaction of the Engineer that it is safe to do so. The Suspended Work shall only be resumed by the Contractor after a Notice to Proceed has been obtained from the Engineer.

(5) Throughout the construction period, all adjacent EBS shall be subject to regular inspections by the Contractor's Engineers. Signs of distress in any structures shall be recorded and steps taken to immediately alleviate such distress.

1.6 Frequency of Monitoring

(1) Sufficient time shall be allowed between installation of instruments and commencement of relevant site activities to enable a reliable set of base readings to be established for all installed instrumentation. The time scale shall be non-objected by the Engineer when the Contractor submits his proposed instrumentation scheme.

(2) All instruments shall be connected to data logging equipment where possible so that measurements can be taken on a continuous 24 hour basis. Data shall be accessible via computers in the Engineer's site offices. An alarm system shall be incorporated into the computer network, with the alarm being activated if gauge readings exceed any of the agreed Alert, Action and Alarm levels.

(3) Reports of monitoring results shall be submitted to the Engineer within 24 hours. A detailed graphical presentation of historical values of monitoring shall be submitted on a weekly basis in a format agreed with the Engineer. All results/information shall be submitted to the Engineer weekly on virus-free digital storage devices. The information on the storage devices must be retrievable using Microsoft Excel software running on IBM PC or compatible systems. Where a greater frequency of monitoring is required than on a 24-hour cycle, the Contractor shall submit the reading taken directly at the site to the Engineer on the same day.

(4) All instruments shall be suitably protected against accidental damage, vandalism and adverse climatic conditions. Any damaged instrument shall be replaced immediately, with a set of base readings being taken as soon after installation as practicable.

(5) The Contractor shall permanently record in both hard and soft (electronic) form for future reference all readings and observations from each installed instrument. On the Monday of each week the Contractor shall provide to the Engineer the updated records (in both hard and soft copy) for all instruments. These records shall show all previous readings in both numerical and graphical form and include the location, type and trigger levels for each instrument, noting any that exceed the trigger levels and any changes to the instrumentation location, type or records.

(6) The Contractor shall permit access to the Works for personnel from academic/research institutions as non-objected by the Employer so that they can collect relevant data for making studies on performance of various subsurface construction elements. The Contractor shall make all such instrumentation data freely available to these academic/research institutions for academic/research purposes only.

1.7 Protection, Maintenance and Repair

(1) The Contractor shall protect and maintain in good working condition all monitoring instruments and devices throughout the Contract period. Any instrument or devices deemed critical to the Works that is not functioning properly or accurately shall be replaced immediately at the Contractor's own cost.

(2) The Contractor shall ensure that all instruments and devices accessible to public shall be protected with sturdy lockable boxes.

1.8 Removal

(1) No instrument or device shall be demolished, abandoned, removed, disposed off, or rendered inaccessible without the non-objection of the Engineer.

(2) All instruments and devices shall be removed on final acceptance of the Works. All terminal boxes and covers shall be removed and disposed of. All boreholes and excavations shall be completely filled and all instruments and devices attached to EBS removed to the satisfaction of the Engineer.

(3) All costs incurred in the satisfactory removal of the instruments and devices are deemed to be included in the Contract rates and price

2 EBS PROTECTION

2.1 General

(1) The Contractor shall be responsible for the control of all ground movements and distortions and for any resulting damage to EBS. During the Preliminary Design phase, the Contractor shall investigate all EBS that may be influenced by the Works and establish allowable movement and distortion criteria for each individual or group of EBS. The respective influence zones and the distances beyond these influence zones, where EBS study shall have to be conducted by the Contractor, shall be proposed by the Contractor with the required backup details during the Preliminary Design Phase for the Notice to Proceed by the Engineer.

(2) The Contractor shall design both his Temporary and Permanent Works to ensure that ground and EBS movements and distortions are maintained within tolerable limits and that operation of EBS, Roads and pavements are not affected by the movements and distortions. The Contractor shall also design these Works such that groundwater regime is not affected post-construction stage and the changes to the groundwater level do not exceed normal seasonal variations during Operations Phase of the Project.

(3) The Contractor shall obtain a Notice to proceed from the Engineer and any relevant Agencies/Authorities and/or utilities companies prior to carrying out any dewatering of the ground. Dewatering may only be carried out within contained excavations once the walls or water cut-offs/barriers which provide that containment are all in place and proven to be effective to the satisfaction of all interested parties and the Engineer.

(4) Groundwater drawdown (a drop of water table during dewatering/construction) outside the excavation/adjacent to works, shall be controlled such that the water table is not lowered by more than one metre below the lowest recorded groundwater table (the lowest recorded groundwater table shall be considered as the lowest level of groundwater table as recorded by the Contractor prior to commencement of construction). For ensuring this the Contractor shall provide recharging well system, if required.

(5) The Contractor's attention is drawn to the Conditions of Contract and Employer's Requirements relating to repair of damage should any arise as a result of the Contractor’s construction activities.

(6) The Contractor shall take due regard of the presence of all utilities and services within and adjacent to the Works.

(7) The Contractor shall instrument and regularly monitor the ground and EBS adjacent to all excavations to determine the rate and magnitude of any movements and distortions.

(8) Movement and distortion shall be limited such that any individual EBS shall not suffer damage greater than "Slight" as defined in the “Damage Classification” in Table 2.1.

(9) Movement and distortion to critical/sensitive structures such as hospitals, bridges, flyovers, underpasses/sub-ways, viaducts, heritage structures and “protected” structures etc. shall be limited to “Negligible” as defined in the “Damage Classification” Table 2.1.

2.2 Minimising Ground Movements

(1) Construction from the surface shall be undertaken with due regard to the settlement associated with the particular method chosen.

(2) The following support methods shall not be permitted.

a. Use of ground anchors beneath adjacent buildings without the prior approval of the Employer.
b. Non-recoverable timber ground support.

2.3 Condition Survey

The Contractor shall carry out a detailed Building Condition Survey, to the extent necessary to ensure compliance with the Employer's Requirements, Specifications and Conditions of Contract. Also refer to Section D8, Volume 3.

The Contractor shall determine the potential influence zones for his Works and undertake condition surveys and EBS study as per clause 3.1 of this Annexure for ensuring compliance with all the provisions of the Contract.

2.4 Prediction of Ground Movements

The Contractor shall provide predictive assessments of the anticipated ground and EBS movements and distortions within the potential influence zones and a certain distance beyond these influence zones as referenced in Clause 3.1(1) of this specification, and submit these predictions to the Engineer when making submittal of his proposed method of construction.

2.5 Assessment of Impact on Structures

(1) The Contractor shall provide an assessment of the effect of the predicted movement on all structures within the zones of influence of construction.

(2) The Contractor shall assign to each and every EBS that may be affected by the Works one of the risk categories referenced in "Damage Classification" in Table 2.1.

(3) Movements and distortions shall be limited to those defined in clause 3.1 above.

(4) Depending upon the level of risk, the Contractor shall propose precautionary and protective measures and submit these to the Engineer for seeking his Notice to Proceed. Once agreed by the Engineer these measures shall be implemented by the Contractor prior to any works within the areas and at no extra cost to the Employer.

2.6 Staged Assessment

The Contractor shall assess the effects of movements and distortions on EBS in one, two or three stages, depending upon the findings at each stage, as described below:-

(1) Stage 1 Assessment

The effect of movement and distortion on EBS foundations is assessed but the pattern of settlement is ignored. Any structure where the predicted settlement is less than 10 millimetres and the predicted ground slope is less than 1/500 need not be subject to further assessment. For critical/sensitive structures, a more stringent slope and settlement criteria shall be adopted to comply with the provisions of clause 3.1(10). All other structures within the zone of influence and at a distance as referenced in Clause 3.1(1) shall be subjected to a Stage 2 assessment.

(2) Stage 2 Assessment

The EBS identified to be having a potential risk as a result of Stage 1 assessment shall be individually assessed using a limiting tensile strain approach. This method of assessment takes into account the tensile strains in the ground and uses a simple idealised model of the building. Tried and tested references from the literature may be utilised as an alternative.

In case of all Cut & Cover excavations, and for those EBS that cannot be satisfactorily represented by a simple idealised model of a building ,Numerical simulation of ground movement due to construction activities shall be done to assess the settlement/distortion subject to the non-objection of the Engineer. The geological features, such as joints orientation and spacing etc., shall also be taken into account for such analyses, where appropriate.

For critical/sensitive structures and based on their structural condition a more stringent damage classification shall be adopted to comply with the provisions of clause 3.1(10)

(3) Stage 3 Assessment

All EBS which are placed in Category 3 or above as referenced in the “Damage Classification” Table 2.1, during the second stage assessment, all critical/sensitive structures for which a more stringent damage classification is required to be adopted to comply with the provisions of clause 3.4.1(10), shall be subjected to a further settlement/distortion assessment. A detailed structural survey shall be undertaken by the Contractor to determine the structural form and condition of all such buildings/structures, followed by an analysis of how individual elements of the building/structure will be affected by the predicted settlement/distortion.

The method, extent and detail of the analysis will be determined on a case by case basis and may include, inter alia, an analysis of the soil/structure interaction, structural behaviour, and an evaluation of the possible effects of differential stiffness of the foundations. As a result of the Stage 3 analysis, the requirement for any protective works shall be established and the details of any protective works including designs and method of working determined. Details of such works shall be submitted to the Engineer for no-objection. All such protective works shall be carried out by the Contractor, accepted by the Engineer at no additional cost to the Employer.

3 FIELD CONTROL AND MONITORING EQUIPMENT

3.1 Setting out of Line, level and Profile

Prior to starting underground work, the Contractor shall submit to the Engineer proposals on the setting out the Works and for correcting any deviations.

3.2 Chainage Markers and Bench Marks.

Chainage markers shall be provided in cut and Cover structure at 10m intervals. The markers shall be painted in white durable paint. The contractor shall provide the Engineer the location and description of all survey stations, and all survey data.

3.3 Monitoring Equipment

(1) The Contractor shall provide basic equipment for measurement of deformations along excavation perimeters and ground surface conditions. The types of basic underground equipment to be provided comprise: levelling instruments, wire extensometer for convergence measurement, 3 D optical targets for 3D displacement monitoring and multi point borehole extensometers. The equipment shall be installed as agreed by the Engineer.

(2) During the execution of excavation works, the Contractor need to procure supplementary types of equipment as may be required for standard cut and covert construction method.

(3) Measurements by all types of equipment shall be performed by the Contractor as directed by the Engineer. Results from each measurement shall be submitted to the Engineer within 24 hours.

4 OTHER SPECIFICATIONS

SPECIFICATION FOR WALKWAY FLOOR

Floor finish for walkway should be made to take wear & tear of the people movement, giving appropriate friction in all the seasons and should be long lasting with minimal maintenance. These floor boards can be made in Nature wood Composite Material. Designing load of 500 kg/sqm should be considered. All of these components should be strictly fixed with nut bolt system made up from high grade stainless steel nut bolts only. The Material of Nature Fiber Composite Material is to be Fire Retardant, Fungal Proof and should be resistant to the Marine Environment. The Proposed Material for Nature Fiber Composite Material should have minimum 50% of nature material in the Composite. Life expected 25 years.

SPECIFICATION FOR BENCHES

Arch Benches (Partially backrest)

Required size thick sub surfaced fixed Seating Slats are of seasonable tough wood.100% water and termite proof, long lasting seating material. Assembly will be provided by vender. Brown in colour with sustainable timber batten from certified managed sources.

Timber requires oiling for every 3 months. Framed and arm colours are available in 3 shades:

1) Palladium Silver 2) Texture Black and 3) Texture monument

Mall Sun Lounge CMM-S

Mall sun lounges, with a reclined profile, present an offer to relax when installed in parks and urban areas.

Sun Lounge made from weather-proof acacia wood and suitable for the outdoor use, as well as the use in the sauna, garden, spa, lawn, patio and indoor area.

A variety of batten options are available, including wood grain aluminium for a timber look with easy maintenance. Mix powder coat colours for fun spaces like playground and water parks.

It range features a system of aluminium casting for comfortable and timeless design. With Plinth fixed option with M.S. Plate and steel base to integrate seating into the landscape. Available length up to 2.5m. Acacia wood is especially durable and thus perfectly suitable for outside furniture.

SPECIFICATION FOR DUST BIN

<u>TECHNICAL SPECIFICATION OF DUST BIN 1</u>

Technical Specification of Garbage Bin	
Product Name	Spotted Granite/Black Dust bin
Size	102 cm x 41 cm x 41 cm

Colour	Black/Grey
Material	High Quality Fibre Reinforced Plastic
Purpose	To dispose commingled / segregated waste
Applications	Malls, Corporate Offices, Hotels, Kitchen, Hospitals, Residential, Industries Factories, Institutes, Railways, Airports, Garden, Park, Parking Area, Roadside, Domestic
Others	UV/ Colour Resistant, Corrosion Resistant & maintenance-free

SPOTTED DUST BIN

TECHNICAL SPECIFICATION OF DUST BIN 2

Technical Specification of Garbage Bin	
Product Name	Trash can with Lid and inner bucket with durable pedestal
Capacity	50 Litres (13.2 Gallon)
Colour	Grey Metal finished

Material	Stainless Steel 410 (Inner bucket – Polypropylene)
Purpose	To dispose commingled / segregated waste
Applications	Malls, Corporate Offices, Hotels, Kitchen, Hospitals, Residential, Industries Factories, Institutes, Railways, Airports, Garden, Park, Parking Area, Roadside, Domestic
Others	UV/ Colour Resistant, Slow and soft open/close, Fingerprint proof, Durable Necessary addition to for lifting to dispose garbage

STAINLESS STEEL DUST BIN

SPECIFICATION FOR PLANTERS /FLOWER POTS

General Specifications:

"PLANTERS" are elegantly designed for Plantation, moulded in one tough piece as per industry standards

Detail Specifications :

Materials:

Fibre Glass planters shall be used ,**Fiberglass** reinforced polyester exhibits high impact resistance, a superior range of temperature limits, excellent dimensional stability, excellent electrical properties, and excellent moisture and overall chemical resistance. ... (1) Unlike metals, fiberglass reinforced polyester is non- corrosive.

Application: Planters will be placed on either side of the board, landscape area and other suitable areas.

Dimensions:

Planter recommended Dimensions (Inches) Length 24", Width 12" , Ht 12" Not less than (+/- 5 %)

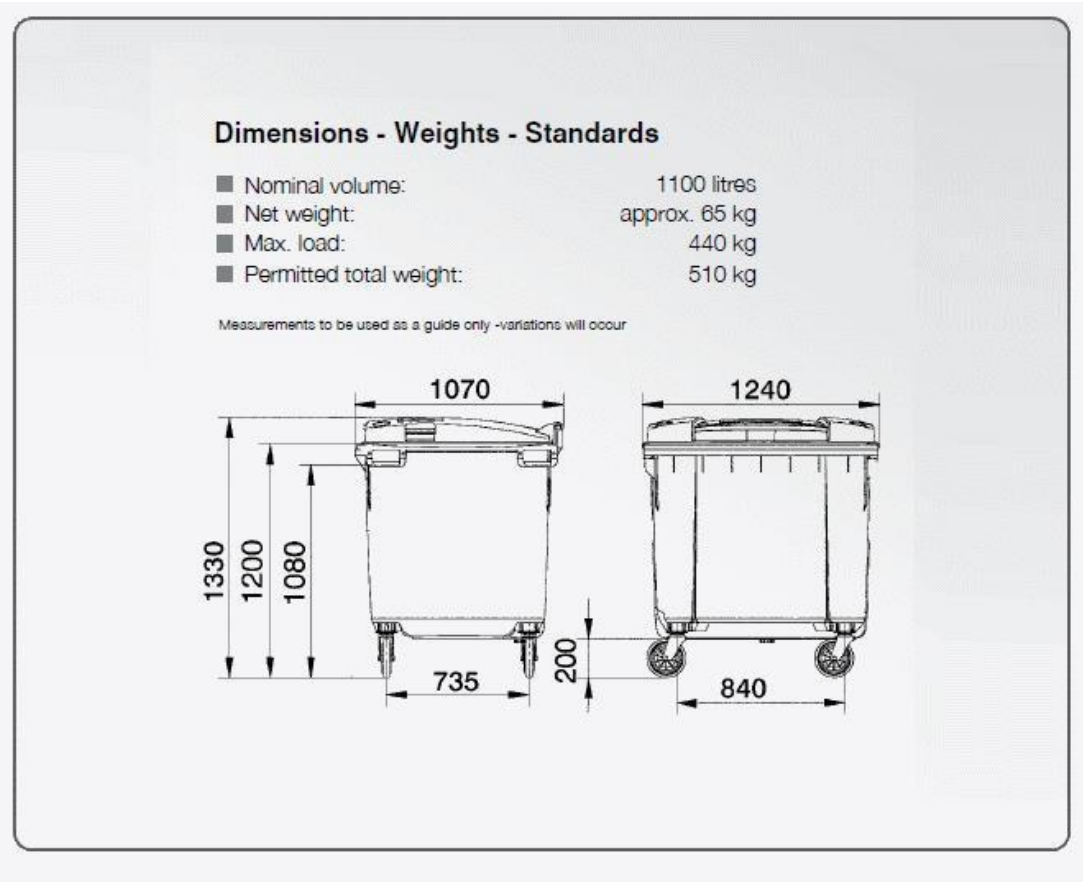
Design : The Planters are made up of Fibre glass materials ,corrosion resistant , Washable, absolutely smooth and to satisfy the critical needs of temperature variation : Shall be painted as per client's requirement.

Drawing : Enclosed herewith.

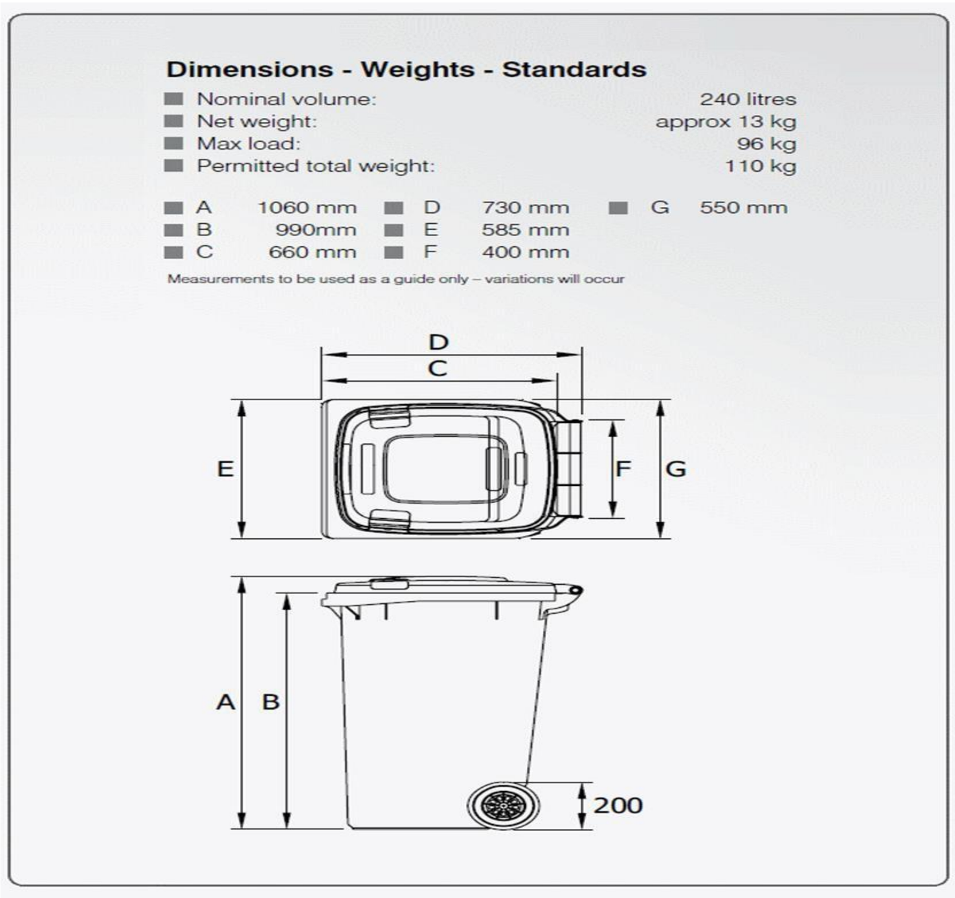
Typical Flower Pot for Walkway

TECHNICAL SPECIFICATION OF DUST BIN 3

Technical Specification of Garbage Bin	
Product Name	Garbage Dust bin - 4 Wheeled Dustbin 1100 Litres
Capacity	1100 Litres
Colour	Green
Material	HDPE
Purpose	To dispose commingled / segregated waste
Applications	Malls, Corporate Offices, Hotels, Kitchen, Hospitals, Residential, Industries Factories, Institutes, Railways, Airports, Garden, Park, Parking Area, Roadside, Domestic
Special character	It is should be lifted by 8 cub meter garbage compactor truck arm
Others	UV/ Colour Resistant, Durable 4 Rubber wheels 2 with break System Necessary addition to for lifting by garbage compactor truck and forklift



Technical Specification of Garbage Bin	
Product Name	Garbage Dust bin – 2 Wheeled Dustbin
Capacity	240-litre
Colour	Green
Material	HDPE
Purpose	To dispose commingled / segregated waste
Applications	Malls, Corporate Offices, Hotels, Kitchen, Hospitals, Residential, Industries Factories, Institutes, Railways, Airports, Garden, Park, Parking Area, Roadside, Domestic
Special character	It is should be lifted by 8 cub meter garbage compactor truck arm
Others	UV/ Colour Resistant, Durable 2 Rubber wheels 2 with break System Necessary addition for lifting by garbage compactor truck and forklift



TECHNICAL SPECIFICATIONS OF TWIN LITTER BIN WITH PERMANENT STRUCTURE

1. General Specifications:

“Twin Litter Bins with Permanent Structure” are elegantly designed Litter collecting bins, moulded in one tough piece by state of the art Rotational Moulding process manufactured from Virgin Grade of Polyethylene material confirming to the requirement of IS 10146 – 1982; Non toxic, free from any contamination, chemical resistant, blended with stabilizers, Anti Corrosive and Anti Acidic, absolutely smooth and sanitary, chemical resistant, and free from joints, welds or rims, provided with fully openable Lid; open from either side for easy garbage drop even from distance and mounting accessories. Permanent Structure duly painted with proper anti corrosive paint, can be provided along with reinforcement welded at Bottom which is to be grouted in the ground ; ideal for Road Side collection and Storage of Raw Garbage to satisfy critical needs of Solid Waste Management.

2. Basic Qualities

- Moulded from Special UV Stabilized grades of Polyethylene.
- 100 % Rust Free and Maintenance free.
- Safe in handling as No corrosion, cracking, blistering etc. Colourful and Elegant.
- Light Weight an Easy to handle. Hygienic and Easy to clean Strong and Durable

Detail Specifications :

Application : For segregated Litter collection at Road sides / Community areas.

Capacity : 100 Liters (2 Nos)

Material : Virgin grade of Polyethylene material, absolutely non-toxic, free from any contamination, chemical resistant confirming to the requirement of IS 10146 – 1982.

Dimensions : (Litter Bin)

Overall Dimensions(MM)(GBR 10-01)		
Top	Bottom	Height
500x500mm	350x350mm	Not less than 690mm

(+/- 5 %)

Permanent structure is designed for oscillating movement of bins in order to get easy and fast emptying.

Permanent : Width : Not less than 1000 mm

Structure : Bottom reinforcement : Not less than 250mm X 250mm welded at Bottom

(Tolerance + / - 5 %)

Fabricated out of not less then 25mm x 25mm square tube with one vertical support at centre and one horizontal support to connect two main vertical supports. All support are of not less then 25mm x 25mm square tube.

Design	:	The bins are fabricated with M.S sheet not less then 1mm thick and 100mm x 100mm on two sides for extra strength during oscillating movement. Oscillating arrangement for easy unloading of Garbage. Specially moulded projections for extra strength High Impact strength; Rough & Tough. User friendly design without sharp corners or welds.
Lid	:	Fully openable lid, open from either side for easy garbage drop even from distance
Colour	:	One Blue and the other is Green
Durability	:	Reusable, Washable, absolutely smooth and sanitary to satisfy the critical needs of SWM
Printing	:	Shall be printed as per client's requirement
Drawing	:	Enclosed herewith

TECHNICAL SPECIFICATION OF STAINLESS STEEL BOLLARDS

Marshalls Street Furniture offer a contemporary range of stainless steel bollards that can add style and elegance to a wide range of landscapes. Rhino Stainless Steel Bollards are made from a carefully selected grade of 316L (1.4401) stainless steel. Exceptionally strong and requiring very low maintenance, they are ideal for protected parking and pedestrian walkways.

In addition, grade 316L (1.4401) has the following advantages:

Higher resistance to corrosion: Whilst stainless steel is corrosion resistant, the naturally forming chromium rich oxide film that protects it can be broken down by chlorine and chlorides. Grade 316L (1.4401) has a higher resistance to corrosion due to the increased levels of nickel in its alloy structure. This makes it highly advantageous when used in the areas mentioned above.

Greater resistance to pitting and staining: When compared to other grades of stainless steel 316L (1.4401) is less susceptible to surface pitting.

Low maintenance: Due to the quality of the steel and the reasons mentioned above, it requires very little maintenance. Grade 316L (1.4401) has attractive 'life-cycle cost' benefits over alternative materials such as carbon steels.

Recyclable: Stainless steel is 100% recyclable. Around 90% of stainless steel is made from recycled scrap. Due to this excellent quality, stainless steel has less of an impact on the environment and scarce resources. As a result, it provides an all round "green" material for architects to specify.

We offer a range of specification, fixing and customisation options including:

Specification Options

Standard: Ideal for demarcation purposes, standard bollards can be used to provide a visual separation between vehicles and pedestrians.

Reinforced: Contains a galvanised steel tube to increase strength. Suitable for areas where there is a higher risk to pedestrians from moving vehicles.

Anti Ram: Reinforced with two galvanised steel tubes to increase strength, intended to provide ram raid deterrence and preventing vehicles from penetrating beyond the bollard.

Reinforced Anti Ram: Reinforced with three galvanised mild steel tubes. For areas requiring maximum protection.

Fixing Options

Root fixing: 1000mm bollards are supplied as standard with a 500mm root to be placed into the ground and secured in place with concrete, a welded cross bar keys into the concrete and ensures that the bollard is secure and cannot be removed. Different height bollards will have other root lengths, specific lengths are available on request.

Base Plate: Bollards can be supplied complete with an integral base fixing plate which is attached to the ground using bolts. Ideal for applications where root fixing is not possible.

Lift Out and Lockable: Removable bollards allow temporary vehicle access and can be replaced when works are complete.

Customisation Options

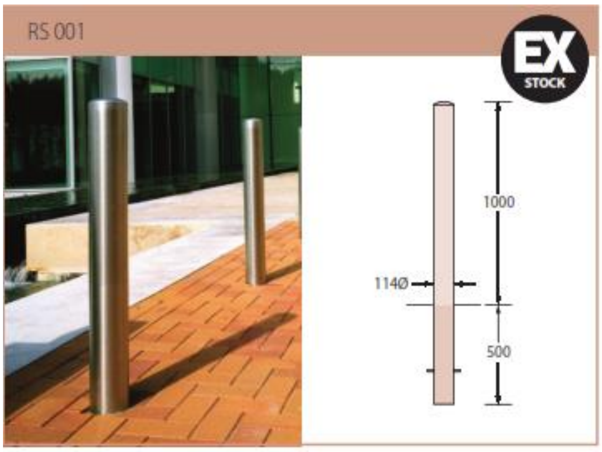
Finish: Supplied as standard with a brushed satin finish, a bright polished finish is available for some models.

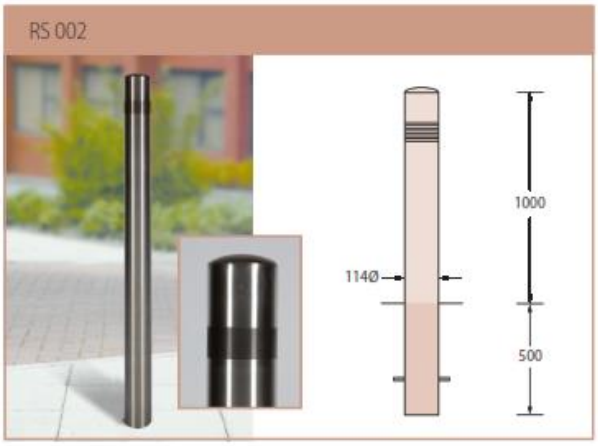
Hazard Banding: for increased visibility and safety

Chain Connectors: Allows chains to be fixed to the bollards to form sections that can be opened.

Marshalls endeavour to meet the needs of all our clients and can offer bespoke solutions to meet specific requirements.

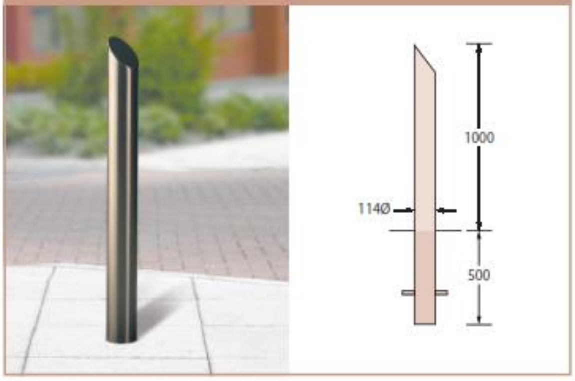
Please contact our Sales Office on 0870600 2425



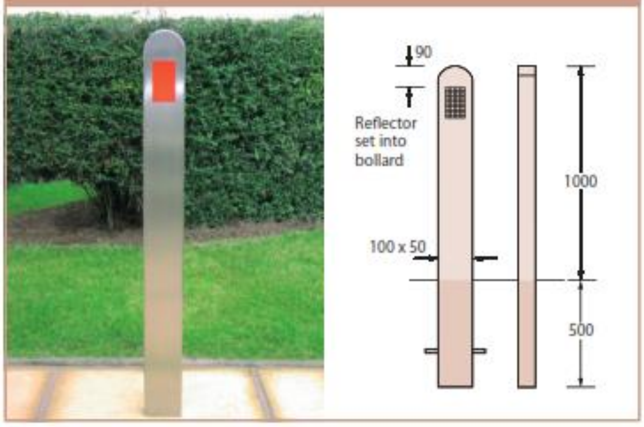


RS 005

RS 004



RS 006



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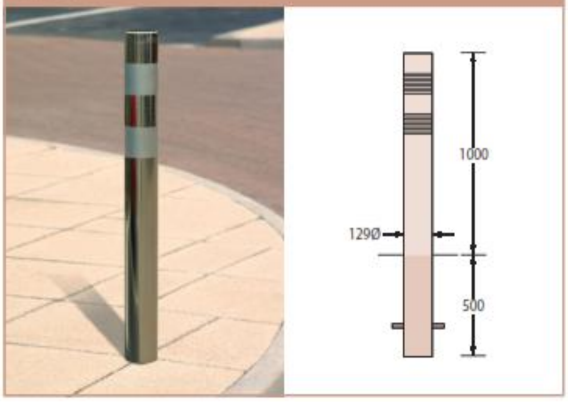

TECHNICAL SPECIFICATION OF STAINLESS STEEL RAILING

1. DESCRIPTION

This work shall consist of furnishing and installing stainless steel pedestrian railing as shown on the contract plans and in accordance with these specifications. The railing is to be anchored to existing concrete wall which is to be clad with stone precast wall panels and granite coping (under Item 11560.3110 M).

2. MATERIALS

A. MATERIAL REQUIREMENTS:

1. Stainless steel round pipe railing shall meet the requirements of ASTM A312/A312 M, Type 316.
2. Stainless steel bars and plates shall meet the requirements of ASTM A666, Type 316.
3. Set screws, anchor bolts, brackets, flanges and other fasteners to be fabricated from Type 316 stainless steel.
4. Postinstalled Anchors: Chemical anchors, fabricated from stainless steel with capability to sustain, without failure, a load equal to six times the load imposed when installed in unit masonry and equal to four times the load imposed when installed in concrete, as determined by test data per ASTM E 488.

CONSTRUCTION DETAILS

A. SUBMITTALS

1. Product data: For each component, submit product data indicating they meet ASTM standards referred under “materials” above.
2. Shop Drawings: Shop drawings shall be submitted to the Engineer for review and approval. Show fabrication and installation of railings. Include plans, elevations, sections, component details, and attachments to other Work.
3. Calculations: Structural analysis data signed and sealed by a qualified Professional Engineer licensed in the state of New York, indicating that the railing installation complies with design loads.
4. Sample: Assembled sample of railing system, made from full-size components, including top rail, post, and midrails. Show method of finishing members at intersections. Sample need not be full height.

B. PERFORMANCE REQUIREMENTS

1. Engineer stainless steel railings to withstand structural loads indicated, and determine allowable design working stresses of railing materials based on ASCE 8, "Specification for the Design of Cold-Formed Stainless Steel Structural Members."
2. Structural Performance: Provide railings conforming to ASHTO 2.7.3 Pedestrian Railings.
3. Thermal Movements: Provide railings that allow for thermal movements resulting from the following maximum change (range) in ambient and surface temperatures preventing buckling, opening of joints, overstressing of components, failure of connections, and other detrimental effects. Base engineering calculation on surface temperatures of materials due to both solar heat gain and nighttime-sky heat loss.
4. Temperature Change (Range): 67 deg C, ambient; 100 deg C, material surfaces.
5. Control of Corrosion: Prevent galvanic action and other forms of corrosion by insulating metals and other materials from direct contact with incompatible materials.

C. FABRICATION:

The railing shall be fabricated to the dimensions and configurations shown on the contract plans and in compliance with these specifications.

1. Assemble railings in the shop to greatest extent possible to minimize field splicing and assembly.
2. Fabrication and welding to comply with NYSDOT Steel Construction Manual.
3. At exposed connections, finish exposed surfaces smooth and blended so no roughness shows after finishing and welded surface matches contours of adjoining surfaces
4. Fabricate anchorage devices capable of withstanding loads imposed by railings.
5. Shear and punch metals cleanly and accurately. Remove burrs from exposed cut edges. Ease exposed edges to a radius of approximately 1mm, unless otherwise indicated.
6. Provide weep holes or another means to drain entrapped water in hollow sections of railing members that are exposed to exterior or to moisture from condensation or other sources.
7. Fabricate joints in watertight manner.

D. FINISHING

1. Grind and polish surfaces to produce uniform, directionally textured polished No.4 finish free of cross scratches. Run grain with long dimension of each piece.
2. When polishing is completed, passivate and rinse surfaces. Remove embedded foreign matter and leave surfaces chemically clean.

E. ERECTION OF METAL RAILING.

1. Inspection of railing: Immediately prior to erection, the railing shall be inspected for damage. Significant bend or kinks in the railing not specifically called for in the contract plans and

documents shall constitute sufficient cause of rejection. Straightening of such bends or kinks shall not be allowed.

2. Erection: all railing shall be erected in accordance with approved shop drawings prepared and submitted as specified in the New York State Steel Construction Manual.
3. Positioning posts. Posts shall be set vertical.
   a. Set posts plumb within a tolerance of 2mm in 1m.
4. Positioning railing: Railing shall be erected so that rails are parallel to each other and to the top of the wall.

a. Do not weld, cut or abrade surfaces of railing components that have been coated or finished after fabrication and that are intended for field connection by mechanical or other means without further cutting or fitting.
   b. Align rails so variations from level for horizontal or from parallel with wall slope do not exceed 5mm in 3m.
   c. Adjust railings before anchoring to ensure matching alignment at abutting joints. Space posts at intervals indicated, but not less than that required by structural loads.

5. Use anchorage devices and fasteners where necessary for securing railings and for properly transferring loads to in-place construction.
6. Welded construction: Use fully welded joints for permanently connecting railing components. Comply with requirements for welded connections listed under the above article “fabrication” whether welding is performed in the shop or in the field.
7. Expansion joints: Install expansion joints at locations indicated but not farther apart than required to accommodate thermal movement. Provide slip-joint internal sleeve extending 50 mm beyond joint on either side, fasten internal sleeve securely to one side, and locate joint within 150mm of post.

METHOD OF MEASUREMENT

The quantity to be measured for payment under this item shall be the number of linear meters of railing, measured along the centerline of railing anchorage, between the extreme outer limits shown on the contract plans, installed in accordance with the plans and these specifications.

BASIS OF PAYMENT

The unit price bid per linear meter of railing shall include the cost of furnishing all labor, materials and equipment necessary to compute this work.

No payment shall be made for those railing pieces, which are replacement for those railing pieces that have been rejected.

7. Street Lights

DS300 Hybrid street light

General Specification			
Wind Turbine	DS300 x1 set	**Wind turbine**	Finish good: :
PV Panel	130W~150W x1 pcs		
Charger	WS320-24Vx1 set		
Pole	**4.5m set (6.5m set)**		
Spot Light	1Wx2 pcs		
Street lamp	24W x1 pcs		
12V Battery	45Ah~55Ah x4 pcs		
Deco light	Full color auto change x1 pcs		
Darrieus blades	3		
Savonius blades	2 layer		
Blades material	Anodized Aluminum		
Axis material	Anodized Aluminum		
Diameter	1.25m x 1.06m		
Weight	25Kg		
Generator	3 phases PMG		
Rated power	300W		
Solar panel			
Material : Poly-Crystalline			
Open circuit V	32Vdc ~ 50Vdc		
Max. power V	29Vdc~38Vdc		
Efficiency	≧13%		
Dimension	1489x666x50		
Weight	15kg		
Charge Controller			
Wind Charging : MPPT			
PV Charging	PWM		
Rated power	300W(Wind)/250W(PV)		
Battery Voltage	24Vdc		
Auto braking	Over speed/temperature		
Discharge ways	2 ways		
Startup lighting	PV Voltage level detection		

Urban Art-Theme based

Urban art combines street art and graffiti and is often used to summarize all visual art forms arising in urban areas, being inspired by urban architecture or present urban lifestyle. Theme based urban art shall be developed and maintained.

Markings & Signages

For material requirements for signages and markings, refer IRC 35 and IRC 67.

Allied works to walkway shall be in accordance to IRC-103.