SECTION – 8B

TECHNICAL SPECIFICATIONS

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1. GENERAL, SITE INSTALLATION & SITE MANAGEMENT

1.1 GENERAL

1.1.1 The specifications contained herein are the minimum required by the Employer.

1.1.2 The Material and Workmanship Specifications shall be adopted by the Contractor and their Designer(s) considering the methodology chosen. The Contractors Material and Workmanship Specifications shall as a minimum comply with all applicable Indian Standards and Codes. If International Standards and Codes are proposed by the Contractor, they shall be submitted to the Engineer for approval. The Contractor shall provide a copy of all Standards and Codes used.

1.1.3 The Contractor shall prepare a Material and Workmanship Specification that complies with the Employer's requirements and their design. Works shall not commence on site until approval has been issued by the Engineer for the Contractors Material and Workmanship Specifications.

1.1.4 The Materials and Workmanship Specifications contained in this Section are the minimum expected to achieve the performance requirements of the design.

1.1.5 The Contractor shall keep monthly records of the average, high and low wage rates for each worker employed on the Site and records shall be made available to the Engineer during inspection. The Contractor shall submit monthly a certified payroll for all direct and subcontracted employees.

1.1.6 The Contractor shall take all necessary precautions to protect the structures or works being carried out by others adjacent to or within the Site from the effects of vibrations, undermining and any other earth movements or the diversion of water flow arising from its work.

1.1.7 The felling of trees in BBMP Limits is governed by Karnataka Forest Act.

a. The Contractor will not be permitted to cut or remove any trees, and this shall be carried out after obtaining the approval by the Engineer / Employer.
b. The Contractor should assess the number of trees existing within right-of-way and identify any that require to be removed and confirm the same to the Engineer.
c. The permission to remove/transplant the trees is granted by "Tree Officer" of BBMP after following the prescribed procedure to the said Act & Rules.

1.2 CARE OF THE WORKS

1.2.1 As far as possible all work shall be carried out in dry conditions.

1.2.2 Work shall be carried out in such a manner that there is no damage to or interference with:

a. watercourses or drainage systems;
b. utilities;
c. structures (including foundations), roads, including street furniture, or other properties;
d. public or private vehicular or pedestrian access;
e. monuments, trees, graves or burial grounds heritage structures etc.

1.2.3 The Works, including materials for use in the Works, shall be protected from damage due to water. Water on the Site and water entering the Site shall be promptly removed by temporary drainage or pumping systems or by other methods capable of keeping the Works free of water. Silt and debris shall be removed by traps before the water is discharged and shall be disposed of at a designated dump yard of concerned authorities.

1.2.4 The discharge points of the temporary systems shall be as per the consent of the Engineer. The Contractor shall make all arrangements with and obtain the necessary approval from the relevant stakeholder authorities for discharging water to drains and watercourses. Water discharge shall not commence until the approved arrangements for disposal of the water have been implemented.

1.2.5 The methods used for keeping the Works free of water shall be such that settlement of, or damage to, of all new and existing structures does not occur.

1.2.6 Measures shall be taken to prevent flooding/ flotation of all new and existing structures.

1.2.7 Works shall not be carried out in such weather conditions that may adversely affect the Works unless proper protection is provided to the satisfaction of the Engineer.

1.2.8 Materials for Works, shall be protected from exposure to weather conditions that may adversely affect the materials stored on site.

1.2.9 During construction of the Works site storm drainage systems shall be provided where appropriate. These systems shall ensure the security of partially completed and ongoing stages of construction during all weather conditions.

1.2.10 The Contractor shall at all times programme and order progress of the work and make all protective arrangements to make safe the Works (Temporary and Permanent) during inclement weather episodes.

1.2.11 The finished works shall be protected from any damage that could arise from any work activities.

1.2.12 Items which are damaged or interfered with as a result of the Works and items which are removed to enable work to be carried out shall be reinstated to the satisfaction of the Engineer and to at least the same condition as existed before the work started. Any claims by Utility Agencies due to damage of utilities by the Contractor shall be borne by the Contractor.

1.2.13 The Contractor shall immediately inform the Engineer of any damage to structures, roads or other properties.

1.2.14 The Contractor shall take all necessary precautions to protect the structures or works being carried out by others adjacent to and, for the time being, within the Site from the effects of vibrations, undermining and any other earth movements or the diversion of water flow arising from its work.

1.3 SURVEY

1.3.1 A survey shall be carried out of the Site to establish its precise boundaries and the existing ground levels within it. This survey shall include a photographic survey sufficient to provide a full record of the state of the Site before commencing the work with particular attention paid to those areas where reinstatement will be carried out later on. The survey shall be submitted to the Engineer.

1.3.2 The survey shall be carried out before the site clearance commences. with the consent of Engineer.

1.3.3 At Handover the Contractor shall carry out a full photographic survey of the alignment and submit it to the Engineer. Reinstatement of the alignment shall be carried out as per the Employer's requirements.

1.4 USE AND ACCESS TO THE SITE

1.4.1 The Site or Contractor's Equipment shall not be used by the Contractor for any purpose other than for carrying out the Works in the scope of this Contract, except that, with the consent in writing of the Engineer, the Site or Contractor's Equipment such as batching and mixing plants for concrete and bituminous materials may be used for the work in connection with other contracts under the Employer.

1.4.2 Rock crushing plant shall not be used on the Site.

1.4.3 The location and size of each stockpile of materials, including excavated materials, within the Site shall be as permitted by the Engineer. Stockpiles shall be maintained at all times in a stable condition.

1.4.4 Entry to and exit from the Site shall be controlled and shall be only available at the locations for which the Engineer has given consent.

1.4.5 The Contractor shall make its own arrangements, subject to the consent of the Engineer, for any further access required to the Site.

1.4.6 In addition, the Contractor shall ensure that access to every portion of the Site is continuously available to the Employer and Engineer.

1.4.7 After completion and handing over of the Works, (as defined in the Employer's Requirements), to the Employer, the Employer will control the Works and will be responsible for all matters relating to security and safety therein. Access to the Works by the Contractor shall be in accordance with any procedures, requirements and conditions defined in the Employer's Requirements.

1.4.8 The Contractor shall be responsible for ensuring that any access or egress through the Site boundaries are controlled such that no disturbance to residents or damage to public or private property occur as a result of the use of such access or egress by its employees and subcontractors.

1.5 SITE RESTRICTIONS

1.5.1 The Contractor shall confine the work activities, including storage of construction materials, movement and packing of equipment, machinery etc. within the allocated Works areas.

1.5.2 The Contractor shall execute his work in such a manner as to cause minimal inconvenience to the public and other contractors.

1.5.3 The Contractor shall fully control his workforce and those of his Subcontractors, to ensure that workers do not loiter in public areas or facilities and do not intimidate local residents.

1.5.4 Unless otherwise stated, the Contractor shall pay all rates and charges of any nature whatsoever arising out of his use of any additional areas as required other than the Site and all Works areas provided therein under the Contract.

1.6 TEMPORARY WORKS

1.6.1 The Contractor shall, prior to commencing the construction of any Temporary Works, submit a certificate to the Engineer signed by him certifying that the Temporary Works have been properly and safely designed and checked and that the Contractor has checked the effect of the Temporary Works on the Permanent Works and has found this to be satisfactory.

1.6.2 All Temporary Works which are not a part of work shall be removed prior to completion of the Works or at other times instructed by the Engineer. The Site shall be cleared and reinstated to the lines and levels and to the same condition as existed before the start of the work or otherwise as stated in the Contract.

1.7 SITE FENCING

1.7.1 The Contractor shall design, construct, install, erect, operate and maintain a boundary fence to ensure the security of the Site and the safety of the general public.

1.7.2 The consent of the Engineer shall be obtained before removal of hoardings, fences, gates, blinkers or signs. Hoardings, fences, gates, blinkers and signs which are required even after the completion of the Works shall be repaired and repainted as informed by the Engineer.

1.7.3 Parameters for this barricade/fence shall be the following:

a. Height is a minimum 2.0 m above the ground level and 30cm below GL.
b. Space between the ground and the bottom edge of the fence is a maximum of 15cm;
c. Painted steel frame;
d. Wooden/painted steel backing;
e. White background which includes a ‘KRIDE Logo’ of suitable size and at appropriate locations as approved by the Engineer;
f. Temporary/precast concrete barriers (such as New Jersey Road Barriers, flexible or rigid barriers) or suitable metal frame which are designed to be movable and able to withstand the environmental conditions experienced in Bangalore.

1.7.4 The Contractor shall fully comply with all regulations of the relevant authorities.

1.7.5 **Deleted**

1.7.6 The width of Right of Way barricaded areas shall not generally be more than 8.0m. However, if the space available at any location is less than 8.0m wide then the Contractor shall manage the work within the available space.

1.7.7 The Contractor shall barricade the absolute minimum length of proposed At-Grade& Elevated Stations, which shall be as the rate of works progress, to minimise any inconvenience to the public and road traffic.

1.8 PROJECT SITE SIGNAGE

1.8.1 The Contractor shall install clearly identifiable bilingual Project Road Signs in Kannada and English, which designate the access roads to the construction sites as per the relevant IRC codes (IRC 67-2012 Code of practice for Road Signs).

1.8.2 The signage of Employer and Contractor shall only be displayed at the work site. The number, location and sizes of these signages shall be approved by the Employer.

1.8.3 The Contractor shall design and install the project signboards. These project signboards shall have the following design parameters:

a. Permanent concrete foundations; signboard of suitable height and size as approved by the Engineer.
b. Of retroreflective sheeting;
c. Painted steel frame;
d. Wooden/painted steel backing;
e. White background which includes a 'KRIDE Logo' of suitable size and at appropriate locations as approved by the Engineer.

1.8.4 The number and positions of the site signboards are to be submitted for consent to the Engineer. The Contractor shall maintain these Signboards till the defect liability period as instructed by the Employer.

1.9 SITE FACILITIES

1.9.1 The following particulars shall be submitted to the Engineer for consent within 15 days after the date of Commencement:

a. Site office layout detailing principal access and other major facilities required along with all service utilities required early in the Contract.;
b. Drawings showing the matter on the project signboards and diversion boards.
c. Diversion boards shall be in accordance with IRC 67-2012 with the project signboards.

1.9.2 Drawings showing the location of stores, storage areas, concrete batching plants and other major facilities and their access roads/paths shall be submitted to the Engineer for his consent as early as possible but in any case, not less than 28 days prior to when such facilities are intended to be constructed on the Site.

1.9.3 The Contractor shall provide latrines and wash places for the use of its personnel and all persons who will be on the Site.

a. The size and disposition of latrines and wash places shall be sufficient for the planned number of persons on the Site.
b. The Contractor shall provide separate facilities for males and females.
c. The capacities and layout shall be subject to consent of the Engineer.
d. The Contractor shall arrange regular disposal of effluent and sludge in a manner that shall be in accordance with local laws and regulations.
e. The Contractor shall be responsible for maintaining all latrines and wash places on the Site in a clean and sanitary condition, and for ensuring that they do not pose a nuisance or a health threat.

f. The Contractor shall make provisions or as directed by the Engineer to ensure that vermin, mosquito breeding etc. are at all times controlled.

1.9.4 The Contractor shall be responsible for providing water, electricity, telephone, sewerage and drainage facilities for contractor's site offices, structures and buildings and for all site laboratories in accordance with the Employer's Requirements, and all such services that are necessary for satisfactory performance of the Work. The Contractor shall make all arrangements and obtain the necessary approvals from the relevant competent authorities for the facilities.

1.9.5 The Contractor shall be responsible for provision of power supply for his works. The Employer cannot guaranty provision of an adequate and continuous power supply; however, assistance will be given in obtaining the necessary permissions for site generators.

1.9.6 Access roads and parking areas shall be provided within the Site as required and shall be maintained in a clean, acceptable and stable condition. For lengths of roadway greater than 100 m, the Contractor shall provide paved surfacing of adequate thickness and quality to the consent of the Engineer.

1.10 CONTRACTORS LABOUR CAMP

1.10.1 The Employer will not provide living accommodation for the use of the Contractor or any of his staff or labour employed on the Works.

1.10.2 The Contractor, shall, at his own expense, make adequate arrangements for the housing, supply of drinking water and provision of bathrooms, latrines and urinals, with adequate water supply, for his staff and workmen directly or through sub-contractors employed on the Works at the location authorised by Engineer. The Contractor at his own cost shall maintain all camp sites in a clean and sanitary condition.

1.10.3 The Contractor shall obey all health and sanitary rules and regulations and carry out at his cost all health and sanitary measures that may from time to time be prescribed by the Local/Medical Authorities and permit inspection of all health and sanitary arrangements at all times by the Employer, Engineer and the staff of the local municipality or other authorities concerned. If the Contractor fails to provide adequate health and sanitary arrangements these shall be provided by the Employer and the cost will be recovered from the Contractor.

1.10.4 The Contractor shall at his own cost, provide First Aid and Medical facilities at the Labour Camp and at work sites on the advice of the Medical Authority in relation to the strength of the Contractor's staff and workmen, employed directly or through sub-contractors.

1.10.5 The Contractor shall at his own cost, provide the following minimum requirements for fire precautions:

a. Portable Fire Extinguishers.
b. Manual Fire Alarms.
c. Water Supply for use by the Fire Service.

1.10.6 The Contractor at his own cost shall provide necessary arrangements for keeping the camp area sufficiently well illuminated to avoid accidents to the workers. He should also ensure that electrical installations are carried out by trained electricians. These installations shall be maintained and daily maintenance records shall be made available for inspection by the Engineer.

1.10.7 The Contractor shall take all precautions and use his best endeavours to prevent any riotous or unlawful behaviour by or amongst his workmen, and others, employed directly or through sub-contractors. These precautions shall be for the preservation of the peace and protection of the inhabitants and security of property in the neighbourhood of the Works. In the event of the Employer requiring the maintenance of a Special Police Force at or in the vicinity of the site, during the tenure of the work, the expenses thereof shall be borne by the Contractor and if paid by the Employer, shall be recoverable from the Contractor.

1.10.8 The sale of alcoholic drinks or other intoxicating drugs or beverages at the site of work, in any labour camp, or in any of the buildings, encampments or tenements owned or occupied by, or within the control of, the Contractor or any of his employees directly or through sub-contractors employed on the work, shall be forbidden, and the Contractor shall exercise his influence and authority to secure strict compliance with this condition. The Contractor shall also ensure that no labour or employees are permitted to work at the site in an intoxicated state or under the influence of drugs.

1.10.9 The Contractor shall remove from his camp any worker and their families who refuse protective inoculation and vaccination when called required to do on the advice of the Medical Authority or by the Engineer. If Cholera, Plague or any other infectious disease break out, the Contractor shall at his own cost burn the sheds, bedding, clothes and other belongings of or used by the infected parties. The Contractor shall promptly erect new sheds on healthy sites as required by the Employer, within the time specified by the Employer, failing which the work may be done by the Employer and the cost will be recovered from the Contractor.

1.10.10 The Contractor shall provide living accommodation that is equal to or exceeds the minimum criteria established in the following sub-sections, needed to house his staff, workers employed directly or through sub-contractors. The buildings shall be constructed with cement panels so as to have a minimum life of not less than the length of the Contract.

a. The roofs shall be watertight and laid with galvalume materials permissible for residential use under local regulations and for which the consent of the Engineer has been obtained.
b. Each hut shall have suitable ventilation. All doors, windows, and ventilators shall be provided with security leaves and fasteners. Back to back units may be avoided.
c. The minimum height of each unit shall be 3.0m and shall have separate cooking place.
d. Bathing facilities for the number of occupants shall be provided.

1.10.11 The Contractor shall provide an adequate supply of potable water from the local authorities for the use of workers in the Camp. The provision shall not be less than two gallons of pure and wholesome water per head per day for drinking purposes and three gallons of clean water per head per day for bathing and washing purposes. Where piped water supply is available, supply shall be at stand posts and where the supply is from wells or river, masonry tanks shall be provided. The Contractor shall also at his expense make arrangements for the provision and laying of water pipe lines from the existing mains wherever available and shall pay for all the fees and charges thereof.

1.10.12 The Contractor shall provide efficient arrangements for draining away surface water so as to keep the camp neat and tidy. Surface water shall be drained away from paths and roads and shall not be allowed to accumulate into ditches or ponds where mosquitoes can breed.

1.10.13 The Contractor shall make arrangements for conservancy and sanitation in the labour camps according to the rules and regulations of the Local Public Health and Medical Authorities.

1.10.14 The Contractor shall provide a sewage system that is adequate for the number of residents in the camp, and which meets the requirements of the statutory Authorities.

1.10.15 The Contractor shall provide welfare and accommodation (if provided) facilities as per the provisions laid down in the relevant laws.

1.11 EXPANSION BOLTS/ FASTENERS:

1.11.1 Unless specified otherwise all expansion bolts/ fasteners shall be fabricated from austenitic stainless-steel sheet, strip or plate conforming to ASTM A 240 Gr 304 or bar to ASTM A 479 Gr 304 of approved make and design. The material of the bolt shall not cause any bimetallic corrosion with the reinforcing bars of the RCC/ brickwork or with any other fixings or doors or windows or skylights etc.

1.11.2 For steel backings the fasteners shall be prevented from contact with other metals, which would lead to bimetallic corrosion.

1.11.3 For brick masonry backing the sleeves of the expansion bolts shall be fixed in wedge shaped pockets having an area of 75mm x 75mm at the surface and 100mm x 100mm at the inner surface and shall be 125mm deep. The wedge could also be as a truncated cone of 75mm dia/ 100mm dia. The dimensions shall be reviewed by the Engineer during execution of the work. The wedge shall be filled with PCC 1:1:2 (1 Cement, 1 Sand and 2 Coarse Aggregate) mixed with non-Shrink Compound in the proportion as recommended by the manufacturer.

1.11.4 The holes drilled for the expansion fasteners shall be cleaned of all ground material, dust, etc. before inserting the expansion sleeves.

1.11.5 All expansion bolts fixed into soffits shall be bonded to the backing with epoxy/ polyester resin of approved make.

1.11.6 All expansion bolt fixings shall be tightened in accordance with the recommended torque figures by the manufacturer. Where such values are not available the Contractor shall test at least 6 samples to determine the safe torque values. All bolts shall be tightened using torque spanner/ wrenches. All bolts shall be checked 24 hours (minimum) after installation and retightened if necessary.

2. MATERIALS AND TESTING

2.1 GENERAL

2.1.1 The materials and workmanship standards contained herein are the minimum required by the Employer. All materials and testing shall comply with Indian standards where applicable, or international standards as approved by the Engineer.

2.2 MATERIALS

2.2.1 The Contractor shall submit Material Submittal Sheets (MSS) to the Engineer for approval which shall include all data related to the materials to be used and their conformance certificates.

2.2.2 Materials for inclusion in the Permanent Works shall all be new.

2.2.3 The Contractor shall submit test certificates and sample of all materials to the Engineer for approval, before they are used in the Works.

2.2.4 The Engineer may reject any materials and goods which in his opinion are inferior and the Contractor shall promptly remove such materials and goods from the Site.

2.3 NOTICE OF PLACE OF MANUFACTURE AND/OR SOURCE OF SUPPLY

2.3.1 The Contractor shall notify the Engineer of the places of manufacture and/or the source of supply of all goods and materials to be incorporated into the Permanent Works and shall give reasonable notice (which shall not in any event be less than thirty (30) days) to the Engineer before the start of any manufacturing and/or the supply of goods and materials.

2.4 CERTIFICATES FOR MANUFACTURED GOODS OR MATERIALS

2.4.1 The Contractor shall obtain certificates for each batch of goods and materials to be incorporated into the Permanent Works. Each certificate shall include all reports of inspections and/or tests carried out at the place of manufacture.

2.5 LABORATORY

2.5.1 The Contractor shall establish and maintain in a clean, stable and secure condition a laboratory, equipped for the routine testing of concrete, soil and aggregate samples with the following minimum apparatus as specified below. Laboratory shall also have the material storage area and water curing tank facility for the concrete cubes and/or cylinders only. This laboratory shall be located at the Contractor's principal work site or at a location agreed by the Engineer.

i. 1 Set of standard sieves for testing grading of sand with mechanical sieve shaker.
ii. Sieves with openings respectively of 4.75mm, 10mm, 20mm, 25mm, 30mm for testing and grading of aggregates.
iii. Weighing Balance of capacity up to 10 Kg. reading up to 5 gm.
iv. Electric Thermostat controlled oven and pans for drying of sand and aggregates.
v. Glass measuring flasks of 1/2, 1 litre& 2 litre capacity.
vi. Flask for determining moisture content of sand.
vii. Slump cone with rod and V B Apparatus, flow table to measure slump or DIN Specifications.
viii. Apparatus to measure permeability of concrete as per Appendix 1700/II of MOST Specifications.
ix. Minimum 24 Nos. steel moulds for 150mm x 150mm x 150mm concrete test cubes. It may be necessary to provide more steel cube moulds depending upon concreting program.
x. 25mmdia vibrator for compaction of concrete in test cubes and also vibrating table.
xi. Concrete cube testing machine of 200 tonnes capacity with 3 dial gauges electrically operated.
xii. Work benches, shelves, desks, sinks and any other furniture and lighting as required by the Engineer.
xiii. Abrasion Flakiness & Impact testing Equipment for testing coarse aggregate.
xiv. Silt Testing Equipment.
xv. Any other equipment specified by Engineer.

2.6 TESTING

2.6.1 Samples shall be of sufficient size and in accordance with relevant Standards to carry out all specified tests.

2.6.2 Samples to be taken on the Site shall be informed to the Engineer 24 hours prior to sampling.

2.6.3 All samples shall be suitably marked for their identification. An identification marking system shall be evolved at the start of work and approved by the Engineer.

2.6.4 Samples shall be protected, handled and stored in such a manner that they are not damaged or contaminated and such that the properties of the samples do not change.

2.6.5 Samples shall be delivered by the Contractor, under the supervision of the Engineer, to the specified place of testing. Samples on which non-destructive tests ha carried out shall be collected from the place of testing after testing and delivered to the Site or other locations as instructed by the Engineer.

2.6.6 Samples which have been tested may be incorporated in the Permanent Works provided that:
a. The sample complies with the specified requirements;
b. The sample is not damaged;
c. The sample is not required to be retained under any other provision of the Contract.

2.6.7 The Contractor shall be responsible for all on-site and off-site testing. All appropriate laboratory tests shall be carried out in the Contractor's laboratory, unless otherwise permitted or required by the Engineer. Where the laboratory is not appropriately equipped and/or staffed for some tests, or if agreed by the Engineer, tests may be carried out in other laboratories provided that:
a. These are accredited for the relevant work to a standard acceptable to the Engineer;
b. The particulars of the proposed laboratory are submitted to the Engineer for approval.

2.6.8 In-situ testing shall be informed to the Engineer prior to a minimum of 24 hours of testing.

2.6.9 Equipment, apparatus and materials for in-situ tests and laboratory tests shall be provided by the Contractor. The equipment and apparatus shall be maintained by the Contractor and shall be calibrated from the accredited laboratories/agencies before the start of testing and at regular intervals as permitted by the Engineer. The equipment, apparatus and materials for in- situ tests shall be removed by the Contractor as soon as practicable after the testing is complete.

~~2.6.10 deleted~~

~~2.6.11 Deleted~~

~~2.6.12 Deleted~~

2.6.13 The Engineer shall be entitled in all cases to attend the testing carried out in the Contractor's or other laboratories, to inspect the calibration certificates of the testing machines and to undertake the testing on counterpart samples. Testing of such samples shall be undertaken in laboratories complying with the Employer's Requirements above and particulars of the laboratory proposed shall be submitted to the Engineer for consent, prior to the testing.

2.6.14 The results of tests on samples or specimens shall represent the whole batch from which the sample was taken.

2.6.15 A batch shall be considered as complying with the specified requirements for a material if the results of specific tests for the specified properties comply with the specified requirements for its properties.

2.6.16 Records of in-situ tests and laboratory compliance tests carried out by the Contractor shall be kept by the Contractor on the Site and a report shall be submitted to the Engineer within seven (7) days after completion of each test. In addition to any other requirements, the report shall contain the following details:

a. Material or part of the Works tested;
b. Location of the batch from which the samples were taken or location of the part of the Works;
c. Place of testing;
d. Date and time of tests;
e. Weather conditions in the case of in-situ tests;
f. Technical personnel supervising or carrying out the tests;
g. Size and description of samples and specimens;
h. Method of sampling;
i. Properties tested;
j. Method of testing;
k. Readings and measurements taken during the tests;
l. Test results, including any calculations and graphs;
m. Specified acceptance criteria;
n. Other details stated in the Contract.

2.6.17 Reports of tests shall be signed by the Contractor's representative or his assistant, or by another representative authorised by the Contractor in presence of Engineer's representative.

2.6.18 If requested, records of tests carried out by the Employer's staff or by the Engineer shall be given to the Contractor.

2.6.19 Storing of Materials at site:

1 All materials used in the works shall be stored on racks, supports, in bins, under cover etc as appropriate to prevent deterioration or damage from any cause whatsoever to the entire satisfaction of the Engineer.

2 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".

3 The materials shall be stored in a proper manner at places at site approved by the Engineer. 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.

3. EARTHWORKS

3.1 GENERAL

3.1.1 This section specifies materials and workmanship required for Earthworks. The materials and workmanship required by other Sections of this Specification shall apply to Earthworks except where modified, amended or excluded herein.

3.1.2 The Contractor shall comply with the requirements of relevant codes for the design of Temporary& Permanent Works, which shall include all excavations.

3.1.3 The Contractor shall clear the Site as required by demolishing and removing vegetation, debris, buildings etc. and other approved locations either on or off the site as agreed by the Engineer.

3.1.4 Stumps and major roots shall be grubbed up and disposed off the site or as directed.

3.2 PRODUCTS AND CLASSIFICATION OF EARTHWORK MATERIAL

3.2.1 The following definitions of earthworks shall apply to this and other clauses of the Employer's Requirements in which reference is made to the following definitions:

a. Final level: The level to which excavation is carried out and the lean concrete is placed prior to the construction of the foundation.
b. Top Soil: The top layer of soil that can support vegetation.
c. Top of ground: The level of the existing ground.
d. Suitable Material shall comprise of all materials which are acceptable for use in accordance with the Contract.

3.3 EXECUTION

3.3.1 The Contractor shall carry out all earthworks in such a manner as to prevent erosion or slips and shall limit working faces to safe slopes and heights. Where space is restricted, the Contractor shall take every measure to protect the sides by providing suitable shoring as per the requirement. The Contractor shall ensure that all surfaces have at all times sufficient gradients to enable them to shed water without causing erosion.

3.3.2 Transportation of material shall proceed only after its consent by the Engineer.

3.3.3 The Contractor shall provide all necessary equipment to keep the earthworks free from water. Dewatering shall be done in accordance with the Employer's Requirements. The Contractor shall ensure that no air pollution takes place during excavation, storage and transportation of earth by providing suitable measures like cover watering etc.

3.3.4 Construction traffic on the final formation level shall be minimized to prevent damage and/or consolidation/depression of the subgrade.

3.3.5 The Contractor shall use appropriate equipment suitable to handle the encountered soil.

3.3.6 The Contractor shall dispose of all material produced during excavation either off the Site or to stockpiles (if material required for later use) on the Site, so as to comply with the Employer's Requirements. The Contractor shall ensure that these stockpiles will not influence traffic and works on site. The Contractor shall liaise with the Engineer regarding the storage and disposal of excavated material.

3.3.7 The Contractor shall make his own arrangements for stockpiling of Topsoil and/or Suitable Material.

3.3.8 Surfaces of excavations or filling should be protected against erosion and any climatic influences on which plain (unreinforced) or reinforced concrete is to be laid and, shall be prepared with a layer of lean concrete or in such other manner to provide a suitable surface.

3.3.9 Materials generated from demolition activities shall not be used for backfilling.

3.3.10 The final level of all excavations shall be free from mud and water, trimmed clean, thoroughly compacted and consolidated.

3.3.11 Trench excavation shall be executed by the use of suitable equipment, in such a manner so as to minimise disturbance to the required finished sides and bottom of the excavation. Trenches for pipes

shall be excavated to a sufficient depth and width to enable the pipe and the specified joint, bedding, hunching and surrounding to be accommodated.

3.3.12 Blasting will not be permitted unless otherwise approved by the Engineer. The Contractor shall seek permission to carry out blasting using explosives from the competent authority of the local administration.

3.3.13 This work shall consist of all excavation for structures, open foundations for piers, culverts, headwalls, catch basins, manholes, inlets, and retaining walls and shall include all necessary clearing and grubbing, all necessary bailing, drainage, pumping, sheeting, strutting and the construction of coffer dams or cribs, including the disposal of all material obtained from such excavation and backfilling around the structure;

3.3.14 Any loose or improperly compacted soil below the structural foundation levels, shall be completely removed and levelling concrete of M15 grade with minimum 150 mm thickness shall be laid. After laying the foundation it shall be backfilled with suitable material.

3.3.15 All rock or other hard foundation material shall be cleaned of all loose material and cut to a firm surface, either level, stepped, or serrated. All open cracks and discontinuities shall be cleaned and grouted. All loose rock shall be removed.

3.3.16 Top soil shall not be used for structural backfill.

3.3.17 The Contractor shall not backfill around new structures until the structural elements have attained adequate strength.

3.3.18 The Contractor shall submit a method statement to the Engineer for review prior to the commencing of backfill operations. The Contractor shall maintain open excavations in an approved condition and shall rectify the effects of deterioration due to weather. Backfilling works shall include the preparation and compaction as specified of the areas upon which suitable fill is to be placed and the placing and compaction of suitable material.

3.3.19 When the weather conditions would adversely affect the placing of backfill, all such work shall be stopped.

3.3.20 Except in the vicinity of structures, excavations shall be backfilled with suitable material, compacted in layers of 300 mm maximum loose thickness to achieve a density of at least 97% of the maximum dry density. The backfill works shall be carried out as per relevant IRC codes.

3.3.21 The Contractor shall verify by site tests that the required field density is being achieved and shall make any adjustments to his compaction methods which may be necessary.

3.3.22 The Contractor shall immediately notify to the Engineer of any movement or damage not noted in the pre-construction report. The Contractor shall take immediate action to prevent further movement or damage.

3.3.23 The Contractor shall arrange to stock pile for the excavated, demolished materials and the classification of these materials.

3.3.24 All excavated suitable material shall, where possible, be incorporated in the Works and the Contractor shall maximise the reuse of excavated material. No excavated suitable material which could subsequently be utilised in the Works shall be removed from the Site unless the Engineer has reviewed the proposal. Should the Contractor be permitted to remove suitable material from the Site to suit his operational procedure, then he shall make good any consequent deficit of filling arising there from.

3.4 EXCAVATION

3.4.1 Excavation shall be carried out to the lines, levels and profiles shown on the Drawings.

3.4.2 The work shall be carried out by the Contractor in such a way as to avoid soil erosion, ground water pollution, disturbance to the surrounding ground or structures, accidents to workmen and the public. Particular care shall be taken to maintain stability when excavating in close proximity to existing works.

3.4.3 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.

3.4.4 The Contractor shall design suitable ground support for all excavations and provide suitable shoring etc. to avoid excavation collapse. The Contractor shall be responsible at all times for the safety of all excavation Works.

3.4.5 The Contractor shall notify the Engineer without delay of any permeable strata, joints, faults, fissures or unusual ground conditions encountered during excavation.

3.4.6 The Contractor shall provide to the Engineer full details of the proposed rock excavation methods for his review. Excavation should be carried out by such manual/mechanical means or methods, so as to eliminate noise and dust up to the prescribed limits and without using any blasting and/ or any expansive chemicals.

3.4.7 All excavations for structural foundations shall be covered with minimum 150 mm M15 levelling course. Prior to the placing of the levelling course the Contractor shall give 24 hours' notice to the Engineer to view the formation.

3.4.8 All service trenches shall be excavated in a controlled manner and shall be inspected daily by a competent person. The excavation ground support shall be designed and followed.

3.4.9 The Contractor shall submit to the Engineer a method statement for all excavations confirming methodology, equipment and personnel.

3.5 FILL

3.5.1 Prior to commencement of filling, the Contractor shall submit their proposal to the Engineer for consent for carrying out the work such that optimum use is made of excavated material. The proposal shall include details of the compaction plant and methods for adjusting the moisture content of the material. Filling shall not commence until the Contractors proposal has been approved by the Engineer.

3.5.2 Fill material shall be obtained only from sources approved by the Engineer.

3.5.3 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 mm size is unlikely to be suitable for use. Clods or hard lumps of earth over 75 mm in greatest dimension shall be broken up before compacting the material in embankment. The material shall comply with Clause 305.2.1 of Specification for Road & Bridge Work of MORTH. Following types of material are considered unsuitable and shall not be used for fill or embankment:

a. Materials brought 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 50 and plasticity index exceeding 25;
e. Materials containing salts prone to inducing leaching in the embankment

3.5.4 The Contractor shall carry out the following initial tests on the proposed material.

a. Wet sieve analysis
b. Dry density/moisture content relationship

Thereafter, one set of tests shall be carried out for each 2000 m³ of fill, supplied to Site or as per the frequency laid down in relevant IRC Code / MORTH Specifications or as required by Employer's Representative.

3.5.5 Except around structures, excavations shall be backfilled with suitable excavated material and/or approved material compacted in layers of 300 mm maximum thickness to achieve a density of at least 95% of the maximum dry density.

3.5.6 The Contractor shall not backfill around structures until the structural elements have attained adequate strength and the Engineer has reviewed the proposed methodology. Unless otherwise

directed, the backfill material shall be selected excavated material or sand, thoroughly compacted in layers not exceeding 200 mm deep to achieve a density of at least 95% of the maximum dry density.

3.6 EMBANKMENTS

3.6.1 The works of embankment shall conform to the Chapter 305 of the Specification for Roads & Bridges issued by MORTH. Prior to placing any embankment upon any area all clearing and grubbing operations shall have been completed in accordance with the Employer's Requirements. 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 15 centimetres shall be processed as necessary and compacted to 90% of the maximum dry density.

3.6.2 Where embankments are to be constructed on slopes, the existing slopes shall be loosened by scarifying or ploughing to a depth of not less than 10 centimetres, to ensure a good bond between the embankment and the embankment foundation, or where this is impracticable, steps in vertical and horizontal face shall be cut in the existing slope and the embankment built up in successive layers. Material which has been loosened shall be re-compacted simultaneously with the first level of embankment material placed. Work shall be carried out as per MORTH Specifications.

3.6.3 Where an embankment is to be placed against sloping ground, having slopes steeper than 4 horizontals to 1 vertical, continuous horizontal bench, each at least 300 mm wide, shall be cut in to the old slope for ensuring adequate bond with fresh embankment being added. Work will be carried out as per MORTH Specifications.

3.6.4 Where existing embankments are to be widened or included in new embankment, the slopes of the existing embankment shall be ploughed or scarified to a depth of not less than 10 centimetres, or where this is impracticable steps in horizontal and vertical faces shall be cut in existing slopes and the embankment built up in successive layers to the level of the old road, before its height is increased.

3.6.5 Unless otherwise confirmed by the Employer's Requirements, where existing unpaved roads are to be covered with less than 30 centimetres 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. Work will be carried out as per MORTH Specifications.

3.6.6 Earthworks in swamps or water-logged area shall be constructed as per relevant IRC codes. The Contractor shall excavate or displace swamp ground and backfill with suitable material. Backfill will be in accordance with the same provisions as for embankment.

3.6.7 Fill material shall not be placed against any abutment or wing wall unless approved by the Engineer.

3.6.8 Except as otherwise required all embankments shall be constructed in layers approximately parallel to the finished grade of the track/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. During construction of embankment, it should be ensured that any work, which is to be done during the course of laying the fill material shall not be left out.

3.6.9 The surface of the finished sub grade shall be neat and workman like 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 shall be constructed to sufficient accuracy to permit the construction of subsequent layers of material to the thickness, surface tolerance, and compaction specified.

3.6.10 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.

3.6.11 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 centre in such a manner that each section receives equal compactive effort. 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 mm between each run of the rollers.

3.6.12 Embankment or backfill compaction shall be carried out ~~as per IS:2720 Part 7 for light compaction & IS 2720 Part 8 for heavy compaction~~ as per relevant IRC Code & MORTH Specifications. Maximum compacted layer thickness should not be more than 150mm in any case and compaction should 95% of the density achieved in laboratory as per IS; 2720 Part 7 or Part 8.

3.6.13 ~~Deleted~~

3.6.14 An inverted filter consisting of stone boulders and coarse aggregates to accepted grading shall be constructed behind the earth retaining structures up to the height as shown in the drawings.
It shall be constructed simultaneously with the filling work. Care shall be taken during laying of filter media that it does not cause damage to structural members or application of excessive pressure against the structure.

3.6.15 The Contractor shall close-sheet and adequately support all trenches across existing roads. Great care shall be taken by the Contractor to ensure that existing roads and services are not damaged by road crossing operations. The trenches on roads shall be back filled and roads repaired on utmost priority taking all safety precautions.

3.6.16 Channels shall be excavated by methods which do not endanger the stability of the side slopes. 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. Side banks of channels shall be trimmed to a neat appearance and even surfaces. Any channels, streams, drains or pipes taking 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 satisfaction of the Employer's Representative. The Contractor shall control the rates of filling and draw-down of water in channels so as not to endanger the stability of earthworks.

3.6.17 The Contractor shall obtain approval of excavations prior to placing pavement layers, fill or concrete. The Contractor shall maintain open excavations in an approved condition and shall rectify the effects of deterioration due to weather.

3.7 TESTING OF FILL

3.7.1 Classification tests as per relevant Standards, as approved by the Engineer, shall be carried out to ensure that true comparisons can be made between in-situ densities, laboratory compaction densities and field trial densities i.e., the variations in properties of materials being used in the tests are not affecting the results.

3.7.2 Tests shall be carried out on fill as per IS:2720 Part 7 for light compaction and IS:2720 Part 8 for heavy compaction to determine the degree of compaction achieved, for each layer. Compacted layers shall not be covered without prior notice to the Engineer.

3.7.3 The density of individual compacted layers shall be determined by a method approved by the Engineer.

3.7.4 In addition, the Embankment and Sub-Grade around Structures shall be done as per Clause 305.4.4 of MORTH Specifications.

3.7.5 All tests shall be carried out as required by the accepted test procedures of relevant IS codes.

4. GROUNDWATER MANAGEMENT

4.1 GENERAL

4.1.1 The Contractor shall keep the Site free from flood water at all times.

4.1.2 Where required the Contractor shall design, provide, install, maintain, operate and remove a complete temporary dewatering and drainage systems for lowering and controlling groundwater levels and hydrostatic pressures to permit excavation, construction and backfilling to be performed in dry conditions.

4.1.3 Before commencing dewatering, the Contractor shall submit the method, installation and dewatering system details including planned testing to the Engineer for review.

4.1.4 The Contractor shall install a pumping system that is available for use at all times and which shall be connected to the dewatering system to allow immediate use.

4.1.5 The Contractor shall obtain all necessary permits from the appropriate authorities independently and at his own expense. This also includes compliance with all requirements given by the authorities including but not limited to discharge.

4.1.6 The control of groundwater shall be such that softening of the bottom of excavations does not occur.

4.1.7 The dewatering system shall be designed and operated so as to prevent removal of the natural soils.

4.1.8 The dewatering system shall maintain at all times the groundwater level at 1000 mm below the final formation level, and the IS 9759 guidelines shall be complied with.

4.1.9 The Contractor shall implement a dewatering system that shall have the necessary capacity and backup.

4.1.10 The dewatering system shall be able to dewater and dispose of water without causing damage to public or private property and without causing a nuisance or danger.

4.1.11 The dewatering system shall be designed, installed and operated so that the groundwater level outside the pit is not reduced to an extent which would cause damage to or endanger adjacent structures or buildings.

4.1.12 The dewatering system may be decommissioned after obtaining consent from the Engineer.

4.1.13 The Contractor shall design and install for each deep excavation observation wells or piezometers. Records shall be maintained containing elevation readings and groundwater levels using observation wells and piezometers. Observation wells and piezometers that become inactive, damaged or destroyed, shall be repaired or replaced within 24 hours. Observation wells/piezometers shall be removed and/or backfilled when no longer required.

4.1.14 Sumps and settling basins shall be backfilled with suitable materials when no longer required.

4.1.15 Copies of all permits obtained for the discharge or disposal of water shall be submitted to the Engineer. Copies of these permits shall be kept on site at all times.

5. ROADWORKS

5.1 GENERAL

5.1.1 The Contractor shall execute all Roadworks in accordance with the Ministry of Road Transport and Highways (MoRTH) specifications and relevant IRC codes.

5.1.2 The Contractor shall develop a detailed Traffic Management Plan conforming to IRC SP 55 for the work under the Contract. The purpose is to develop a Traffic Management Plan to cope with the traffic disruption as a result of construction activities by identifying strategies for traffic management on the roads and neighbourhoods impacted by the construction activities. The Contractor shall implement the Traffic Management Plan throughout the whole period of the Contract.

5.1.3 The Contractors Traffic Management Plan shall take into consideration four principles:

a. To minimise the inconvenience of road users and the interruption to surface traffic through the area impacted by the construction activities;

b. To ensure the safety of road users in the impacted area;

c. To facilitate access to the construction site, and to maintain reasonable construction progress.
d. To ensure traffic safety at each construction site.

5.1.4 The Traffic Management Plan shall confirm the arrangements to be made for accommodating road and pedestrian traffic, at all main construction sites and continuously along the alignment, to smooth traffic operations and for the safety of both construction workers and road users. The Plan shall consider different measures such as:

a. Proper phasing and timing of traffic signals;
b. Modifications to intersection geometry;
c. Changes in lane usage;
d. Parking prohibitions;
e. Re-location of bus stops;
f. Reducing width of footpaths and median;
g. Right-turn prohibition;
h. Work site access management;
i. Minimising the duration of any road closure;
j. Reversible lane operations;
k. Modification of roadway alignment affected by the construction, which shall be in conformance with the requirements and regulations defined by the relevant authorities; and may include widening of roads, Construction of temporarily new road etc.
l. Other traffic engineering measures as may be applicable

5.1.5 The Contractor shall manage the vehicular and pedestrian right of way during the period of construction. The Contractor shall take account of the need to maintain essential traffic requirements, as these may influence the construction process. The Contractor shall include local traffic diversion routes and assess traffic impacts caused by the construction in the affected areas. Signage layout shall be included to ensure that adequate motorist information will be provided for traffic diversions. Where it becomes necessary to close a road or intersection, or supplementary lanes are required to satisfy the traffic demands, traffic diversion schemes to adjacent roadways shall be developed with quantitative justifications. The Contractor shall co-ordinate with all relevant authorities. This shall include:

a. The minimum lane widths for fast traffic and mixed traffic shall follow the regulations of the different authorities;
b. Any roads or intersections that have no alternative access shall not be fully closed for construction;
c. Emergency access to all properties shall be maintained at all times;
d. Access to business premises and property shall be maintained to the extent that normal activities are not seriously disrupted;
e. Minimum footpath width shall be 1.5 m, unless otherwise indicated. The footpath shall be separated from vehicle traffic and not necessarily immediately adjacent to vehicle traffic;
f. Where existing footbridges and underpasses are demolished or closed, provisions shall be made for pedestrian crossing to minimise the conflicts between a traffic lane;
g. Construction traffic shall be separated from other traffic wherever possible;
h. Any traffic related facilities (bus stops, parking, etc.) which are affected by the construction works shall be maintained or relocated to appropriate locations. The route diversion notification shall be published in local print & electronic media;
i. Motorists, pedestrians, workmen, plant and equipment shall be protected from accident at all times;

j. Roadway designs, traffic management schemes, and installation of traffic control devices shall be in conformance with the requirements and regulations defined by the relevant authorities;

k. Where applicable, utility diversions shall be incorporated in the traffic management plan.

5.1.6 The Contractor shall make all arrangements with and obtain the necessary approval from district Administration and the Police Department for temporary traffic arrangements and control on public roads. In the event that the Contractor, having used its best endeavours, fails to secure the necessary approval from the district Administration and the Traffic Police Department for temporary traffic arrangements and control on public roads, then the Employer will use its best endeavours to assist the Contractor to secure such approval but without responsibility on the part of the Employer to do so.

5.1.7 Temporary traffic diversions and pedestrian routes shall be surfaced and shall be provided where work on roads or footpaths obstruct the existing vehicular or pedestrian access. The relevant work shall not be commenced until the approved temporary traffic arrangements and control have been implemented.

5.1.8 Temporary traffic arrangements and control for work on public roads and footpaths shall comply with the requirements of the Traffic Police. Copies of documents containing such requirements shall be kept on the Site at all times.

5.1.9 Temporary traffic signs, including road marking, posts, backing plates and faces, shall comply with the requirements of the Traffic Police and should be in accordance with the requirements of Ministry of Road Transport and Highways (MoRTH). All overhead traffic management signs that are fixed to bridges and gantries shall be illuminated at night. Pedestrian routes shall be illuminated at night to a lighting level of not less than 50 lux.

5.1.10 The following particulars of the proposed temporary traffic arrangements and control on public roads shall be submitted to the Engineer for consent at least 7 days before the traffic arrangements and control are implemented:

a. Details of traffic diversions and pedestrian routes;

b. Details of lighting, signage, guarding and traffic control arrangements and equipment;

c. Any conditions or restrictions imposed by Traffic Police or any other relevant authorities, including copies of applications, correspondence and approval.

5.1.11 Where concrete barriers are used to separate flows of traffic, the barriers shall be in a continuous unbroken line. No gaps shall be left between any section of the barrier.

5.1.12 Site perimeter fencing and barriers along the roadway, shall have flashing amber lights positioned on the top of them every 50 metres apart and at every abrupt change in location. Directly below the flashing light shall be fixed, in the vertical position, a white fluorescent light with a waterproof cover.

5.1.13 Public roads and footpaths on the Site in which the work is not being carried out shall be maintained in a clean and passable condition.

5.1.14 Measures shall be taken to prevent the excavated materials, silt or debris from entering gullies on roads and footpaths; entry of water to the gullies shall not be obstructed.

5.1.15 Surfaced roads on the Site and leading to the Site shall not be used by tracked vehicles unless protection against damage is provided.

5.1.16 Contractor's Equipment and other vehicles leaving the Site shall be loaded in such a manner that the excavated material, mud or debris will not be deposited on roads. All such loads shall be covered or protected to prevent dust being emitted. The wheels of all vehicles shall be washed when necessary, before leaving the Site to avoid the deposition of mud and debris on the roads.

5.1.17 Temporary diversions, pedestrian access and lighting, signages, guarding and traffic control equipment shall be removed immediately when they are no longer required. Roads, footpaths and other items affected by temporary traffic arrangements and control shall be reinstated to the same condition as existed before the work started or as permitted by the Engineer immediately after the relevant work is complete or at other times permitted by the Engineer.

5.1.18 The Contractor shall submit his design for the reinstatement to the relevant authorities and obtain their prior approval to carrying out the work. Reinstatement works shall include:

a. Parking bays
b. Footpath and kerbs
c. Road Signage
d. Street Lighting
e. Landscaping
f. Traffic Lights and Control Cable
g. Road painting

5.2 GRANULAR SUB-BASE (NON-BITUMINOUS)

This work shall consist of laying and compacting well-graded material on prepared subgrade in accordance with the requirements of these specifications or as per MORTH standards, as acceptable to Highway authorities & road owing agency. The material shall be laid in one or more layers according to lines, grades and cross-sections shown on the drawings.

5.2.1 Material

The Material to be used for the work shall be natural sand, moorum, gravel, crushed aggregate, or combination thereof depending upon the grading specified in MORTH specifications for Roads and Bridges. The material shall be free from organic or other deleterious constituents.

5.2.2 Physical requirements

The material shall have a 10 percent fines value of 50 KN or more (for sample in soaked condition) when tested in compliance with BS:812 (Part III). The water absorption value of the coarse aggregate shall be determined by IS:2386 (Part 3); if this value is greater than 2 percent, the soundness test shall be carried out on the material delivered to site as per IS: 383. CBR Value shall be determined at the density and moisture content likely to be developed in equilibrium conditions which shall be taken as being the density relating to a uniform air voids content of 5 percent.

5.2.3 Strength of sub-base

It shall be ensured prior to actual execution that the material to be used in the sub-base satisfies the requirements of CBR and other physical requirements when compacted and finished.

5.2.4 Construction Operations

a. Preparation of sub-grade

Immediately prior to the laying of sub-base, the sub-grade already finished or existing surface shall be prepared by removing all vegetation and other extraneous matter, lightly sprinkled with water if necessary and rolled with two passes of 80 – 100 KN smooth wheeled roller. Damage to the subgrade shall be made good before subbase is laid.

b. Spreading and compacting

The approved sub-base material shall be spread on the prepared sub-grade by a grader of suitable type and adequate capacity.

When the sub-base material consists of combination of materials, mixing shall be done mechanically by the mix-in-place method.

The equipment used for mix-in-place construction shall be approved equipment capable of mixing the material to the desired degree.

Moisture contents of the loose material at the time of compaction shall be checked in accordance with IS: 2720 (Part 7) and suitably adjusted.

Rolling procedure shall be as described under relevant Subsection except stated herein.

Rolling shall be continued till the density achieved is at least 98% of the maximum dry density for the material determined as per IS:2720 (Part 8).

5.3 WATER-BOUND MACADAM SUB-BASE/ BASE (NON-BITUMINOUS)

5.3.1 Description

The work shall consist of furnishing, placing, watering and compacting sub-base material mechanically interlocked by rolling and bounded together with screening and/ or binding material to the required degree on a prepared sub-grade/ sub-base or the existing surface as the case may be in accordance with these Specifications, and to the lines, levels, grades, dimensions and cross sections as shown on Drawings and/ or required by the Engineer.

5.3.2 Materials

a. Coarse aggregate

The coarse aggregates shall be hard and durable crushed stones, free from deleterious matter conforming to one of the grading as set forth in Table below, the physical requirements given in Table 15.3.2 subject to the Engineer's consent.

b. Screenings

Screenings to fill voids in the coarse aggregate shall generally consist of the same material as the coarse aggregate or of gravel (other than round material) or moorum as approved by Engineer. However, where permitted non-plastic material such as moorum may be used for this purpose provided liquid limit and plasticity index of such material are below 20 and 6 respectively and fraction passing through 75-micron sieve does not exceed 10 percent.

c. Binding material

Binding material to be used for water-bound macadam as a filler material meant for preventing ravelling, shall be a suitable material and having a Plasticity Index (PI) value of less than 6 as determined in accordance with IS: 2720 (Part-5).

Table 5.1- Grading requirements of coarse aggregates

Grading	Size Range	IS Sieve Designation	Percent Passing by weight
1	90 mm to 45 mm	125 mm 90 mm 63 mm 45 mm 22.4 mm	100 90-100 25-60 0-15 0-5
2	63 mm to 45 mm	90 mm 63 mm 53 mm 45 mm 22.4 mm	100 90-100 25-75 0-15 0-5
3	53 mm to 22.4 mm	63 mm 53 mm 45 mm 22.4 mm 11.2 mm	100 95-100 65-90 0-10 0-5

Note: The compacted thickness for a layer with Grade 1 shall be 100 mm while for a layer with Grade 2, it shall be 75 mm.

Table 5.2- Physical requirements of coarse aggregates or water-bound macadam sub-base and base courses

S.No.	Test	Test Method	Requirement (Maximum)
1.	* Los Angeles Abrasion value	IS :2386 (Part-4)	50 per cent
2.	* Aggregate Impact value	IS :2386 (Part-4)	40 per cent
3.	Flakiness Index	IS : 2386(Part-1)	15 per cent

* Aggregate may satisfy requirements of either of the two tests

5.3.3 Construction Method

a. Preparation of Sub-grade/ sub-base

i. The surface of the sub-grade/ sub-base or existing surface shall be shaped and prepared to the lines, levels, grades, dimensions and cross sections as shown on the Drawings. Damage to or deterioration of sub-grade/ sub-base shall be made good before sub-base/ base is overlaid.

ii. Inverted Choke

If water bound macadam is to be laid directly over the sub grade, without any intervening pavement or soling course, a 25 mm course of screenings or coarse sand shall be spread and compacted on the prepared subgrade before application of the coarse aggregate. In case of fine sand or silty or clayey sub grade, a 100 mm insulating layer of screenings or coarse sand shall be laid, the gradation of which will depend on drainage requirements. Alternatively, appropriate geosynthetics performing functions of separation and drainage layer may be used over the prepared sub-grade subject to the satisfaction of the Engineer.

b. Spreading coarse aggregates

i. The coarse aggregates of specified size and grading shall be spread uniformly in layers with each compacted layer thickness not more than 100mm for Grading 1 and 75 mm for Grading 2 and in a manner that prevents segregation into fine and coarse materials.

ii. Sub-base/ or base material shall contain moisture nearly equalising the optimum moisture content at the time of compaction.

iii. Immediately after each layer has been spread and shaped satisfactorily, each layer shall be thoroughly compacted with suitable and adequate compaction equipment. Rolling operations shall begin from the outer edge of roadbed towards the centre, gradually in a longitudinal direction; except on super-elevated curves, where rolling shall begin at the lower edge and progress towards the upper edge.

The rolling shall be continued until the aggregates are thoroughly keyed, well-bounded and firmly set in its full depth.

c. Tolerances

The finished sub-base/ base at any point shall not vary more than 15mm below and 12mm above the planned grade or adjusted grade with 3m straight edge applied to the surface parallel to the centreline of the road. With the template laid transversely the maximum permissible variation from specified profile shall be 12mm and 8mm respectively.

The sub-base/ base course completed in each day's work shall have an average thickness not less than the required thickness.

Sub-base/ base course which does not conform to the above requirements shall be reworked.

5.4 BITUMINOUS MATERIALS

5.4.1 Materials

Materials shall meet the requirements of the relevant IS Codes. These shall be of the following types.

a. Cut back Bitumen

Cut back bitumen shall be Rapid Curing (RC), Medium Curing (MC) or Slow Curing (SC) conforming to IS : 217.

b. Cationic Emulsion

Bitumen emulsions of the cationic type for roads shall conform to IS: 8887. Emulsified bitumen shall be Rapid Setting (RS), Medium Setting (MS), or Slow Setting (SS).

The physical and chemical requirements of the three types emulsions shall comply with the requirements specified in Table 1 of IS: 8887.

c. Paving Bitumen

Paving bitumen shall be conforming to IS: 73 and of the following two types:

Type 1 Paving bitumen from non-waxy crude shall satisfy the requirements given in Table 1 of IS: 73.

Type 2 Paving bitumen from waxy crude shall satisfy the requirements given in Table 2 of IS: 73.

The temperature at application of bituminous materials shall be maintained as per manufacturer's instructions and/or as directed by the Engineer's Representative.

An anti-stripping and bonding agent should be used in all final restoration road works. It should confirm to IS: 14982-2001 Specifications. The percentage can be from 0.5% to 1.25% by weight of bitumen content. The optimum dose can be ascertained using M.O.S.T. / BIS guidelines.;

5.4.2 Methods of Storage and Handling

Asphaltic material shall be handled and stored with due regard for safety and in such a way that at the time of use in the work the material conforms to the Specifications. Following precautions shall be taken while using these materials:

a. Work with these materials shall be carried out in good weather conditions and it shall be carried out in warm and dry weather, and not in wet or extremely cold weather.

b. Emulsified asphalt shall be handled with care and not subjected to mechanical shocks or extremes of temperature likely to cause separation of the asphalt. Emulsified asphalt showing sign of separation shall not be used.

c. During heating, no water or moisture shall be allowed to enter the boiler.

d. Heating of bitumen shall be done to the correct temperature range, as prescribed by the manufacturer for the grade used. The temperature shall be controlled with the use of a suitable thermometer, and the material shall be drawn and used while still at such temperature as is prescribed by manufacturer or in accordance with MOST specifications.

e. It shall be ensured that mixing of ingredients is through and all particles of aggregates are coated uniformly and fully.

5.5 PRIME COAT

5.5.1 Description

This work shall consist of the cleaning and preparing of the surface to be primed to specified lines, grade, and cross-section, booming and clearing thoroughly and applying bituminous material in accordance with these Specifications.

5.5.2 Materials

The choice of the primer shall depend upon the porosity characteristics of the surface to be primed. The primer shall be Medium Curing Cutback (MC) and the particular grade to be used for the work shall have the consent of the Engineer. Slow setting Cationic emulsion conforming to IS: 8887 may also be used. Sampling and testing of bituminous primer shall be as per IS: 217, IS: 454 and IS : 8887.

5.5.3 Construction Methods

a. Weather Limitations

Prime coat shall not be applied at a time when the surface is wet or when the weather is foggy, rainy or windy.

b. Equipment

The equipment used for the work shall include a power broom and primer material distributor spraying it uniformly at specified rates and temperatures. It shall be equipped with self-heating arrangement, suitable pump, adequate capacity compressor and spraying bar with nozzles having constant volume or pressure system.

Spraying by manual methods may be allowed for inaccessible or small areas with the consent of the Engineer.

c. Cleaning Surface

Immediately prior to applying the prime coat the surface to be primed shall be swept clean from all loose dirt and other objectionable material and shall be shaped to the required lines, grades, cross section.

a. Application of bituminous primer

The primer material shall be applied by means of a distributor at rates usually from 0.8 to 1.4 litres per square metre and at a temperature within the allowable range corresponding to the material used and porosity condition of surface over which it is laid. The temperature of primer at time of application may vary from 400 C to 600 C for cutback bitumen and 400 C to 600 C for bitumen emulsion Prime coat shall be allowed to penetrate for at least 48 hours to allow penetration into the base course and aeration of volatile from the primer material, then covered with clean dry sand or stone screening.

Areas containing an excess or deficiency of priming material shall be corrected by the addition of sand or primer.

5.6 TACK COAT

5.6.1 Description

This work shall consist of furnishing and applying bituminous material to an existing road surface or to an existing bituminous prime coat surface which has dried out or preparatory to laying another bituminous layer over it.

5.6.2 Materials

The material for tack coat shall be a bituminous or cut back emulsion of suitable type and grade.

5.6.3 Construction Methods

a. Cleaning Surface

The whole surface on which the tack coat is to be applied shall be cleaned of dust and any extraneous material before the start of application of tack coat by using a power broom or any other equipment/ method.

b. Application of tack coat material

The tack coat material shall be applied uniformly by means of a distributor at controlled rates as per MORTH specifications and at the temperature within the allowable range corresponding to the material used It shall be done with self-propelled or towelled bitumen.

Surfaces of structures and trees adjacent to the areas being treated shall be protected in such a way as to prevent their being spattered or marred.

5.7 BITUMINOUS MACADAM

5.7.1 Description

The work shall consist of one or more applications of compacted crushed aggregates premixed with bituminous binder (suitable grade) to a primed non-bituminous surface or previously constructed bituminous surface and in conformity with the lines, grades, dimensions and cross-sections shown on the Drawings This shall comprise of a single course of 50mm to 75mm thickness as specified in the approve or as Directed by Engineer.

5.7.2 Materials

a. Bitumen

The bitumen shall be paving bitumen of suitable grade approved by the Engineer and conforming to IS: 73.

b. Additives

Adhesion and Ant-stripping agent shall be added to the bitumen subject to Engineer's consent at the required percentage of additive. The additive shall be thoroughly mixed with the bituminous material in accordance with the manufacturer's instructions.

5.7.3 Aggregates

Aggregates shall consist of clean and hard crushed stone free from dust, clay, dirt and any other deleterious matter. The physical requirements shall be as given in Table below.

Table 5.3- Physical requirements of aggregates for bituminous macadam

S. No	Test	Test Method	Requirement (maximum)
1.	* Los Angeles Abrasion value	IS :2386 (Part-4)	40 per cent
2.	* Aggregate Impact value	IS :2386 (Part-4)	30 per cent
3.	Flakiness Index and Elongation Indices (Total)	IS: 2386(Part-1)	30 per cent
4.	Coating and Stripping of Bitumen aggregate mixtures	AASHTO T-182	Minimum retained coating 95%
5.	Soundness: (i) Loss with Sodium Sulphate 5 cycles (ii) Loss with Magnesium Sulphate 5 cycles		12 percent 18 percent
6.	Water absorption	IS : 2386(Part-3)	2 per cent

* Aggregates may satisfy requirements for either of the two tests.

Aggregates shall conform to one of the two grading given in Table below depending on the compacted thickness; the actual grading shall have the consent of the Engineer.

Table 5.4- Aggregate grading for bituminous macadam

IS Sieve Designation	Per cent by weight passing the sieve	
	Grading 1	Grading 2
45.0mm	100	-
26.5mm	75-100	100
22.4mm	60-95	75-100
11.2mm	30-55	50-85

IS Sieve Designation	Per cent by weight passing the sieve	
	Grading 1	Grading 2
5.6mm	15-35	20-40
2.8mm	5-20	5-20
90.0 micron		

*Bitumen content for premixing shall be 4% by weight of total mix unless otherwise approved by Engineer.

5.7.4 Construction Methods

a. Weather and Control of Work

The work of laying shall not be undertaken during rainy or foggy weather or when the base course is damp or wet, or during dust storm or when the atmospheric temperature in shade is 150C or less.

The Engineer may order work to cease temporarily on account of adverse weather, unsatisfactory condition of materials, equipment or any conditions which he considers may affect the work adversely.

b. Cleaning and Preparation of Surface

Prior to the application of binder, loose dirt and other objectionable material shall be removed from the surface to be treated by means of the power broom or blower or both. If this does not provide a uniformly clean surface, additional sweeping shall be done by hand, using stiff brushes or similar brooms. The areas inaccessible to the cleaning means shall be cleaned manually. The sweeping shall extend 200mm beyond each edge of the area to be treated.

Adherent patches of objectionable material shall be removed from the surface by steel scraper or other approved method and where the Engineer so directs the scraped area shall be washed down with water and hand brooms.

No application of bituminous material shall be undertaken until the surface has been cleaned to the satisfaction of the Engineer.

Before application of the bituminous material any necessary preliminary patching of the surface of the road (To fill in potholes.) shall be done to the complete satisfaction of the Engineer.

Tack coat shall be applied in accordance with these Specifications. Prime coat if required, shall conform to Subsection 5.5.

c. Plant and Equipment

All plant used by the Contractor for the preparation, hauling and placing of asphalt mixtures shall be subject to the consent of the Engineer and shall minimise smock, dust and noxious emission and odours. These shall generally meet the following requirements:

i. The mixing plant shall be a batching plant and shall have adequate capacity sufficient to supply the finisher on the road continuously when spreading the asphaltic mix at normal speed and required thickness.
ii. Scale for any weigh box shall be designed to be accurate to within 1% of the maximum load required and shall be fully automatically controlled.
iii. The Contractor shall provide and have at hand not less than ten 25 kilogram weights for frequent testing of all scales.
iv. Weigh box or hopper shall include a means for accurately weighing each bin size of aggregate in a weight box or hopper, suspended on scales, ample in size to hold a full batch without running over.
v. The asphaltic materials shall be stored in storage tanks designed to keep the temperature of the asphaltic material at maximum temperature of 1100 C. The

properties of the asphaltic material kept in that storage tanks shall be in good condition before mixing. The plant shall be provided with a circulating system to ensure continuous circulation between the storage tank and the mixer.

vi. The plant shall be provided with a cold bin for feeding the aggregates. Bin shall have a calibration gate and a mechanical means to ensure uniform feeding of the aggregates into the drier as required by the Engineer.

vii. The rotary drier shall be capable of drying and heating the aggregates to the specified temperature.

viii. The plant shall be provided with plant screens capable of screening all aggregates to the specified sizes.

ix. The plant shall include at least 3 hot bins for storing the aggregates fed from the drier after passing through the screen. Each bin shall be provided with an overflow pipe to prevent any backing up of material into other bins.

x. The plant shall be provided with asphaltic control unit by weighing to obtain the proper amount of asphaltic material in the mix within the tolerance specified for the job-mix.

xi. The batch mixer shall be an approved twin pugmill type and capable of producing a continuous uniform mixture within the job-mix tolerances. The mixer capacity shall not be less than 1,000-kilogram batch.

xii. An armoured thermometer reading from 500 C to 2000 C shall be fixed in the asphaltic feed line at a suitable location near the discharge valve at the mixer unit.

xiii. The plant shall be further equipped with an electric pyrometer, or other approved thermometric instrument so placed at the discharge chute of the drier as to register automatically or indicate the temperature of the heated aggregate.

xiv. The plant shall be equipped with a dust collector.

xv. The plant shall be equipped with accurate positive means to govern the time of mixing and to maintain it constant. The time of mixing shall be divided into two steps, dry mixing and wet mixing. For dry mixing, the aggregate from hot bins shall be mixed for a period of 5-15 seconds. For wet mixing, the mixing time shall begin with the start of the asphalt spray after dry mixing. The wet mixing shall take about 30-45 seconds. The mixing time shall be extended if in the consideration of the Engineer the material obtained is not homogeneous.

a. Equipment for Hauling and placing

i. Trucks for hauling asphaltic mixtures shall have tight, clean, and smooth metal beds that have been sprayed with soapy water, thinned fuel oil, or lime solution to prevent the mixing from adhering to the beds (The amount of sprayed fluid shall however be kept to the practical minimum. Each load shall be covered with a canvas or other suitable material of such size as to protect the mixture from the weather). Any truck causing excessive segregation of material by its spring suspension or other contributing factors, or that shows oil leaks in detrimental amounts, or that causes undue delays, shall upon direction of the Engineer be removed from the work until such conditions are corrected.

ii. The equipment for spreading and finishing shall be mechanical, self-powered pavers, capable of spreading and finishing the mixture true to the lines, grades, dimensions and cross sections.

The pavers shall be equipped with hoppers and distributing screws of the reversing type to place the mixture evenly. The pavers shall maintain trueness of grade and confine the edges of the pavement to true lines without the use of stationary side forms. The equipment shall include blending or joint levelling devices for smoothing and adjusting

longitudinal joints between lanes. The assembly shall be adjustable to give the cross-section shape prescribed and shall be so designed and operated as to place the thickness or weight per square metre of material required.

Pavers shall be equipped with activated screeds and devices for heating the screeds to the temperature required for the laying of the mixture without pulling or marring.

The term “screed” includes any cutting, crowing, or other practical action that is effective in producing a finished surface of the evenness and texture specified, without tearing, shoving, or gouging.

If, during construction, it is found that the spreading and finishing equipment in operation leaves in the pavement surface tracks or indented areas or other objectionable irregularities, the use of such equipment shall be discontinued, and other satisfactory spreading and finishing shall be provided by the Contractor forthwith.

b. Preparation and transport of mix

Bituminous macadam mix shall be prepared in a hot-mix plant either owned by the Contractor or it may be taken from an approved hot mix plant before supply of mix for the work, consent for the use of the mix shall be taken from the Engineer. The hot-mix plant should be of adequate capacity of batch mix type with the features as described under Subsection 5.7.4 (c) or otherwise approved by Engineer unless some work specific features are required and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregates. The plant shall meet the overall requirements through stringent quality control practices.

The mineral aggregates shall be dried and heated to a temperature between 1500 C and 1630 C. The contractor shall submit for consent the exact temperature to the Engineer. Surfaces of aggregates shall be clean and free of carbon and unburnt fuel oil. The aggregates, immediately after heating, shall be screened into three or more fractions and conveyed into separate bins ready for combining and mixing with asphaltic material.

The dried mineral aggregates prepared as prescribed above, shall be combined in the plant in the amount of each fraction of aggregate required to meet the job-mix formula for the particular mixture. The proper amount of asphaltic material shall be distributed over the mineral aggregate and the whole thoroughly mixed for a period of at least 30 seconds, or longer if necessary, to produce a homogeneous mixture in which all particles of the mineral aggregates are coated uniformly. The total mixing time shall be regulated by a suitable locking means.

The mixture shall when have emptied from the mixer be at a temperature between 1500 C and 1630 C even for tolerances. The mixture shall be transported from the mixing plant to the point of use in vehicles conforming to the requirements of Subsection 5.7.4 (d)unless otherwise approved by the Engineer.

c. Application of the Pre-mix

The application of the mix shall proceed immediately after application of tack coat. The mix shall be spread immediately by means of self-propelled mechanical paver with suitable screeds capable of spreading, tamping, and finishing the mix true to lines, levels, dimensions and cross-sections specified. Any bare or insufficiently filled areas shall be re-treated by the mechanical spreader or covered by hand as necessary to give uniform and complete coverage. Any aggregate spread in excess of the agreed rate shall be scattered and evenly distributed on the road or otherwise removed and stockpiled. The temperature of the mix at the time of laying shall be in the range of 120 or 1600 C.

5.7.5 Rolling

After the spreading of the mix, the rolling shall be done by road roller of suitable type and capacity. Rolling shall start as soon as possible after the material has been spread and it shall be completed within limited time frame, and to meet this, the Contractor shall deploy a set of rollers. Rolling shall be done with care to avoid unduly roughening of the pavement surface. It shall commence at the edges and progress towards the centre longitudinally except that on super-elevated and unidirectional cambered portions, it shall progress from the lower to the upper edge parallel to the centre line of the pavement.

The speed of the rollers shall not exceed 5 kilometre per hour for steel wheeled rollers and 7 kilometre per hour for pneumatic tired rollers and shall be at all times slow enough to avoid displacement of the hot mixture. Any displacements occurring as a result of reversing the direction of the roller or from any other cause shall at once be corrected with rakes and fresh mixture where required. Care shall be exercised in rolling not to displace the line and grade of the edges.

Rolling shall progress continuously as may be necessary to obtain uniform compaction while the mixture is in a workable condition and until all roller marks are eliminated.

Heavy equipment or rollers shall not be permitted to stand on the finished surface until it has thoroughly cooled or set. Any petroleum products dropped or spilled from the vehicles or equipment employed by the Contractor upon any portion of the pavement under construction is cause for the removal and replacement of the contaminated pavement by the Contractor.

When the roller has passed over the whole area once, any high spots or depressions which become apparent shall be corrected by removing or adding premixed material. Rolling shall then be continued until the entire surface has been rolled to 95 % of the average laboratory density, and there is no crushing of aggregates. and all roller marks are eliminated. In each pass of the roller, preceding track shall be overlapped uniformly by at least 1/3rd width. The roller wheels shall be kept damp to prevent premix from adhering to the wheels and being picked up. In no case shall fuel/ lubricating oil be used for this purpose.

Along kerbs, manholes etc., and at any other locations where proper consolidation by rollers is not practicable, alternative means such as steel rammers shall simultaneously be used to secure adequate consolidation.

Table 5.5-Mixing, Laying and Rolling Temperatures for Bituminous Mixes (Degree Celcius)

Bitumen Viscosity Grade	Bitumen Temperature	Aggregate Temperature	Mixed Material Temperature	Laying Temperature	*Rolling Temperature
VG 40	160-170	160-175	160-170	150 Min	100 Min
VG 30	150-165	150-170	150-165	140 Min	90 Min
VG 20	145-165	145-170	145-165	135 Min	85 Min
VG 10	140-160	140-165	140-165	130Min	80 Min

*Rolling must be completed before the mat cools to these minimum temperatures.

5.7.6 Surface Control

a. Surface Regularity

Maximum permissible undulation in longitudinal profile with 3m straight edge shall be as 12mm.

Maximum permissible variation from specified cross profile under camber template shall be as 8mm. Surface evenness requirements in respect of both longitudinal and cross profiles should be simultaneously satisfied.

Tests for conformity with the specified crown and grade shall be made immediately after initial compaction, and variations shall be corrected by removing or adding materials as may be necessary. Rolling shall then be continued as specified. After final rolling, the smoothness of the course shall be checked again and any irregularity of the surface exceeding the permissible limits corrected as agreed by the Engineer's Representative, including removal and replacement.

5.7.7 Surface Finish

The bituminous macadam shall be covered with either the next pavement course or wearing course, as the case may be, without any delay. If there is to be any delay, the course shall be covered with the seal coat. The seal coat in such cases shall be considered incidental to the work and shall not be paid separately.

5.8 OPEN-GRADED PRE-MIX CARPET

5.8.1 Description

This work shall consist of laying and compacting an open-graded carpet generally of 20mm thickness or as otherwise specified in a single course composed of suitable small sized aggregates premixed with a bituminous binder on a previously prepared base to serve as a wearing course.

5.8.2 Materials

a. Binder

Binder shall be bitumen of suitable grade meeting the requirements of the work and other environmental conditions. This shall be conforming to the requirements of IS: 73, IS : 217 and IS : 454 or other approved cut back bitumen as applicable.

b. Coarse aggregates

Coarse aggregates consist of crushed stones and shall be clean, strong, durable, and free from organic or other deleterious materials. The aggregates shall be hydrophobic and of low porosity. If hydrophilic aggregates are to be used, bitumen shall preferably be treated with anti-stripping agents of approved quality in suitable doses.

The aggregates shall meet the requirements given in Table 15.7.1 except that the water absorption shall be limited to 1 per cent. The Stone Polishing Value as measured by BS: 812-(Part-114) shall not be less than 55.

c. Proportioning of Materials

They shall comprise of a mix of stone chipping 13.2mm size (passing 22.4 mm sieve and retained on 11.2 mm size) and 11.2 mm size (passing 13.2 mm sieve and retained on 5.6 mm sieve.)

The contractor shall propose material proportions to the Engineer for his consent.

5.8.3 Construction Methods

a. Weather and Control of Work

This shall be as carried out per Subsection 5.7.4 (a).

b. Cleaning and Preparation of Surface

This shall be as carried out per Subsection 5.7.4(b).

c. Tack Coat
This shall be applied as per Subsection 5.6.

d. Preparation and transport of Premix
The binder shall be heated to a temperature appropriate to the grade of bitumen in boilers of suitable design avoiding local overheating and ensuring a continuous supply.
The aggregates shall be dry and suitably pre-heated to the required temperature before they are placed in a mixer. After about 15 seconds of dry mixing, the heated binder shall be distributed over the aggregates at the rate specified. Mixing shall be continuous and thorough to ensure a homogeneous mixture in which all particles are coated uniformly, and the discharge temperature shall be within the specified range.
The mixing of binder with chippings shall be continued until the chippings are thoroughly coated with binder. The mix shall be discharged and immediately transported from mixer to the point of use in suitable vehicles or wheelbarrows. The vehicles employed for transport shall be clean and the mix being transported should be covered in transit and protected from any kind of damage.

e. Spreading and Rolling
Immediately after the application of tack coat, premixed material shall be spread by means of mechanical paver finisher truly to lines, levels, dimensions and cross section as specified. The areas not covered by the mechanical means shall be treated with manual means for which the Engineer has given his consent.

f. Rolling
This shall be carried out as per Subsection 5.7.5

5.9 BITUMINOUS CONCRETE

5.9.1 Description

This work shall consist of a surfacing of single-layer bituminous concrete of specified thickness on previously prepared bituminous surface to the lines, grades, dimensions and cross section as shown on Drawings. It shall be 25mm/40mm thick as required by Engineer.

Materials

a. Bitumen
The bitumen shall be paving bitumen of suitable penetration grade within the range S 35 to S 90 or A 90 to IS: 73. The actual grade of bitumen to be used shall be appropriate to the requirements of the work and environmental conditions.

b. Coarse aggregates
The aggregates shall satisfy the physical requirements given in Table below Flakiness index shall not exceed 30% and water absorbed not more than 1%.

Table 5.6- Physical Requirements for Coarse Aggregate for Bituminous Concrete

Test	Specification	Method of Test
Grain Size Analysis	Max 5% Passing from 0.075 IS Sieve	IS: 2386 Part 1
Combine Flakiness and Elongation Indices	Max 35%	IS: 2386 Part 1
Los Angeles	30% Max	IS: 2386 Part 4
Impact Value	24% Max	IS: 2386 Part 4
Soundness: Sodium Sulphate Magnisium Sulphate	 12% 18%	IS: 2386 Part 5
Stone Polish Value	Minimum 55	BS: 812 -114

Test	Specification	Method of Test
Water Absorption	Max 2%	IS: 2386 Part 3
Stripping Value	Minimum Retained Coating 95%	IS:6241

c. Fine aggregates

Fine aggregates shall be the fraction passing 2.36 mm sieve and retained on 75-micron sieve, consisting of crushed run screenings, natural sand or a mixture of both. These shall be clean, hard, durable, uncoated, dry and free from any injurious, soft or flaky pieces and organic or other deleterious substances.

d. Filler

Filler shall consist of finely divided mineral matter such as rock dust, hydrated lime or cement. The filter shall be graded within following limits:

IS Sieve (mm)	% Passing by Weight of Total Aggregate
0.6	100
0.3	95 – 100
0.075	85 – 100

The filter shall be free from organic impurities and have a Plasticity Index not greater than 4. The Plasticity Index requirement shall not apply if filter is cement or lime. When coarse aggregate is gravel, 2 per cent of mass of total aggregate of Portland cement or hydrated lime shall be added and percentage of fine aggregate reduced accordingly. Cement or lime is not required when the gravel is limestone.

e. Aggregate gradation

Mineral aggregates, including filler shall be so graded or combined as to conform to grading set forth in Table below.

Grading	1	2
Nominal Aggregate Size	19mm	13.2mm
Layer Thickness	50mm	30 – 40mm
IS Sieve (mm)	% by Weight of Total Aggregate Passing	
26.5	100	
19	90 – 100	100
13.2	59 – 79	90 – 100
9.5	52 – 72	70 – 88
4.75	35 – 55	53 – 71
2.36	28 – 44	42 – 58
1.18	20 – 34	34 – 48
0.600	15 – 27	26 – 38
0.300	10 – 20	18 – 28
0.150	05 – 13	12 – 20
0.075	02 – 08	04 – 10
Bitumen Content % by mass of total mix	Min 5.2*	Min 5.4

5.9.2 Mix Design

a. Requirement of Mix

Apart from conformity with grading and quality requirements of individual ingredients, the mix shall also meet the requirements set forth in Table below.

Requirements of Bituminous Concrete Mix

S. No.	Description of Required Tests	Requirement/Specifications
1	Marshall stability (ASTM Designation: D-1559) determined on Marshall specimens compacted by 75 compaction blows on each end	
2	Marshall flow (mm)	Minimum 2 - 4
3	Per cent air voids in mix	
4	Per cent voids in mineral aggregate (VMA)	Minimum 11 - 13
5	Percent voids in mineral aggregates filled by bitumen (VFB)	
6	Binder content, per cent by weight of mix	As per grade described in the table above
7	sensitivity (ASTM: D-1075) loss of on immersion in water at 60 deg. C	Minimum 75% retained Tensile Strength
8	Test (Asphalt Instt. MS-2, No. 2)	Minimum 1.5%

Binder content

Binder content shall be so determined as to achieve the requirements of the mix set forth in Table above. Marshall method for arriving at binder content shall be adopted.

5.9.3 Job Mix Formula

Before starting work the Contractor shall submit to the Engineer for his consent. The job mix formula for the mixture shall fix a single percentage of aggregate passing each required sieve size, a single percentage of asphalt to be added to the aggregate, and a single temperature at which the mixture is to be delivered on the road, all of which shall fall within the ranges of the composition and the temperature limits.

Application of job-mix formula and Allowable Tolerances

The approved job mix formula shall remain effective unless and until modified. Each day as many samples of the materials and mixtures shall be taken and tested considers necessary for checking the required uniformity of the mixture.

All mixture furnished shall conform to the job-mix formula within the range of tolerances set in forth in Table below;

Permissible variations from the job-mix formula

Sl No	Description of Ingredients	Permissible Variation by Weight of Total mix in Percentage
1	Aggregate passing 13.2mm sieve and larger	+ 8
2	Aggregate passing 9.5mm sieve and 4.75mm sieve	+ 7
3	Aggregate passing 2.36mm sieve & 1.18mm sieve	+ 6
4	Aggregate passing 600-micron sieve &300 micron sieve	+ 5
5	Aggregate passing 150-micron sieve	+ 4
6	Aggregate passing 75-micron sieve	+ 3
7	Binder	+ 0.3
8	Mixing Temperature (Centigrade)	+ 10

When unsatisfactory results or changed conditions make it necessary, a new job mix shall be submitted to the Engineer.

Should a change in a material be encountered or should a change in a source of material be made, a new job mix formula shall be submitted before the mixture containing the new material is delivered.

5.9.4 Construction Methods

a. Weather Limitation

The control over the weather conditions shall be as described under Subsection 15.7.3 (1) above.

b. Progress of Work

No work shall be performed when there is insufficient hauling, spreading or finishing equipment, or labour to ensure progress at a rate not less than 75% of the capacity of the mixing plant.

c. Preparation of Existing Surface

The surface on which the mix is to be laid shall be swept thoroughly and cleaned of all loose dirt and other objectionable material using mechanical broom immediately before start of work. In portions where mechanical means cannot reach, the surface shall be prepared, shaped and conditioned to specified levels, grade and cross-fall (camber).

d. Preparation of Mix

A Hot-mix plant of adequate capacity and capable of producing a proper and uniform quality mix shall be used for preparing the mix. The plant may be either a weigh batch type or volumetric proportioning continuous or drum mix type. The plant shall have co-ordinated set of essential units capable of producing uniform mix as per the job-mix formula.

The temperature of the binder at the time of mixing shall be in the range of 150° to 163°C and of aggregates in the range of 155° to 163° C, provided also that at no time shall the difference in temperature between the aggregates and binder exceed 14°C. The Contractor shall submit the exact temperatures and total mixing time for the consent of the Engineer.

Mixing shall be thorough to ensure that a homogeneous mixture is obtained in which all particle of mineral aggregates is coated uniformly.

e. Transportation and Delivery of Mix.

The mix shall be transported from the mixing plant to the point of use in suitable tipper vehicles. The vehicles employed for the transport shall be clean and be covered in transit.

f. Spreading and Finishing

The mix transported from the hot mix plant to the site and shall be spread by means of a self-propelled mechanical paver with suitable screeds capable of spreading, tamping and finishing the mix to specified grade, elevation, and cross-section. However, in restricted locations and narrow widths, where available equipment cannot be operated, other suitable means shall be employed subject to the consent of the Engineer. The mixture shall be laid upon an approved surface and only when weather conditions are considered suitable. The temperature of the mix, at the time of laying, shall be in the range of 120° C to 160°C.

The prime coat and tack coat to be applied shall be as per Subsections 15.5 and 15.6 respectively.

Spreading, finishing and compacting of the mix shall be carried out during daylight hours only, unless satisfactory illumination is provided by the Contractor.

g. Compaction of Mixture

Immediately after spreading of mix by paver, it shall be thoroughly and uniformly compacted by rolling with a set of self-propelled rollers moving at a speed not more than 5 km per hour, immediately following close to the paver. Generally, with each paver, two steel wheeled tandem rollers and one pneumatic tired roller will be required. The initial or breakdown rolling

shall be with 8 to 10-ton static weight smooth three wheeled steel roller and finish rolling with 6 to 8 Tonne tandem roller. The breakdown rolling shall preferably be followed by an intermediate rolling with a smooth wheel pneumatic roller of 10 to 25 ton having a tire pressure of 7kg/Sq.cm moving with a speed not more than 7 km per hour and shall be at all times slow enough to avoid displacement of the hot mixture. Means shall be provided for checking and adjusting the tire pressure on the job at all times. All compaction operations, i.e., breakdown rolling can be accomplished by using vibratory roller of 8 to 10-ton static weight. During initial or breakdown rolling and finished rolling, the vibratory shall be switched off. The joints and edges shall be rolled with a 8 to 10 ton three wheeled static roller.

No delays in rolling the paved surface shall be tolerated, the breakdown roller must be right up to the paver at all times and the intermediate pneumatic roller right up to the breakdown roller. The compaction of the asphaltic concrete shall be controlled by temperature as described in temperature table before.

Rolling shall be continued till the density achieved is at least 98% of that of laboratory Marshall specimen.

h. Joints

Both longitudinal and lateral joints in successive courses shall be staggered so as not to be one above the other. Longitudinal joints and edges shall be constructed true to delineating lines parallel to the centre line of the road. Longitudinal joints shall be offset by at least 150mm from those in the lower course.

Longitudinal and transverse joints shall be made in a careful manner so that well bonded and sealed joints are provided for the full depth of the course.

i. Surface regularity

Surface shall be tested for undulations in longitudinal and cross profiles with 3 m straight edge and crown template respectively. Crown template shall conform to the typical cross section.

Maximum permissible undulation in longitudinal profile with 3m straight edge shall be as 8mm.

Maximum permissible variation from specified cross profile under camber template shall be as 4mm.

Surface evenness requirements in respect of both longitudinal and cross profiles should be simultaneously satisfied.

j. Protection of the pavement from traffic

Subsection 15.1 shall apply except as stated below.

Section of the newly finished works shall be protected from traffic of any kind until the mixture has cooled to approximately ambient air temperature and well set.

5.10 SEAL COAT

5.10.1 Description

This work shall consist of application of a seal coat for sealing the voids in a bituminous surface laid to the specified levels, grade, and cross fall. Seal coat used shall be of premix type unless otherwise approved by the Engineer.

5.10.2 Materials

a. Binder

The binder shall be bitumen of a suitable grade appropriate to the requirements of the work and other environmental conditions as directed by the Engineer and satisfying the requirements of IS: 73, 217, 454 or another cut back as applicable.

b. Aggregates

The aggregates shall be sand or grit and shall consist of clean, hard, durable, dry particles and shall be free from dust, soft or flaky/ elongated material, organic matter or other deleterious substances. The aggregates shall pass 2.36mm sieve and be retained on 180-micron sieve. The quantity used for premixing shall be 0.06 cum per 10 sq m area.

5.10.3 Construction Methods

a. Preparation of base

The seal coat shall be applied immediately after laying of bituminous course which is required to be sealed. Before application of seal coat materials, the surface shall be cleaned free of any dust or other objectionable matter.

b. Preparation and Application of Mix

Mixtures of approved type shall be employed for mixing aggregates with suitable bituminous binder.

The binder shall be heated in boilers of suitable design, to a temperature appropriate to the grade of bitumen. The aggregates shall be clean, dry and suitably heated to a temperature before the same are placed in the mixture. Mixing of binder with aggregates to specified proportions shall be continued till the latter are thoroughly coated with the former.

The mix shall be immediately transported from the mixing plant to the point of use and spread uniformly on the bituminous surface to be sealed.

c. Rolling

As soon as sufficient length has been covered with pre-mixed material, the surface shall be rolled with 8-10-ton smooth wheeled steel, suitable vibratory or other equipment.

As regards procedure for rolling it shall be as specified under Subsection 5.7.5.

5.11 CEMENT CONCRETE PAVEMENTS

5.11.1 General

This work shall consist of constructing Plain/ or Reinforced Cement Concrete Pavements as required in accordance with these Specification and in conformity with the lines, levels, grades and dimension in accordance with the design.

5.11.2 Materials

a. General

The concrete materials viz. cement, aggregates, water, steel reinforcement, admixtures shall be in accordance with Section 3 (Concrete: Plain and Reinforced) except as specified herein.

b. Dowel and Tie bars

Dowel bars shall be plain round bars. They shall be free from burring or other deformation restricting slippage in the concrete. Before delivery to the Works, one half of the length of each dowel bar shall be painted with one coat of bituminous material.

Tie bars shall be deformed bars free from oil, dirt, loose rust and scale.

These shall conform to the requirements of IS: 432, IS: 1139 and IS: 1786 as relevant.

c. Sleeves

The sleeves for dowel bars of expansion joints shall be of plastic material. This shall be designed to cover the dowels specified by the Designer, with a closed end, and with a suitable stop to hold the end of the sleeve a distance equal to the thickness of joint filler or at least 30mm from the end of the dowel bar. These shall be of such design that they do not deflect or collapse during construction, and the arrangement of sleeves shall be in accordance with these Specifications.

d. Waterproof Membrane

Where Waterproof membrane is to be provided, it shall be an impermeable polythene plastic sheeting. Where an overlap of underlay material is necessary this shall be at least 300mm. Water shall not be allowed to pond on the membrane which shall be completely dry when the concrete is laid.

i. Joint Filler

The expansion joint fillers shall conform to the requirements of IS: 1838. They shall be punched to admit the dowels where called for as specified by the Designer. The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint. When the use of more than one piece is authorized for a joint, the abutting ends shall be fastened closely together securely and accurately to shape by stapling or other satisfactory positive fastening.

ii. Joint Primer

Joint primer shall be fully compatible with the joint sealant and shall be applied strictly in accordance with the manufacturer's instructions.

iii. Joint Sealing Compound

The Sealing Compound of hot poured, elastomeric type shall conform to AASHTO M282 and cold applied sealant shall be in accordance with BS 5212 (Part 2).

5.11.3 Equipment and Tools

a. General

The concrete paving shall be carried out by use of mechanised method. Equipment and tools necessary for handling materials and performing the work shall have the consent of the Engineer as to design, type, capacity and mechanical, condition shall be at the site of the work before work is started. In special cases like a very short length of road to be laid at a location, other methods may be approved by Engineer.

b. Batching and Mixing Plant

This shall be of suitable type, capacity and make meeting the requirements of work.

c. Paving Equipment

The concrete shall be placed with an approved fixed form or slip form paver with independent units designed to (i)spread, (ii)consolidate, screed and float finish, (iii)texture and cure the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary and so as to provide a dense and homogeneous pavement in conformity with the plans and Specifications.

Vibrators for full width vibration of concrete paving slabs may be either the surface pan type or the internal type. They may be attached to the spread finisher. They shall not come in contact with the joint, subbase or side forms.

The frequency of the surface vibrators shall not be less than 3500 impulses per minute and for the internal type not less than 5000 impulses per minute. The variable vibration setting shall be provided in the machine.

At least two spare vibrators and one generating unit shall be on hand in case of any breakdown of the vibrating equipment being used.

d. Concrete Saw for joint cutting

The mechanical saw for cutting concrete shall be adequately powered to cut rapidly with a water-cooled diamond edge saw blade to the depth required. A water tank with flexible hoses and pump shall be made available in this activity on priority basis. The Contractor shall have at least one standby saw in good working condition.

e. Forms

Straight side forms shall be metal forms having a thickness of at least 5mm and have a depth equal to the prescribed edge thickness of the pavement slab.

Curved forms shall be of the radius called for as specified by the Designer and acceptable flexible forms shall be installed with that radius. Built-up forms with horizontal joints shall not be used. Forms shall be free from kinks, bend or wraps. Forms shall not deflect more than 6 mm when tested as a simple beam with a span of three metres under a load equal to that which the finishers or other construction equipment will exert on them. The top of the form shall not vary from a three-metre straight edge by more than 3mm at any point and the side by more than 6mm at any point.

The forms shall contain provision for locking together tightly the ends of abutting from sections and for secure setting.

f. Curing Compounds

The curing compounds shall have a water retention efficiency index of 90% in accordance with BS 7542.

5.11.4 Construction Methods

a. Preparation of Sub-base

The sub-base, which shall generally be of water-bound macadam (WBM) conforming to Subsection 3.3. The subbase shall be wetted adequately or provided with a waterproof membrane so that it does not absorb any water from the concrete to be laid over it.

Concrete shall not be placed on any portion of the sub-base until the consent of the Engineer is given.

b. Setting Forms

The sub-base under the forms shall be compacted and cut to grade so that forms, when set to the position are within + 3mm of a straight line formed by the top of the forms. If the sub-base is found to be below the required grade at the form line, the grade line shall be lifted by placing lean concrete mix 1:4:8 beneath the form and setting the form when it is set. Imperfections and variations above grade shall be corrected by tamping or cutting to the degree required.

The alignment and grade elevations of the forms shall be checked, and the necessary corrections made by the Contractor immediately before and after placing the concrete. When any form has been disturbed or any roadbed has become unstable, the form shall be reset and rechecked.

On final setting of the forms, these shall be checked for at least half the length of pavement to be concreted in a particular day before concreting commences on that day. While concreting long lengths, the setting up of forms to the exact grade and alignment shall be in advance of the concreting operation by at least 60 m.

Forms shall be cleaned and oiled prior to the placing of concrete. The forms shall be removed not earlier than 24 hours after the concrete has been laid.

c. Preparation of Concrete

i. Trial Mix / Mix Design

ii. Section 12.7 shall be followed for the design mix concrete. Minimum grade of concrete shall be as per drawing.

iii. Batching, Mixing and Transporting Materials

Subsection 12.10 shall apply.

The Ready-Mixed Concrete (RMC) shall conform to Subsection XXXXX.

d. Placing Concrete

Concrete shall be placed only on a prepared sub-base as specified in Subsection 15.11.4(1). No concrete shall be placed around structures until they have been brought to the required grade and alignment nor until expansion joint material has been placed around them.

The concrete shall be spread, compacted and finished by a mechanical paver and in accordance with Subsection 15.11.3 (3). The mixing and placing of concrete shall progress only at such a rate as to permit proper finishing, protecting and curing of the pavement.

The truck mixers, truck agitators and other approved hauling equipment shall be equipped with means for discharge of concrete into the hopper of the paver without segregation of the materials. In all cases, the temperature of the concrete shall be measured at the point of discharge from the delivery vehicle.

The acceptance criteria regarding level, thickness, surface regularity, texture, finish, strength of concrete and all other quality control measures for hand laid concrete shall be the same as in the case of machine laid work.

The concrete shall be thoroughly consolidated against and along the faces of all forms by means of vibrators inserted in the concrete. Vibrators shall not be permitted to come in contact with a joint assembly, the sub-base or a side form. In no case shall the vibrator be operated longer than 30 seconds in any location. The vibrator shall be inserted in the concrete and worked along the full length and both sides of a joint.

Concrete shall be deposited as near to expansion and contraction joints as possible without disturbing them but shall not be dumped from the discharge bucket on to a joint assembly.

Except at construction joints, concrete shall be shovelled against both sides of the joint simultaneously, maintaining equal pressure on both sides. It shall be deposited to a height of approximately 5 cm more than the depth of the joint and shall be vibrated so that all honeycombing and voids are prevented. The vibrator shall be inserted in the concrete and worked along the full length and both sides of the joints.

e. Initial strike-off and Placement of Reinforcement

Where the concrete is laid in two layers, the bottom layer of concrete shall be struck off for the full width between longitudinal construction joint true to crown at the required distance below the finished surface elevation, for placement of reinforcement or for placement of a top layer of the required thickness.

The striking-off shall be accomplished by use of the finishing machine, unless some other approved device is allowed. The reinforcement shall be placed as called for by the Designer and pouring of concrete over it shall only be allowed after placement of reinforcement is proper in all respects and approved by the Engineer.

f. Joints

i. General

Joints shall comply with the design approved for the construction.

A strip of the preformed expansion joint filler shall be placed around each structure which extends into or through the pavement before concrete is placed.

ii. ii. Transverse Expansion Joints

These shall be formed at the design spacings. The material for a transverse joint shall be assembled at the roadbed and placed into position as a unit.

iii. iii. Transverse Contraction Joints

Transverse Contraction joints shall consist of planes of weakness created by forming or cutting grooves in the surface of the pavement. Transverse contraction joints shall also include load transfer dowel-bars where these are specified by the Designer.

The contraction joints shall be cut as soon as the concrete has undergone initial hardening and is hard enough to take up the load of joint sawing machine without causing damage to the slab. Grooves shall be at right angles to the centreline of the pavement and shall be true to line, subject to a tolerance of 5 mm in the width of the slab.

Any procedure for sawing joints that results in premature and uncontrolled cracking shall be revised immediately by adjusting the sequence of cutting the joints or the time interval involved between the placing of the concrete and cutting of the joints.

Load transfer assemblies for transverse contraction joints shall consist of dowel bars without sleeves and an approved auxiliary spacing and supporting element.

The assembly shall be placed into position so that the dowels are parallel to the centreline and shall be staked into position in such a way as to hold the assembly securely in position throughout construction.

iv. Longitudinal Joints

Longitudinal joints shall be constructed in conformity with the design. Planes of weakness shall be created by forming or cutting grooves in the surface of the pavement in accordance with the applicable provisions of this Section.

When adjacent lanes of pavement are constructed separately, steel side forms shall be used which will form a keyway along the construction joint. The bars may be bent at angles against the form of the first lane constructed and straightened into final position before the concrete of the adjacent lane is poured.

v. Transverse Construction Joint

Transverse construction joints shall be placed whenever concreting is completed after a day's work or is suspended for more than duration permissible for continuous pouring of concrete.

Joints shall be formed by placing installing bars or suitable bulkhead material so that a vertical face with approved key is formed or shall be butt joints formed with suitable material so that a vertical face is formed with no key. No tie bars shall be necessary when key joints are formed but dowel bars of the same dimensions and at the same spacing as for contraction joints shall be necessary at all butt joints.

g. Finishing

i. Machine Finishing

As soon as the concrete has been placed, it shall be struck off and screeded by an approved finishing machine or tools to the grades and cross sections specified by the Designer and to a level slightly above grade so that when properly consolidated and finished the surface of the pavement will be at the exact level and grade. The machine or tool shall go over each area of pavement as many times and at such intervals as necessary to give the proper compaction and to leave a surface of uniform texture, true to grade and cross section.

Excessive operation over a given area shall be avoided. The tops of the forms shall be kept clean by an effective device attached to the machine and the travel of the machine on the forms shall be maintained true without lift, wobble or other variation tending to effect the precision finish.

After concrete has been placed on both sides of the joint and struck off, the installing bar or channel cap shall be slowly and carefully withdrawn, the concrete shall be carefully spaded, and additional freshly mixed concrete worked into any depression left by the removal of the installing bar.

A diagonal finishing machine shall be used if available.

ii. Hand Finishing

A portable screed shall be provided for use. The screed shall be at least 60 cm longer than the width of the slab to be struck off and consolidated. It shall be of approved shape, sufficiently rigid to retain its shape and constructed either of metal or of other material shod with metal. (If necessary, a second screed shall be provided for striking off the bottom layer of concrete).

The screed shall then be placed on the forms and slip along them, without lifting, in a combined longitudinal and transverse shearing motion moving always in the direction in which the work is progressing. If necessary, this shall be repeated until the surface is of uniform texture, true to grade and contour, and free from porous areas.

h. Edging at Forms and Joints

After the concrete's initial set, the edges of the pavement along each side of each slab, and on each side of transverse expansion joints, planes of weakness except when sawed transverse construction joints, and emergency construction joints shall be worked with an approved tool and rounded to a radius of 5 mm. A well-defined and continuous radius shall be produced, and a smooth, dense mortar finish obtained. The surface of the slab shall not be unduly disturbed by tilting of the tool during use.

All joints shall be tested with a straight edge before the concrete has set, and correction shall be made if one side of the joint is higher than the other or if they are higher or lower than the adjacent slabs.

i. Surface Texture

The surface of the carriageway shall be textured by wire brushing in a direction at right angles to the longitudinal axis of the carriageway. The pavement shall be given this broomed texturing as soon as surplus water has risen to the surface.

The wire brushes shall be either mechanically operated or manual methods may be allowed depending upon the type of paver being used on the Work. In either case the wire broom shall be not less than 450 mm wide with two rows of spring steel. At least two brooms in working order shall be on the site at all times.

The surface texturing shall be completed before the concrete is in such condition that the surface is torn or unduly roughened by the brooming. The broomed surface shall be free from rough areas, porous areas, irregularities, or depressions.

ii. Surface Requirements

After the concrete has hardened sufficiently, the surface shall be given a further test for tureens, using an approved 3 m straight edge laid on the surface. Any portion of the surface, when tested in the longitudinal direction, which shows a variation or departure from the testing edge of more than 3.5mm but not exceeding 7mm shall be marked and immediately ground down with an approved grinding tool until the variation does not exceed 3.5mm.

Whenever the variation or departure from the testing edge is more than 7.0mm the pavement shall be removed and replaced. Such removal shall be of the full depth and width of the slab and at least 3m long.

i. Curing

Immediately after the surface texturing, the surface and sides of the slab shall be cured by approved curing method for not less than 7 days. During this period measures shall be taken to prevent the loss of moisture.

The concrete shall not be left exposed between stages of curing.

The surface shall be inspected regularly to ascertain the earliest time at which it is able to withstand the spreading of moisture retaining material. This shall be by ponding of water or spreading and wetting either two layers of burlap or two mats of cotton / jute or a layer of sand or other approved highly absorbent material. Whatever material is used it shall be kept continuously moist for not less than 7 days and to a degree which will ensure that 100% humidity is maintained adjacent to the concrete surface. A membrane curing compound meeting the requirements of BS 7542 may be used subject to the consent of the Engineer.

Concrete surfaces which are subjected to heavy rainfall within three hours after the curing compound has been applied shall be resprayed by the method and the coverage specified above.

Concrete surfaces to which membrane curing compounds have been applied shall be adequately protected for the duration of the entire curing period from the pedestrian and vehicular traffic, except as required for joint sawing operations and surfaces tests, and from only other cause which will disrupt the continuity of the membrane. The curing membrane so formed shall be maintained intact for a period of not less than 14 days. The entire surface shall be protected from the effects of solar radiation and in addition by the use of frames covered with material with heat and light reflecting properties.

Concrete liable to be affected by running water shall be adequately protected from the damage during the setting period.

j. Removing Forms

Forms shall be removed only after stipulated period and carefully so as to avoid damage to the pavement.

k. Protection of Pavement

The Contractor shall erect and maintain suitable barricades and shall employ watchmen to exclude public traffic and that of his employees and agents from the newly constructed pavement until opened for use. These barriers shall be arranged as not to interfere with public traffic on any lane intended to be kept open and necessary signs and lights shall be maintained by the Contractor clearly indicating any lanes open to the public.

Where any stipulated public traffic lane is contiguous to the slab or lane being placed, the Contractor shall provide, erect, and subsequently remove a substantial temporary guard fence along the prescribed dividing line, which shall be maintained there and protected by signages until the slab is opened to traffic. The Contractor's plan of operation shall be such as to obviate any need for encroachment on the public traffic lane or lanes under use.

The same shall be approved by the local competent authority.

Any part of the pavement damaged by traffic or other cause prior to its final acceptance shall be repaired or replaced by the Contractor.

l. Sealing Joints

Before the pavement is opened to traffic, and as soon after the curing period as is feasible, all joints both longitudinal and transverse, shall be filled with the material approved for use as seal.

Both primer and sealing compound shall be treated and applied strictly in accordance with the manufacturer's specifications/ instruction and by use of approved equipment.

The sealing material shall be poured into each joint opening as directed by the Engineer. The pouring shall be done in such a manner that the material will not be spilled on the exposed surfaces of the concrete. Any excess material on the surface of the concrete pavement shall be removed immediately and the pavement surface cleaned.

6. SURVEY AND SETTING OUT

6.1 GENERAL

6.1.1 The Contractor is wholly responsible for the setting out of the Works. The Contractor shall have a third party verify stating that the setting out is in compliance with the Employer's requirements.

6.1.2 A method statement for the survey for the setting out shall be submitted to the Engineer for review. This method statement shall include, but not be limited to:

a. Surveying Equipment;
b. Inspection and acceptance criteria;
c. Specific strategy for Site conditions including but not limited to:
   i. Climatic conditions;
   ii. Dusty environment.
d. Calibration of instruments and certification.

6.1.3 Records of all raw and processed survey data shall be kept for inspection by the Engineer.

6.2 **SURVEY CONTROL**

6.2.1 Survey Markers shall be durable, appropriate to location and intended use and shall have an unambiguous centre point. Survey Marker shall be steel plates.

6.2.2 Benchmarks shall be established as per Indian standard practice.

6.2.3 The method statement shall contain proposals for conducting regular surveys of all existing survey control points including the benchmarks.

6.2.4 A comprehensive level survey of the Contract area shall be conducted before any work

6.3 **FINAL AS-BUILT SURVEY**

6.3.1 Upon completion of the survey connection shall be made and the survey misclosure determined. A survey report shall be prepared and submitted to the Engineer detailing the final adjusted values for all the survey control to remain for the purpose of track laying.

6.3.2 As-built surveys of all platform edges, columns and any other adjacent structures shall be conducted to ensure that there is no infringement with the Schedule of Dimensions (SOD). The Contractor shall be responsible to demonstrate to the Engineer that there is no infringement of structure gauge specified in the SOD. All out of tolerance areas shall be highlighted and corrected on site.

6.4 **MONITORING SURVEYS**

6.4.1 As a minimum requirement, the design of a monitoring scheme shall take into consideration the likely range of movements to be incurred, accuracy required, accessibility to the area of interest, instrumentation to be used, the use of any special accessories, frequency of monitoring, particular Site conditions, safety, data collection/processing techniques, real time or post process, maintenance of the system, stability of the points of reference and the presentation format.

6.4.2 All 2D and 3D monitoring schemes shall be coordinated on the Project grid and datum. All elevation monitoring shall be conducted on the Project datum. All monitoring points shall be clearly identified.

7. Not Used

8. Not Used

9. PILING

9.1 **GENERAL**

9.1.1 This section specifies the materials and workmanship required for bored piles. The design and installation of this work shall be in accordance with the Employer's Requirements.

9.1.2 Particular attention shall be paid to all safety aspects of the work by the deployment of barriers and covers as necessary.

9.1.3 Compliance with all applicable environmental Laws shall be achieved. Polymer shall be used in place of Bentonite to stabilized the soil. The Contractor shall carry out the piling work in such a manner and at such times as to minimise noise and disturbance. Relevant permits and licenses shall be acquired by the Contractor.

9.1.4 The Contractor shall take precautions adequate enough to avoid damage to existing utilities and services and adjacent structures. The Contractor shall ensure that damage does not occur to any part of completed piling works and shall submit to the Engineer for review his proposed sequence and timing for boring piles having regard to the avoidance of damage to adjacent piles.

9.1.5 If during the execution of the Works the Contractor encounters obstructions in the ground, he shall forthwith notify the Engineer accordingly, and submit proposed remedial methods for overcoming the obstruction. Any cost incurred in dealing with obstructions shall be borne by the Contractor.

9.1.6 The Contractor shall be responsible for any damage or movement in adjacent utilities, buildings, highways and underground structures of any type. Allowance shall be made for all ancillary treatment and all work necessary to ensure the stability of roadworks, adjacent structures and underground constructions and utilities.

9.1.7 The Contractor shall provide all the necessary monitoring instrumentation for the continuous

checking of the movements of adjacent structures, service utilities and other underground constructions.

9.1.8 Method statements giving the full details of the Contractor's proposed materials, equipment and operations to be used in the construction of bored piles, bored pile walls and diaphragm walls shall be submitted to the Engineer for review. They shall include, but not be limited to:

a. Dimensions, lengths and cut-off levels of piles
b. Stabilisation of foundation excavations
c. Definition of type and kind of drilling method and excavation
d. Concrete mix design
e. Method of concrete placement
f. Reinforcement schedule and how lapping will be carried out
g. The sequence of excavation and concreting
h. A proposal for load testing and integrity testing
i. Monitoring and checking the tolerances of all bored pile and diaphragm wall
j. Monitoring and checking the stability of neighbouring properties, highways, services and other underground structures
k. Disposal of contaminated polymer slurry
l. Records to be maintained.

9.2 **PILING WORKS**

9.2.1 The construction of piles shall be in accordance with the following Indian Standard Codes of Practice for Design and Construction of Pile Foundations: IS:2911 Part I Section 2 Bored Cast in-situ Concrete Piles Or IRC: 78 Standard Specifications and Code of Practice for Road Bridges Foundation and Substructure.

9.2.2 The Engineer shall be given at least 24 hours Request for Inspection (RFI) prior to any works commencing.

9.2.3 The Engineer shall be notified by the Contractor of his working hours and workweek.

9.2.4 In the event of rapid loss of drilling fluid from a pile excavation, the bore shall be backfilled immediately with lean concrete or other material as approved by the Engineer.

9.2.5 All reasonable steps shall be taken to prevent the spillage of drilling fluid on the site, or in areas outside the immediate vicinity of boring.

9.2.6 For a pile constructed in a stable cohesive soil, without the use of temporary casing or drilling fluid, the pile shall be bored and concrete shall be placed as soon as practical.

9.2.7 The method of placing and the workability of the concrete shall be such that a continuous monolithic concrete shaft of full cross section is formed.

9.2.8 Piling Tolerances shall be stringent of relevant IS/IRC codes.

9.2.9 Records of the installation of each pile shall be kept. Any unusual or difficult driving or boring operation shall be noted in these records. Records of as-built details of the piling works, including soil and rock conditions encountered during boring shall be kept and delivered to the Employer.

9.2.10 The Piling in Water Body:

a. The exposure condition for environment and consideration for crack width shall be considered as 'severe'. The grade of RCC and PCC concrete shall also be applicable accordingly.
b. Permanent steel casing shall be provided with the minimum thickness of 10mm for full depth excluding the socketing length.
c. All the necessary temporary and suitable works to perform the piling work in water shall be carried out in accordance with provisions IS: 5121 safety code of piling and other deep foundations
d. Initial Load test shall be conducted on initial test pile at the initialstage of the project to determine the load carrying capacity of the pile in accordance with the IS 2911 (Part 4) latest version.

9.2.11 Socketing length of Bored Piles in Rockshall besuch that the pile can carry its structural strength as

safe load based on;

a. Uniaxial Compression
b. Shear Strength of Parameters of Rock

9.2.12 Foundation analysis and design shall be based on IRS Code for Substructure &IS: 2911.The rotary rig shall be calibrated, Energy concept method shall be adopted for termination of piles. Pile Termination Criteria shall be as per IRC: 78 Clause 10; Point 3) PPR (for rotary piles).

Following shall be followed:

a. Bored-cast-in-situ multiple pile groups shall be adopted.
b. Minimum 1.2m diameter bored cast-in-situ vertical piles in soil/rock.
c. Minimum number of piles in each pile cap shall not be less than 4.
d. Distribution of reactions from pier in pile shall be calculated using Rivet theory.

9.2.13 The special precaution in pile construction shall be maintained for the period between the completion of pile bore excavation and the placement of concrete should not be greater than 6 hours, it must be as short as possible.

9.2.14 In case of underground water accumulated at the bottom of the hole, then it shall be bailed out using suitable means such as pumps to dry out the base of the hole prior to concrete. If this issue cannot be solved and the water cannot be taken out completely, then it shall be advised to use underwater concreting to tackle such problem.

9.3 **PILE CAPS**

9.3.1 Pile Cap Tolerances shall be as per relevant IS codes.

9.3.2 Pile caps shall be of reinforced concrete. A minimum offset of 250mm 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 80mm thickness of concrete shall be poured.

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.

9.3.3 The top portion of a pile shall be shipped off to a natural horizontal plane until sound concrete is achieved. 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 50mm into the pile cap. Concreting of the pile cap shall be carried out in dry conditions. All the operations and tools required for making the pile in dry condition is included in the item.

9.4 **PILE LOAD TESTING**

9.4.1 Prior to start of any Pile activities, Pile Method Statement, plans, procedure, design, code provision, soil parameters, rock parameters, machinery to be used including Pile Rig,Rock Penetration rate, Type of Piles etc., shall be submitted to Engineer's approval.

9.4.2 Pile Load Tests (PLT) shall be performed safely and according to IS: 2911 (Part IV). The Contractor shall submit to the Engineer for review their proposed Pile Test Schedule and Methodology. On completion of each PLT the Contractor shall submit the findings to the Engineer. The Contractor shall notify the Engineer at least 48 hours before commencement of the test and shall provide all the facilities to the Engineer for witnessing the test. All equipment used for PLT shall be calibrated by NABL accredited laboratory.

9.4.3 The PLT shall be carried out by either the gravity method, Anchor method or bidirectional method with reference to the relevant IS code and standard practice.

9.4.4 The Contractor shall identify and propose to the Engineer the location of the test pile for each station for approval. The PLT is to be performed for each diameter of pile and each rated pile design capacity of pile being used for each station. The initial test pile shall not be carried out on a working pile.

9.4.5 The Contractor shall undertake routine load tests on working piles and shall submit the methodology before carrying out the tests.

9.4.6 The initial PLT's shall be undertaken well in advance of working piles being installed. No working pile shall be commenced until the initial PLT's have been completed and approved.

9.4.7 On completion of each PLT the Contractor shall submit to the Engineer a report of the test.

9.5 **PILE INTEGRITY TESTING**

9.5.1 Low Strain Integrity Testing shall be carried out as per IS: 14893 on all the piles installed.

9.5.2 All piles shall be provided with tubes for Ultrasonic Cross-hole Testing. Cross-hole Sonic Integrity testing of Piles shall be carried out as per ASTM: D6760-08 on 25% of Piles, as directed by the Engineer.

9.5.3 All tests shall be conducted on concrete with a minimum age of 15 days.

9.5.4 The Contractor shall submit to the Engineer for review a method statement confirming their proposed methodology, materials, equipment and personnel.

9.5.5 All tubes installed for Sonic Testing shall be filled with cement grout before casting of pile cap.

9.6 **RECORDS**

9.6.1 The following records shall be maintained and kept for each pile and such records shall be available for inspection by the Engineer.

a. Name of work
b. Pile number 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 pile concreting;
g. A log of soil type encountered from start to finish of excavation;
h. Volume of concrete used and time of any interruptions in concrete supply where these exceed 15 minutes. Volumes of normal and lean mix concrete;
i. Cut-off level of concrete below top of pile level;
j. Concrete test cubes, water/cement ratio, slump markings, date and results obtained on testing;
k. Details of reinforcement and cage type;
l. A graph of theoretical versus placed concrete volume by depth.

9.7 **OPEN FOUNDATIONS**

9.7.1 Open foundations refer to those foundations constructed by carrying out excavation up to the founding level. When suitable founding strata is available at nominal depth open foundations may be adopted. The type of foundation shall be selected depending upon loading conditions and soil characteristics.

9.7.2 The open foundations shall be with isolated or raft footing depending on load and soil bearing capacity.

9.7.3 The various activities such as, excavations, back filling, reinforcement, concrete, formwork etc, shall comply with relevant clauses mentioned in thisSection.

One plate load test shall be carried out to ascertain the bearing capacity of the foundation bottom each station/area where the open foundations are proposed. Geo mapping to confirm the bearing capacity shall be carried out to all open foundation level by third party/experienced geologist.

9.8 **PILE FOUNDATION**

9.8.1 **General**

a. Piling plant and Methods:

Suggested method for piling is cast in situ-bored piles with hydraulic drilling rigs using partial depth casing with polymer and oscillator arrangement.

i. Not less than 2 weeks before any piling work is commenced the Contractor shall submit to the Engineer for approval full details of his proposed piling plant and detailed method statements for carrying out the Works.

ii. The Contractor shall not commence any piling until the plant and methods which he proposes to use have been approved by the Engineer, but such approval 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 which have been approved by the Engineer, he shall not make any such change without having first obtained the Engineer approval thereof.

iii. List and nos. of equipment's& accessories proposed to be used for the present job shall be submitted along with the technical bid.
Details of casings and concreting methods in respect of bored cast in place concrete piles are to be provided.

b. Records:
The Contractor shall keep complete records of all data 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 noon of the next working day after installation of the piles.

c. Programme and Progress Report:
i. The Contractor shall inform the Engineer each day of the programme of piling for the following day and shall give adequate notice of his intention to work outside normal hours and at weekends, where approved.
ii. The Contractor shall submit to the Engineer on the first day of each week, or on such other date as the Engineer may decide, a progress report showing the rate of progress to that date and progress during the previous week or period of all main items of piling works, as required by the Engineer.

d. Setting Out:
i. The Contractor shall establish and maintain permanent datum level points, base lines and grid lines to the satisfaction of the Engineer and shall set out with a suitable identifiable pin or marker the position of each pile. The setting out of each pile shall be agreed with the Engineer at least 8 working hours prior to commencing work on a pile and adequate notice for checking shall be given by the Contractor.
ii. Notwithstanding such checking and agreement, the Contractor shall be responsible for the correct and proper setting out of the piles and for the correctness of the positions, levels, dimensions, and alignment of the piles.

e. After all piles are cast and weak concrete is chipped out the Contractor shall submit the drawing showing the exact location of piles with respect to the column centre line.

f. Disturbances and Noise:
i. The Contractor shall carry out the piling work in such a manner and at such times as to minimise noise and disturbance.
ii. The Contractor shall take precautions adequate enough to avoid damage to existing services and adjacent structures. IS: 2974 (Part 1) – 1982 may be used as a guide for studying qualitatively the effect of vibration of persons and structures. In case of deep excavation adjacent to piles, proper shoring or other suitable arrangement shall be done to guard against the lateral movement of soil stratum or releasing the confining soil stress. Any such damage shall be repaired by the contractor to the satisfaction of the Engineer.
iii. The Contractor shall ensure that damage does not occur to complete piling works and shall submit to the Engineer for approval his proposed sequence and timing for driving or boring piles having regard to the avoidance of damage to adjacent piles.

g. Obstructions:
If during the execution of the Works the Contractor encounters obstructions in the ground, he shall forthwith notify the Engineer, accordingly, submit to him details of proposed methods for

overcoming the obstruction and proceed according to the Engineer instructions.

9.8.2 **Scope of Work:**

a. These specifications cover the works of providing pile foundations. Work included consists of all necessary services and furnishing of all labour material, tools, equipment and related items for the full and satisfactory performance of the contract, conforming to these specifications and as shown in the Contract Drawings or reasonably implied therein or any authorised conditions or alterations thereof.

b. The tenderer is advised to visit the site and familiarise himself with the conditions at site. The Engineer shall not be held responsible for the accuracy of the soil data, furnished in good faith with the tender.

c. The construction of piles shall be in accordance with the following Indian Standard Codes of Practice for Design and Construction of Pile Foundations:IS : 2911 (Part 1/ Section 2) : 2010 Bored Cast in-situ Concrete Piles Or IRC:78 Standard specifications and code of practice for road bridges Foundation And Substructure

b. With the tender the Contractor shall submit the detailed method of construction to be used. For cast-in-situ concrete piles the Contractor shall indicate the methods he proposes to concrete the piles in order to prevent necking of piles.

a. The items of work will generally be as follows:

i. Boring/drilling including provision of temporary casing.
ii. Supplying, fabrication, and placement of all reinforcing bars.
ii. Casting of concrete piles as per specifications.
iii. Load testing of piles.

9.8.3 **Materials:**

a. General:

Unless otherwise specified in this section all materials shall conform to the requirements specified in separate sections for Concrete, Formwork and Reinforcement.

b. Cement :

The cement to be used for piling and all foundation work shall be conforming to following Indian Standard Specifications:

If the soil and ground water conditions are found satisfactory on chemical testing in labs, Portland Slag Cement conforming to IS 455 shall be used in all foundations (including pile cap, open foundations, etc)

Cement shall be free from lumps and caking.

i. Concrete Mix Design :

The minimum grade of concrete shall be M35. The maximum size of coarse aggregate shall not exceed 20mm. For cast-in-situ piles concrete with a slump of 150 to 175mm (consistent with the method of concreting) will be required. For slumps more than 150mm the workability should be tested by “determination of flow” as per IS:9103. Minimum cementitious contents for design mix shall not be less than 400 kg/m3 of concrete in piling. For piling quantity of cement shall be as per the design mix or the minimum cementitious content whichever is greater shall be used.

ii. The contractor shall submit mix design calculations and get the same approved by the engineer well before the starting of installation of piles and carry out adequate numbers of tests to ensure the minimum specified strength as indicated in drawings.

iii. Concrete cube tests :

Concrete cubes shall be cast, tested and evaluated as specified in Section 3.

c. Reinforcement:

i. The reinforcement shall conform to the requirements specified in Section 5 extending for the full length of the pile and shall project above the cut off level as specified in the drawing. Only circular concrete cover blocks (of at least same grade as of the pile)

threaded on to the outermost reinforcement shall be used for ensuring the specified cover.

ii. Joints in main longitudinal bars will be permitted only where, in the opinion of the Engineer, each bar cannot be 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 extra links or stirrups and staggered in position from those of adjacent longitudinal bars, all to the approval of the Engineer.

iii. All main longitudinal bars shall be tack weld at lapping if any and to the pile cap reinforcement. The last one circle of helical stirrups at each end shall be welded to main longitudinal bars.

d. Casings and Tremie Pipes :

The casings and tremie pipes shall be in mild steel. The temporary casing plates and permanent liners shall have adequate wall thickness and strength to withstand driving stresses, stresses due to soil pressure, etc. without damage or distortion. All joints shall be watertight. The internal diameter of the casing shall not be less than the nominal diameter of pile.

9.8.4 **Cast In-Situ Bored Piles:**

a. General:

i. Diameters of the piles shall be the concrete shaft diameters and shall not be less than the diameters specified in the drawing.

ii. These shall be formed by boring to the founding strata specified on the drawings or as directed at site. The sides of the boring shall be prevented from collapsing by one of the following:

iii. permanent mild steel liner (cased pile)

iv. removable mild steel casing (uncased pile)

v. Piles shall be constructed in a sequence approved by the Engineer. During boring, the Contractor shall, where required by the Engineer, take soil, rock or ground water samples and transport them to an approved testing laboratory or carry out soil tests as directed.

vi. The method adopted shall be chosen giving due consideration to the subsoil data, ground water conditions and to the other relevant conditions at site as well as to the presence of adjacent structures.

vii. The bottom of the steel lining shall be sufficiently in advance of the boring tool so as to prevent settlement of outside soil and formation of cavities.

viii. Removable mild steel casings shall be used only with extreme caution. Individual casings shall be joined together by screwing or any other approved method and not by direct butting with external lug connections. The inner surface of casings shall be smooth and free of all internal projections.

b. Boring :

i. Boring shall be done using hydraulic drilling rigs with oscillator arrangement suiting to different kinds of strata encountered.

ii. As a general guideline, size of cutting tool shall in no case be less than the diameter of the pile minus 75mm. However, the size of cutting tool shall be chosen by contractor depending on the type of substrata and equipment employed by contractor so that executable pile shall not have diameter less than nominal diameter of pile as specified in drawing. The contractor shall also ensure that there is no reduction in poured concrete quantities. These calculations shall be based on consumption of concrete poured in bore (as recorded in pour log) and actual concrete required in bore on theoretical basis i.e. based on nominal diameter of pile and actual bore hole length (based on actual sounding of founding level). Although 5% reduction in consumption

of poured concrete quantities in pile may be rejected. In general piling shall be done by using hydraulic rig with temporary liner. Use of liner for top 4 to 6 metres from ground level or more depth, to protect loose soil falling in bore hole as directed by engineer, is essential. No extra payment shall be made to the contractor for using temporary liner, over the item of piling as in BOQ.

iii. Polymer Slurry as approved by Engineer-in-Charge shall only be used. Use of bentonite slurry is strictly prohibited. The polymer slurry shall conform to the following specifications:

Acceptable Range of Values for Polymer Slurry

Property	In Hole atTime of TestConcreting	Method
Density (1) pounds per cubic foot (kilograms per cubic meter)	64 max. (1025 max.)	Density balance API 13B-1(2), Section 1
Viscosity Seconds per quart (Seconds per litre)	32-135 (34-143)	Marsh Funnel AP 13B-1(2), Section 2.2
pH	8-11	pH paper or meter
Sand content%	1.0 max.	API 13B-1(2), Section 5

- Density values shown are for fresh water. Increase density values by 2 pounds per cubic foot (23 kilograms per cubic meter) for salt water. Perform tests when slurry temperature is above 40□F (4.5□C).
- American Petroleum Institute, API 13B-1, Recommended Practice for Field Testing Water-based Drilling Fluids.

c. Concreting:

i. Prolonged delays in the commencement of concreting after the completion of the boring shall not be permitted. The time interval between the completion of boring and placing of concrete shall not exceed 6 hours. Measures to prevent collapse of bore shall continue to be in force during the gap between boring completion and concreting. The depth of bore shall be ensured before start of concreting.

- The concrete shall have a minimum slump of 150mm and maximum 175 mm in case of concreting in a water-free bore. Suitable precautions shall be taken for prevention of segregation. Internal vibrators shall not be used unless the Contractor is satisfied that segregation will not result because of vibration and unless the method of use has been approved by the Engineer.
- The concrete for piles underwater or in drilling mud shall be placed with a tremie pipe. The tremie pipe shall not be less than 200mm diameter for 20mm aggregate. The joint between the hopper and tremie pipe as well as the joints in the tremie pipe shall be watertight and the tremie pipes shall be thoroughly cleaned after each use. The concrete shall have a minimum slump of 150mm and maximum 175 mm.
- It is essential that the water level within the pile bore be in equilibrium before commencement of concreting.
- The Contractor shall ensure that heavily contaminated drilling mud has not accumulated at the base of boring since this could impair free flow of concrete from the tremie pipe.
- If the specific gravity of the drilling mud at the base of the bore exceeds 1.20 the placing of concrete shall not proceed.
- The first charge of concrete shall be placed in the hopper over a sliding plate of the bottom of the hopper. The charge should be adequate in volume to ensure flushing action to prevent mixing of water or drilling mud and concrete. Alternatively, floating plugs of approved specification may be used before the first charge of concrete.

- The tremie pipe shall at all times penetrate the previously placed concrete with adequate margin against accidental withdrawal. The tremie pipe shall not be withdrawn until the completion of concreting. At all times a sufficient quantity of concrete shall be maintained within the pipe to ensure that the pressure from it exceeds that from the seepage water.
- Spot measurements shall be taken at suitable intervals to check that the tremie pipe has an adequate penetration into previous concrete.
- Concreting of the pile shall be in one single and continuous operation. In case of long piles of large diameter, large size mixers or more mixers shall be used so that the entire concreting operation is completed in not more than two hours.
- The top of concrete in a pile shall be brought above the cut-off level since the top concrete is loose and is weak because of contamination with water/drilling mud. This ensures good concrete at the cut-off level.
- Cut off level (COL)

  Cut off level of piles (150mm inside the pile cap) shall be indicated in working drawings or as indicated by Engineer.

  The top of concrete in pile shall be brought above the cut off level to remove all laitance & weak concrete and to ensure good concrete at cut off level.

  As general guidelines, for cut off level up to 1.5m below working level, the concrete shall be cast of 300mm above COL. For each additional 0.3m increase in depth of COL an additional coverage of 50mm shall be required. In the circumstance where COL is below ground water level, the need to maintain a pressure should be observed & accordingly length of extra concrete above COL shall be determined by the Contractor and approval of Engineer obtained before concreting.

  In case of concrete being placed by tremie method and pile cut off level less than 1.0meter below the ground level, concrete shall be cast to the piling platform level to permit overflow of concrete for visual inspection. In case COL of pile is more than 1.0 meter below working level then concrete shall be cast to a minimum of one meter above COL. Before concreting contractor shall obtain the approval of the Engineer of the height above COL up to which the concrete is to cast.

  Any defective concrete in the head of the completed pile shall be cut away and made good with new concrete.
- When a casing is being extracted a sufficient quantity of concrete shall be maintained within the bore to ensure the pressure from external ground water and soil is adequately exceeded by the pressure of concrete. Otherwise necking of the pile may result. A minimum embedment of 1.5 to 1.8 m is required.
- No concreting shall be placed in the bore once the bottom of the casing has been lifted above the top of concrete.
- After each pile has been cast any empty bore shall be protected and carefully backfilled as soon as possible with approved materials.
- Complete boring and concreting records shall be submitted to the Engineer for each pile. The records shall include the duration of concreting, tremie lengths (individual and cumulative), tremie pipe lengths removed, theoretical sounding, actual sounding, actual lengths of pile concreted, and the volume of concrete placed, cut off level, founding levels etc. For piles with temporary casings, records of sequence of casing withdrawal and levels of concrete before and after withdrawal shall also be included in the reports. Data about used polymer slurry shall also be placed on record.

9.8.5 **Alignment of Piles:**

a. Piles shall be installed as accurately as possible according to the drawings either vertically or to the specified batter. All deviations will be measured at the cut off level of the piles. The deviation from the true axis shall not be more than 1.5% for vertical piles and 4% for rake

piles. Piles should not deviate in location by more than 75mm when used in groups. For single or 2 piles used under columns, deviation shall not be more than 50mm.

b. The Contractor shall maintain a record of actual pile locations in the form of drawing and submit the information to the Engineer at suitable intervals.

9.8.6 **Pile Caps**

a. Pile Cap Tolerances shall be as per relevant IS codes.

b. Pile caps shall be of reinforced concrete. A minimum offset of 250mm 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 80mm thickness of concrete shall be poured.

c. 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.

d. The top portion of a pile shall be shipped off to a natural horizontal plane until sound concrete is achieved. 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 50mm into the pile cap. Concreting of the pile cap shall be carried out in dry conditions. All the operations and tools required for making the pile in dry condition is included in the item.

e. The road surface after casting of pile cap should be repaired immediately. If the surface is not repaired immediately, penalty will be imposed as decided by the Engineer.

9.8.7 Testing of Piles:

a. The load tests shall be in accordance with the Indian Standard Code of Practice for Design and Construction of Pile Foundations IS 2911 (Part IV) Load Tests on Piles. For initial load test, test load will be 2.5 times the theoretical designed capacity of pile. For initial load, test arrangement to be designed shall also cater for additional 25% above test load and nothing extra will be paid on this account. Permissible stresses in test arrangement (steel truss or plate girder) to cater for test load plus additional 25% load shall be within permissible stresses as per IS: 800 (as for permanent structure). For test frame, steel of Grade –B conforming to IS: 2062 shall be used.

b. Engineer will decide the locations of initial and routine horizontal and vertical load test. One no. Initial load test is to be performed in each km for each diameter of pile being used in Stations. The contractor shall undertake test piles required for initial pile load test in the initial stages of work using the same methodology and equipment's which will be subsequently used for working piles. These tests shall be undertaken well in advance of working pile. No working pile would be allowed to undertake till initial satisfactory initial pile load tests have been completed.

c. Non-granting of permission for pile/ pile cap by Engineer in such respect will not be considered as reason for delay or any claim thereof. The test arrangement to be employed shall be of nature which is quick to install and remove and easily transferable. At every one KM of Station initial load test both vertical and horizontal are to be performed by the contractor for each type of pile. Also, one initial load test both vertical and horizontal per station are to be performed by the contractorfor each type of pile.

d. Routine horizontal & vertical load tests are performed as à check on the load carrying capacity and settlements of the pile foundations. At least one routine test shall be performed for every 100 piles. The number of tests may be increased up to 2% in particular cases depending upon the nature, type of structure and sub-strata condition.

e. The Contractor shall give the Engineer at least 48 hours notice of the commencement of

construction of these piles which are to be subjected to Initial Tests.

f. The load tests shall not normally be conducted unless the concrete is at least 28 days old. However, in special circumstances, permission can be given by Engineer for prior testing.

g. All testing shall be done under the direction of experienced personnel conversant with the equipment and the testing procedure.

h. Before the commencement of the tests all the particulars regarding the test pile including boring data and concrete cube strengths shall be made available at site and shall form a part of the test report.

i. On completion of each load test the Contractor shall submit a report of the load test which shall include the following information.

i. Description of soil conditions, ground water table, actual boring and installation records, concrete cube test results.
ii. Method of load application
iii. Load settlement readings during loading and unloading
iv. Time load-settlement curve
v. All other observation relevant to the test being conducted.

j. Integrity test

Two types of pile integrity tests will be performed:

i. Dynamic Integrity Test:

The Dynamic Integrity test using pile driving analyser or approved equivalent for pile integrity shall be performed on all the piles. The top of the pile shall be made accessible, chipped off up to hard concrete, levelled by trimming it back as far as practicable. The reinforcing bars of the piles tested shall be bent sideways. The test shall be performed after removal of bad/ weak concrete at top so that the wave propagation is steady through hard concrete. The test shall becarried out at minimum 3 locations on each pile in such a way that the entire cross section of the pile is evenly covered. The test shall be conducted with a minimum age of concrete of 15 days. A specialist approved agency shall be employed for the test and the tests shall generally be as per recommendations of the agency unless directed by the Engineer. A complete report indicating the graphical display of wave propagation under each flow shall be submitted along with interpretation of results showing discontinuities, cross-sectional changes or material changes if any are to be co-related with Site data.

ii. Cross Sonic Logging Test

'Cross Sonic Logging' test should be conducted to verify the structural integrity of piles by means of the measurement of the time travel of a sound waveform an emitter to a receiver through the concrete of a pile. The emitter and the receiver shall generally be at the same level. Cross-hole Sonic logging testing is compulsory for 25% of piles with 100% of piles installed with recess tubes and equipped for testing. The Engineer in Chief from client will randomly select and conduct tests of 25% of piles (one in each pile group).

iii. Sonic Logging Tubes

Material

Every pile must be provided with sonic logging tubes cast into it. The tubes shall be manufactured from steel of 50mm ID and 1mm thick. The tubes assembly should be manufactured in a factory which is ISO 9001.2008 (or higher revision) certified. To form single tube the pipes to be connected with an enlarged end Bell Mouth – push fit arrangement provided with rubber gasket only. The bell mouth should have serrations so as to ensure the proper engagement of joint and avoid any leakages. The bell mouth connection should be provided strictly with rubber gasket to ensure a concrete-tight joint to maintain the tube integrity and prevent entry of foreign material. PVC or any kind of plastic material is strictly prohibited as it cannot resist great compression pressure. The expansion factor between PVC and concrete is

not the same (unlike steel and concrete). When the concrete is setting, its temperature goes up and leads to the expansion of the PVC. Once the concrete has set and the temperature goes back to normal there will be a void between the tube and the concrete: this will lead to bad reading of the test and the rejection of the pile. One tube in each pile should be installed of internal diameter 50mm in order to allow for coring of the concrete at the base of the pile.

Tests to be conducted for Sonic Tubes assembly and desired results

The entire lot supplied to site should be batch-tested for following test with pressure test conducted on 100% of sonic tubes. The supplier should have in-house testing facility so as to ensure 100% pressure test and batch-test is conducted on sonic tubes before supply to site. The Sonic Tubes assembly should be tested for following tests -

1. External Pressure Test –

The 50 mm diameter, 1 mm thickness should be applied with external pressure upto 5 Mpa. Following are the desired results –

Description	Pressure in Mpa	Hold Time	Desired Results
Sonic Tubes Diameter 50 mm X 1.0 mm Thick	>= 5 Mpa	>= 60 Sec	No Leakages from Inner Surface of Tubes and No Distortion of Tubes

100% sonic tubes to be tested prior despatch

2. Pull Out Test for Tubes-

Description	Tensile Force to be applied	Desired Results
Sonic Tubes Diameter 50 mm X 1.0 mm Thick	>= 0.5 KN	No Distortion found and should withstand the test load of >=0.5 KN

Minimum 3 samples to be tested of the lot being despatched.

3. Pull Out Test for tubes 'Fixing Ears'

Description	Tensile Force to be applied	Desired Results
Sonic Tubes Diameter 50 mm X 1.0 mm Thick	>= 0.5 KN	No Distortion found and should withstand the test load of >=0.5 KN

Minimum 3 samples to be tested of the lot being despatched.

4. Crush Test –

For 50 mm diameter and 1 mm tick Tube following is the criteria for Crush test

S. No.	Description	Tests	Desired Results
1	Direction Tube	1500 mm	1. No Crack 2. After test 30mm steel ball can go through the tubes.
2	Drop Weight	4000 (+ 150g and -0g)	
3	Diameter of Drop	50.03 mm	

Minimum 3 samples to be tested of the lot being despatched.

Installation

The agency supplying sonic tubes should submit a detailed installation methodology and conduct a demo for one pile before being implemented for all piles.

Frequency

Four tubes shall be required for each pile, any other configuration is not allowed.

a. Sonic Coring

At least 7 days after the pile has been cast, but before carrying out any sonic logging test, a core of concrete and soil or rock from the founding material shall be taken. The core shall be taken from the base of the 50mm diameter sonic logging tube. The core shall be kept in a suitable wooden box with

depths clearly recorded on rigid markers, shall be photographed along with a scale and colour chart. Thereafter, these shall be delivered to a core store designated by the Engineer. The scanning of the pile toe for its integrity by measuring the propagation time of transmitted waves between the vertical tubes and the pile toe/ founding strata shall also be carried out.

b. Sonic Logging Equipment

The equipment shall be properly maintained and calibrated. Where necessary, means shall be provided to centralise the probes within the tubes, so that variation in the separation of the emitter and receiver resulting from clearance between the probes and the tubes does not occur.

c. Test Procedure

The tubes shall be filled with water. The tests shall be repeated for each pair of tubes, i.e. three runs for a pile with three tubes and six runs for a pile with four tubes.

d. Analysis of Test Results

A report shall be prepared for each pile tested. The photographic record of the oscilloscope displays shall be analysed in detail. Any deviation from the record to be expected from a pile constructed entirely of sound concrete and without defect shall be reported. The report shall indicate the nature, location and severity of the defect and recommendations shall be made for further testing. The implication of the existence of the defect on the performance of the pile shall be evaluated.

e. Submission of Results

Immediately after testing, a signed copy of all the raw test data of a pile shall be given to the Engineer. A test report shall be submitted to the Engineer within 7 days after testing.

f. Anomalous Sonic Logging Test Results

The piles with anomalous sonic logging results shall be rejected at the Engineer discretion unless the Contractor is able to demonstrate that the pile integrity is acceptable through proof coring.

g. Grouting of Pile after Testing

Upon completion of sonic logging test, the access tubes and sonic coring holes, if any, shall be grouted up.

9.9 SHALLOW FOUNDATION

9.9.1 Description

The work shall cover furnishing and providing plain or reinforced concrete foundation placed in open excavation, in accordance with the drawings and as per MORTH Specifications or as directed by the Engineer.

9.9.2 Materials

Materials shall conform to Section 1000 of MORTH Specifications.

9.9.3 General

A method statement indicating the following shall be submitted by the Contractor for approval of the Engineer, well in advance of the commencement of construction 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. Quality Management System to be adopted including Quality Manual
viii. Any other relevant information

Details of necessary arrangements for execution under water wherever necessary, shall be included in the method statement.

Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent benchmark so that the foundations are located correctly and in accordance with the drawings.

Formwork, steel reinforcement and structural concrete for open foundations shall conform to Sections 1500, 1600 and 1700 respectively of MORTH Specifications.

9.9.4 Workmanship

9.9.4.1 Preparation of Foundations

Excavation for laying the foundation shall be carried out in accordance with Section 300 of MORTH Specifications. The last 300 mm of excavation shall be done just before laying of lean concrete below foundation. Excavation shall be made only to the exact depth as shown on the drawing. 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 M10 concrete in case of foundation resting on soil and with concrete of the same grade as that of the foundation, in case of foundation resting on rock. This shall be done at the cost of the Contractor and shall be considered as incidental to the work.

Open foundations shall be constructed in dry conditions and the Contractor shall provide for adequate dewatering arrangements, wherever required, to the satisfaction of the Engineer.

Where light blasting is required for excavation in rock or other hard strata, the same shall be carried out in accordance with Clause 302 of MORTH Specifications. Where blasting is likely to endanger adjacent foundations or other structures, controlled blasting with all necessary precautions shall be resorted to.

9.9.4.2 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.

9.9.4.3 Construction

a. Excavation for open foundations shall be carried out in accordance with Section 300 of MORTH Specifications. For guidance regarding safety precautions to be taken, IS: 3764 may be referred.
b. For foundation resting on soil, a layer of M10 concrete of minimum thickness 100 mm shall be provided above the natural ground to provide an even surface to support the foundation concrete. 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 part of the surface has become muddy due to over-wetting, the same shall be removed. If required, the M10 concrete may be laid to a thickness of more than 100 mm, as per the direction of the Engineer. No construction joint shall be provided in the lean concrete. For foundations resting on rock, the rock surface shall be cleaned of any lose material and then levelled with a layer of concrete of the same grade as that of the foundation, so as to provide an even surface.
c. 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 on 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 3 metres centre-to-centre in each direction, subject to a minimum of nine levels on the surface.
d. No formwork is necessary for the lean concrete layer. Side formwork shall be used for foundation concrete Work. 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 of freshly placed concrete down the slope. 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.
e. 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 up to the location of construction joint shown on the drawing or as directed by the Engineer.
f. 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 1700 of MORTH Specifications. Formwork shall not be removed 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 100 mm thickness of loose moistened sand free from clods or gravel, over the concrete. The sand shall be kept continuously moist for a period of 7 days. Before backfilling is commenced, the loose sand shall be removed and disposed of as directed by the Engineer.

g. Normally, open foundations shall be laid dry. Where dewatering is necessary for laying of concrete, it shall be carried out adopting anyone of the following methods or any other method, approved by the Engineer:

   i. A pit or trench of suitable size, deeper than the founding level as necessary, is dug beyond the foundation excavation so that the water flows into it and the excavated surface at founding level is fully drained.
   ii. Water table is depressed by well point system or other methods.
   iii. Steel/concrete caissons or sheet piling are used for creating an enclosure for the foundations, which can subsequently be dewatered. No pumping of water shall be permitted from the time of placing of concrete up to 24 hours after placement.

h. In situations where foundations cannot be laid dry or where percolation is too heavy to keep foundation strata dry, concrete may be laid under water only by tremie. In case of flowing water or artesian spring, the flow shall be stopped or reduced to the feasible extent at the time of placing the concrete.

i. Where blasting is required, it shall be carried out in accordance with Section 300 of MORTH Specifications, observing all precautions indicated therein. 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.

j. All spaces excavated and not occupied by the foundations or other permanent works shall be refilled with earth up to surface of surrounding ground with sufficient allowance for settlement. All backfill shall be thoroughly compacted and in general, its top surface shall be neatly graded. Backfilling shall be in accordance with Section 300 of MORTH Specifications.

k. In case of excavation in rock, the annular space around the footing shall be filled with M15 concrete up to the level of top of rock. Filling with M 15 concrete shall also be carried out for excavations having depth up to 1.5 m in ordinary rock or 0.6 m in hard rock. In case, the excavations are even deeper so as to require further filling up to the level of top of rock, the same shall be done by boulders grouted with cement.

l. Protective works, where provided shall be completed before the onset of floods so as to avoid the risk of the foundation getting undermined.

9.9.4.4 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

9.9.4.5 Tolerances

a. Variation in dimensions : +50 mm, -10 mm
b. Misplacement from specified position in plan : 15mm
c. Surface unevenness measured with 3 m straight edge : 5mm

d. Variation of levels at the top : ±25 mm

10. ANCHORING, BRACINGS, NAILS & BOLTS

10.1 GENERAL

10.1.1 This section specifies the materials and workmanship required for anchoring, bracings, soil nails and rock bolts. The design and installation of this work shall be in accordance with the Employer's Requirements.

10.1.2 This section specifies materials and workmanship requirements for pre-stressed anchoring, bracings, soil nails and rock bolts. The design and installation shall be in accordance with the relevant IS/IRS & International codes. The minimum requirements of anchoring, bracings, nails and bolts are that they support the structures or soil into which they are fixed to and are fit for their purpose as described in the Contract.

10.1.3 Anchoring includes soil nails and rock bolts

10.1.4 Method statements of anchoring, bracings, nails and bolts shall be submitted to the Engineer for review. This detailed method statement shall include as a minimum;

a. Installation method and Contractor's Equipment used;
b. Materials, samples and supplier data;
c. Design calculations;
d. Testing regime and acceptance criteria;
e. Method of working for specific Site conditions.

10.1.5 Temporary anchors shall have a minimum design life of 10 years.

10.1.6 All steel components for bracings shall be in accordance with the relevant IS & International codes.

10.1.7 All concrete components for bracings shall be in accordance with the relevant IS & International codes.

10.1.8 All metal components of all anchors, rock bolts and soil nails, shall conform to the standard specification.

10.1.9 Anchoring shall be executed according to the guideline and specifications of the manufacturer and/or supplier.

10.1.10 Anchoring shall avoid damage to all existing buildings, structures and utilities.

10.1.11 In the event temporary anchors are required to be placed under adjacent land or property the approval of the stakeholder shall be obtained. If the stakeholder requires the temporary anchors to be removed on completion of the Works this shall be carried out.

10.1.12 The Contractor shall test all anchors according to the relevant IS & International codes.

10.1.13 Anchors shall be protected against corrosion during service life.

10.1.14 The tolerances for anchoring shall be in accordance with the relevant IS & International codes.

10.1.15 All bracing shall be installed so that the waterproofing will not be damaged.

11. GROUND IMPROVEMENT

11.1 GENERAL

11.1.1 This section specifies the materials and workmanship required for ground improvement. The design and installation of this work shall be in accordance with the Employer's Requirements and in accordance of Clause 314 of MORTH Specifications.

11.1.2 Ground improvement may be required in order to improve stability of the excavation faces and/or walls, reduce ground subsidence due to excavations and its potential adverse effects on surface structures and utilities, reduce the ingress of groundwater in the tunnel, improve the foundation soil of buildings and generally any other related to excavation operations for the needs of the Contract.

11.1.3 Based on the provisions herein, a detailed specification and method statement shall be submitted for any ground improvement Works to the Engineer for consent. Ground improvement Works may include, but are not limited to:

a. Permeation and compaction grouting;

b. Soil stabilization injections of all kinds (cement grout, chemicals etc.);
c. Jet grouting;
d. Compensation grouting;
e. Ground freezing.

11.1.4 The Contractor's ground improvement detailed specification and method statement shall include, but not be limited to:

a. Soil grading and stratification;
b. Pour water pressures and drain characteristics;
c. Excavation dimensions;
d. Time period beyond which the excavation may remain open;
e. The size of any open-cut excavations for station pier foundations;
f. Full calculations;
g. A detailed description of the proposed instrumentation plan and program for the monitoring and controlling of the soil improvement works during the ground treatment;
h. One or more test programs for the examination and confirmation of the implementation likelihood and suitability of the method;
i. Provision for constant validation of the methodology, verified by in situ testing, confirming that the required ground improvement has been achieved during its implementation.

12. STRUCTURAL CONCRETE

12.1 GENERAL

12.1.1 This work shall consist of the construction of all or portions of structures with Portland cement concrete, of the required class or classes, with or without reinforcement, and with or without admixture. Constructed in accordance with standard specifications, also satisfies the lines, levels, grades and dimensions shown on the Drawings having consent of the Engineer.

12.1.2 Constituent materials for concrete shall, except where otherwise described in the Contract shall comply with the requirements of IS:456.

12.1.3 For high performance concrete the product shall conform to IRC SP70.

12.2 CEMENT

12.2.1 Cement shall comply with the requirements confirmed with IS 456.

12.2.2 Prior to commencing any concrete work, the Contractor shall obtain the Engineer's consent to proposed types and sources of cement.

12.2.3 Unless otherwise described in the Contract, Ordinary Portland cement shall conform to the IS 456.

12.2.4 If soil has soluble salts sulphate resistant cement shall be used conforming to IS:12330.

12.2.5 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 certificate to affirm that the cement complies with the relevant standard.

12.2.6 Before ordering cement, the Contractor shall submit details of the proposed supplier and information on the proposed methods of transport, storage and certification for the Engineers consent and show that the quantity and quality required can be attained and maintained throughout the construction period. Representative samples of the proposed cement may be required to be taken and forwarded to an independent laboratory for analysis before the source is approved. If cement is imported, fresh tests as per relevant IS code shall be conducted in an approved laboratory.

12.2.7 Each consignment of cement shall be accompanied by a certificate which shall be submitted to the Engineer immediately after delivery showing the place of manufacture and the results of standard tests carried out by the manufacturer. Additionally, the Contractor may be required to take samples of cement and test such samples in accordance with the relevant or equivalent Indian or other Standard. The Contractor shall store the cement so that separate consignments can be identified

and so that they are used in order of delivery.

12.2.8 In fair faced elements, the cement used in the concrete for any complete element shall be from a single consignment. All cement for exposed concrete shall be from the same approved source and uniform in colour

12.2.9 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 approved coverings.

12.2.10 The Contractor shall provide approved silos to store sufficient bulk cement for continuity of work, and the cement shall be placed therein upon delivery. All necessary precautions shall be taken to prevent cement dust causing a nuisance.

12.2.11 On receipt of written notification regarding Cement that, in the opinion of the Engineer, has been damaged or does not comply with the specification shall not be used in the Works and shall be removed from the Site within 3 days of the Contractor's receipt of such opinion notification.

12.3 **FLY ASH**

Pozzolonic fly ash Grade 1 can be used for all concrete structures except track supporting structures.Minimum/Maximum quantity of fly ash should confirm clause 5.4 of IS:10262.

12.4 **MICRO SILICA**

12.4.1 Micro silica (Silica fume) when used as a mineral admixture in concrete shall conform to IS:15388 to establish specified strengths, durability and to meet special design objectives included in the scope of this outline design specification Quality.

12.4.2 To combat the Alkali Silica Reaction, Micro silica may be used minimum 5% cement and shall not exceed 10% by the weight of cement in order to bind free alkalis early in plastic concrete and to reduce the permeability of concrete to prevent the moisture and external alkalis penetration.

12.5 **AGGREGATE**

12.5.1 Aggregates shall comply with the IS:383.

12.5.2 Prior to commencing any concrete work, the Contractor shall obtain the Engineer's consent to proposed types and sources of aggregate. Sampling of aggregates shall be as per IS:2430.

12.5.3 All aggregates shall be stored in such a way that they shall be kept free from contact with deleterious matter and aggregates of different sizes shall be stored separately and in such a way that segregation is prevented.

12.5.4 All aggregate stockpiles 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 if necessary. All aggregate hoppers shall be painted white.

12.5.5 Water absorption of coarse aggregates shall be as per IS:2386 (Part III).Coarse aggregate for concrete shall be;

a. Coarse aggregate shall be supplied in two separate sizes; either 20 mm and down for structural concrete and or 40 mm and down for lean concrete as called for in the design.

b. All coarse aggregate shall conform to IS:383 and tests for conformity shall be carried out as per IS:2386, Parts I to VIII. The coarse aggregate shall be crushed stone or crushed gravel. Coarse aggregate obtained from crushed or broken stone shall be angular, hard, strong, dense, durable, clean and free from soft, friable, thin plate, elongated or flaky pieces and any deleterious material.

c. Except where it can be shown to the satisfaction of the Engineer that a supply of properly graded aggregate of uniform quality can be maintained over the said period of the works, the grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in correct proportions as and when required. Aggregate shall be stored in such a way as to prevent segregation of sizes and avoid contamination with fines.

d. The maximum size of coarse aggregate shall be such that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of formwork. The grading of coarse aggregate shall be as per relevant IS codes.
e. The Contractor shall establish a grading curve envelop as per relevant IS code for each grade of concrete for the given maximum size of aggregates and this shall be submitted to the Engineer for review before finalising the mix design.
f. Clean, free from dust and other deleterious material.
g. For reinforced and Pre-stressed concrete, it shall be well graded with nominal 20 mm size.

12.5.6 Fine aggregate shall conform to the requirements of IS:383 , and IS:2386 or as required to meet the design requirements.

12.5.7 Fine aggregate shall be river sand crushed stone sand / manufactured sand / suitable combination of both as per IS:383. It shall be free from clay, loam, earth or vegetable matter, salt or other harmful chemical impurities.

12.5.8 Aggregates shall be clean, sharp, strong, angular. material.

12.5.9 If considered necessary by the Engineer, the sand shall be washed in screw type mechanical washers in potable water to remove silt, clay and chlorides. This shall be done at least one day before using it in concrete.

12.5.10 The total acid soluble sulphate content of the concrete mix, expressed as SO3, shall not exceed the recommended limit in IS:456.

12.5.11 The chloride content of aggregates shall be within the recommended limits stated in IS:383 and the chloride content of the concrete mix shall be within the recommended limit of IS:456. Chloride levels shall be determined once in six months/change of source.

Alkali-Silica Reactivity

If aggregates contain any materials which are reactive with alkalis in any of the constituents of the concrete, or in water which will be in contact with the finished work, then the Contractor shall take samples of these materials every week. The Contractor shall ensure that the concrete mix complies with the requirements of this Specification regarding "Minimising risk of alkali-silica reaction in concrete", Vide sub section 3.3.1. The results of the Contractor's weekly monitoring tests shall be submitted in writing to the Engineer-in-charge.

12.5.12 Aggregate shall be stored in masonry or concrete-based bins or on stages to prevent intermixing and the inclusion of dirt and foreign materials. Each size of aggregate shall be stored separately. Washed sand shall be stored on a sloping concrete platform and in such a manner as to avoid contamination. All storage bins shall be emptied and cleaned regularly.

12.6 **WATER**

12.6.1 Water to be used for mixing and curing shall be clean and free from oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel and shall comply with the requirements of IS:456 and Clause 1010 of MORTH Specifications.

12.6.2 The Contractor shall make his own arrangements and obtain consent for the provision of fresh potable water for the manufacture and curing of concrete.

12.6.3 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 Contract. Testing shall be in accordance with IS:3025. Now at er shall be used until tested and found satisfactory. The cost of all such tests shall be borne by the Contractor.

12.6.4 Where a potable mains supply is not available the Contractor shall obtain confirmation of the quality and reliability of the proposed source from the appropriate water authority and shall thereafter seek consent from the Engineer to use the proposed source. Water from other than from a public utility supply shall be sampled at a frequency to be determined by the Engineer and tested in accordance with the relevant provisions of IS:3025.

12.6.5 The sodium oxide and potassium oxide content of the water supply shall be tested and confirmed as equivalent Na_2O and this shall be considered when calculating the total reactive alkali content of the concrete mix. Chloride content in water for RCC shall not exceed 500 mg/litre.

12.7 **ADMIXTURES**

12.7.1 The Engineer's approval shall be obtained prior to using any admixture in any concrete mix and admixture should be as per Clause 1012 of MORTH Specifications. Admixtures containing chlorides or other corrosive agents shall not be used. Admixtures shall conform to IS:9103.

12.7.2 If admixtures are permitted, they shall be used in the correct quantities. Approved 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.

12.7.3 The concrete tests described herein shall be conducted as per IS:9103, with the admixture incorporated to establish that specified strengths are achieved, and that densities are not reduced.

12.7.4 Admixture should be high water reducing agent as per IS:10262 (2019) and confirm IS:9103.

12.7.5 Admixtures and pigments shall comply with the requirements of IS:9103 and IS:6925 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 submitted for Engineer approval.

12.7.6 The chloride content of any admixture used shall not exceed 2 percent by weight of the admixture as determined in accordance with IS:6925 and hall conform to IS:9103. The total chloride and sulphate contents in concrete mix shall not exceed 0.15 and 4.0 percent respectively by weight of cement.

12.7.7 The addition of calcium chloride to concrete containing embedded metal will not be permitted under any circumstances.

12.7.8 The alkali content of admixtures shall be considered when determining the total equivalent alkali content of the concrete mix.

Minimising The Risk of Alkali-Silica reaction (ASR) in Concrete

a) Precautions against ASR in Concrete
Concrete mixes for use in the Permanent Works shall comply with one of the Subsections (b), (c) or (d). The Contractor shall notify the Engineer of his proposals for complying with this requirement.

b) The cementitious material shall have a reactive alkali content not exceeding a maximum value of 0.6% by mass when defined and tested in accordance with Subsections 3.3.1 ((e) to (k) inclusive).

OR

c) The total mass of reactive alkali in the concrete mix shall not exceed 3.0 kg/m3 of concrete when defined, tested and calculated in accordance with Subsections 3.3.1 ((e) to (k) inclusive) and 3.3.1 ((l) to (o) inclusive).

OR

d) The aggregate shall be classed as non-reactive in accordance with the definition in Subsection (n).

e) Cementitious Material (Hydraulic and Latent Hydraulic Binders):

f) 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 (Na2O) calculated from:-
% equivalent Na2O = % acid soluble Na2O + 0.658 x (% acid soluble K2O)

g) 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.

h) The Contractor shall make available the certified average acid soluble alkali content of

Portland cement on a weekly basis.

i) 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 for consent with notification of the change.

j) Minimising the Risk by Using Cementitious material Containing less than 0.6% Reactive Alkali

The requirements of Subsection (b) will be met by Subsection (k) provided that the contribution of alkalis from other sources does not exceed 0.2 kg/m3 (see Subsections (n) and (u)). Where alkalis exceed 0.2 kg/m3 the requirements of Subsections (l) to (o) shall apply.

k) The cementitious material shall be Portland cement complying with Indian Standard 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 Specification.

l) Minimising the Risk by Limiting the Reactive Alkali content of the concrete to 3.0 kg/m3.

The requirements of Subsection (c) will be met provided that Subsections (m), (n) and (o) are satisfied.

m) The reactive alkali content of the concrete contributed by the Portland cement to the concrete shall be calculated from :

Portland cement

A = (C x a)/100

Where,

A = reactive alkali content of the concrete to the nearest 0.1 (kg/m3)

C = target mean Portland cement content of the concrete (kg/m3)

a = certified average acid soluble alkali content of the Portland cement (%).

n) Where reactive alkalis in excess of 0.2kg/m3 are contributed to the concrete from sources other than the cementitious material the limit of 3.0 kg/m3 from the cementitious 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 = 0.76x {(NFxMF)+(NCxMC)}/100 kg/m3

100

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/m3).

The factor 0.76 is obtained from a consideration of the composition of sea 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 approved method. When the chloride ion level is less than 0.01% it shall be regarded as nil.

n) The Contractor shall provide certificates on request confirming compliance with the Specification andstating :

i. The target mean cementitious material content of the concrete.

ii. The names of the works manufacturing the cement.

iii. A weekly report of the cement alkali determinations in accordance with Subsection (f).

iv. The certified average acid soluble alkali content of the Portland cement.

12.8 CONCRETE WORKMANSHIP

12.8.1 Concrete shall be provided in accordance with IS:456, as per Clause 1700 of MORTH Specifications or IRC: SP:70-2016 Guide Lines for The Use of High-Performance Concrete (Including Self Compacting Concrete) except where required otherwise by these Specifications.

12.8.2 The total chloride content of the concrete mix shall be in accordance with the limitations given in IS:456.

12.8.3 The total water-soluble sulphate content of the concrete mix shall not exceed the limitations given in IS:456.

12.8.4 The Designer shall design concrete mixes and confirm as a minimum the following;

a. Type of Mix
b. Grade
c. Type of Cement
d. Type of Aggregate, course & fine, including fine aggregate %
e. Nominal Aggregate maximum size (mm)
f. Minimum cement content (kg/m³)
g. Maximum cement content (kg/m³)
h. Maximum free water/cement ratio
i. Admixtures
j. Air content
k. Maximum temperature at batching
l. Maximum temperature for placement
m. Density
n. Workability, slump (mm) and VB(s)
o. Sampling Rate e.g. 7-day, 28 days

12.9 CONCRETE MIX DESIGN

12.9.1 The Designer shall design concrete mixes by approved standard methods conforming to IS:10262, IS:SP23, IRC 112 and as per Clause 1700 of MORTH Specifications to produce concrete following their design and specifications. Once finalised the Contractor shall submit their proposed mix designs to the Engineer for review and consent.

12.9.2 The maximum water/cement ratio for both reinforced and pre-cast elements shall be as per Table 1700-2 of MORTH Specifications. If the Contractor proposes to vary this, they shall submit their proposal to the Engineer for consent.

12.9.3 The maximum cement content excluding any mineral admixture (Portland Cement Component alone) shall not exceed 450 kg/cum. If contractor use Fly Ash/ Micro Silica etc. then cementitious content shall not exceed 500kg/cum.

12.9.4 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/cementitious content, sufficiently low water-cement ratio, dense packing of fine particles, by ensuring thorough compaction of the concrete, and by timely, and adequate curing.

12.9.5 Additional Specifications for Concrete of Grade M50 and above:

a. Mineral admixture in the form of micro silica or condensed silica fume shall be usedin the design mix. It shall comply with ASTM C 1240 “Specifications for Silica Fume for use in Hydraulic Cement Concrete and Mortar”. It shall be obtained from proven and reliable

manufacturer/supplier to the satisfaction of the Engineer.

b. Adequate and complete dispersal of the micro silica during the concrete mixing shall be ensured.

c. When micro silica is used in powder form the contractor shall take all precautions against potential health hazards during handling of the material.

d. Chilled water and/ or ice shall be used in the concrete mix depending on the ambient temperature, dimensions of the concrete element, rate of pouring and design mix constituents.

e. Special profuse curing arrangements shall be made for dissipation of the heat of hydration. The water curing shall be continued for a period of 21 days.

f. The concrete design mix and arrangement for mixing, transportation, and curing of concrete shall be subject to the approval of the Engineer.

12.10 CONCRETE TRIAL MIX TESTING

12.10.1 The Contractor shall carry out trial mixes for Mix Design prior to the placement of any Permanent Works as per IS:10262, IS: SP23, IRC 112 and Clause 1700 of MORTH Specifications.

12.10.2 Concrete shall be designed to provide compressive strength in accordance with acceptance criteria of IS:456.

12.10.3 Not less than 45 days before commencement of concreting, the Contractor shall carry out trials, to which the Engineer shall be invited, to determine the concrete mixes which will satisfy the design. 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 tested at 7 days and three at 28 days as per procedure laid down in relevant code.

12.10.4 After carrying out the Concrete Mix Designs, the Contractor will submit a detailed report to the Engineer for consent.

12.10.5 If the values obtained are unacceptable, the mixes shall be re-designed.

12.10.6 Trial mixes shall be prepared under full-scale site conditions and tested in accordance with IS:10262.

12.11 CONCRETE QUALITY CONTROL

12.11.1 Cubes shall be cast on site and tested in controlled conditions in an on-site laboratory, which shall be specially equipped for the purpose. Cubes shall be made, cured, stored, transported and tested to IS:516. The cube-testing machine shall be housed in a laboratory and calibrated to IS:14858 when delivered; the calibration shall be verified at 3-monthly minimum intervals by an approved testing authority.

12.11.2 Standard deviation of concrete cubes result shall be calculated as per Table no. 11 of IS:456.

12.11.3 Thereafter one sample shall be taken at random for each class of concrete from every group of 25 batches made by each 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. 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.

12.11.4 The frequency of sampling shall be as per IRS-CBC. Sampling procedure shall be adopted to ensure that each transit mixer batch shall have a reasonable chance of being tested i.e. the sampling should be spread over the entire period of concreting and cover all mixing units.

12.11.5 The procedures shall be repeated when materials or design mixes are changed.

12.11.6 Cube strength calculation procedure and values should conform to Cl. 9,15,16,17 of IS:456. The acceptable limits shall be as per relevant IS Code.

12.11.7 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. The qualities shall be equal to those obtained in the initial field tests. 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.

12.11.8 Tests shall be carried out at least daily for the moisture content and monthly 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 moisture content variations before production.

12.11.9 Should any concrete be found honeycombed or in any way defective, such concrete shall be cut out partially or wholly by the Contractor and made good at his own expense. If Engineer feels that repaired structure will not be having same strength or shape or uniformity with other exposed surface as original desired structure / original structure, the same shall be rejected by the Engineer and required to be dismantled and disposed by the Contractor at his own cost as instructed by the Engineer. All decisions of the Engineer shall be final and binding in this regard.

12.11.10 Permeability test shall be performed as per IRS CBC. Minimum 60 samples per mix design shall be tested, sampling spread throughout the contract period.

Permeability Test for Concrete

The concrete will be verified for permeability by the following procedure and shall confirm to IS: 3085-1965 – „Permeability of Cement Mortar & Concrete", Section 1717. 7..5 of MOST Specification and DIN 1048.

a. The Engineer shall select random batches of concrete for examination at his discretion and sampling will generally be done at the point of discharge from the mixer and at placing point.

b. From the batches thus selected two concrete cylinders shall be made in accordance DIN 1048.

c. All cylinders shall be made, cured, stored, transported and tested in accordance with clause 1717. 7..5 of MOST Specifications. The tests shall be carried out in a laboratory approved by the Engineer.

d. At least two cylinders shall be made on each day's concreting until 60 cylinders have been made for each grade of concrete. The cylinders will be tested as per the procedure, given in Clause (e) next.

e. Test Procedure:

The permeability of concrete will be verified by the following procedure:

i. Prepare a cylindrical test specimen 150 mm dia and 160mm high.

ii. After 28 days of curing, test specimen will be fitted in a machine such that the specimen can be placed in water under pressure up to 7 bars. The typical machine shall be similar to one shown in Appendix 1700/II of MOST.

iii. At first a pressure of one bar is applied for 48 hours, followed by 3 bars for 24 hours and 7 bars for next 24 hours.

iv. After the passage of the above period, the specimen is taken out andsplit in the middle by compression applied on two round bars on opposite sides above and below.

v. The water penetration in the broken core is measured with scale and the depth of penetration assessed in mm (max permissible limit 25 mm).

f. Acceptability Criteria:

The concrete shall pass the permeability test if it is properly compacted and is not considered permeable when tested as per DIN, and the water penetration in the broken core is less than 25mm.

No extra payment shall be made for this test and cost of the same will be included in his rate for concrete work.

Chloride in Concrete

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

1.0% if made with OPC

0.2% if made with SRPC

The Contractor shall test the constituents of the concrete to establish these contents as provided for elsewhere in this Specification.

In addition, regular tests to BS 1881: Part 6 for chloride content shall be made on the hardened concrete. The following values are acceptable:-

iii. For reinforced concrete made with OPC

95% of the test results less than 0.40% NaCl by weight of cement and no result greater than 0.50% NaCl by weight of cement.

iv. 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.

v. For mass concrete made with OPC

95% of the test results less than 1.0% NaCl by weight of cement, and no result greater than 1.30% NaCl by weight of cement.

vi. 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.

In the event that the SRPC used contains a proportion by weight of tri-calcium aluminate which approaches 4 - 8%, then consent may be sought for an appropriate adjustment of the relevant chloride content limits.

Sulphate in Concrete

The level of acid-soluble sulphates (SO3) in the mix shall be no greater than:

Coarse aggregate -0.4% by weight

Fine aggregate -0.4% by weight

Water 500 mg/l

The total estimated sulphate content (SO3) of the mix including that present in the cement shall not exceed 3.7% by weight of cement in the mix.

In addition, regular tests to BS 1881: Part 6 shall be made on the hardened concrete to determine the total sulphate content, which shall not exceed 4% by weight of cement in the mix.

Permissible Level of Chloride and Sulphates

The permissible level of chlorides and sulphates quoted in the above Subsections shall not be considered as mean values for the whole of the Works, but shall apply to any concrete.

Concrete for water-retaining structures shall in addition be as per IS: 3370.

12.12 BATCHING

12.12.1 Concrete shall be produced in computerized automatic weigh batching plants having facility to print out records of each batch with moisture measurement and also with automatic pump for dispensing admixtures 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.

12.12.2 Batched materials shall be measured out within the following tolerances and discharged into the mixer without loss as per IS:4925.

a. Cement: ± 1% of the weight of the cement in the batch
b. Aggregate: ± 2% of the weight of each aggregate in the batch
c. Water: ± 1% of the weight of water added to the batch
d. Admixture: ± 3% of the amount to be added to the batch

12.12.3 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 month. A calibrated container shall be used to check the accuracy of admixtures dispensers once each month. The results of these checks shall be notified to the Engineer.

12.12.4 Concrete constituents shall be thoroughly mixed in batches. Yield of the concrete shall be checked monthly.

12.12.5 Ready-mixed concrete shall be allowed to be used after consent from the Engineer and shall comply with the requirements specified herein and those of IS:4926.

12.12.6 The supply and use of ready mixed concrete shall be subject to the Contractor's Quality Assurance procedures. It shall be obtained from a plant consented to by the Engineer. The concrete shall be transported to the Site in truck type mixers and shall be continuously agitated. The concrete shall be placed in its final position and compacted within 2 hours of the introduction of cement to the aggregates.

12.12.7 The concrete delivered to the Works shall comply with this Specification. 1 m^3 of each mix shall be supplied to site before it is required in the Works to allow the Contractor to carry out workability tests. The supply and delivery of the ready-mixed concrete shall comply with the recommendations of IS:4926.

12.12.8 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.

12.12.9 When truck-mixed concrete is used, water shall only be added under supervision either at the Site or at the central batching plant in accordance with the Quality Procedures. In no circumstances shall extra water be added to the concrete after the original mixing is complete.

12.12.10 Samples for work tests shall be taken as the concrete is placed in its final position.

12.12.11 The Contractor shall arrange for the supplier to provide the facilities stated in IS:456 and IS:1199.

12.12.12 Daily records shall be submitted to the Engineer confirming the quantities of cement and the total volume batched of each class of concrete for each section of the Works and temporary works. The Contractor shall submit detailed records of all test cubes and specimens taken and without delay submit the test results to the Engineer.

12.13 PLACEMENT OF CONCRETE

12.13.1 The concrete placement shall conform to best practices and be compliant with IRS-CBC, IS:456 and Clause 1708.5 of MORTH Specifications. Concrete shall be placed in the position and sequence indicated on the Drawings, or as directed. Placing shall not be commenced until the fixing and condition of reinforcement and items to be embedded and the condition of the containing surfaces or formwork has been approved. 24 hours written notification shall be given of the intention to place concrete.

12.13.2 Concrete shall be transported in accordance with MORTH Clause 1708.4 by such means which prevent contamination (by dust, rain etc.) segregation or loss of ingredients, and shall be transported and placed without delay.

12.13.3 Concrete shall be placed directly in its final position without segregation or displacement of the reinforcement, embedded items and formwork. Concrete shall not be placed in water, except as specified. Concrete shall not be dropped through a height greater than 1.5 metres.

12.13.4 The limit of individual pours and the height of lifts shall be as confirmed by the Designer and submitted to the Engineer;

a. 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.
b. Floors, roofs and ground slabs shall be placed in a sequence of pours to the consent of the Designer and the consent of the Engineer.
c. If the use of slip-forms or paving trains is proposed by the Contractor, these limits may be revised. The sequence of pours shall be arranged to minimise thermal and shrinkage strains.

12.13.5 Concrete shall 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.

12.13.6 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.

12.13.7 Concrete shall be compacted during placing by approved 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. The performance of vibrators shall suit the working conditions. The radius of influence shall ensure that the mass under treatment is compacted at a speed commensurate with the rate of supply of concrete.

12.13.8 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. 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. The Contractor shall have a minimum of two spare vibrators available during each concrete pour in case of mechanical breakdowns.

12.13.9 Placing in each section of work shall be continuous between construction joints. The Contractor shall make provision for standby equipment. 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, or as directed.

12.13.10 Placement shall not take place in the open during storms or heavy rains. If such conditions are likely to occur the Contractor shall provide protection for the materials, plant and formwork so that work may proceed. If strong winds are prevalent protection from driving rain and dust shall be provided.

12.13.11 The temperature of concrete shall not exceed 30°C nor below 5°C or the temperature stated in the table of concrete mixes whichever is the lower at the time of placing concrete. Also, the maximum concrete temperature after placing shall not exceed a temperature 40°C. The procedures the Contractor wishes to employ shall be subject to the Engineer consent. The Contractor shall supply suitable maximum/minimum thermometers and record the shade and sun temperatures at locations where concrete is being placed. Mass concrete pours shall have thermo-couples installed to monitor heat within the concrete pour.

12.13.12 If consent has been given for placing at night or in dark interiors, adequate lighting shall be provided where mixing, transportation and placing are in progress.

12.13.13 Underwater concrete shall be in accordance with Clause 1710 of MORTHSpecifications and shall be placed with minimum disturbance of the water. Running water and wave wash shall be controlled. The specified concrete grade shall be used and the mix design shall provide for good flowing ability. Tremie pipes, bottom-dump skips or other approved placing equipment shall be used. Segregation shall be avoided. Placing shall be commenced in approved sections and continued to completion. The tremie pipe shall be buried in the concrete for at least 1.5 metres and the pipe must not be emptied until the pour is complete. 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.

12.13.14 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.

12.13.15 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. For mass concrete placed against masonry or brickwork the following shall apply: -

a. The mortar joints in the facework shall have fully hardened.
b. The water-cement ratio of the concrete shall be increased to compensate for the absorption of moisture by the existing work.
c. The surface shall be soaked prior to placing.
d. The concrete shall be worked around ties and bond stones and into open joints.
For piers and pier heads, portal columns the concreting is to be carried out in single stage i.e. in first stage concreting will be from kicker to just below pier head bottom and second stage of concreting will be pier head including shear key and cross girder (in station zone stages as given in drawings for all heights by using tremie/ pumps at the rate not more than 1.5m / hr or as approved by the Engineer.

Compaction:

Internal (needle) and surface (screed board) vibrators of approved make shall be used for compaction of concrete.

Internal vibrators shall be used for compaction of concrete in foundations, columns, buttresses arch section, slabs etc, and if required surface vibrators shall also be used. Depending on the thickness of layer to be compacted, 25 mm, 40 mm, 60 mm and 75 mm dia internal vibrators will be used. The concrete shall be compacted by use of appropriate diameter vibrator by holding the vibrator in position until:

a. Air bubbles cease to come to surface.
b. Resumption of steady frequency of vibrator after the initial short period of drop in the frequency, when the vibrator is first inserted.
c. The tone of the vibrated concrete becomes uniform.
d. Flattened, glistening surface, with coarse aggregates particles blended into it appears on the surface.
e. Use of curing compounds may be permitted with specific approval of Engineer.
After the compaction is completed, the vibrator should be withdrawn slowly from the concrete so that concrete can flow into the space previously occupied by the vibrator. To avoid segregation during vibration the vibrator shall not be dragged through the concrete nor used to spread the concrete. The vibrator shall be made to penetrate, into the layer of fresh concrete below if any for a depth of about 150mm. The vibrator shall be made to operate at a regular pattern of spacing. The effective radii of action will overlap approximately half a radius to ensure complete compaction.
f. To secure even and dense surfaces free from aggregate pockets, vibration shall be supplemented by tamping or rodding by hand in the corners of forms and along the form surfaces while the concrete is plastic.
g. A sufficient number of spare vibrators shall be kept readily accessible to the place of deposition of concrete to assure adequate vibration in case of breakdown of those in use.
h. Form vibrators whenever used shall be clamped to the sides of formwork and shall not be fixed more than 450 mm above the base of the new formwork and concrete shall be filled not higher than 230mm above the vibrator. The formwork must be made especially strong and watertight where this type of vibrator is used.
i. Care must be taken to guard against over vibration especially where the workability of the concrete mix is high since this will encourage segregation of the concrete.
j. Plain concrete in foundations shall be placed in direct contact with the bottom of the excavation, the concrete being deposited in such a manner as not to be mixed with the earth. Plain concrete also shall be vibrated to achieve full compaction.

Concrete placed below the ground shall be protected from falling earth during and after placing. Concrete placed in ground containing deleterious substances shall be kept free from contact with such ground and with water draining there from during placing and for a period of seven days or as otherwise instructed thereafter. Approved means shall be taken to protect immature concrete from damage by debris, excessive loading, abrasion, vibrations, deleterious ground water, mixing with earth or other materials, and other influences that may impair the strength and durability of the concrete.

12.14 CONSTRUCTION JOINTS

12.14.1 Construction joints shall be located and the sequence of placing arranged as approved, to minimise shrinkage and thermal strains in the concrete. Concrete placing shall not be interrupted except where joints occur and shall continue after normal hours, if necessary, to achieve this. The construction joints shall be in conformance with IS:456 and Clause 1709 of MORTHSpecifications.

12.14.2 Joints shall be formed square to the work with keyways included.

12.14.3 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.

12.14.4 Chemical surface-retarders shall not be used.

12.14.5 Construction joints shall be sealed with an approved sealant at external and liquid-contact faces. Construction joints in water-retaining structures shall incorporate an approved water stop.

12.15 EXPANSION, CONTRACTION AND MOVEMENT JOINTS

12.15.1 Expansion, contraction and other movement joints shall be incorporated in the works as shown on the Drawings. The expansion joints shall be in conformance with IRC: SP: 69.

12.15.2 Where shown on the Drawings approved, 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.

12.15.3 Movement joints shall be sealed with an approved 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.

12.15.4 Dowel bars shall be installed and cast in across the movement joint where shown on the Drawings as per relevant IS/IRC codes. The bars shall be straight with clean cut ends of the diameters and lengths as shown on the Drawings or in the Schedules.

12.15.5 Dowel 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 approved 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 an approved manufacturer.

12.15.6 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.

12.16 WATER STOPS

12.16.1 The layout and installation of the water-stops shall be in accordance with the manufacturer's recommendation and shall be subject to the approval of Designer and consent of the Engineer.

12.17 CRACKS

12.17.1 The method(s) to be used to control cracking due to shrinkage and/or thermal stresses shall be submitted to the Engineer for review. All concrete elements with a smallest dimension larger than 600 mm shall require implementation of method(s) to control thermal stresses.

12.17.2 The Contractor shall inspect unformed concrete surfaces and identify and record the width, depth, and density (in linear meters per square meter) of any cracks after removal of burlap or curing tarpaulins. Results shall be reported to the Engineer.

12.17.3 If cracks, which in the opinion of the Engineer may be detrimental to the strength of the construction, develop in concrete construction, the Contractor at his own expense shall test the structure as specified in “Loading Tests” of these Specifications.

12.17.4 If under such test loads the cracks develop further, the Contractor shall dismantle the construction, carry away the debris, replace the construction and carry out all consequential work thereto.

12.17.5 If any cracks develop in the concrete construction, which in the opinion of the Engineer, are not detrimental to the stability of the construction, the Contractor at his own expense shall grout the cracks with neat cement grout or with other composition as directed by Engineer and also at his own expense and risk shall make good to the satisfaction of the Engineer all other works such as plaster, moulding, surface finish, which in the opinion of the Engineer have suffered damage either in appearance or stability owing to such cracks. The Engineer's decision as to the extent of the liability of the Contractor in the above matter shall be final and binding.

12.17.6 External crack width shall be as per IRS: CBC.

12.18 CURING AND PROTECTION

12.18.1 The Contractor shall submit their method of curing all concrete elements to the Engineer for review and consent. The curing method shall conform to IS:456/IRC/MoRTH Clause 1712 and IRS-CBC.

12.18.2 Concrete shall be protected from the weather elements; sunshine and drying winds by approved 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
   i. Polythene sheeting shall be placed immediately.
   ii. After final set has taken place, the polythene shall be replaced by wet hessian covered with polythene; the hessian shall be kept permanently damp.
   iii. After 7 days the hessian and polythene shall be removed and an approved aluminised or white resin- based curing compound applied unless alternative method is agreed to by Engineer or provided for in Contract. The rate of application shall be as recommended by the manufacturer.
   iv. Alternative methods of curing must be approved before use where special finishes are required.

b. Vertical surfaces
   i. Polythene over wet hessian shall be secured to the surfaces immediately after removal of the formwork. The hessian shall be kept permanently damp.

ii. After 7 days the hessian and polythene shall be removed and an approved aluminised or white resin-based curing compound applied unless alternative method is agreed to by Engineer or provided for in Contract. Alternatively, the hessian and polythene shall remain for a further 7 days.

12.18.3 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 will be as approved by Engineer.

12.18.4 Concrete shall be protected from contamination by oil, fuel and other deleterious materials for a minimum period of 30 days after placing.

12.18.5 Where required insulating formwork shall be left in place for 72 hours after placing or until the temperature peak of the concrete is reached. The initial curing period may then be reduced in proportion, if approved by Designer and Engineer.

12.18.6 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.

12.19 PRECAST CONCRETE

12.19.1 Casting of members shall not begin until consent to the shop drawings, required computation, prestressing system (if required) and method of manufacture has submitted to the Engineer for review and consent.

12.19.2 When the drawings and method of manufacture have been approved, no changes shall be made without the approval of Designer and consent of the Engineer.

12.19.3 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.

12.19.4 A copy of all cube test results to the work shall be sent to the Engineer as soon as they become available.

12.19.5 Where the Engineer requires tests to be carried out, no members to which the tests relate shall be dispatched to the Site until the tests have been satisfactorily completed and accepted.

12.19.6 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.

12.19.7 The design and engineering of the forms and falsework as well as their construction shall be as per IRC:87 & as per para 1503.2 of MoRTH specification. Design of the falsework for all concrete shall be done under the direction of a competent design engineer. 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 and approved by the Engineer prior to authorizing casting operations. Details shown on the Drawings shall be built into the forms. Worn, damaged, or otherwise unacceptable forms shall be rejected.

12.19.8 The forms may be made either of steel or of plywood. If the Contractor elects to use plywood forms, it shall be a high-quality plywood, 19mm minimum thickness, marine grade and it shall be subject to Engineers review and consent.

12.19.9 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.

12.19.10 Forms shall be coated with form release agent prior to use. Form release agent shall be a commercial quality form oil or other equivalent coating which will permit the ready release of forms

and will not discolour the concrete. Excess form release agent 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.

12.19.11 Anchor devices may be cast into the concrete for later use in supporting forms, provided the arrangement is approved by the designer and consented by Engineer. The use of driven or drilled types of anchorages for fastening forms or form supports to concrete will not be permitted.

12.19.12 The steam curing process may be used as an alternative to water curing. It should conform to MoRTH Clause 1712.3.

12.19.13 If the Contractor elects to cure by any other special method, the method and its details shall be subject to the approval of the Designer and consent by Engineer.

12.19.14 When members are stored, they shall be firmly supported only at the points specified by the Designer. The accumulation of trapped water and deleterious matter in the units shall be prevented. Care shall be taken to avoid rust staining and efflorescence.

12.19.15 Members shall be lifted or supported only at points specified by the Designer or otherwise agreed by the Engineer and shall be handled and placed without impact.

12.19.16 The method of lifting, the type of equipment and transport to be used, and the minimum age of the members to be handled shall be subject to the Designer's requirements.

12.19.17 The method of assembly and erection described in the Contract shall be as practicable and be strictly adhered to on site. 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. The final structural connections shall be completed as soon as possible.

12.19.18 No structural connections shall be made until the Engineer's consent has been given.

12.19.19 Unless otherwise agreed 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.

12.19.20 Levelling devices shall only be released or removed with the consent of the Engineer.

12.20 **EPOXY GROUT FOR STRUCTURAL CONNECTIONS.**

12.20.1 Epoxy shall be furnished as 2 components which shall be mixed together at the Site.It should conform to relevant MORTH specifications.

12.20.2 All tests will be conducted in accordance with the latest test methods of IS/ ASTM, Federal Test Method Standard No. 141 or equivalent British Standard.

12.20.3 All epoxy grouts shall be stored, used and tested as per the manufacturer’s recommendations.

12.20.4 Packaging, Labelling and Storing

12.20.5 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. The containers shall have lug type crimp lids with ring seals, shall be new, not less than 0.6 mm nominal thickness, and shall be of such character as to resist any action by the components. 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.

12.20.6 "CAUTION”

a. "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."

b. Attention is directed to the characteristic of some epoxy components to crystallize or thicken

excessively prior to use when stored at temperatures below 2□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.

12.20.7 Directions for Use

a. At the time of mixing, components A and B shall be at a temperature between 16°C and 29°C, unless 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 2 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 0.50% 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 2 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.

12.20.8 Epoxy Grout Strength Requirements

a. The compressive strength of 38 mm cubes of epoxy grout tested in accordance with ASTM C39 after 10 hours of curing at 20□C shall be not less than the design strength of the precast number.

12.21 **TEMPORARY SUPPORTS AND CONNECTIONS:**

a. Temporary supports provided during erection should take into account all construction loads likely to be encountered during the completion of joints between any combination of precast and in-situ concrete structural elements. The supports should be arranged in a manner that will permit the proper finishing and curing of any in-situ concreting and grouting associated with the precast member being supported when the gaps of joints have to be filled with concrete or mortar. They should first be cleaned and faces of the joints should be wetted. The mixing, placing and compacting of cement and mortar should be done with special care. Mortar of a dry consistency should be in the proportion of 1:1½ (1 part of cement to 1½ parts of sand) and should be placed in stages and packed hard from both sides of the joint.

12.22 **TOLERANCES:**

a. The following tolerances apply to finished precast products at the time of placement in the structure. The forms must be constructed to give a casting well within these limits:

i. Overall dimensions of members should not vary more than + 6mm per 3m length with a maximum variation of + 20mm.

ii. Cross-sectional dimensions should not vary more than the following:
+ 3mm for sections less than 150mm thick
+ 4mm for sections over 150mm & less than 450mm
+ 6mm for sections over 450mm to 1000mm

+ 10mm for sections over 1000mm

iii. Deviation from straight line in long sections should not be more than + 6mm up to 3m, + 10mm for 3m to 6m, + 12mm for 6m to 12m.

- For tolerances on precast components, standard documents shall be followed
- Structural steel inserts/bolts for connecting precast concrete elements (Parapet to Box Girder)

12.23 **CONNECTION OF PRECAST CONCRETE PARAPET WITH SEGMENTAL BOX GIRDER:**

a. Square rods with internal threading and base plate/stiffener, shall be firmly fixed in the mould to the true line, level and alignment as shown in drawings. If required by engineer MS template may use for above purpose. The threaded hole/pipe shall be properly protected so as to prevent ingress of mortar etc (by providing dummy bolts, PVC cover, cotton waste etc).

b. For connection of parapet with segmental box girder bolts of required length having threads at both ends shall be provided as shown in drawings. Grade of steel will be in accordance with the values specified in the drawing. Welding to bolts is not permitted. Grade of nuts will be same as grade of respective bolts. It is imperative to verify that that bolts can be threaded smoothly at all times. Dummy blots shall be used in the stacking yard as a protection measure to keep the threads clean free of dust / rust. Threading, bolts materials, tests etc shall be as per IS: 1367 part 1 to 16,18, IS: 1821-1987, IS: 4206.

c. Levelling bolts as shown in tender drawings are for facilitating alignment of the precast parapet.

12.24 **READY MIX CONCRETE AND PUMPING**

a. Ready-mixed concrete may be manufactured in a central automatic weigh Batching plant and transported to the place of work in agitating transit mixers.

The maximum size of coarse aggregate shall be limited to one-third of the smallest inside diameter of the hose or pipe used for pumping. Provision shall be made for elimination of over-sized particles by screening or by careful selection of aggregates. To obtain proper gradation it may be necessary to combine and blend certain fractional sizes of aggregates. Uniformity of gradation throughout the entire job shall be maintained.

The quantity of coarse aggregate shall be such that the concrete can be pumped, compacted and finished without difficulty.

b. Fine aggregates:

The gradation of fine aggregate shall be such that 15 to 30 percent should pass the 0.30 mm screen and 5 to 10 percent should pass 0.15 mm screen so as to obtain pumpable concrete. Sands, which are deficient in either of these two sizes, should be blended with selected finer sands to produce these desired percentages. With this gradation, sands having a fineness modulus between 2.4 and 2.8 are generally satisfactory. However, for uniformity, the fineness modulus of the sand should not vary more than 0.2 from the average value used in proportioning.

c. Water, Admixtures and Slump:
The amount of water required for proper concrete consistency shall take into account the rate of mixing, length of haul, time of unloading, and ambient temperature conditions.
Additions of water to compensate for slump loss should not be resorted to nor should the design maximum water-cement ratio be exceeded. Additional dose of retarder be used to compensate the loss of slump at contractor's cost, when permitted by Engineer. Retempering water shall not be allowed to be added to mixed batches to obtain desired slump.

d. Transportation:
The method of transportation used should efficiently deliver the concrete to the point of placement without significantly altering its desired properties with regard to water-cement ratio, slump, and homogeneity.
The revolving-drum truck bodies of approved make shall be used for transporting the concrete. The numbers of revolutions at mixing speed, during transportation, and prior to discharge shall be specified and agreed upon. Reliable counters shall be used on revolving-drum truck units. Standard mixer uniformity tests, conforming to ASTM standards C 94-69 "Standard

e. Specifications for Ready Mix Concrete", shall be carried out to determine whether mixing is being accomplished satisfactorily.

f. Pumping of concrete:
Only approved pumping equipment, in good working condition, shall be used for pumping of concrete. Concrete shall be pumped through a combination of rigid pipe and heavy-duty flexible hose of approved size and make. The couplings used to connect both rigid and flexible pipe sections shall be adequate in strength to withstand handling loads during erection of pipe system, misalignment, and poor support along the lines. They should be nominally rated for at least 3.5 MPa pressure and greater for rising runs over 30 m. Couplings should be designed to allow replacement of any section without moving other pipe sections and should provide full cross section with no construction or crevices to disrupt the smooth flow of concrete.
All necessary accessories such as curved sections of rigid pipe, swivel joints and rotary distributors, pin and gate valves to prevent backflow in the pipe line, switch valves to direct the flow into another pipe line, connection devices to fill forms from the bottom up, extra strong couplings for vertical runs, transitions for connecting different sizes of pipe, air vents for downhill pumping, clean-out equipment etc, shall be provided as and where required. Suitable power-controlled booms or specialized crane shall be used for supporting the pipe line.

g. Field control:
Sampling at both truck discharge and point of final placement shall be employed to determine if any changes in the slump and other significant mix characteristics occur. However, for determining strength of concrete, cubes shall be taken from the placement end of line.

h. Planning:
Proper planning of concrete supply, pump locations, line layout, placing sequence, and the entire pumping operation shall be made and got approved. The pump should be as near the placing area as practicable, and the entire surrounding area shall have adequate bearing strength to support concrete delivery pipes. Lines from pump to the placing area should be laid out with a minimum of bends. For large placing areas, alternate lines should be installed for rapid connection when required. Standby power and pumping equipment should be provided to replace initial equipment, should breakdown occur. The placing rate should be estimated so that concrete can be ordered at an appropriate delivery rate.

As a final check, the pump should be started and operated without concrete to be certain that all moving parts are operating properly. A grout mortar should be pumped into the lines to provide lubrication for the concrete, but this mortar shall not be used in the placement. When the form is nearly full, and there is enough concrete in the line to complete the placement the pump shall be stopped and a go-devil inserted and shall be forced through the line by water under pressure to clean it out. The go-devil should be stopped at a safe distance from the end of the line so that the water in the line will not spill into the placement area. At the end of placing operation, the line shall be cleaned in the reverse direction.

12.25 SPECIFICATION FOR CRYSTALLINE DURABILITY ADMIXTURE

a. Apart from the regular workability admixtures, Integral Crystalline Durability admixtures shall be added in the Concrete to enhance the Concrete Durability. It shall be used for structural concrete for all Underground structures (including shotcrete inside tunnel but excluding foundations of elevated structures such as pile, pile cap, etc). The Crystalline Admixture shall be added either at the time of batching at the batching plant or in the drum of the transit mixer, when the concrete arrives the point of pouring.

b. The crystalline durability admixture must confirm to the Annexure-A of S.12.

c. Wherever the use of crystalline durability admixture (as per Annexure-A of S.12) is provided to reduce the carbonation/corrosion in the structure, the waterproofing over the same structure (if any) is achieved by providing crystalline slurry (as per Annexure-B of S.12) in addition to the already added crystalline durability admixture (as per Annexure-A of S.12).

12.26 TESTING CONCRETE STRUCTURE FOR WATER TIGHTNESS & ACCEPTANCE CRITERIA

a. Underground Structures, Pump Rooms and Sumps

In the case of structures whose external faces are submerged and are not accessible for inspection, such as underground structures, the structures shall be filled with water and after the expiry of seven days after the filling, the level of the surface of the water shall be recorded. The level of water shall be recorded again at subsequent intervals of 24 hours over a period of seven days. Backfilling shall be withheld till the tanks are tested. The total drop in surface level over a period for seven days shall be taken as an indication of the water tightness of the structure.

A structure shall be deemed to be watertight if the total drop in the surface level over a period of seven days does not exceed 40 mm.

b. Roofs

The roofs of liquid-retaining structures shall be water-tight and shall be tested on completion by flooding the roof with water to a minimum depth of 25 mm for 24 hrs. Where it is impracticable, because of roof falls or otherwise, to contain a 25 mm depth of water, the roof shall have water applied by a continuous hose of sprinkler system to provide a sheet flow of water over the entire area of the roof for not less than 6 hrs. In either case the roof shall be considered satisfactory if no leaks or damp patches show on the soffit. Should the structure not satisfy either of these tests, then after completion of the remedial work it should be re-tested in accordance with this clause. The roof insulation and covering should be completed as soon as possible after satisfactory testing. Contractor shall give warranty for leak tightness of joints for 10 years.

12.27 PROTECTIVE COATING ON CONCRETE STRUCTURES OF AT-GRADE& ELEVATED STATIONS

a. Water based, UV resistant, dust pick up resistant, algae and fungus proof anti-carbonation protective paint on Concrete surface/porous exposed surfaces which penetrate into the surface to make the surface water repellent and provides anti-carbonation barrier (CO2 & SO2

diffusion) and allow surface to breathe.

b. After cleaning and preparation of the surface application of one coat of penetrative clear primer followed by two coats of pigmented Anti-carbonation coating in approved colour and shade applied by brush/roller or spray gun, as per manufacturer's specification with the direction of Engineer-in-Charge.

c. Protective coating shall be applied on elevated structures (excluding pile foundations, open foundations, etc.) as directed by engineer in charge (if indicated in the Scope of Work).

13. FORMWORK AND CONCRETE FINISHES

13.1 GENERAL

13.1.1 The materials and workmanship standards contained herein for formwork and concrete finishes are the minimum required by the Employer.

13.1.2 The Contractor shall comply with the requirements of both IRC 87-2017 and BS 5975 for the design of all Temporary Works for the design of all formwork installations, including pre-cast launching girders.

13.1.3 At many location's formwork will be erected over trafficked roadways the Contractor shall design and fabricate prefabricated type staging and shuttering which can be erected and dismantled with disrupting the flow of traffic. There shall be a 5.5m minimum traffic clearance from the road to the lowest part of the formwork support structure.

13.2 FORMWORK

13.2.1 The Contractor shall submit to the Engineer for review the planned methods and materials. All the materials (Marine ply, steel plate, structural sections etc.) planned to be used for fabrication of formwork shall be new and usage (no. of repetitions) shall be proposed by the contractor and approved by the Employer/Engineer. To maintain high quality finishes formwork shall preferably be of steel plate and sections suitably designed. Details of formwork for special finishes shall be approved before materials are ordered.

13.2.2 All temporary works such as formwork, false work, staging, launching girder, cantilever form traveller scheme etc. shall be designed by the Contractor or their proposed supplier/manufacturer. The permissible stresses in materials of formwork, false work, staging, launching girder & cantilever form traveller shall be limited as same as for the permanent structure. All calculations and drawings shall include the construction sequence shall be certified by Contractor's DDC before submission to the Engineer for consent.

13.2.3 All temporary works shall be constructed so that the concrete can be properly placed and thoroughly compacted to obtain the required shape, position and level subject to specified tolerances. Consent 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.

13.2.4 New shuttering and formwork shall be used for Pier and designed to ensure the total deflection (taking account of combined deflection of plate, stiffeners, walers or any other supporting arrangement) shall be new and as per tolerance given in the relevant IS/IRC codes.

13.2.5 All formwork, launching truss and cantilever form travellers and other selected temporary works shall be tested for the designed load, including a factor of safety confirmed by the Designer, for which the truss/formwork/traveller is designed before use. The planned formwork test loading methodology shall be submitted to the Engineer for review.

13.2.6 The design of false work should be such as to facilitate easy and safe access for erection, dismantling and inspection to all parts of the installation.

13.2.7 The methodology for erection and removal of all form work shall be planned as a part of total formwork design. In case of pre-stressed concrete, careful consideration shall be given to re-distribution of loads due to pre-stressing.

13.2.8 Formwork shall form concrete of the shape, lines and dimensions shown on the Engineer approved Design Drawings.

13.2.9 Formwork shall be constructed from materials of sufficient strength, supported to provide rigidity during placing and compacting concrete without discernible deflection and shall be removable without disturbing the concrete.

13.2.10 Internal ties shall be metal. Removable ties shall be located so that the specified cover to reinforcement is maintained to all surfaces including that of the tie-holes. If ties are left in the cover shall be as specified for the reinforcement or as approved. Tie cavities shall be roughened and filled with approved non-shrink concrete or epoxy mortar.

13.2.11 Formwork panels shall have true edges for accurate alignment and shall be fixed with either vertical or horizontal joints. Where chamfers are required the fillets shall be cut to provide an even line.

13.2.12 Joints shall not permit leakage of grout, nor steps and ridges in exposed surfaces.

13.2.13 Due allowance shall be made for deflection of formwork during concrete placement as per relevant IS/IRC codes.

13.2.14 Wrought formwork shall be steel, Glass Reinforced Plastic (GRP) or lined plywood to produce a fine finish. Lining to plywood shall be clear-lacquered extra-hard hardboard. Where formwork is required and unless otherwise stated, wrought formwork shall be used to produce the finishes defined herein.

13.2.15 Rough formwork can be of butt-jointed, seasoned, sawn timber with joints made leak proof.

13.2.16 Formwork and supports shall be cleaned; before preparing for concreting temporary openings shall be provided for the removal of rubbish. The formwork shall be coated with an approved release agent and the excess removed. Release agent shall not be allowed to come into contact with concrete already placed or with reinforcement.

13.2.17 Not less than 24 hours request shall be given for the inspection and consent of the formwork and reinforcement, prior to which concrete shall not be placed.

13.2.18 Formwork shall be removed without damage to the concrete, but not until the concrete has sufficient strength to support itself. Centres and props may be removed when the member has sufficient strength to carry itself and any loading with a reasonable factor of safety. External loading shall not be applied until the concrete has reached the 28-day design strength unless otherwise confirmed by the Designer and reviewed by the Engineer.

13.2.19 Formwork 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 commence immediately. The minimum periods between placing and the removal of formwork shall be confirmed by the Designer and be in compliance withIS:456.

13.2.20 After formwork removal remedial work shall not be undertaken until the concrete has been inspected and approved. The Contractor shall submit to the Engineer a Concrete Repair Method Statement for approval which shall confirm the actions to be taken to identify and minor, medium and major non-conformances. The Contractors QC team shall supervise all repairs and the Designer shall approve the method for any major repairs on a case-by-case basis.

13.2.21 The Contractor shall not be permitted reuse of timber facing formwork brought new on the works 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. The Engineer may in his absolute discretion order rejection of any forms he considers unfit for use, as per IRC 87-2017, for a particular item irrespective of the number of times shuttering has been used. The Engineer may order removal from the site of any formwork considered unfit for use in the Works. 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 no. of times they can be used will be determined by the Engineer.

13.3 FORMWORK FOR PRE-CAST/PRE-STRESSED CONCRETE

13.3.1 The provisions in this section shall be considered supplementary to the general provisions stated above and additional Technical Specifications for pre-cast segments.

13.3.2 The Contractor shall submit detailed drawings of formwork for the consent of the Engineer.

13.3.3 Precast concrete members and panels shall be made in accurately constructed moulds, on a properly prepared casting bed. All aspects of the making, curing and erection of precast units shall be subject to the consent of the Engineer.

13.3.4 Finishing with cement mortar shall not be allowed.

13.3.5 Formwork shall be designed so 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 shall be designed and sealed so that no cement grout can escape, and there is no wedging or keying to the concrete.

13.3.6 The effect of curing on the formwork should be given special consideration.

13.3.7 As soon as the precast units have attained sufficient strength, the formwork shall be stripped. The precast unit shall be lifted uniformly out of the formwork without being subjected to tilting or restraint effects.

13.4 BOLTS, INSERTS AND OPENINGS

13.4.1 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 without the permission of the Engineer. Bolts and other inserts to be cast into 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.

13.4.2 Unless shown otherwise on the Drawings or the Engineer has given consent, reinforcement shall be locally moved so that the minimum specified cover is maintained at the locations of inserts, holes, chases, etc.

13.4.3 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.

13.5 FINISHES

13.5.1 Concrete faces shall not be rendered and defective concrete shall be cut out and replaced or made good as directed. The finished faces of concrete shall be sound, even-coloured, even-textured and free from defects.

13.5.2 Mock-ups (trial panels) for formed finishes shall be produced prior to the commencement of each major component element (columns, beams, slabs, pre-cast sections etc.), and shall be subject to the review and consent from the Engineer. The mock-ups shall contain reinforcement which is representative of the design. The Contractor shall submit to the Engineer their proposed concrete element mock-up program.

13.6 FORMED FINISHES

13.6.1 Finishes to formed surfaces of concrete shall be classified as F1, F2 and F3, or such other special finish as may be designated by the Designer and approved by the Engineer.

13.6.2 All exposed visible concrete surfaces shall have a Class F3 finish. An F3 Finish shall be;

a. Care shall be taken to ensure that the finish to the exposed concrete on the external and internal surfaces are of the highest quality to produce a smooth concrete surface of uniform texture and appearance without visible imprint of grains, stepping or ridges.

b. The resulting concreting shall be free from honeycombing, stains, fins, lipping, nail and screw marks, raised grain marks or any other imperfections and shall be of a uniform surface texture and colour. Only very minor surface blemishes caused by entrapped air or water will be accepted provided that they do not exceed 0.5% by area of each square metre considered separately and in addition they shall not be concentrated in a manner such that they are noticeable.

c. Grooves in exposed concrete shall be formed by attaching tapered planed timber battens accurately aligned to the face of formwork.

d. All exposed concrete corners and edges shall have 20 mm by 20 mm chamfers.

13.6.3 Where the class of finish is not designated all internal concrete shall be finished to Class F3. External non-visible concrete below ground may be finished to Class F1.

13.6.4 Formwork for Class F3 finish shall be lined with as large panels as possible of non-staining material with a smooth unblemished surface such as sanded plywood or hard compressed fibre board, arranged in a uniform approved pattern and fixed to back formwork by oval nails.

a. The same type of lining shall be used throughout any one structure

b. unfaced wrought boarding or standard steel panels shall not be permitted.

13.6.5 Formwork for Class F2 finish shall be faced with wrought tongued and grooved boards or plywood arranged in a uniform approved pattern free from defects likely to detract from the appearance of the surface. Forms shall be manufactured in a workman like 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.

13.6.6 Formwork for Class F1 finish shall be constructed of timber, or of any suitable materials which will prevent loss of grout when the concrete is vibrated. 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 shall not leak mortar when concrete is vibrated. Forms may be manufactured with a minimum of refinement.

13.7 UNFORMED SURFACES

13.7.1 Initial finishing of unformed surfaces shall commence immediately after the placing and compaction have taken place.

13.7.2 Suitable access boards or platforms shall be provided to allow access to all parts of unformed surfaces to be finished. Where a protective treatment or topping layer is to be applied to the concrete the manufacturers and supplier's recommendations shall be followed concerning the required finish.

13.7.3 The addition of small quantities of water to the finishing trowel will be permitted to aid finishing.

13.7.4 Unformed finishes shall be;

a. U4, steel trowel finish

b. U3, timber trowel finish

c. U2, brush finished

d. U1 other screeded finishes as designated by the Designer, which may include: Screeded Finish, Floated Finish, Dustproof Finish, Non-slip Finish, Hardened Finish

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 as directed by the Engineer.

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 or as directed by Engineer 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 1cm per 30cm of width. Broader surface such as roadways, platform and decks, shall be sloped approximately half centimetre per 30cm of width. Finishes of floor and roof slabs shall be sloped, if required, by the Engineer.

Information to be supplied by manufacturers of proprietary systems of form work

13.8 GENERAL

i. 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.

ii. The user shall refer unusual problems of erection/assembly not in keeping with intended use of equipment, to the manufacturer of the equipment.

13.9 INFORMATION REQUIRED

i. Description of basic functions of equipment.

ii. List of items of equipment available, giving range of sizes, spans and such like, with manufacturer's identification number or other references.

iii. The basis on which safe working loads have been determined and whether the factor of safety given applies to collapse or yield.

iv. 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.

v. Instructions for use and maintenance, including any points which require special attention during erection, especially where safety is concerned.

vi. Detailed dimensional information, as follows:

1. Overall dimensions, depths and widths of members.
2. Line drawings including perspectives and photographs showing normal uses.
3. Self weight.
4. Full dimensions of connections and any special positioning and supporting arrangements.
5. Sizes of members, including tube diameters and thicknesses of material.
6. Any permanent camber built into the equipment.
7. Sizes of holes and dimensions giving their positions.
8. Manner of fixing including arrangements for sealing joints.

vii. Data relating to strength of equipment as follows:

1. Average failure loads as determined by tests.
2. Recommended maximum working loads for various conditions of use.
3. Working resistance moments derived from tests.

4. Working shear capacities derived from tests.
5. Recommended factors of safety used in assessing recommended loads and deflections based on test results.
6. Deflections under load together with recommended pre-camber and limiting deflections.
7. 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.
8. Information on the design of sway bracing against wind and other horizontal loadings.
9. Allowable loading relating maximum extension of bases and/or heads.
10. Any restrictions regarding usage of any component or full assembly with regard to spans, heights and loading conditions.

13.10 TOLERANCES

Overall dimensions of members should not vary more than the permissible tolerances specified in relevant IS/IRC codes.

14. STEEL REINFORCEMENT

14.1 GENERAL

14.1.1 Steel reinforcement shall comply with the requirements set out in this Section.

14.1.2 All reinforcement shall be high-yield deformed bars and shall conform to Indian Standard IS:1786.

14.1.3 Tying wire shall be galvanised steel of core diameter 18 gauge.

14.1.4 Steel reinforcement shall be stored in an approved manner above ground, on timber supports or on a concrete slab, under cover and racked as necessary for protection from aggressive elements. Steel reinforcement shall not come in direct contract with the floor of slab.

14.1.5 Reinforcement for structural concrete shall be cut, bent and fixed to IS:2502.

14.1.6 Cold bending shall be used which does not damage the material.

14.1.7 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.

14.1.8 Reinforcement shall be grit-blasted before use if instructed by the Engineer 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.

14.1.9 Partially-set concrete adhering to exposed bars during concreting operations shall be removed.

14.1.10 Reinforcement temporarily projecting from the concrete at joints shall not be bent out of position without the consent of the Engineer, in which event the reinforcement shall be bent over a suitably sized former to prevent any damage or over-stressing.

14.1.11 The Contractor will submit to the Engineer drawings detailing the reinforcement required and shall also submit bar bending schedules in accordance with IS:2502 and IS:5525. Laps and anchorages shall be as stated in IS:456.

14.1.12 Electric arc welding may be used, if approved by the Designer, for joining bars. Covered-alloy or shielded-arc electrodes shall conform to IS:814. Workmanship shall be to IS:2251

14.1.13 Minimum cover shall be as specified in IS:456 unless otherwise approved by the Engineer. Control of the minimum thickness of concrete cover to reinforcement shall be achieved by the use of approved concrete or PVC/other approved spacers. Cover blocks used also should be same mix as the concrete of member and be with roughened faces.

14.2 COUPLERS

14.2.1 Introduction

14.2.1.1 Only cold-forged, parallel threaded mechanical coupler system are recommended. All mechanical couplers shall be of Type 2 (or Class H as specified in IS-16172) and should be simple to install and which can be confirmed by quick visual inspection to have been correctly installed and to have achieved the required full-strength connection. Any other types of mechanical coupler systems are not permitted provided the same meet the specification indicated below.

14.2.1.2 The couplers shall be of standard parallel thread type. Ends of the reinforcement bars, which are to be joined, shall be enlarged by cold forging/upsetting, threaded in such a way that root thread diameter is not lesser than the parent bar to be joined. The coupler shall be of TYPE – II and qualified/Certified as per UK CARES, IS code 16172:2014, ACI 318, ASME, Section III, and Div.2, Caltrans.

14.2.1.3 Couplers installed shall be strictly in accordance with the manufacturer's recommendations. Couplers shall preferably be located away from high stress zones in the various structural elements and shall be staggered.

14.2.1.4 All the couplers should be manufactured in a factory which is ISO 9001:2008 (or higher revision) certified for "Manufacturing of Mechanical Steel Rebar Couplers & Accessories" and also be certified for "Site Management of Threading & Processing of Rebar including Sales and Distribution". All the couplers shall undergo quality checks on uniformity of threads, dimensional accuracy etc. Each coupler shall be clearly stamped indicating batch number and diameter. This number shall be traceable to the original cast. The relevant material mill certificate shall be submitted with supply of a particular lot. The certificate shall give salient material properties. The coupler manufacturer shall operate at least an ISO 9000 approved quality assurance programme or equivalent for the manufacture of couplers.

14.2.2 Threading of ends of the reinforcing bars

14.2.2.1 This threading activity shall preferably be done at Site. The various stages involved in threading are as given below:

a. Cutting (Rebar End Preparation):
   The ends of reinforcement bars shall be cut by mechanical means to get a perfect plain and surface perpendicular to the axis of the bar.

b. Cold forging & threading:
   After cutting the ends of the bar shall be enlarged by cold forging such that the area of cross section after threading shall not be less than the area of cross section of the parent bar. The length of cold forging shall be adequate for proposed thread length as per manufacturer's design. Threading shall be done preferably on threading machine. The threads shall be square parallel type to suit the couplers. The thread length and depth shall be as per manufacturer's design. After threading is completed, the threaded length of the bars shall be protected by providing plastic end caps before taking the bars out of the shop.

14.2.3 Quality control in making of threads:

14.2.3.1 Double forging of bars is not permitted. In case of improper cold forging the forged of the bar shall be square cut and fresh cold forging shall be undertaken. 100% threading at threaded rebars shall be checked with 'go' and "no go' gauges for the correctness of the thread profile on the rebar. A proper record for same shall be maintained at site.

14.2.4 Qualification tests

The coupler shall be qualified as per IS code 16172:2014, ACI 318, ASME - Section III, and Div.2, Caltrans and must have conducted & qualified for the following tests:

14.2.4.1 Static tensile test

Mechanical connections shall be tested for all reinforcing rebar sizes. For each rebar size, a minimum of three connections (3 joints + 1 Parent bar) in each load direction shall be tested in accordance with ASTM A370 test method to meet code requirement. A tensile test on an unsliced

specimen from the same bar used for the spliced specimens shall be performed to establish actual tensile strength. The tensile strength of an individual splice system shall not be less than the 125% of the specified minimum yield strength (fy of rebar) of the spliced bar.The test samples shall be tested till the breakage of the bar. A failure located inside the length of the mechanical splice shall be recorded as a splice failure (length of mechanical splice is as per clause no. 3.4 of IS 16172:2014).

Minimum percentage elongation at maximum force in the reinforcing bar outside the length of mechanical splice shall be minimum 3% before the failure of the test piece in accordance with IS 16172.

14.2.4.2 Cyclic tension and compression test

Mechanical connections shall be tested in all reinforcing rebar sizes. For each rebar size, a minimum of three connections shall be tested for cyclic tension & compression test. Each specimen shall withstand cycles of stress variation of the specified minimum yield strength of the reinforcing bar. The test should be carried out as per the table mentioned below:

Loading Stages and Cycles per stage for cyclic load test

Stage	Tension	Compression	Cycles
1	0.95 fy	0.5 fy	20 cycles
2	2 εy	0.5 fy	4 cycles
3	5 εy	0.5 fy	4cycles

Note:

fy is specified yield strength of the reinforcing bar.

εy is the strength of reinforcing bar at actual yield stress

14.2.4.3 Cyclic tensile test

Mechanical connections shall be tested in all reinforcing rebar sizes. For each rebar size, a minimum of three connections shall be tested for low cyclic tensile test. Each specimen shall withstand 100 cycles of stress variation from 5% to 90% of the specified minimum yield strength (fy) of the reinforcing bar. One cycle is defined as an increase from the lower load to the higher load & return.

14.2.4.4 Low cycle fatigue test (for 10,000 cycles)

Fatigue test shall be conducted on splice sample from +173 Mpa to -173 Mpa for 10,000 cycles. A sine wave form @ 0.5 Hz shall be followed for bar dia 36 mm & above and 0.35 Hz shall be followed for bar dia less than 36 mm. Test shall be conducted confirming to IS 16172:2014 & Caltrans specifications. Past certificates for low cycle fatigue test shall be accepted; however, these should not be more than 3 years old.

14.2.4.5 High cycle fatigue test (for 2,000,000 cycles)

In high cycle fatigue test, the test specimen is subjected to an axial tensile load which varies cyclically according to the sinusoidal wave form of constant frequency in the elastic range, as accordance with IS-16172. Past certificates for high cycle fatigue test shall be accepted; however, these should not be more than 3 years old.

14.2.4.6 Slip test

Slip Test Shall be performed on each diameter coupler specimen as per ASTM A 370 section 10. Test shall be conducted confirming to IS 16172:2014 & Caltrans specifications. Total slip shall not exceed the max value of 0.1 mm.

14.2.4.7 Proof loading test

Every cold-forged, threaded bar end shall undergo a proof load test prior to leaving system supplier's workshop. Every threaded bar must be subjected to proof load testing to a minimum test loading of 75% of the characteristic strength (theoretical fy). The system supplier shall essentially

install a proof load tester equipment within its threading workshop premises and ensure to test each and every threaded bar. A positive indication shall be marked on the rebar to indicate that this operation has been carried out.

14.2.5 Installation of Couplers in the field

14.2.5.1 The installation of couplers in the field, for joining reinforcing bars shall be undertaken by trained manpower and as per manufacturer's instructions. Threads of both the couplers and the bars shall be thoroughly cleaned just before installation. Where couplers are cast-in the concrete, but connection is not to be completed immediately, the couplers shall be internally greased and plastic capped to a protection detail acceptable to the Engineer. This cap shall be removed only when next bar is to be attached, then the same to be cleaned before joining the next bar.

14.2.5.2 The contractor shall arrange for a suitably qualified manufacturer's representative experienced in mechanically connecting reinforcement to be present at site before the start of work for initial training of personnel, and also to demonstrate the equipment and techniques as necessary. The threading workshop is to be fully supervised by the manufacturer's representative.

14.2.5.3 The contractor shall submit to the Engineer, for his acceptance a method statement for mechanically connecting the reinforcement and for the installation and verification in the field. This shall take into account any special requirements for horizontal, vertical and inclined couplers and shall include a rectification procedure, if the connection is incorrectly made. It shall also cover the correct methodology for handling of tools and equipment for mechanical connection on site. The following information shall also be included:

a. Requirements for cleanliness
b. Equipment for threading bars
c. Method flocking the connections on both rebars
d. Method of verification of final rebars alignment and coupler integrity

14.2.5.4 Each coupler shall be visually examined prior to use to ensure the absence of rust and of any foreign material on the inside surface. All completed couplers shall be inspected and verified in accordance with the approved QAP. The Contractor shall ensure the acceptance of the Engineer for a procedure for documenting the inspection of the couplers. The contractor shall retain inspection records and shall submit copies to the Engineer within 7 days. The Couplers that do not meet the acceptance shall be completely removed and the bars re-connected as required.

14.3 LAPPING, WELDING AND MECHANICAL SPLICING

14.3.1 As far as possible bars of maximum length shall be used, and the number of laps minimised. Laps shown on drawings shall be based on the use by the Contractor of bars of maximum length. In case the Contractor wishes to use shorter bars, laps/couplers shall be provided in the manner and at locations approved by the Designer.

14.3.2 Bars having lap welds shall be provided as specified in the drawings;

a. Wherever specified all welding of bars shall be carried in accordance with IS:2751 and IS:9417.
b. Only qualified welders shall be permitted to carry out such welding.
c. For cold twisted reinforcement welding operations must be controlled to prevent a supply of large amount sof heat larger than that can be dissipated. The extreme non-twisted end portion shall be cut off before welding. Electrodes with rutile coating should be used.
d. Bars shall be free from rust at the joints to be welded.
e. Slag produced in welding after alternative run should be chipped and removed by brush.
f. Electrode should not be lighted by touching the hot bar.
g. The welding procedure shall be approved by the Engineer and tests shall be made to prove the soundness of the welded connection.

h. E7018 electrode shall be used for Fe415 grade and E8018 electrode shall be used for Fe500 above as per AWS (American Welding Society)standards.

i. The inspection of welds shall be carried out in accordance with IS:822.

14.4 INSPECTIONS AND TESTING

14.4.1 The Contractor shall provide copies of the manufacturer's certificates of tests results relating to the steel reinforcement to be supplied and shall additionally provide independent test results obtained from an approved laboratory in respect of samples taken from reinforcement delivered to the Site.

14.4.2 Every bar shall be inspected before installation in the Works and any defective, brittle, excessively rusted or burnt bars shall be removed. Cracked ends of bars shall be cut out.

14.4.3 No work shall be commenced without the Engineer's consent of the bar bending schedule.

14.4.4 The sampling and tests on reinforcement steel supplied to site shall be carried out in accordance with IS:1786.

15 PRECAST AND PRE-STRESSED CONCRETE STRUCTURE

15.1 GENERAL

15.1.1 The stress is usually imposed by tendons of individual hard-drawn wires, cables of hard-drawn wires, or bars of high strength alloy steel. The Prestressed Concrete work shall comply with IS:1343 and IRS CBC

15.1.2 The contractor shall use complete prestressing system components from any of the manufacturing agency as per approved vendor list. It is preferable that the same agency is engaged for performing the prestressing activity at site. All prestressing hardware shall be from one vendor only, wherever possible. However, the Contractor shall ensure that different components of pre-stressing such as jacks, bearing plates, wedges, anchorages, strands and HDPE ducts are compatible to each other and the same shall be exchanged in between all the suppliers to ensure the same.

15.1.3 All precast segmental concrete decks shall be designed to ensure minimum residual compression in compliance with IRC SP: 65 under any service load combination. All joints shall be glued and the deck waterproofed to its full width to minimize water leakage from the joints. Surfacing trials shall be arranged to demonstrate the suitability and compatibility of the waterproofing layer and the surfacing. For Precast Segmental Concrete decks,the design and construction shall comply with IRC SP:65-2018.

15.1.4 The Contractor shall provide a method statement which confirms the methodology and resources that they propose to use to the Engineer for consent.

15.1.5 Some Precast configurations are being used profusely in constructions. The specifications for the same are being provided herewith.

15.2 MATERIAL SPECIFICATIONS

15.2.1 Cement

Ordinary Portland Cement of 53 grade conforming to IS: 12269 shall be used. For prestressed concrete, cement conforming to IRS T-40 specification or OPC-53 with flyash or without flyash Grade shall be used. All other specification will remain same as indicated in section S.03.

15.2.2 Reinforcement

Only TMT bars shall be used. All other specification will remain same as indicated in section16.

15.2.3 Prestressing Steel

Uncoated stress relieved Low Relaxation Steel conforming to IS: 14268, Class 2, shall be used. The nominal dia shall be 15.2mm with minimum breaking strength of 260.7 kN and minimum 0.2% proof load of 234.6 kN.

The prestressing steel accessories shall be subjected to an acceptance test prior to theiractual use on the works. (Guidance may be taken from BS: 4447). Only multi-strand jacks shall be used for

tensioning of cables. Direct and indirect force measurement device like Pressure Gauge) shall be attached in consultation with system manufacturer.

15.2.4 Concrete

The 28-day concrete strengths measured on 150mm cubes to be adopted for various structural elements have been indicated in the Bill of Quantities.

The physical and chemical properties of the constituents of concrete and so also of the green and hardened concrete shall meet the requirements of MORTH Specifications for Road and Bridge Works, where relevant or where the standard specifications referred to in the Technical Specifications are silent.

15.2.5 **Permanent Prestressing**

The permanent prestressing (for pre-cast piercap or other type of span where post tensioning is required cables shall generally be of the type 19K15 and 12K15, as suited to 19 nos. and 12nos. strands of 15.2mm nominal dia. Intermediate numbers of strands may also be specified in the design, for which suitable anchorage heads shall be used. All aspects of prestressing including the system proper shall be subject to the approval of the Engineer. The corrugated sheathing shall be of HDPE.

Maximum anchorage set- in shall be 6mm. Maximum friction ratios shall be 0.0020 m-1 and 0.17 rad-1

Shop Drawings and Design Calculations for Construction Procedures

15.2.6 **General**

The Contractor shall submit according to a schedule, complete details and information concerning the method, materials, equipment and procedures he proposes to use. These shall be called “Method Statements”. Method Statements shall be submitted sufficiently in advance of the start of superstructure field construction operations, so as to allow the Engineer adequate review period, which shall not be less than 30 days. The submittals shall invariably include step-by-step erection procedure.

The Contractor’s Method Statements shall also include all calculations, drawings and information as may be relevant.

15.2.7 **Design Calculations for Construction Procedures**

Design assumptions and calculations shall be submitted for temporary prestressing, false work, erection devices, formwork or other temporary construction which may be required to complete the work.

Assumptions and Calculations shall also be submitted to substantiate the system and method of permanent and temporary prestressing proposed by the Contractor.

15.2.8 **Casting, Handling, Transportation and Erection of Girder**

General

The Contractor shall submit detailed Method Statements for casting, handling, transportation and erection of girder. The superstructure shall be erected by the method indicated in the tender or by alternate method submitted by the Contractor, subject to the approval of the Engineer. The stressing system, cage of reinforcement and lifting details shall be successfully demonstrated on sample segment prior to casting any permanent segments.

All handling and erection plant and equipment shall be load tested prior to their use at site or when specifically asked for by the Engineer. Any additional material required to cater to any temporary condition including temporary prestressing shall be borne by contractor and nothing extra will be paid in this account.

Casting

Casting bed and forms shall be structurally adequate to support the girders without settlement or distortion. The casting bed shall be designed for the hardware needed to adjust and maintain grade and alignment. Special consideration shall be given to those parts of the forms that have to change

in dimensions. To facilitate alignment or adjustment, special equipment such as wedges, screws or hydraulic jacks shall be provided. Fittings shall not interfere with stripping of forms. External vibrators shall supplement the internal vibration if necessary and be attached at locations that will ensure maximum consolidation.

Details for casting bed and hardware for adjustment shall be submitted by the Contractor for the Engineer's approval. Casting of girders shall be done in a single pour. Construction joint is not permitted in girder.

Care shall be taken to ensure that deformations due to thermal gradients caused by the heat of hydration of the new cast concrete are negligible. These deformations shall be prevented by properly protecting with curing blankets and plastic sheeting.

Reinforcing steel shall be fabricated in cages and placed according to the Execution Drawing issued by concerned organisation. Any conflict or interference with the proper location of reinforcement or block-outs shall be promptly resolved and corrections made as directed by the Engineer/Engineer's Representative.

All girders shall be marked on the inside with a unique identification at the time of form removal.

15.2.9 **Handling / Erection of Girders**

The Contractor shall be responsible for the proper handling, lifting, storing, transporting and erection of all girders so that they may be placed in the structure without damage. Only HTS bar shall be used for lifting/handling of girder at any stage of construction, with due care forfatigue considerations (multiple re-use).

Girders shall be maintained in an upright position at all times and shall be stored, lifted and/or moved in a manner to prevent torsion and differential deformation other undue stress. Members shall be lifted, hoisted or stored with lifting devices approved on the shop drawings.

The Contractor shall furnish calculations to establish that the stresses induced during any stages of construction shall not exceed 50% of the cube strength achieved at that stage, nor 40% of the specified 28days cube strength. In addition, the following limitations shall be observed:

a. The girder shall not be lifted from the casting bed till the concrete reaches a minimum cylindrical strength of 20 MPa (or 25MPa Cube strength).

b. The age of the concrete shall not be less than 14 days at the time of its erection provided it has achieved its specified strength as per design requirements.

Girders shall be stacked with three point support in curing tank / stacking yard as shown in tender drawing, or as approved by concerned organisation Curing shall be done using sprinkler system (assisted by steam curing in the initial stages if adopted) and it has to be ensured that all parts of girder are water cured during water curing period. Curing compound as per relevant specifications may be applied after approval of Engineer-In-Charge.

15.2.10 **Cleaning of Girders**

Before transportation of girder, surface shall be cleaned by water rinsing or sand blasting as approved by the Engineer.

Miscellaneous

The entire construction work shall be geared towards minimising disruptions to road traffic. Also, the occupation of roads during all construction activities shall be reduced to a minimum and subject to the approval of the Engineer. Reinforcement shall be fabricated in cages in casting yard for piles, pile caps and piers before being brought into position for expediting the activities.

All elements of sub-structure below bearing pedestals viz piles, pile caps, piers and pier caps shall each be cast in single pour.

15.2.11 **Load Testing of Standard Span of Superstructure**

The contractor shall conduct full scale load test for one Girder (simply supported span, erected in position, including arrangements for applications of serviceable vertical load for measuring deflections and rotations and submit the report).

The sequence of placement and position of loading on the girder shall be as directed by the engineer.

15.3 BOX GIRDER/PRECAST SEGMENTS

15.3.1 Construction Method

The box girder superstructure for almost the entire length shall be constructed by precast segmental construction with epoxy bonded joints. The prestressing cables will be internal to the concrete. The methodology of construction will be "span by span". Only one end prestressing of permanent cables is contemplated, the other end of the cable being pre-blocked.

The usual segments shall be 3.0m in length except the pier segments which shall be 1.975m each. Standard spans shall be made to either add or subtract usual segments of 3.0m each.

Where this is not possible or advisable for some reason, the segments will be of length between 1.5m and 3.0m. Hence the mould / casting bed shall be adaptable to cast non-standard length of segment.

The maximum span length contemplated for precast segmental construction will be of the order of 37.0m.

Multiple Shear keys shall be provided at segmental joints at the webs as well as at top flange and soffit slab of the box girder.

Box girder segments shall be match cast at the casting yard and later transported to location and erected in position. Post-tensioned cables shall be threaded-in-situ and tensioned from one end. Box girder shall cater to two tracks.

All precast S1 segment girders shall be tested for Ultra Sonic Pulse Velocity as per IS 13311 (Part I) and rebound hammer as per IS 13311 (Part II). Testing cost shall be borne by the contractor. Sleeves for the grouting shall be provided in all S1 precast segment, if honey combed found after the SPV test then the segment can be grouted.

15.4 MATERIAL SPECIFICATIONS

15.4.1 Cement

Cement shall comply with IRS CBC Clause 4.1 as per clause 3.3.1 clause of in this Section.

15.4.2 **Fly Ash**

Fly ash is not allowed in PSC concrete

15.4.3 **Reinforcement**

Reinforcement shall be as per clause 14 of this Section.

15.4.4 **Concrete**

Concrete shall be as per clause 12 of this Section.

15.5 SHEATHING

15.5.1 All pre-stressing sheathing duct shall be corrugated High Density Polyethylene (HDPE). The sheathing material and thickness shall conform to IRS CBC clause 7.2.6.4.2.4 and MORTH clause 1803.2.3 & 1803.2.4.

15.5.2 The residual wall thickness after loss (wear resistance) shall not be less than 1.5mm for ducts up to 85mm diameter and 2mm for ducts diameter above 85mm shall comply with IRS CBC and or IRC 112

15.5.3 The ducts shall be corrugated on both sides. The duct shall transmit full tendon strength from the tendon to the surrounding concrete over a length not greater than 40 duct diameters. Material and formulation of sheathing ducts shall conform to test and acceptance criteria of IRC 112.

15.5.4 These ducts shall be joined by adopting any one or more of the following methods, as convenient to suit the individual requirements of the location, subject to satisfactory pressure tests, before adoption.

a. Screwed together with male and female threads.
b. Joining with thick-walled HDPE shrink couplers with glue. This can also beused for connection with trumpet, etc.
c. Welding with electrofusion couplers

15.5.5 The joints shall be able to withstand an internal pressure of 0.5 Bar for 5 minutes as per water loss test procedure as confirmed by in Appendix B of the IRS CBC.

15.5.6 The initial acceptance tests such as bond test, compression test is required to be performed as acceptance criteria for the system. In addition to the HDPE ducts supplier must have conducted friction tests at least once as given in FIB bulletin No. 7 to establish and confirm the friction values (K & u) using the HDPE ducts produced by them. The test details shall be submitted to the Engineer for consent.

15.5.7 Routine tests such as workability test, transverse load rating test, tension load test and water loss test shall be applicable for both post threading and pre-threading system of cables. Load`s to be imparted on the 107mm ID sheathing during transverse load rating test and tension load test shall be extrapolated from values given for smaller diameter sheathing in compliance with IRC: 112. At least 3 samples for one lot of supply (not exceeding 7000 mm length) shall be tested.

15.5.8 The prestressed segmental construction methodology shall comply with IRC: SP:65. In At-Grade& Elevated stations constructed by precast segmental construction, cables shall be threaded after application of temporary pre-stressing. In continuous units, constructed by cantilever construction techniques the cantilever cables will be stressed as various segments are cast progressively. Such cables shall be threaded after concreting. In such cases a temporary flexible PVC tube of 90mm OD shall be homed through sheathing which will provide adequate stiffness to sheathing during concreting and also prevent blockage of sheathing in case of possibility of leakage. The temporary PVC tube shall be pulled out before the threading of the permanent cables.

15.6 ANCHORAGES

15.6.1 Anchorages shall comply with IRS CBC Anchorages shall be procured from manufacturers approved by the Engineer.

15.6.2 Load transfer test and anchorage efficacy shall be conducted as confirmed by FIP 1993. The Contractor shall select at random, the required anchorage/wedges sample from completed lots for testing by the manufacturer. The concrete unit of required size/R/F will be made by Contractor using the same design mix of concrete which will be required for the load transfer test. The load transfer test shall be conducted at the strength of concrete at which stressing are proposed in the design.

15.6.3 No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times. Threaded parts shall be protected by greased wrapping 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 coating.

15.6.4 After completion of pre-stressing and grouting of cables in girders, the extra length pre-stressing strands projecting outside the anchorage are required to be cut and the anchor end is to be sealed.

15.6.5 Pre-stressing strands shall develop strength of at least 95 per cent of the specified breaking load of the strand.

15.6.6 Un-tensioned steel reinforcement around anchorages shall be furnished by a pre-stressing system supplier. This shall be job specific and based on the edge distance of anchorage and strength of concrete at the time of stressing of cables as defined in design.

15.6.7 A minimum of 3 tests shall be conducted for load transfer and anchorage efficacy testing. The manufacturer/supplier shall complete the required testing and confirm compliance with FIP 1993 before transport action of each lot to site.

15.7 PRE-STRESSING STEEL

15.7.1 Uncoated stress relieved low relaxation steel in compliance with IRS CBC and IS:14268 shall be used. Testing shall comply with IS:14268 and it shall be conducted before transportation of each lot to site.

15.7.2 In addition to the 1,000 hours relaxation tests conducted by manufacturer/supplier, a minimum of two tests are required to comply with IRS CBC, shall be conducted by a nationality accredited/certified laboratory prior to work commencing on site.

15.8 PRE-STRESSING STRANDS

15.8.1 All high tensile steel for pre-stressing work shall be stored about 30 cm above the ground in a suitably covered and closed space to protect it from dampness. It shall be wrapped in gunny cloth or tar paper or any other suitable materials.

15.8.2 Tendons shall be free from loose rust, oil, grease, tar, paint, mud or any other deleterious substance.

15.8.3 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.

15.8.4 All strands to be transported to the site shall be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be transported shall also be individually identified.

15.8.5 All samples submitted shall be representative of the lot to be furnished and in the case of strand, shall be taken from the same master roll. The Contractor shall furnish samples of at least 03 pieces of 5 metre length, selected from each lot for testing at a nationality accredited/certified laboratory. Also, two anchorage assemblies, complete with distribution plates of each size or types to be used, shall be furnished along with short lengths of strands as required.

15.8.6 High tensile 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.

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

15.9 EPOXY BONDED JOINTS

15.9.1 A minimum compressive stress of 3 kg / sq. cm shall be provided uniformly over the cross-section for the closure stress on the epoxied joint until the epoxy has set.

15.9.2 This temporary compressive stress can be applied by temporary prestressing bars.

15.9.3 The curing period for application of the compressive stress, method of mixing and application of epoxy and all related aspects including surface preparation shall be as per approved manufacturer's specifications.

15.9.4 The Epoxy shall be spread with the help of a stubby brush to a thickness of about 1.5 mm each on both the joining surfaces.

15.9.5 The purpose of the epoxy joint shall be to serve as lubricant during segment positioning, to provide water proofing of the joints for durability in service conditions and to provide a seal to avoid cross-over of grout during grouting of one cable into other ducts.

15.9.6 Prior to grouting, all cables shall be tested with water pressure of 0.3 MPa for approximately 3 minutes, to investigate leakages and connectivity of ducts. Since the epoxied joint is of paramount importance to ensure long-term durability of prestressing cables, this field test shall be taken as indication of the Contractor's quality of work in general and effectiveness of the epoxy joint executed by him. All other aspects of grouting of cables shall be governed by MORTH Specifications.

15.9.7 The epoxy shall be special purpose proprietary material for the proposed usage with proven past record. Selection of epoxy shall be subject to the approval of the Engineer. It shall meet the requirements of relevant provision of FIB (International Federation of Concrete, previously "FIP - International Federation of Prestressed Concrete"). For selection of epoxy, all tests which govern the properties of epoxy for its application and subsequently determine the durability of joint are required to be done in laboratory temperature-controlled condition. Some tests for evaluating properties of epoxy are critical in the upper limit of specified application temperature range while other tests are critical for evaluating the properties in the lower limit of specified application temperature range. The tests shall be conducted in laboratories equipped to handle controlled temperature conditions. All tests shall conform to FIB requirements.

15.9.8 After receiving every batch, all tests (except shear modulus, instantaneous and deferred modulus in compression and water absorption, heat resistance, shear strength and solubility in water) are required to be done at the site laboratory at prevailing ambient temperature to conform to the uniformity of standard of supplied product. In case the received batch is kept at site for a period of more than three months all tests are required to be re-done.

15.9.9 With every erection, tests for pot life and open time are required to be done at site at prevailing ambient temperature. Nothing extra shall be payable for providing epoxy and all related operations.

15.9.10 The uniform compressive stress during the curing period may be applied by approved external temporary bar prestressing. This shall be accomplished using short HTS bar connecting the adjoining segments. The bars shall be anchored on temporary steel frame, passing through dedicated holes within the girder through. No passing-through holes shall be used in soffit slab or web. Passing-through holes used in soffit slab should be filled with free flow, high strength, non-shrink cement grout.

15.9.11 In order to prevent intrusion of epoxy in sheathing, an O-ring with diameter compatible with the size of HDPE sheathing (10-20mm wide and 4mm thick) of polypropylene shall be provided on both mating surfaces.

15.9.12 Nothing extra shall be payable for such temporary stress application including all related works.

15.10 EPOXY BONDING AGENTS

15.10.1 Epoxy bonding agents for match cast joints shall be thermosetting 100 percent solid compositions that do not contain solvent or any non-reactive organic ingredient except for pigments required for colouring. Epoxy bonding agents shall be of two components, a resin and a hardener. The two components shall be distinctly pigmented. So that mixing produces a third colour similar to the concrete in the segments to be joined, and shall be packaged in proportioned, labelled, ready-to-use containers.

15.10.2 Epoxy bonding agents shall be formulated to provide application temperature ranges that will permit erection of match cast segments at substrate temperatures from 5oC to 45oC. If two surfaces to be bonded have different substrate temperatures, the adhesive applicable at the lower temperature shall be used.

15.10.3 Epoxy bonding agents shall be insensitive to damp conditions during application and after curing, shall exhibit high bonding strength to cured concrete, good water resistively, low creep characteristics and tensile strength greater than the concrete. In addition, the epoxy bonding agents shall function as a lubricant during the joining of the match cast segments, as a filler to accurately match the surface of the segments being joined and as a durable water light bond at the joint.

15.10.4 Epoxy bonding agents shall be tested to determine their workability get time, open time, bond and compression strength, shear, and working temperature range. The frequency of the tests shall be as stated in the Special Provisions of the Contract.

15.10.5 The contractor shall furnish the Engineer with samples of the material for quality assurance testing and a certification from a reputable independent laboratory indicating that the material has passed the required tests

15.10.6 Specific properties of epoxy and the test procedures to be used to measure these properties shall conform to FIP requirement.

15.11 MIXING AND INSTALLATION OF EPOXY

15.11.1 Instructions furnished by the supplier for the safe storage, mixing and handling of the epoxy bonding agent shall be followed. The epoxy shall be thoroughly mixed until it is of uniform colour. Use of a proper sized mechanical mixer operating at no more than 600 RPM will be required. Contents of damaged or previously opened containers shall not be used. Surfaces to which the epoxy material is to be applied shall be at least 400F and shall be free from oil, laitance form release agent or any other material that would prevent epoxy from bonding to the concrete surface. All laitance and other contaminants shall be preferably removed by water rinsing, or, alternatively, by light sandblasting. Wet surfaces shall be dried before applying epoxy bonding agents. The surface shall be at least the equivalent of saturated surface dry (no visible water).

15.11.2 Mixing shall not start until the segment is prepared for installation. Application of the mixed epoxy bonding agent shall be according to the manufacturer's instructions using trowel rubber glove or brush on one or both surfaces to be joined. The coating shall be smooth and uniform and shall cover the entire surface with a minimum thickness of 1/16-inch applied on both surfaces and 1/8-inch if applied on one surface. Epoxy should not be placed within 3/8th inch of prestressing ducts to minimise flow into the ducts. A discernible bead line must be observed in all exposed contact areas after temporary post-tensioning. Erection operations shall be coordinated and conducted so as to complete the operations of applying the epoxy bonding agent to the segment's erection assembling and temporary post-tensioning of the newly joined segment within 70% of the open time period of the bonding agent.

15.11.3 The epoxy material shall be applied to all surfaces to be joined within the first half of the gel time as shown on the containers. The segments shall be joined within 45 minutes after the application of the first epoxy material placed and a minimum required temporary prestress over the cross section should be applied within 70 percent of the open time of the epoxy material. The joint shall be checked immediately after the erection to verify uniform joint width and proper fit. Excess epoxy from the joint shall be removed where accessible. All tendon ducts shall be swabbed immediately after stressing while the epoxy is still in the non-gelled condition to remove or smooth out any epoxy in the conduit and to seal any pockets or air bubble holes that have formed that joint.

15.11.4 If jointing is not completed with 70 percent of the open time, the operation shall be terminated, and the epoxy bonding agent shall be completely removed to the maximum possible extent from the surfaces. The surface must be prepared again, and fresh epoxy shall be applied to the surface before resuming jointing operations. As general instructions cannot cover all situations specific recommendations and instructions shall be obtained in each case from the Engineer.

15.12 SHOP DRAWINGS AND DESIGN CALCULATIONS FOR CONSTRUCTION PROCEDURES

15.12.1 General

a. The Contractor shall submit according to a schedule, complete details and information concerning the method, materials, equipment and procedures he proposes to use. These shall be called "Method Statements". Method Statements shall be submitted sufficiently in advance of the start of superstructure field construction operations, so as to allow the Engineer adequate review period, which shall not be less than 30 days. The submittals shall invariably include step-by-step erection procedure.

b. The Contractor's Method Statements shall also include all calculations, drawings and information as may be relevant.
c. Design Calculations for Construction Procedures
d. Design assumptions and calculations shall be submitted for temporary prestressing, false work, erection devices, formwork or other temporary construction which may be required to complete the work.
e. Assumptions and Calculations shall also be submitted to substantiate the system and method of permanent and temporary prestressing proposed by the Contractor.
f. In the sections that follow, specific recommendations for precast segmental construction for superstructure are given apart from certain special aspects of construction
g. Shop Drawings for Precast Segmental Construction
h. The Contractor shall submit detailed shop drawings for approval. The shop drawings shall be based on Execution Drawings issued by concerned organisation to the Contractor and shall include:
    i. Fully and accurately dimensioned views showing the geometry of segments including all projections, recesses, notches, openings, block-outs, blister if any and where acceptable, as well as other relevant details.
    ii. Details of any special reinforcing required for handling of segments or for other purposes. Also all bar bending schedules shall be presented based on reinforcement schedules given in Execution Drawings issued by concerned organisation.
    iii. Sheathing supports, grout tubes, vents and drains shall be shown including size, type and locations.
    iv. Details and locations of all other items to be embedded in the segments such as inserts, lifting devices and post-tensioning hardware shall be shown.
    v. Prestressing system details shall include sizes and properties of tendons, anchorages, plates, assemblies and stressing procedure, and details and locations of additional reinforcement necessary to resist anchor block stresses.
    vi. Graphs, charts or tables showing the theoretical location of each segment, as erected or placed shall be furnished to the Engineer for his use in checking the erection of the superstructure. Detailed procedures for making geometry corrections shall be described.
    vii. Details of grouting equipment, grout mix design and method of mixing and placing grout shall be provided.
    viii. Method of installing bearings and expansion joints shall be given including approved manufacturer's recommendations.

15.13 FORMS FOR PRECAST SEGMENTAL CONSTRUCTION

15.13.1 Forms for precast segmental construction shall be steel form work only. Shop drawings shall be submitted for all formwork. The segments during storing /curing shall always be supported as shown in tender drawings or as approved by Engineer only.

15.13.2 In addition to the requirements of the Standard Specifications, the forms used for precasting the concrete segments shall be capable of:

a. Match casting for precast segmental construction.
b. Producing the segments within the tolerances permitted in Section 10.2.8.
c. Accommodating block-outs, openings and protrusions. Protruding re-bars will be needed at least for diaphragm segments and for second-pour plinths. Anchorages and inserts for OHE poles, signalling equipment and cable routing supports shall also be included where needed in precast segments.

d. Adjusting to changes in segment geometry as shown in Execution Drawings issued by concerned organisation, or for correcting previous minor casting errors to prevent accumulation.
e. Adjusting the profile to take into account design camber values
f. Stripping without damage to the concrete.
g. The form design shall provide a tight leak-proof jointing to the previous segment. The bulkhead must be capable of connecting the sheathing in a manner to hold their position and prevent intrusion of grout.

15.13.3 Joints in external formwork shall be avoided as far as possible. Where sections of forms are for some reason to be joined on the exterior face of the segment, an offset in excess of 0.5mm for flat surfaces and 1 mm for corners and bends will not be permitted.

15.13.4 Forms shall not be removed until the concrete has attained adequate strength. Care should be exercised in removing the forms to prevent spalling and chipping of the concrete.

15.13.5 All side, bottom, inside and header forms for precast segmental construction shall be constructed of steel.

15.13.6 Forms shall be of sufficient thickness, with an adequate external bracing and stiffeners, and shall be sufficiently anchored to withstand the forces due to placement and vibration of concrete. Internal bracing and holding devices in forms shall be limited to stay bolts in webs, which can be removed from the concrete surface to permit patching following form removal. Joints in the forms shall be designed and maintained for mortar tightness. The grade and alignment of forms shall be checked each time they are set and shall be maintained during the casting of concrete.

15.13.7 Metal forms shall be reasonably free from rust, grease or other foreign materials. All forms shall be cleaned thoroughly prior to each casting operation. End headers shall be maintained to provide a smooth casting surface.

15.13.8 All formed surfaces for casting members shall be constructed and maintained to provide segment tolerances in accordance with Section 10.2.8.

15.13.9 The faces of all forms, other than end headers, shall be properly cleaned and treated with form oil or other bond breaking coating prior to placing concrete. Between adjacent match cast segments and headers bond breaking materials shall be provided as indicated elsewhere in these Additional Specifications. The oil or other .materials used shall be of a consistency and composition to facilitate form removal. Materials which stain or react with concrete shall not be used. Care shall be exercised to facilitate formwork and segment removals without damage to the concrete.

15.14 CASTING, HANDLING, TRANSPORTATION AND ERECTION OF PRECAST SEGMENTS

15.14.1 General

a. The Contractor shall submit detailed Method Statements for casting, handling, transportation and erection of precast segments. The superstructure shall be erected by the method indicated in the tender or by alternate method submitted by the Contractor, subject to the approval of the Engineer. The stressing system, cage of reinforcement and lifting details shall be successfully demonstrated on sample segment prior to casting anypermanent segments.
b. All handling and erection plant and equipment shall be load tested prior to their use at site or when specifically asked for by the Engineer. Any additional material required to cater to any temporary condition including temporary prestressing shall be borne by contractor and nothing extra will be paid in this account.

15.14.2 Casting of Segments

a. Casting bed and forms shall be structurally adequate to support the segments without settlement or distortion. The casting bed shall be designed for the hardware needed to adjust and maintain grade and alignment Special consideration shall be given to those parts of the forms that have to change in dimensions. To facilitate alignment or adjustment, special

equipment such as wedges, screws or hydraulic jacks shall be provided. Fittings shall not interfere with stripping of forms. Grading of the forms and the deck of each segment shall take into consideration the relative position of the member in the structure. External vibrators shall supplement the internal vibration if necessary and be attached at locations that will ensure maximum consolidation.

b. Details for casting bed and hardware for adjustment shall be submitted by the Contractor for the Engineer's approval. Casting of segments shall be done in a single pour. Construction joint is not permitted in segment.

c. After the first segment of each unit is cast, all succeeding segments shall be cast against previously cast segments to ensure complete bearing and proper alignment on all mating surfaces.

d. The anchorage system shall permit tendons to be inserted in the member after erection of segments and tensioned from one end only.

e. Care shall be taken to ensure that deformations of match cast segments due to thermal gradients caused by the heat of hydration of the new cast concrete are negligible. These deformations shall be prevented by properly protecting both the match cast and new cast segments with curing blankets and plastic sheeting. Both the previous segment and the new segment will be maintained at the same temperature.

f. Reinforcing steel shall be fabricated in cages and placed according to the Execution Drawing issued by NCRTC. Any conflict or interference with the proper location of sheathing and / or reinforcement or block-outs shall be promptly resolved and corrections made as directed by the Engineer.

g. All segments shall be marked on the inside with a unique identification at the time of form removal. This identification shall be used to identify each segment on shop plans, post-tensioning details and calculations and any other document pertaining to the fabrication and erection of precast concrete segments.

h. Positive means of holding the sheathing in its correct position shall be provided in all cases and shall be indicated on the shop drawings submitted for approval. The sheathing shall be stiffened from the inside by rubber or plastic hoses or by inflatable rubber tubes.

15.14.3 Casting Methods

a. Match cast segments may be cast by the “long line” or “short line” method. The Contractor has to select the option carefully and provide appropriate type of formwork as well as casting and handling operations. The "short line" method requires much greater precision in the work as compared to the "long line" method.

15.14.4 The "Long Line" Method

a. The principle of the long line method is the casting of the segments, in their correct relative position, on a long line casting bed which exactly reproduces the profile of the structure. A long line is easy to set up, while the geometry of the segments is easily controlled. The segments shall be cast by long line method for spans curved in plan.

b. After stripping the forms, it is not necessary to take away the segments immediately. Water curing/curing compound as per relevant specifications shall be applied to segments immediately.

c. Substantial space may be required for the long line. The theoretical length for casting alone is normally slightly more than the length of the longest span of the structure. It must be constructed on a firm foundation which will not settle or deflect under the weight of the segments. In case the structure is curved, the long line must be designed to accommodate horizontal and vertical curvature as well as twists, if any, because the forms are mobile, equipment for casting, curing, etc has to move from place to place.

15.14.5 The “Short Line” Method

a. The short line method is mentioned here as a possible alternate.

b. The segments are cast at the same place in stationary forms and against a neighbouring element. After casting, the neighbouring element is taken away and the last element is shifted to the place of the neighbouring element, clearing the space to cast the next element.

c. The space needed for the short line method is small in comparison to the long line method, approximately three times the length of a segment for one short line. The entire process is centralised. Horizontal and vertical curves and twisting of the structure are obtained by adjusting the position of the neighbouring segment and through specified formwork.

d. To obtain the desired structural configuration, the neighbouring segments must be accurately positioned. Care must be taken that the formwork be sufficiently flexible to allow for adaptation at the joint with the accurately positioned matching segment.

e. If short line method is adopted, the deck segments should follow profile as given below;

15.14.6 Suggested Deck Alignment on Vertical Curves

a. On Vertical Summit Curves
On vertical summit curves, deck will follow the path of straight line joining the two points on adjacent piers. These two points shall have the minimum offset from rail level to deck level as specified by Engineer at all points along the length of girder.

b. On Vertical Valley Curves
On vertical valley curves, deck will follow the path of straight line joining the two points on adjacent piers. The minimum offset from rail level to deck level as specified by Engineer shall be ensured at all points along the length of girder.

15.14.7 Suggested Deck Alignment on Circular / Transition Horizontal Curves

a. On circular / transition horizontal curves, each segment of the deck will follow the profile of short chord line. The bottom and side form for segment to be cast are positioned to span between the stiff fixed end bulkhead and the previously match cast segment. The previously match cast segment shall be oriented w.r.t. segment to be cast and it should be ensured that fixed bulkhead always remain perpendicular to end face of formwork.

b. Due to orientation of match cast segment, the length of segment towards inner side of curve will be less and towards outer side of curve will be more than segment length along centre line. The formwork to be used should have flexibility to adjust the segment length on both sides by adjusting the position of the match cast segment without any additional pieces and it shall be ensured that offset of match cast segment and segment to be cast is limited to value so calculated.

15.14.8 Separation of Match-Cast Segments

a. The Contractor shall provide equipment to be used for uniform separation of match case segments without damage. The method as well as details of the equipment to be used for separating match cast segments shall be included in the shop drawings. A bond breaking material shall be used in the form of wax only on the webs and soffit slab of the previously cast segment and a newly cast segment, as well as the end headers when required. The material shall not be injurious to the concrete and shall permit removal of a segment without adhesion of the concrete.

b. Any breakage in segment end face during separation / handling shall not be repaired, unless specifically accepted by the Engineer, in which case repairing at end face of segment shall be done with epoxy at the time of epoxy application. Segments with excessive breakage shall be rejected. Decision of the Engineer shall be final binding in this regard.

15.14.9 Handling / Erection of Segments

a. The Contractor shall be responsible for the proper handling, lifting, storing, transporting and erection of all segments so that they may be placed in the structure without damage. Only HTS bar such as Macalloy or Dywidag shall be used for lifting/handling of segment at any stage of construction, with due care for fatigue considerations (multiple re-use).

b. Segments shall be maintained in an upright position at all times and shall be stored, lifted and/or moved in a manner to prevent torsion and differential deformation other undue stress. Members shall be lifted, hoisted or stored with lifting devices approved on the shop drawings.

c. The Contractor shall furnish calculations to establish that the stresses induced during any stages of construction shall not exceed 50% of the cube strength achieved at that stage, nor 40% of the specified 28days cube strength. In addition, the following limitations shall be observed:

   i. The segment shall not be lifted from the casting bed till the concrete reaches a minimum cylindrical strength of 20 MPa (or 25MPa Cube strength).

   ii. The age of the concrete shall not be less than 14 days at the time of its erection provided it has achieved its specified strength as per design requirements.

d. Segment shall be stacked with three-point support in curing tank / stacking yard as shown in tender drawing, or as approved by concerned organisation Curing shall be done using sprinkler system (assisted by steam curing in the initial stages if adopted) and it has to be ensured that all parts of segment are water cured during water curing period. Or curing compound as per the relevant specifications in this document

15.14.10 Cleaning, Transportation and Erection of Segments

a. Before transportation of segment, mating surface shall be cleaned by water rinsing or sand blasting as approved by the Engineer.

b. When sand blasting is employed surface shall be abraded to an extent that;

   i. Bond breaker such as wax applied during match casting is removed.

   ii. Laitance is removed so that small aggregates are just exposed.

   iii. Cleaned surface is neither polished nor excessively rough

c. Two methods of erection have been suggested: Side beams method, and as an allowed alternate, the top beams method. Only the side –beams method is referred to in these special specifications. The launching girder (or more accurately, the "assembly truss") must be capable of supporting all the loads with in permissible limits as stipulated in codes and transferring it to the temporary cross girder, which transfer the loads directly on pier cap using trestles. The launching girder envisaged is slightly greater than 2 spans. It must also be able to negotiate curves and accommodate for the camber if any of the structure. As far as practical, the movement of segments shall be done at the deck level of the already constructed portion of the continuous length so that the disturbance to traffic at the ground level is minimised. Mobile crane of adequate capacity and boom length shall be mobilised by the Contractor for transferring the segment from ground level to deck level for the purpose. The launching girder should be capable of lifting the segments for the span to be erected from below and in case required, it should also be capable of feeding the segments from the rear end over the already erected span.

d. A suitable number of separate sets of launching girders are essential in order to proceed at the contemplated pace for completion of project in time. However, Contractor shall furnish the construction scheme and nos. of launching girders, he proposes to deploy in order to ensure completion of project within scheduled time.

e. It is emphasised that for precast segmental construction only one-end prestressing shall be used. The superstructure shall be constructed "span by span" sequentially.

f. The diaphragm segments shall need specific additional temporary supports under the webs during those various stressing operations. Those temporary supports shall be flexible enough in rotation. The precise load transfer during the stressing operations between the various supports shall be monitored at least once with adequate jacks during the destructive testing of one span in precast yard.

g. It is emphasised that

i. The spans must be assembled on a higher level to avoid conflicts with already built concrete shear key.

ii. The launching truss supports must be at same location than temporary bearings.

15.15 POST-TENSIONING

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

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

15.15.3 The location of pre-stressed cables shall be such as to facilitate easy placement and vibration of concrete in between the tendons.

15.15.4 Sheathing shall be placed in correct position and profile by providing suitable ladders and spacers. Such ladders may be provided at intervals of preferably 1 metre. Sheathing shall be tied rigidly with such ladders/spacer bars so that they do not get disturbed during concreting.

15.15.5 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.

15.15.6 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.

15.15.7 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.

15.15.8 Cutting and trimming of wires or strands shall be carried out by suitable mechanical cutters.

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

15.15.10 Pre-stressing steel shall be continuously protected against corrosion, until grouted. The corrosion protection shall have no deleterious effect on the steel or concrete or on the bond strength of steel to concrete.

15.15.11 Grouting shall comply with IS/IRS CBC.

15.15.12 The joints of all sheathings shall be water-tight. 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 adhesive water proof tape as per approved manufacturer.

15.15.13 The sheathing and all joints shall be water tight. 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. Sheathing shall be firmly tied so that while concreting they should not float up. Sheathing shall be aligned accurately with respect to vertical and horizontal coordinate.

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

15.15.15 Grout vents of at least 20 mm diameter shall be provided at both ends of the sheathing and at all valleys and crests along its length. Additional vents with plugs shall also be provided along the length of sheathing such that the spacing of consecutive vents does not exceed 20m. Each of the grout vents shall be provided with a plug or similar device capable of withstanding a pressure of 1.0 MPa without the loss of water, air pressure or grout.

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

15.15.17 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.

15.15.18 The anchorages shall be recessed from the concrete surface as per the design.

15.15.19 After the pre-stressing operations are completed and pre-stressing 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.

15.15.20 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 of all strands.

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.

e. The load-measuring device shall be calibrated to an accuracy within ± 2% and checked at intervals to the consent of the Engineer. Elongation of the tendon shall be measured to an accuracy within 2% or 2mm, whichever is the more accurate.

f. The tensioning equipment shall be calibrated before the tensioning operation and at every three months.

g. Pressure gauges shall be concentric scale type gauges accurate to within two per cent of their full capacity. The minimum nominal size of gauge shall be 100 mm. The gauge shall be so selected that when the tendon is stressed to 75 per cent of its breaking load, the gauge is reading between 50 percent and 80 percent of its full capacity.

h. Suitable safety devices shall be fitted to protect pressure gauges against sudden release of pressure.

i. Provision shall be made for the attachment of the master gauge to be used as a check whenever requested for by the Engineer.

j. The jacks and pumps shall be got calibrated, by an approved laboratory, prior to use and then at intervals not exceeding three months. Before initial use & subsequently at suitable intervals, the pre-stressing equipment shall be checked to determine any variation from the normal values during use. So far as these variations depend upon the external influences, they shall be taken into account.

15.15.21 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 approved by the Engineer.

15.16 GROUTING

15.16.1 The water/cement ratio (W/C) shall be as low as possible consistent with the necessary workability, and under no circumstances shall the W/C ratio exceed 0.45 by weight and comply with IRS CBC, MoRTH Clause 1809 Appendix 1800/3.

15.16.2 The grout shall not be subject to bleeding in excess of 2% after 3hours or 4% maximum when measured at 25°C or such other temperature as may be approved by the Engineer, in a covered cylinder approximately 100 mm diameter with a height of grout of approximately 100 mm, and the water shall be reabsorbed by the grout during the 24hours after mixing.

15.16.3 Admixtures may be used with the Engineer's consent and shall be applied strictly in accordance with the manufacturer's instructions. Admixtures shall not contain chloride ions in excess of 0.25 percent by weight.

15.16.4 The mixing equipment shall produce a group of homogeneous consistency and shall be capable of providing a continuous supply to the injection equipment.

15.16.5 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.

15.16.6 Grouting shall be carried out as soon as is practicable after the tendons have been stressed and anchors trimmed. Injection 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 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.

15.16.7 The injection tubes shall then be sealed off under pressure until the grout has set. The filled ducts shall not be subjected to shock or vibration within 1 day of grouting.

15.16.8 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.

15.16.9 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.

15.17 TOLERANCES

15.17.1 Permissible tolerances for positional deviation of pre-stressing tendons in cast-in-situ construction 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

15.18 TESTING

15.18.1 All testing data shall be submitted to the Engineer.

15.18.2 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 6m 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 centred on the cross-sectional area of the bench. 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 percent of ultimate to 0 in 10 increments. For each increment, the gauge pressure, elongation and load cell force shall be recorded.

15.18.3 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. Revisions to the theoretical elongations shall be submitted to the Engineer for consent. Apparatus and methods used to perform the tests shall be proposed by the Contractor and be subject to the consent of the Engineer. After the initial testing, five (5) more tests shall be performed. These tests shall be spaced evenly throughout the duration of the Contract.

15.19 LOAD TESTS ON INDIVIDUAL PRECAST UNITS AND SUPERSTRUCTURE.

15.19.1 Load test on individual Units and Super structure shall be carried out in accordance with IRS CBC.

15.19.2 The load tests for individual precast units described in IRS CBC are intended as checks on the quality of the segment units.

15.19.3 Where members require special testing, such special testing procedures should be in accordance with the specification of that particular test and as approved by the Engineer. Test loads are to be applied and removed incrementally.

15.19.4 The unit should be supported at its designed points of support and loaded for 5 min. with a load equal to the sum of the characteristic dead load plus 1.25 times the characteristic imposed load. The deflection should then be recorded. The maximum deflection measured after application of the load should be in accordance with the requirements that should be defined by the engineer.

15.19.5 The recovery should be measured 5 min. after the removal of the applied load and the load then re imposed. The percentage recovery after the second loading should be not less than that after the first loading nor less than 90% of the deflection recorded during the second loading. At no time during the test should the unit show any sign of weakness or faulty construction as defined by the engineer in the light of reasonable interpretation of relevant data. When testing prestressed concrete, allowance should be made for the effect of prestress at the time of testing being above its final value.

15.19.6 The load test on Spans shall be carried out in accordance with IRS CBC. The method of testing shall be approved by the Engineer. The Contractor shall give minimum 48 hours notice to the Engineer before commencement of testing.

15.20 MISCELLANEOUS

15.20.1 The entire construction work shall be geared towards minimising disruptions to road traffic. Also, the occupation of roads during all construction activities shall be reduced to a minimum and subject to the approval of the Engineer

15.20.2 All elements of sub-structure below bearing pedestals viz piles, pile caps, piers and pier caps shall each be cast in single pour.

15.21 LOAD TESTING OF LAUNCHING GIRDER

15.21.1 Contractor shall conduct full scale load traveller test of all launching girder prior to using it for execution purpose. Such tests are required to be done for all the launching girders engaged for project, even if the similar design of launching is adopted.

15.21.2 Nothing extra will be payable for conducting such test and the rate shall be included in respective item.

15.22 LOAD TESTING OF STANDARD SPAN OF SUPERSTRUCTURE

15.22.1 The contractor shall conduct full scale load test for one critical span of each category of superstructure.

15.22.2 The sequence of placement and position of loading on the girder shall be as directed by the engineer.

Completed Segment Tolerance for Segmental Box Girder Bridge Construction.

Finished segment tolerances should not exceed the following:

Length of match-cast segment (not cumulative)	+ 1/8 in/ft. (10.4 mm/m, + 1 in. max. (25 mm)
Length of totally assembled span	+ 1/2 in. (12.5 mm)
Web Thickness	+3/8 in. (9.5 mm)
Depth of bottom slab	+3/8 in. (9.5 mm)
Depth of top flange	+1/4 in. (6.5 mm)
Overall top flange width	+1/16 in/ft (5.2 mm/m),+3/4 in. max(25mm)
Top flange width (transverse position on track side)	+1/5 in (5 mm). max
Diaphragm thickness	+1/2 in. (12.5 mm)
Grade of form edge and soffit	+1/8 in. in 10 ft (1.0 mm/m)
Tendon hole location	+1/8 in. (3.2mm)
Position of shear key	+1/4 in. (6.3 mm)

15.23 TOLERANCE FOR ERECTION OF THE SPAN

Horizontal and vertical position of the at-pier-segment shall be within 15mm of the longitudinal alignment and grade.

15.24 PRECAST PRESTRESSED I/T GIRDERS

15.24.1 General

The super structure shall comprise of pre-cast pre-tensioned girders made monolithic by cast-in-situ deck slab and R.C.C. diaphragm. The Pre-casting Yard shall be established by the contractor at site or at any other location approved by Engineer-In-Charge. These girders after attaining the required strength at the pre-cast yard shall be transported to site and eventually erected at appropriate position over the pier caps.

Adequate Nos of casting beds and form work sets shall be established by the contractor for pre-casting of the T/I-girders so that progress of casting matches with the overall execution stand of the work.

The contractor shall submit detailed construction methodology for casting, curing, stacking, transportation, launching and equipment for shifting and launching of the girders for approval of Engineer-In-Charge.

15.24.2 Construction Sequence:

The programme of casting shall be so planned that the girders are cast continuously so as to avoid age difference between adjacent girders in any span and to minimise the time lag (say up to 90 days) for casting of deck slab cross diaphragms at site.

15.24.3 Concreting for Precast Girders

Unless otherwise mentioned hereunder, the concrete shall be prepared, mixed and placed in position in accordance with the specifications given earlier. The Contractor shall maintain a record of the proportions of mix at the batching plant and produce the same for checking by Engineer-In-Charge whenever required.

The contractor shall take care in placing reinforcement cage so that cables/ strands are not disturbed and the minimum cover as recommended in the drawing is available.

The reinforcement protruding from each girder shall be bent to the shape so as to match with the reinforcement of cross diaphragm. The protruding reinforcement shall be coated with cement wash. Finished concrete shall have rough finish on top for proper bond with cast-in-situ deck at site.

The precast pre-stressed girders constituting the top flange, web and the bottom flange shall be concreted in single operation without any construction joint.

15.24.4 Forms for Precast Pre-stressed Girders

The precast girders shall be cast at casting yard. The steel formwork shall only be used for casting of girder. Top of casting bed shall also be provided with steel pining. The exposed surface of the concrete shall be shutter finished as mentioned elsewhere in the tender document.

15.24.5 Permissible Tolerances

The formwork of precast girder shall be so made as to produce a finished concrete true to shape, lines, levels, plumb and dimension shown on the drawings subject to the following tolerance unless otherwise specified in these documents or directed by Engineer-In-Charge.

Length of Girder

Per 3 m length	- ±3 mm
Maximum for entire length	-±10 mm

Cross-Sectional Dimension

Web	- ±3 mm
Flanges	- ±3 mm
Depth	- ±3 mm
Plumb	- 1 in 1000

Marking of Precast Girders

Precast girders shall be marked immediately after removing the side forms with paint of approved quality. The girders shall be marked at minimum four places on both faces of web at the ends with the following details.

i Girder Number

ii Date of casting of girder

15.24.6 Tests of Precast Girders

a. Initial Test

The first precast Pre tensioned girder shall be tested till its failure in order to determine the strength of girder during service. Stress and strain gauges shall be fixed in the test girder for observing the results of load testing. The contractor shall carry out the initial load test including providing all instrumentation, testing infrastructure, T&P, labour and incidental works at no extra cost to the department. However, the cost of test girder shall be payable to the contractor in the respective main items as per Schedule of Quantity. The contractor shall submit testing methodology and final test report to the engineer-in-charge.

b. Routine Load Tests

Routine load tests shall be conducted on working pre-cast girders. Total number of such tests shall be 2% of the total number of girders. The girders shall be subjected to a midpoint load (in addition to the self-weight of the girder) so as to subject the girder equivalent to 1.5 times the moment during service.

Prior to carrying out initial and routine load tests, the contractor shall submit arrangement of testing, loading etc. and shall carry out any modifications, if needed, on the existing testing arrangement to the satisfaction of Engineer-In-Charge at no extra cost. The contractor shall submit a report containing test results and observations etc. to the department.

15.24.7 Handling, Stacking, Launching and Placing of precast girders

Handling of pre-cast members shall be allowed only after the same have attained the specified strength. The members shall be lifted only from the positions specified for this purpose. All necessary precautions will be taken to avoid any accident and damage during handling of pre-cast units.

The contractor shall submit detailed plan showing stacking of precast girders at casting yard and at site and shall obtain approval of the Engineer-In-Charge. Proper precautions shall be taken during handling of precast units during transportation and all traffic safety measures taken. The contractor shall be required to execute all handling and re-handling of girders including interim storages etc., till these are finally erected, within his quoted rate. Contractor can plan the activities in advance to

reduce such handling if practicable.

When placing the precast units in position, care should be taken to place the right unit in the right position with minimum handling of units. Care should also be taken to prevent any damage to the precast units. Units damaged by improper storing or handling/re-handling shall be repaired for non-structural damages and replaced if there is structural damage, by the contractor at his own expense. The methodology proposed by the contractor for placing these units, shall be got approved from the Engineer-In-Charge, before commencement of the work. The rate for the reinforcement in the girders shall also include cutting of temporary handles (rebar), if required. The contractor shall prepare and submit a plan for each span indicating the location and girder number of each girder.

The individual precast girders shall be erected at its exact location on pier caps. The alignment should be true to the lines and levels placed adjacent to one another as per approved construction drawing. Unless otherwise mentioned hereunder, the concrete shall be prepared, mixed and placed in position in accordance with the specification given elsewhere in the tender documents.

Precast girders shall be placed on bearings correct to line and levels.

16 DRAINAGE

The drainage of deck shall be designated to cater the maximum envisaged rainfall intensity and a suitable longitudinal and transverse slope should be provided. The design shall comply with of IRS-CBC Clauses 10.4.1.1 & 15.2.2.

16.1 SOLID PIER

The drainpipe of double wall HDPE corrugated pipes with water collection box at top, which will be located outside the solid pier.

16.2 DECK

The top of the soffit slab will be profiled so as to collect the water run-off at multiple points.

16.3 DRAINAGE SPOUTS AND DRAINAGE PIPE

General

This work shall consist of supply and fixing in position of drainage spouts and drainage pipes for bridge decks and piers true to lines, levels and position in accordance with details shown on drawings and to the requirements of these.

specifications and drainage plan for structure. Where details are not given on drawings, contractor should prepare and submit his own drawings for approval of Engineer before commencement of work.

All drainage pipes to be embedded in pier shall be HDPE corrugated double wall as approved by engineer-in-charge.

16.4 FABRICATION

Drainage assembly shall be fabricated to dimensions shown in drawings. All materials shall be corrosion resistant; steel components shall be of mild steel conforming to IS:2062. The drainage assembly shall be seam welded for water tightness and then hot dip galvanised.

16.5 PLACEMENT

The galvanised assembly shall be given two coats of bituminous paint before placement. The whole assembly shall be placed in true position, lines and level as shown in drawing with necessary cut-out in the shuttering for deck slab and held in position firmly. Where reinforcement of the deck is required to be cut, equivalent reinforcement shall be placed at the corners of the assembly.

16.6 FINISHING

After setting of deck slab concrete, shrinkage cracks around the assembly shall be totally sealed with polysulphide sealant or bituminous sealant as per IS:1834 and excess sealant trimmed to receive the wearing coat. After the wearing coat is completed, similar sealant, finished to cover the wearing coat surface all-around the drainage assembly, shall be provided at least 50 mm.

17 MISCELLANEOUS

17.1 BEARINGS, SHEAR KEY DEVICES, HOLD DOWN DEVICES, EXPANSION JOINTS.

17.1.1 BEARINGS, SHEAR & EXPANSION JOINT

GENERAL

This work shall consist of design supply and fixing in position of bearings for bridge girders in accordance with details shown on drawings and to the requirements of these Specifications, codes and standards quoted therein and as directed by Engineer.

Bearing plates, assemblies and other expansion or fixed devices shall be constructed in accordance with details shown on drawings.

When bearing assemblies or plates are shown on drawings to be placed (not embedded) directly on concrete, the concrete bearing area shall be constructed slightly above grade and shall be finished by grinding.

It shall be ensured that the bearings are set truly level and in exact position as indicated on drawings so as to have full and even bearing on the seats. This shall be checked with spirit level in both directions. Thin epoxy mortar pads (not exceeding 5 mm) may be made to meet with this requirement.

It shall be ensured that the bottoms of girders to be received on the bearings are plane at the location of these bearings and care shall be taken that the bearings are not displaced while placing the girders.

When elastomeric bearing pads, or preformed fabric pads are to be provided, the concrete surfaces on which pads are to be placed shall be wood float finished to a level plane, which shall not vary by more than 1.5 mm from a straight edge placed in any direction across the area.

17.2 POT BEARING

Material specifications of Pot bearing

The material such as PTFE lubrication, Confined elastomer, stainless steel & internal seal shall conform to requirement of IRC: 83 Part-III. The Pot base, saddle & top plate shall be of Cast steel conforming to IS: 1030 Gr 280-520 W. The anchor bolts shall conform to IS: 1364. All welding shall conform to IS: 816 & IS: 9595 with electrode as per IS: 814. Painting on non-working surface of bearing shall be as per IRC: 83 Part-III. The mating surface of Piston and cylinder shall behardened to 350BHN (Min).

Guides of sliding pot bearing shall be monolithic to parent component.

Design of the bearing and all accessories shall be the responsibility of the Contractor and got approved from the Employer's Representative.

17.2.1 Permissible stresses in steel component of Pot bearing

All the design requirements for Pot bearing as specified in IRC: 83 Part-III has to be fulfilled with following modifications.

a. No increase in permissible stresses in any material of bearing or bearing stress between concrete and bearing is permitted in seismic condition.

17.2.2 Permissible bearing stresses in concrete

The allowable bearing stresses in concrete as defined in IRC: 83 Part-III has to be followed with following modifications.

a. No increase in permissible bearing stress between concrete and bearing is permitted in seismic condition.

17.2.3 Anchor sleeve

All the part of bearing such as anchor sleeves embedded in concrete shall be hot dip galvanized @ 300gm/ m^2. The anchor sleeves have to be designed taking account of difference in elasticity of steel of sleeve and concrete. The effect of shifting of centre of rotation of sleeve should be also taken into account

The contractor shall furnish along with tender documents in technical bid, the name of the manufacturer of bearings, his qualifications with all details including roof of satisfactory performance, certification and testing facilities of the bearing proposes to use. Products of reputed manufacturers shall only be used. The design, drawings and detailed method statements for installation and replaceability of the bearings shall be checked and certified by approved independent agency before submitting to the Engineer for approval.

Pot bearings shall be measured in numbers, Pin Pot Bearing, Longitudinal guidepost bearing, transverse guide bearing & free pot bearing shall be counted separately, according to their capacities. The rate shall include the cost of supplying and fixing the bearing in position. The cost shall also include the cost of samples and their testing as required and conforming to specification.

17.2.4 Testing of Pot Bearing

Proof Load Test

A test bearing shall be tested as defined in IRC-83 Part-III.

The bearing will be visually examined both during the test and upon disassembly after the test. Any resultant visual defects, such as extruded or deformed elastomer or PTFE, damaged seals, or cracked steel, shall be cause for rejection.

During the test, the steel bearing plate and steel piston shall maintain continuous and uniform contact for the duration of the test. Any observed lift-off will be cause for rejection.

17.2.5 Sliding Coefficient of Friction

For all guided and non-guided expansion type bearing, the sliding coefficients of friction shall be measured at the bearing's design capacity.

The sliding coefficient of friction shall be calculated as the horizontal load required to maintain continuous sliding of one bearing, divided by the bearing's vertical design capacity.

The test result will be evaluated as follows: -

a. The measured sliding coefficients of friction shall not exceed 3%.

b. The bearing will be visually examined both during and after the test. Any resultant visual defects, such as bond failure, physical destruction, cold flow of PTFE to the point of debonding, or damaged components shall be cause for rejection.

17.2.6 Sampling and Testing

a. Lot Size

Sampling testing and acceptance consideration will be made on a lot basis. A lot shall be defined as those bearings presented for inspection at a specific time or date. A lot shall be further defined as the smallest number of bearings as determined by the following criteria.

i. A lot shall not exceed a single contract or project quantity;

ii. A lot shall not exceed 25 bearings;

iii. A lot shall consist of those bearing of the same type regardless of load capacity. (Fixed or expansion bearings types, Guided and non-guided expansion bearing shall be considered a single Type).

17.2.7 Sampling and testing requirements

The manufacture shall furnish the required number of samples to perform testing in accordance with Table Given below: -

Sampling and Testing Requirement

Test Sample Required

Proof load	One production bearing per lot
Coefficient of Friction	One production bearing per lot
Physical Properties of elastomeric rotational elements	One elastomeric element per lot
Physical properties of PTFE sheet	One 10" x 15" sheet of PTFE material per project

A minimum of thirty (30) days shall be allowed for inspection, sampling and testing of production bearings and component materials.

All exterior surfaces of sampled production bearings shall be smooth and free from irregularities or protrusions that might interfere with testing procedures.

The manufacturer shall select, at random, the required sample bearing(s) from completed lots of bearings for testing by the manufacturer. He shall complete the required testing and determine compliance with this specification before submitting the lot(s) for inspection, sampling, and acceptance consideration.

The Engineer shall select, at random, the required sample bearing(s) from completed lots of bearings to be tested by independent agency approved by concerned organisation. The testing charges shall be borne by contractor.

Necessary test certificates for all raw material shall be furnished by manufacturer

Test specified in IS: 1030 for cast steel shall be performed. Casting shall be ultrasonically got tested by approved testing agency.

17.2.8 Fabrication Details

The Contractor shall provide the Engineer with written notification thirty (30) days prior to the start of bearing fabrication. This notification shall include all of the information shown on the shop drawings which are required as explained in subsequent section.

The finish of the mold used to produce the elastomeric rotational element shall conform to good machine shop practice.

All steel surfaces exposed to the atmosphere, except stainless steel surfaces and metal surfaces to be welded, shall be shop painted in accordance with the Contract Plans. Prior to painting, the exposed steel surfaces shall be cleaned in accordance with the recommendations of the coating's manufacturer. Metal surfaces to be welded shall be given a coat of clear lacquer, or other protective coating approved by the Engineer, if the time of exposure before welding takes place is to exceed three months, the coating shall be removed at the time of welding. No painting will be done to these surfaces prior to the completion of welding.

Stainless steel sheet shall be attached to its steel substrate with an approved epoxy to ensure complete contact and then sealed with a continuous seal weld.

The steel piston and the steel pot shall each be machined from a solid piece of cast steel.

The outside diameter of the piston shall be not more than 1mm less the inside diameter of the pot at the interface level of the piston and elastomeric rotational element. The sides of the piston shall be bevelled to facilitate rotation. Except as noted all bearing surfaces of steel plates shall be finished or machined flat in accordance with tolerance written below:

17.2.9 Tolerances:-

a. Manufacture tolerance shall be as per IRC: 83 Part-III.

All these measurements were taken using dial height gauges, vernier calliper, surface finish measurement instrument etc has to be arrange by manufacturer at the workshop.

Every bearing shall have the Project Identification Number, Lot Number, and individual bearing number indelibly marked with ink on a side that will be visible after erection.

After assembly bearing components shall be held together with steel strapping, or other means, to prevent disassembly until the time of installation. Packaging shall be adequate to prevent damage from impact as well as from dust and moisture contamination during transportation and storage.

17.2.10 Shop Drawings

Along with detailed design of different types of bearing, shop drawings shall be submitted. The shop drawings shall contain the following information, which is necessary for proper design and detailing of the bearings.

Quantity, type (fixed, guided expansion, non-guided expansion), and location of all bearing units.

A table containing maximum and minimum vertical and horizontal loads, design rotation requirements, and magnitudes and directions of movements.

Allowable contact stresses, maximum dimensions, and anchorage requirements at the bearing interfaces; grades, bevels, and slopes at all bearings; and allowable coefficients of friction of all sliding surfaces.

The painting system to be used on the steel components to guard against corrosion.

Any special consideration such as earthquake requirements, uplift details, or temporary attachments.

Installation scheme of pot bearing

The Contractor shall submit detailed shop drawings in conformance with the applicable requirements.

17.3 ELASTOMERIC BEARINGS

The terms “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.

17.3.1 Raw Material

Chloroprene (CR) only shall be used in the manufacture of bearing.

Grades of raw elastomer of proven use in elastomeric bearings, with low crystallization rates and adequate shelf life (e.g. Neoprene with low crystallization rates and adequate shelf life (e.g. Neoprene WRT, Beyerene 110 Styrene B- and Denka S-40V) shall be used.

No reclaimed rubber or vulcanized wastes or natural rubber shall be used.

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 percent (as per tests conducted in accordance with ASTM D-297, sub-section 10).

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

17.3.2 Properties

The elastomer shall conform to the properties specified in Clause 4.3.1 of the IRICEN publication titled "Bearings for Railway Bridges" and those specified in Table 2000-1 of the publication titled "Specifications for Road and Bridge Works", published by IRC on behalf of MORTH (Roads Wing).

17.4 FABRICATION AND TOLERANCES

Fabrication and Dimensional tolerances shall be governed by the specifications laid down in Clause 4.3.2 of the IRICEN publication & Clause 2005.3 of the MORTH specifications mentioned above.

17.5 ACCEPTANCE SPECIFICATIONS

For inspection and testing requirement Clause 4.4 of the above mentioned IRICEN publication shall be referred with modifications of lot size as mentioned below: -

Sampling testing and acceptance consideration will be made on a lot basis. A lot shall be defined as those bearings presented for inspection at a specific time or date. A lot shall be further defined as the smallest number of bearings as determined by the following criteria.

i. A lot shall not exceed a single contract or project quantity;
ii. A lot shall not exceed 50 bearings;
iii. A lot shall consist of those bearing of the same type regardless of load capacity.

Accepting and testing requirements shall also conform to the specifications laid down in Clause 2005.4 of the referred MORTH specifications.

In addition to tests mentioned above, all bearings shall be also weight actually and compared with the theoretical weight.

All bearings shall carry a warrantee of not less than 15 years in an approved format. The contractor shall be responsible for immediate repair or replacement of the bearings in case of failure / distress to the satisfaction of the owner at no extra cost to the Owner within the warrantee period.

Criteria for Selection of bearing manufacturer shall conform to requirement of Most letter No-RW/NH-34057(1) / 95-(S & R) dated 2nd November,2000. It is necessary that all manufacturers of all elastomeric bearings shall have in house facilities for carrying out Infrared Spectro-Photometry as per ASTM D-3677.

17.6 DESIGN

The design of elastomeric bearings shall be in accordance with UIC 772 &EN1337 Part 1 and Part III. The design, drawings and detailed method statements for installation and replaceability of the bearings shall be checked and certified by approved independent agency appointed by the contractor before submitting to the Engineer for approval.

17.7 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.

17.7.1 Installation

Installation procedure shall conform to the guidelines listed in clause 4.5 of the IRICEN publication and clause 2005.7 of the MORTH specifications. cost of non- specifications for spherical bridge bearings with special sliding material (humped)

a. GENERAL

Spherical-type bearings

Spherical bearings consist of a spherical rotational component, where typically a steel convex surface either made up of stainless steel or chrome plated surface (alternatively made of highly corrosion resistant sliding alloy) slides against a concave steel plate covered with a low friction sliding material. This is a compact bearing able to accommodate larger rotations and vertical loads as it does not depend on the limitations of an elastomeric element and the necessary sealing.

b. Work Included

Furnish all labour, materials and equipment required for the design, manufacture, supply and installation of bearings shown on the Drawings and/or in the Specifications and include the following:

c. Related Work

i. Examine work done by other trades:

Before commencing fabrication of the work of this Section, the Contractor installing the bearings is required to inspect and take field measurements of work done by other trades

which may affect the work. Before commencement of the work, the contractor shall notify the engineer in writing, of his acceptance of work done under other divisions or by other trades. If any conditions exist which will prejudice a proper Installation of the work, the engineer shall be notified in writing, and installation shall not proceed until deficiencies are corrected and the engineer has received the letter of acceptance.

ii. Cooperation:

Where items of other trades are to be built into the work of this Section or items under this Section are to be built into the work of other trades, e.g. anchorage to be inserted / affixed into the pedestal / superstructure concrete, such items shall be procured and provided in ample time to avoid delay. The Contractor shall attend upon and cooperate with other trades in respect of the work of this Section and do everything necessary to enable the work of other trades to be completed without delay.

d. Approvals

Prior to manufacturing the bearings and prior to the construction of the bearing seats, the Contractor shall submit the following information to the engineer for consideration and approval:

i. The Design standards, materials, manufacture and technical data.

ii. The Contractor shall submit a document from International Approving Bodies like ETA, FHWA or similar which will guarantee the working life of the bearings to be not less than 50 years.

iii. Shop drawings detailing all of the work of this section.

iv. Friction properties based on actual tests at a temperature of +70°C and -50°C conducted on relevant materials and all other tests completed in accordance with the Specifications.

v. Design calculations clearly indicating how the bearing satisfies the design criteria indicated on the Drawings and in the specifications.

vi. Detailed procedures to be followed during the installations of bearings.

vii. The Contractor shall submit evidence of the successful installation and operation of comparable proprietary bearings to the satisfaction of the Engineer. These should demonstrate the suitability of the system and materials proposed, in particular, for heavy loads, heavy traffic and for the aggressive environment and high temperatures conditions that comparable to the project. The approval of the Engineer shall not relieve the Contractor of any responsibility under the Contract for the successful completion of the work. The bearing manufacturer shall be open and offer his full co-operation and assistance for one or more visits by the engineer or his representative to his workshop for the purpose of quality control.

17.7.2 Shop Drawings

The Contractor shall submit shop drawings to the engineer for approval which shall include, but not limited to, the following information:

a. Erection drawings, plan, elevations and complete details and sections showing all materials incorporated in the bearings.

b. Bearing present details, if applicable.

c. Protective coating requirements.

d. The maximum and minimum vertical loads and co-existing horizontal loads as well as the maximum horizontal load and co-existing vertical load.

e. Bearing seat and all bearing connection and anchorage details.

f. The location of the top and bottom bearing adapter plates drawn in plan and in elevation on the deck soffit and on the support, structures showing edge distances.

g. The bearing orientation (uni and multi directional bearings) with respect to the direction of Bridge / traffic movement.

h. The drawings and design calculations shall be duly signed & stamped by company seal.

17.7.3 Standards

Unless otherwise specified, the design and the manufacture of the bearings shall comply with the following requirements:

a. Mandatory Standard:
IRC:83 Part (IV) with its applicable Amendments & Errata issued up to the date of this Tender.
Supporting Standards:
EN 1337-7 Spherical Bearing
ETA or equivalent approval document
EN 1337-1 General Design of bearings
EN 1337-2 Sliding Surfaces

b. Other standards and / or approval documents which should be used in special conditions to accommodate design constraints and to comply with the local conditions.

c. All the above and any other documents and specifications referred to in this document shall be the latest edition or superseding document and specification.

17.8 QUALIFYING CRITERIA FOR MANUFACTURER / SUPPLIER

17.8.1 The manufacturer / supplier should be empanelled as an approved manufacturer / supplier of Bearings by the leading approval bodies in the country viz. MORT&H & RDSO.

17.8.2 Manufacturer / supplier either themselves or under the joint collaboration / Technology Transfer agreement with a foreign Counterpart of repute should have adequate experience & needed certifications viz. ETA etc. for designing & manufacturing the Spherical Bearing with the Special Sliding Material.

17.8.3 The manufacturer / their foreign Counterpart or Technology partner should have the valid ETA approval and EC Certificate of conformity or equivalent certification for the product i. e. Spherical Bearings with Special Sliding Material which shall be in existence for at least 5 (five) consecutive years preceding to the date of Tender.

17.8.4 The manufacturer plant from where the Bearings are to be manufactured & supplied shall have the Quality Certification ISO 9001 :2008, Certification for Factory Production Control EN : 1090-2 and Welding Quality Certifications DIN EN ISO 3834-2 and EN:287 etc.

17.8.5 In addition to the EC Certificate of conformity of the foreign Counterpart or Technology partner, the manufacturer plant from where the Bearings are to be manufactured & supplied shall also have in existence the same valid EC Certificate of conformity, ETA or equivalent certification in the name of plant.

17.8.6 The Design Calculations and shop drawings for the Spherical Bearings shall be submitted from the foreign counterpart / technology partner or at-least counterweighted by them.

17.8.7 Technology partner should certify that the raw material properties and manufacturing process adopted by their counterpart shall be duly in line with the quality norms & practices that in accordance with EN & ETA requirements and announced in the design & drawings counter weighted by them.

17.8.8 Manufacturing or sourcing of the raw material or finished components of the Bearings or the Bearing as a whole from China is not permitted.

17.8.9 The Special Sliding Material shall be supplied with Class 3.2 Inspection Certificate according DIN EN 10204 by third party control according EN 1337-2 & ETA. The same shall be sourced directly from the foreign Counterpart / Technology Partner or their approved sources having valid ETA approval & CE Certification for such material.

17.8.10 It shall be preferred that in addition to the Special Sliding Material. The remaining major Steel Components of the Bearings including the bottom (concave), saddle (convex) and top plates shall also be procured from reputed producers in India, preferably “CE” / “ISI” / “ISO” Certified.

17.9 MATERIALS

When requested by the engineer, the Contractor shall submit test certificates from the approved, independent testing authority to show that the respective materials comply with the specified requirements, or a certificate from the patent holder or designer certifying that the manufactured item complies in all respects with relevant product specifications. The bearings shall be fabricated from only new and unused materials. Reclaimed materials are not acceptable.

Materials shall conform to the following standards:

17.10 STRUCTURAL STEEL

All Steel Components of the Bearings shall be made from structural steel conforming to the requirements of EN 10025 Grade S355J2+N or country equivalent viz. Grade E350 min of IS: 2062, Steel convex surface either made up of stainless steel or chrome plated steel surface or alternatively made of highly corrosion resistant sliding alloy, Al-Mg6M or Al-Si7MgTF in accordance with the requirements of ISO 3522, Stainless steel in accordance with AISI 316L or in accordance to the equivalent EN Norm. Metal to metal contact surfaces within bearings shall be prepared machining. Machining shall always be carried out after welding has been finished.

MSA - Highly Corrosion resistant sliding alloy in accordance with the EN 1337 and technical approval ETA 06/0131.

The high corrosion resistant material shall be approved in the form of Technical Approval released by the Ministry of Traffic from a country with experienced suppliers of spherical Bearings.

If used for the manufacture of the convex element of a spherical bearing, the following properties shall be at least equal to that of stainless steel for the proper functioning of the bearing during its design life:

i Hardness of surface.

ii Durability of surface resistant to wear during life of bridge.

iii Frictional resistance with the sliding material.

iv Bright annealed mirror finish (less than 3 μm RMS) for the surface in contact with the sliding material.

v Capacity to resist vertical loads during bearing rotation.

The permissible combination of materials of the main sliding surfaces adjacent to the convex plate (spherical part) of a spherical bearing shall consist of MSM (See 3.5.2) with stored silicone grease against

1. Austenitic steel for the flat sliding surface.
2. Highly corrosion resistant sliding alloy MSA or similar for the curved sliding surface.
3. Structural steel with a polished hard chrome finish.

17.11 STAINLESS STEEL SHEET

Shall conform to AISI 316L or equivalent to EN standards and be continuously welded to the steel plate. Locate the weld outside the contact area with the sliding material surface.

17.12 ANCHOR BOLT ASSEMBLIES

All anchor bolt assemblies, inclusive of anchor studs / dowels, anchor bolts and washers shall be of Grade 8.8 / 10.9 steel to suit the applied loads. The anchor bolts and washers shall be galvanized. The anchor studs/dowels shall be welded to the outer faces of the top and bottom adapter plates with holes machined into the welded end of the dowels to receive the anchor bolts. The anchor studs / dowels shall receive the same corrosion protection as that of the adapter plates. The friction

between the bearing and the superstructure and substructure shall not be considered to assist in resisting horizontal forces.

17.13 SLIDING MATERIALS

17.13.1 Ultra-High Molecular Weight Polyethylene (UHMWPE)
(Low friction Sliding Material):

Special sliding material made of modified UHMWPE - Ultra high molecular weight polyethylene e.g. MSM is permitted for use as main sliding surface.

The use of the proprietary UHMWPE material as a sliding surface shall require the necessary certificates proving compliance with the German Institute for Civil Engineering, National Technical Approval Z-16.4-436 or special type approvals from ETA or similar.

UHMWPE constant performance in Service as a low friction material shall be confirmed by a long-term test by an independent testing institute (Material Testing and Controlling Institution, MPA Stuttgart for instance) with the following conditions:

a. Average test contact pressure 60 N/mm²
b. Constant test sliding velocity 15 mm/s
c. Test sliding path 50 km

Sliding material with low friction behaviour (μ < 2,0% with temperature range of -50 to + 70 °C).

Maximum sliding coefficient during 35°C test shall not exceed μ < 3.5% over the long-term testing distance.

Because of the hot ambient temperatures, the characteristic permissible pressure of the sliding material shall not less than:

d. With room temperature (20°C), fk = 180 N/mm²
e. With 70°C, fk = 90 N/mm²

Creep behaviour with both values shall be made available from an independent test institute like Material Testing and Controlling Institution, MPA Stuttgart for instance.

For Spherical Bearings with special sliding materials like UHMWPE, it shall be ensured that the same is supported by valid technical approval documents like ETA in the name of Manufacturer / supplier or their Technology Partner and also that in the name of local manufacturer's plant.

Manufacturing or sourcing of the raw material or finished components of the Bearings or the Bearing as a whole from China is not permitted.

17.14 LUBRICANT

Silicone grease shall be used as lubricant for sliding surfaces.

17.15 ADHESIVE MATERIAL

Care shall be taken to ensure that the adhesive is applied uniformly over the entire surface of the sliding material so as not to cause an uneven sliding surface that could lead to premature wear.

17.16 DESIGN REQUIREMENTS

The following minimum requirements shall be provided.

17.16.1 General:

a. Serviceability Limit State:

The design should be such that bearings will not suffer damage which would affect their correct functioning or incur excessive maintenance costs during their intended life.

In general, bearings are not recommended for horizontal to vertical load ratios of over 40%. In such cases allowance for external restraint shall be provided.

b. Ultimate Limit State:
The strength and stability of bearings should be adequate to withstand the ultimate design loads and movement of the structure.

c. Design Life:
Bearings and their installations should be designed to be compatible with the design life of the bridge; taking into account the consequences of maintenance and / or replacement.

d. Durability:
Bearings should be detailed to exclude crevices and the like which allow moisture and dirt to be trapped. The materials used in their manufacture and the protective and maintenance measures adopted against corrosion and deterioration due to environmental effects should be such as to ensure that bearings continue to function correctly throughout their design life.

e. Replacement of bearings:
The substructure and superstructure design shall permit the bearings to be removed for inspection or rehabilitation with minimal jacking of the structure.
Sufficient space shall be made available on top of bridge supports (at abutments and piers) and on the soffit of bridge superstructures within the width of deck diaphragms to enable the location of jacks during bearing replacement.
Bearings shall be designed so that they can be replaced by lifting the deck no more than 15 mm or the distance specified.

f. Top (sole) and bottom (masonry) adapter plates:
Top and bottom adapter plates shall be provided to allow for simple bearing replacement.
The fixing arrangement of the bearing to the top and bottom adapter plates shall be such as to enable the bearings to be replaced without the need for cutting into the bridge superstructure or substructure.
The plates shall be designed to distribute the bearing loads into the surrounding substructure and/or superstructure.
The thickness of the adopter plates or any other component of the Bearing shall not be less than 20 mm.
The top and bottom adapter plates shall be sufficiently stiff to remain rigid under all service load conditions.
The surfaces of the adapter plates in contact with the bearing elements shall be prepared by machining to ensure full contact of surfaces during loading and shall have an evenness of at least 0.0003 x length of the diagonal of the attached bearing element. Machining shall always be carried out after welding has been finished.

g. Average Bearing Stress on Concrete:
The outer plates of bearings should be so proportioned that concentrated loads are sufficiently distributed to ensure that the permissible stresses on the adjacent bridge structure are not exceeded.
The maximum average contact stress and maximum edge stress from the bearing on the concrete shall not exceed 0.5 and 0.6 times the 28-day cube characteristic compressive strength under the serviceability limit state respectively, unless otherwise prescribed by the engineer.

h. Rotation of the bearings:
The rotational capacity of all types of bearings about any horizontal axis, which includes rotations due to all applicable service loads and movements, maximum rotations caused by fabrication and installation tolerances, and allowance for uncertainty, should be at least ± 0.02 radians.

17.17 SLIDING MATERIALS

17.17.1 Methods of attachment:

a. Horizontally installed sliding material shall be recessed and/or bonded into its steel substrate. The bearing manufacturer shall guarantee the performance in service of the sliding material during the warrantee period of the bearing.

b. Vertically installed sliding material sheet shall be bonded and recessed into or bonded to and mechanically fastened to its steel substrate.

c. The recess into the steel substrate shall be designed in accordance to the technical approval of the bearing for the sliding material sheet thickness but shall be at least one half of the thickness of the sliding material. The shoulders of the recesses shall be sharp and square.

17.17.2 Guides

Guides are used to prevent movement in one direction such as in uni-directional bearings.

They shall be designed at the strength limit state for the larger of either:

i The design horizontal force at the strength limit state

ii 15% of the total vertical force at the serviceability limits state

The top plate shall be restrained by guide bar(s).

Guide bars which are located on the outer edges of the top plate and which use the bottom or base plate as the restraining device have limited rotational capabilities and may restrict the free rotation of the bridge in transverse direction. For Bridges requiring rotation in transverse direction, special adaptations to the side guides (such as by the addition of tilding bars) will need to be considered to accommodate the rotations of the bridge. Such details shall be subject to the approval of the engineer prior to manufacture.

The guide bar(s) shall be fabricated integral with the bearing base element when they are centrally located at the top of the convex spherical element in spherical bearings. In such cases bolted down or welded guide bar(s) shall not be permitted.

Guides which are located along the outer edges of the bearing may be welded to the bearing top sliding plate. The following shall apply:

i Under no circumstance shall there be separation between the bearing top plate supporting the guide and the top adapter plate when the guide is subjected to 150% of the design horizontal force on serviceability condition applied to the bearing.

ii The transverse dimension of the top plate shall extend to the outer edges of the guides and shall be in contact with the top adapter plate for at least the top plates entire width and length. The longitudinal dimension shall be determined by considering full movement range of deck superstructure and possible movement of the substructure.

iii A full penetration weld shall be used for the connection between the guide and the top plate. The bearing manufacturer shall provide to the engineer for his approval details of his calculations and of the welded connection taking into consideration long term durability of the bearing.

iv Machining of the inside face of the top plate and guides and that of the top surface of the top plate shall be done after welding is completed.

v The option of welding shall only be permitted to manufacturers having adequate welding certifications viz. DIN EN ISO 3834-2, EN: 287 and Factory production control Certification EN: 1090-2.

The guides shall be self-aligning to ensure complete contact of the sliding material and the stainless-steel surfaces along the entire length of the guide providing the lateral restraint.

Guides used for lateral restraint shall be faced with a low-friction material to ensure that the frictional resistance to movement due to the guides is not significant.

The low friction material shall be either of the following:

i Filled PTFE or UHMWPE, which have better resistances to creep than pure PTFE, is preferred for guides.

ii PTFE filled with fiberglass or carbon fibres, and a PTFE and sintered metal mixture have also been used with success

iii Alternative sliding materials to filled PTFE and UHMWPE may be permitted provided that it can be demonstrated to the Engineer that such materials are fully compatible with all other requirements of this specification.

The total gap between guides and guided members shall not exceed 2 mm. However, it should be noted that free slip causes the load to be distributed unevenly which could potentially lead to overloading of one guide / bearing and this needs to be taken into account in the design.

17.18 MULTIDIRECTIONAL BEARINGS:

Bearings which are not required to provide lateral restraint, shall also be attached to the structure by anchor bolts or other approved methods. The friction between the bearing and the superstructure and substructure shall not be considered to assist in resisting horizontal forces.

17.19 ANCHOR BOLT ASSEMBLIES:

The anchor studs / dowels welded to the underside of the adapter plates shall be at least 20 mm in diameter. They shall be corrosion protected together with the adapter plate. The insides of the anchor bolt holes machined into the top of dowels may be left unpainted as these holes shall become sealed after tightening of the anchor bolts.

The dowels set in the bearing plinths shall extend beyond the top mat of reinforcement in the abutment and / or pier.

The dowels shall be located in their sockets using an approved high strength shrinkage compensated cementitious grout applied strictly in accordance with the material recommendations and specifications. The grout shall be subject to the approval of the engineer.

The anchor bolts shall be limited in length by the need to remove the anchor bolts during future bearing replacement. There shall be no obstruction which will impede the unfastening of the anchor bolts during bearing replacement.

The anchor bolts shall be designed to resist the full horizontal design loads from the bridge superstructure without any reliance on the frictional forces developed from steel to steel contact between the bearing elements and the adapter plates.

17.20 STAINLESS STEEL SHEET:

Stainless steel sheets shall be attached to their backing plates by continuous welding along their edges so as to prevent ingress of moisture and shall be clean, sound, smooth, uniform; without overlaps and ensure that the stainless-steel sheet remains flat throughout its service life. Minimum thickness of the stainless-steel sheet shall be 2 mm.

Mechanical fastening of sheets without welding along edges is also permitted.

The attachment of the stainless steel to the steel substrates shall be able to withstand a minimum of 10% of the maximum applied bearing load in the shear plane. This shall be justified by the design calculations by the manufacturer.

The backing plates shall extend beyond the edge of the stainless-steel sheets to accommodate the welds and the welds shall not protrude above the stainless-steel sheets.

The stainless-steel sheets shall completely cover the UHMWPE sheets in all operating positions, plus at least 25 mm in the direction of movement.

17.21 WELDING:

Welding shall be in accordance with IS: 816 and IS: 9595 with electrodes of suitable grade as per IS: 814 or applicable equivalent national Standard.

17.22 SPECIFIC DESIGN REQUIREMENTS FOR SPHERICAL BEARINGS

Spherical Bearings shall preferably be installed with the concave spherical surface down and horizontal sliding surface above the concave spherical element whenever the resulting center of rotation is not detrimental to the system geometry.

The concave and convex spherical element will be machined from a solid block of structural and non-corrosive steel respectively. Other non-corrosive materials such as a highly corrosion resistant sliding alloy offered as an alternative to the stainless steel or chrome plated steel may be considered.

The spherical convex element of a spherical bearing shall be manufactured from the either of the following non-corrosive materials.

i Type 304, stainless steel conforming to ASTM A240 or equivalent.

ii Highly corrosion resistant sliding alloy material MSA Maurer Sliding Alloy or equivalent in accordance with the technical Approval documents ETA 06/0131 or similar.

iii Structural steel with a polished hard chrome finish.

iv Other non-corrosive materials such as anodized aluminium. This material may be considered if documentation of experience, acceptable to the engineer, is provided in addition to the technical approval documents.

All non-corrosive materials shall be subject to the approval of the engineer prior to manufacture.

The finish of the convex spherical element is extremely important because it affects the coefficient of friction and because of the many variables involved it is best verified by friction testing.

The sliding material (MSM, UHMWPE etc.,) shall be recessed and seated to the steel substrate.

The minimum centre thickness of the concave spherical element backing plate and the minimum edge thickness of the convex spherical backing plate shall be at least 20 mm.

Unseating of the curved spherical surfaces relative to each other shall be prevented by transferring horizontal forces through specifically designed restraints. Curvature of the spherical surfaces alone shall not be relied for the transfer of the horizontal forces.

If rockers are utilized to allow transversal rotation in uni-directional bearings with outer side guides they shall be made from steel EN10025, S355J2+N or stainless-steel type 304 conforming to ASTM A240. Locating pins utilized to prevent the rockers from sliding out between the side guides and bearing main component shall also be of stainless-steel type 304.

17.23 EXECUTION

17.23.1 Dimensional Tolerances

a. Bearings shall be located within ± 3 mm of their correct position in the horizontal plane and oriented to within an angular tolerance of 0.005 rad for guided bearings.

b. Except as noted, all bearing surfaces of steel plates shall have a finish or machined flat within 1 mm per metre. Out-of-flatness exceeding this limit shall be cause for rejection.

c. Overall dimension of assembled bearings shall be ± 5 mm in plan and + 3 mm in height.

d. Tolerance of flatness of sliding materials: 0.2 mm when the diameter or diagonal is less than 800 mm and 0.025% of the diameter or diagonal when this dimension is greater than 800 mm. These conditions apply to the diameter or diagonal dimension of the inscribing circle or rectangle around the sliding material.

e. Dimensional tolerances on the sliding material as follows:
Diameter/Diagonal Tolerance on Tolerance on Thickness
Plan Dimension Recessed Bonded

Up to 600 mm ±1.0 mm -0 / +0.54 mm -0 /+ 0.12 mm
Over 600 - 1200 mm ±1.5 mm -0 / +0.60 mm -0 /+ 0.18 mm
Above 1200 mm ±2.0 mm -0 / +0.72 mm -0 /+ 0.18 mm

f. Tolerance on size for the recess for confined UHMWPE sliding materials: 0 mm and +1 mm of the corresponding plan dimensions of the sheet for plan dimensions up to 500 mm and 0 and +0.2% of the corresponding plan dimensions above 500 mm.

17.23.2 Corrosion protection of bearings

All exposed steel surfaces including backing plates shall be made free from rust and rust inducing contaminants by shot blasting to SA 2 ½ roughness and protected against corrosion by a suitable method such as zinc rich epoxy paint etc. as per manufacturers specification. The thickness of such protective layer including the prime & topcoats shall be 150 µm min.

A transition zone of at least 50 mm in width on the circumference of the top and bottom adapted plates in contact with concrete shall receive the same paint system.

All surfaces of steel parts in contact with concrete and other steel mating surfaces shall be protected against corrosion by zinc rich primer coating or zinc metallization.

The bearing manufacturer shall guarantee the long-term protection against corrosion of any unpainted surfaces of steel such as the inside of bolt holes, etc.

17.24 IDENTIFICATION:

All bearings must be clearly coded by the manufacturer. The coding must prevent mix-up and remain clearly visible on the bearings.

Each bearing shall be stamped with the number, bearing number, direction of installation and the installed location which must correspond with the information contained on the approved drawings for the bearings. The stamp shall be on a surface visible after installation.

17.25 HANDLING, TRANSPORT AND STORAGE:

Protect bearings from damage or distortion during handling, transport, storage and installation and keep clean and free of all deleterious matter and contaminants including moisture and dust.

Provide suitable handling arrangements on the Bearings as required. Use temporary clamping devices to maintain correct orientation of the parts during handling, transport, storage and installation but do not use for slinging or suspending bearings unless specifically designed for this purpose.

All bearings, whether in the fabrication shop or an independent warehouse or at the bridge site shall be stored on a platform above ground surface, in a clean, dry, well ventilated and covered roofed facility, away from sunlight, heat, oils and chemicals deleterious to the bearings.

The bearings shall not be staked in a manner or on a surface which will cause distortion of the bearings.

When in storage the bearings will be kept banded, wrapped and secured in a condition suitable for shipment.

17.26 INSTALLATION OF BEARINGS IN GENERAL:

Install bearings in the structure as specified and shown on the drawings and directed by the bearing supplier. Installation procedure shall be subject to review and approval by the engineer. The manufacturer will have its technical representative present for the placement of the first few bearings unless the contractor gains confidence about the installation of the remaining Bearings.

Bearings shall be set to the dimensions and offsets prescribed by the manufacturer and the drawings. When placed, bearings shall be dry, clean, and free from dirt, oil, grease, or other foreign substances.

They shall be adjusted as necessary to take into account the temperature at time of installation and future movements of the bridge due to temperature changes, release of falsework and shortening due to prestressing.

At the instructions of the engineer, option of the manufacturer or the design engineer, the technical representative may be required to be present for the placement of any number of additional bearings.

Under no circumstances shall bearings be taken apart and reassembled on the site, except where it is an unavoidable feature, in which case the dismantling, installation and reassembly shall be under the supervision of the Manufacturer or his agent.

Rehabilitation, modification and repair work to the bearings shall be carried out only in the factory or in an approved engineering works.

Agree to the position of any temporary packing between the outer bearing plates and the structure with the Consultant.

Locate bearings so that their centre lines are within ± 3 mm of their correct positions.

Level of a single bearing or the mean levels of more than one bearing at any support shall be within a tolerance of ± 0.0001 times the sum of the adjacent spans of a continuous girder but not exceeding ± 5 mm.

Tighten threaded fixings uniformly to avoid overstressing any part of the bearing.

Bed bearings over their entire area. Voids or hard spots after installation are not acceptable. Care shall be taken to ensure that no air pockets exist below the bearing bottom adapter plate after installation.

The bedding material shall be capable of transmitting the applied load to the structure without damage. The bedding mortar thickness shall not be less than 20 mm. The bedding mortar shall extend beyond the bearing perimeter by at least 50 mm or twice the thickness of the bedding mortar; whichever is greater. Fall away (slope) the top surface of this mortar extension from the bearing to prevent the collection of water around the bearing.

After installation leave bearings and their surrounding area clean. Remove temporary transit clamps at a time to be agreed upon by the supplier and the Consultant.

17.27 DOCUMENTATION TO BE SUPPLIED WITH THE BEARING.

The Contractor shall provide all necessary documentation for the long-term inspection, maintenance, and replacement of the bearings. This shall include full documentation of the design, working drawings, a certificate of compliance from the supplier, third party testing certificates, welding certificates, documentation of the load tests, quality records and as installed details, procedures for the inspection of the bearing, procedures for maintenance and a fully detailed method statement for the replacement of the bearings.

17.28 SAMPLING, TESTING AND INSPECTION

17.28.1 General

In addition to any tests required by the special approval documents, Specification and Drawings, testing of the finished bearings shall be carried out in accordance with this specification.

The number of tests shall be in accordance with the requirements of lot classification unless otherwise stated in this document. All tests shall be carried out by the Contractor and witnessed by the Engineer and the Employer.

The shipment of bearings must be accompanied by certificate of origin confirming that bearing has been manufactured at country of origin. Bearings or components made out of China shall not be acceptable.

The manufacturer of the bearings shall provide at his expense for the testing and inspection of materials and of the completed bearings, in his plant or at an independent test facility approved by the Engineer or his representative.

17.28.2 Lot Size

A lot shall be defined as those bearings presented for inspection at a specified time and date.

A lot shall not exceed 25 bearings. It shall consist of those bearings of the same type and may consist of different vertical load capacities but not exceed a range of capacity by more than 5000 KN.

The test and number of samples to perform tests shall be in accordance with the following table:

Test	**Samples Required**
Proof load and compression strain	One production bearing per lot
Rotation	One production bearing per lot
Coefficient of friction	One production bearing per lot (test must be Completed using two identical bearings)

17.28.3 Proof Load Test

Bearings shall be simultaneously subjected to a vertical load of 125% SLS design load and rotation of 0.02 radian or design rotation, whichever is greater, for a period of 30 minutes. Note any deformations, cracks, or separations (lift off) of plates from each other or from the sliding material.

Test for Coefficient of Friction (applies to movable bearings only)

The aim of this test is to verify the sliding capability of the bearing. The bearing shall be first loaded in compression with 100% of the SLS design load.

While the vertical load held constant, the bearing is subjected to 3 sliding cycles of 25 mm minimum movement at a speed not exceeding 300 mm / min and determine the average sliding coefficient of friction for the two sliding surfaces. Note any deformation or cold flow of the sliding material.

The sliding coefficient of friction shall be calculated as the horizontal force required to maintain continuous sliding of one sliding surface, divided by the vertical load under test.

17.28.4 Guide Horizontal Test

The aim of this test is to verify the capability of the bearing to withstand horizontal load. The bearing shall be subjected to a combination of vertical and horizontal load corresponding to 110% of their respective Vertical & Horizontal SLS design loads and held under load for a period of 30 minutes.

17.28.5 Acceptance Criteria upon Inspection after Testing

If all tests performed on the selected bearings in a given load range meet the specified requirements, all bearings within that load range will be acceptable. In the event that any test on a bearing in a given load range does not meet the specified requirements, the tested bearings and all other bearings in that same load range will be rejected unless each individual bearing is satisfactorily tested and approved by the Engineer. There shall be no liftoff or separation between plates during rotation. There shall also be no separation between plates and sliding material under rotation. The sliding material shall not travel (cold flow).

Measured sliding coefficients of friction shall not exceed 3% for bearings using UHMWPE sheet sliding material.

There shall be no cracks, separation, or permanent deformation of the sliding material, stainless steel, other components, or welds.

17.28.6 Guarantee

The Contractor is to provide a written guarantee stating that the bearings have been fabricated such that they will perform satisfactorily within the design range of movement and under the design loads for a period of fifteen year from the date of supply. The Contractor shall indicate that they have reviewed the installation procedures and find it in accordance with the bearing recommendations. Provide in the guarantee for the replacement (including supply and installation) of the bearing components or the bearing as a whole at no cost to the Owner in the event that the bearings do not perform satisfactorily within the design range of movement and under the design loads.

The Contractor shall submit from the bearings manufacturer the bearing technical approval document for Spherical Bearings with Special Sliding Material issued by MPA Stuttgart or equivalent approval bodies, which will indicate that the Manufacturer / their technology partner is allowed to design & produce the Bearings utilizing the special sliding material (MSM / UHMWPE) up to a diameter of 2500 mm and that the working / service life of the bearing shall not be not less than 50 years.

17.29 MEASUREMENT AND PAYMENT

17.29.1 Method of Measurement

The bearings shall be measured and paid for per unit at the relevant price entered in the Bill of Quantities.

17.29.2 Basis of Payment

The tendered rate shall include full compensation for all engineering, labour, design, fabrication, installation and equipment necessary to complete the work, including all subsidiary and incidental items thereto for which separate payment is not elsewhere provided. Payment shall include supply of all materials, protection system, dust cover, all necessary bedding, anchor bolts, jacking plates (if required) and temporary works, etc., and shall include shop drawings, quality control, testing, supply and installation, storage, shipping and delivery.

17.30 SHEAR KEY DEVICE

17.30.1 General description of the system

a. General

The shear key is made of concrete cast in place in second pour after concrete decks are assembled.

The shear keys shall take all horizontal loads (longitudinal and transverse).It is equipped with a system of fixation with high strength bars to one end of the deck, and with 5 vertical bearings taking the transverse horizontal loads and the rotations.

b. Description of the proposed system

The system of fixation of the shear key to the deck is performed by high strength tensile bars installed.

The system shall satisfy with the two main following requirements:

- construction easiness

- maintenance easiness

The high strength tensile bars shall have a good resilience and a good resistance to fatigue because due to the rotation of the deck and the braking/acceleration loads the bars are almost continuously loaded. The shear key supplier must be a manufacturer (not a trader, agent, distributor, etc.) having ISO 9001:2008 certification for “Design and Manufacturing of Threaded Tensile Bars along with Nuts”.

The elastomeric bearings shall be of sufficient quality to avoid premature ageing. All the external surfaces shall be made of polychloroprene.

17.30.2 Materials characteristics

a. High tensile bars

Quality of steel: the quality of the raw material steel shall be according to the DIN EN 10083-1 or equivalent. The chemical composition shall be such as to guarantee the following mechanical characteristics:

- Yield stress Fy>1050 MPa
- Tensile stress Fu >1200 MPa
- Elongation at breaking >10%
- Relaxation at 1000 hrs < 3.5%
- Resilience at 20°C > 50 Joules;

Due to high fatigue, resilience and ductility requirement for seismic cases, the properties or mechanical characteristics cannot be lower than as mentioned above. The threading of the bars shall be made by rolling method (cold plastic deformation of the metal between two dies). The threads shall have a triangular profile H7 according to ISO 262 - NFE 03014 and 03053.u

The tolerance of the length of the bars is +/- 5mm

Diameters of bars: the stress in the bar will not exceed 0.85 Fu. The following U.T.S of bar are contemplated, but may be adjusted during detailed design phase:

U.T.S. of Shear Key Bar	**Diameter of Shear Key Bar**
2436 kN	53mm
2109 kN	49mm
1567 kN	43mm
1171 kN	37mm

Due to the repetitive loading that will be applied to the bars, some tests shall be carried out to demonstrate the fatigue resistance of the bars. The test criteria shall be as follows:

- mean stress: 0.57 Fy
- stress range: +/- 0.03 Fy
- 4 million cycles
- after 4 million cycles, no breaking at less than 0.80 Fy.

Ultimate tensile strength test shall be conducted at manufacturers or any other approved independent laboratory in presence of Engineer in charge, same test conducted in the past will not be considered. 4 million cycles fatigue test report for tests conducted in last 5 years to be submitted. The test reports have to be issued strictly in the name of supplier responsible for supply of shear key bar to the project; its important to ensure the responsibility of supply and performance of the system.

17.30.3 Other materials

The repartition plates shall be of S355 JR steel quality or equivalent, and each shall include an injection pipe.

The bars end shall be equipped with a protection cap filled up with grease and fixed on repartition plate by threading.

The nuts at the bars ends shall be spherical in order to ensure that the tensioning is well axed.

Sheaths shall be made with 2 mm thick steel / 5 mm thick HDPE pipe.

The injection product shall be high-density grease in order to provide a good time-resistance and to provide flexibility under the deck rotations. The product shall be equivalent as for use for protecting stay cables. The injection product at end caps would be wax or grease in order to facilitate site installation and inspection during service life.

17.31 ELASTOMERIC BEARINGS SYSTEM

On the movable side of deck, one sliding elastomeric bearing shall be installed longitudinally on each side of the shear key. This sliding elastomeric bearing shall be made of one laminated elastomeric pad and of one sliding plate.

On the fixed side of deck, one laminated elastomeric bearing shall be installed longitudinally on each side of the shear key. In addition, at the interface between the shear key, one laminated elastomeric with adequate recesses to allow for replacement without taking out the high tensile bars shall be installed transversally.

These elastomeric bearings shall be made of polychloroprene and manufactured according to Euronorm EN 1337-3 or equivalent.

The sliding plate shall be PTFE, with elongation at break >300% and tensile strength from 29 to 40 MPa.

17.32 CORROSION PROTECTION

17.32.1 High tensile bars

The protection against corrosion of the high tensile bars shall be performed by using high-density grease injected in tube. So, the bars will be protected against corrosion only for the time of transportation and storage by means of sprayed oil or equivalent system.

17.32.2 Other materials

The upper repartition plate and the protection cap shall be sandblasted and shall receive 3 layers of coating.

The articulation room, the coupler and the lower ring shall be sandblasted and shall receive 3 layers of coating and a petrolatum tape.

The articulation room and the upper protection cap shall be filled up with grease.

17.32.3 TRANSPORTATION & STORAGE

The bars and the accessories shall be transported in wooden cases and in containers, or equivalent.

The bar threading shall be temporarily protected against shocks by a greased tape and a steel ring, or equivalent. The protection of the threads shall be taken off only right before the installation of the bars.

The bars and accessories shall be carefully stored in the jobsite in the following conditions:

- They shall be protected from rain, and the storage room shall have ventilation.
- If the bars have to be kept stored for a long time, it will be necessary to protect them with a layer of solvable oil or equivalent in order to protect them against corrosion.
- Before installation of the bars, if there is some corrosion, they shall be cleaned up.

Acceptance of the bars shall be subject to concerned organisation approval.

17.32.4 Installation procedure

Installation of these shear key high tensile bars must be done under the expert supervision of the system supplier agency. The agency here means “the direct manufacturer & supplier or its sister concern (legally affiliated) or holding company or 100% subsidiary”. No agent, other representative or third party nominated by manufacturer or distributor shall be permitted. The agency supervisor must be available at site full time during installation. The installation procedure is proposed as follows. Alternate methods can be submitted by the contractor, subject to concerned organisation approval.

- Shear Key is poured before precast concrete deck segments are installed. The span must be assembled on higher level to avoid conflicts with already built concrete key.
- Superstructure should have recess of 20mm for grouting by non-shrinkage grout at later stage.
- Erect the superstructure on temporary bearings/jacks with sliding surface at top at both ends.
- Provide some arrangement to prevent deck sliding (e.g. under seismic load).

- Move the girder by hand screwing/jacking bar be nearly 20mm.
- At this stage vertical faced elastomeric pad is in position (resting on tubes).
- Replace the temporary bearing with the permanent elastomeric bearing.
- Grout the gap between the girder (with hacked surface at grouting location) and the elastomeric bearing.
- Bar stressing.
- Wax or Grease injection and capping.

Notes:

The bars are installed after alignment check, and the bars are installed inside the spherical nut at movable end. Then the bars are prestressed with jack. The bars are tensioned step by step (50% one bar, then 50% the other, then the remaining 50%).

Injection is then made from the movable end, with heated wax or grease through injection tube. Alternatively, pre-greased shear key bars can as well be used.

17.32.5 Maintenance procedure

The system shall be such that any device can be replaced without any destruction of concrete part of the structure.

The system shall be such that the maintenance procedures described below can be undertaken.

a. Lateral elastomeric bearings

For the lateral vertical bearings, a theoretical gap of 2mm shall be provided on each side of the shear key. If it is needed to change one or all of these lateral bearings, then, as the deck will not be in contact on each side at a time, the lateral bearings on the non-compressed side are taken out first. First the sliding plate is taken out, then the elastomeric bearing. Then the deck may need to be translated laterally to take out the elastomeric bearings on the compressed side. For this, steel angles can be split in the concrete on each side of the elastomeric bearings to provide support for jacks or threaded bars. The needed force to distort the neoprene bearings supporting the deck will be calculated.

b. Transversal elastomeric bearings

Thanks to the opening on the bearing, it will only be necessary to un-stress temporarily the tie-bars to take out the bearings and replace it.

c. Prestressed tie-bars

Bars will be un-stressed, then simply taken out thanks to the device provided at the movable end. Bars will be taken out easily because the connection between the spherical nut and the protection cap will not allow the spherical nut to turn. The wax or grease product will come out with bar. New bars are introduced as per first installation, then tensioned and wax or grease is injected.

17.33 HOLD-DOWN DEVICES

17.33.1 General Description of the System

a. General

The holds down devices are designed to take the lifting loads between the pier caps and the girders that may occur mainly during earthquakes in curved sections. The system of hold down device must take relative horizontal movements between the pier and the girder without any significant tensile stresses in the bars due to these movements.

b. Description of the proposed system

i. Movable end of the deck

On the movable end, the system shall be composed of the 3 following devices:

1. A lower high tensile bar embedded in the pier cap concrete.

– The bar is smooth and it is threaded only at its two ends. The bars are only threaded at their ends and they are smooth on the full length in order to increase the fatigue performances. The bar is equipped with a repartition plate and a nut.

2. A system of spherical articulation allowing the relative angular rotation between the lower and the upper bar. This device shall be composed with :

– A washer with adequate thickness to permit à good setting of the articulation device. Between the washer and the concrete shall be installed an elastomeric membrane to provide the waterproofing of the device.
– A lower nut with an internal threading to be assembled with the lower bar and an external threading to be assembled with the spherical room.
– An articulation room equipped with a spherical contact surface.
– A spherical nut in contact with the spherical surface of the articulation room.
– A rubber protection skirt installed between the articulation room and the upper bar to avoid any dust in the upper opening of the articulation.
– A rectangular repartition plate to take into account the oblong recess.
– A spherical nut.
– A protection cap that shall be equipped such as to avoid the rotation of the nut and to adjust precisely the gap between the nut and the repartition plate.

3. A high tensile upper bar installed in an oblong recess provided in the girder.

– As for the lower bar, the upper bar shall be smooth and threaded at the two ends. The threading shall be made by rolling method. The corrosion protection of the bar shall be done by a heat shrinkable sleeve. In order to ensure that the lower bar will never break because this lower bar will not be replaceable, the diameter of the lower bar shall be always greater than the upper bar diameter, so that the upper bar shall always break (fuse principle) before the lower bar.
– The upper threading shall be longer in order to take the variation of distance between the girder and the pier cap, and the variation of height of the lower part of the girder. It shall also take into account the construction tolerance.

Important:

a. The articulation system will be designed in order to permit a rotation of at least 8° in all the directions without any tensile stress in the bar.
b. The articulation system will be designed in order to avoid any rotation of any component under the vibrations.

17.33.2 Fixed end of the deck

In that case, the articulation device can be simplified and replaced by a coupler having two different threading diameters. The other devices are the same as for the movable end.

Nevertheless, attention is brought to the fact that the design of the articulations and of the couplers shall be such that there is the possibility to replace a coupler by an articulation in case of non-verticality of the lower bar. Therefore the “fixed end” device may need to be replaced with the more complex “movable end” device if construction tolerances are not met.

17.33.3 Materials Characteristics

a. High tensile bars

Quality of steel: the quality of the raw material steel shall be according to the DIN EN 10083-1 or equivalent. The chemical composition shall be such as to guarantee the following mechanical characteristics:

– Yield stress Fy >1050 MPa
– Tensile stress Fu >1200 MPa
– Elongation at breaking >10%
– Resilience at 20°C > 50 Joules;

The threading of the bars shall be made by rolling method (cold plastic deformation of the metal between two dies) in order to give a good resistance to the fatigue. The threads shall have a triangular profile H7 according to ISO 262 - NFE 03014 and 03053.

The tolerance of the length of the bars is +/- 5mm

Foreseen Diameters of bars:

The stress in the bar will not exceed 0.85 Fu. The lower bar shall not reach the yield strength before upper bar is broken. The following upper/lower U.T.S bars are contemplated, but may be adjusted (+/-) during detailed design phase:

Upper Diameter (U.T.S.)	Lower Diameter (U.T.S.)
500kN	700kN

17.33.4 Corrosion Protection

a. High tensile bars

The protection against corrosion of the high tensile bars shall be performed by using a heat shrinkable sleeve in order to give a very good protection against corrosion due to humidity, ozone, UV rays and shocks.

b. Other materials

The upper repartition plate and the protection cap shall be sandblasted and shall receive 3 layers of coating.

The articulation room, the coupler and the lower ring shall be sandblasted and shall receive 3 layers of coating and a petrolatum tape.

The articulation room and the upper protection cap shall be filled up with grease.

17.33.5 Transportation & Storage

The bars and the accessories shall be transported in wooden cases and in containers, or equivalent. The bar threading shall be temporarily protected against shocks by a greased tape and a steel ring, or equivalent. The protection of the threads shall be taken off only right before the installation of the bars.

The bars and accessories shall be carefully stored in the jobsite in the following conditions:

- They shall be protected from rain, and the storage room shall have ventilation.
- If the bars have to be kept stored for a long time, it will be necessary to protect them with a layer of solvable oil or equivalent in order to protect them against corrosion.
- Before installation of the bars, if there is some corrosion, they shall be cleaned up. Acceptance of the bars shall be subject to concerned organisation approval.

17.33.6 Installation Procedure

The installation procedure is proposed as follows. Alternate methods can be submitted by the contractor, subject to concerned organisation approval.

a. Installation of the lower bars

- Place the bar with the repartition plate and the nut into the reinforcement of the pier cap.
- Check that the length out of the concrete pier cap concrete is sufficient to install the articulation or the coupler.
- Check that the bar is installed vertically.
- Poor the pier cap concrete.

b. Installation of the articulation (or the coupler) and the upper bar

- Install the lower washer and the elastomeric pad on a plane and horizontal layer of mortar.
- Install the lower ring with the external and internal threading around the lower bar.
- Bring the upper bar equipped with the articulation room and the spherical nut and put in position the nut and the upper bar; the length of the pins installed between the nut and the ring shall be such to avoid any gap between the lower nut and the spherical articulation.
- Screw the articulation room until it is in contact with the lower washer.

- Apply a closing tape or equivalent between the bar end and the spherical nut.
- Fill the upper hole of the articulation room with grease or equivalent.
- Install the upper repartition plate on a plane and horizontal mortar.
- Apply a closing tape or equivalent between the end of the bar and the spherical nut.
- Install the upper spherical nut around the bar in order to be in contact with the spherical surface of the repartition plate. At this stage, there shall be no gap between the two spherical nuts, the articulation room and the repartition plate.
- The installation of the protection cap will allow to give a 2mm gap necessary to let the system free of rotation when there is any horizontal movement.
- Install a tape around the articulation room and the lower ring.
- Install the rubber protection skirt between the articulation room and the upper bar (the rubber skirt shall be filled up with grease).

NOTE: the same procedure can be applied for the fixed end, where the articulation room is replaced by a coupler.

17.33.7 Maintenance procedure

The system shall be such that the maintenance procedures described below can be undertaken.

a. Periodical inspection

- Every 5 years or after an earthquake, a visual inspection of the articulation room and the rubber protection skirt will have to be made to check the corrosion protection.
- At the same time, the upper protection cap will be taken off to check if the 2mm gap is still there and to adjust again this gap if necessary.
- The protection against corrosion of the upper bar will also be checked.

17.33.8 Maintenance

The system does not need any maintenance if it works in normal conditions. Nevertheless, if there is an earthquake, a special inspection will be carried out. If it is necessary to change the upper bar, the articulation device or the coupler, it will be necessary to take off the upper bar first, and to change the damaged devices according to the installation procedure.

17.34 EXPANSION JOINTS

17.34.1 Scope of Work

The scope of work will include:

a. Preparation of detailed engineering and installation drawings, supply and supervision during fixing of strip seal/compression seal expansion joints conforming to specifications. The expected expansion/contraction of the superstructure at the location of expansion joints are shown in relevant drawings.

b. Design, manufacture, providing and seating of expansion joints by the specialised agency and approved by the Engineer.

c. Necessary technical supervision for installation of each and every expansion joint during different stages of installation including rectification of any deficiency or defect attributable to fixing and installation will be provided by the manufacturer/supplier.

d. The expansion joint shall be provided for the full width of Stations including the railing.

Leak tightness of all joints shall be ensured which shall also carry a warranty of 10 years from the contractor.

The expansion joints provided over elevated structure decks should be so designed as to be compatible with the bearings wherever provided where the structure passes through stations, specially designed completely waterproof expansion joints should be provided.

The contractor shall submit design and drawing of expansion joints based on design criteria mentioned under “scope of Work” to the Engineer for approval. The design of expansion joint shall be done as per Revised Highways “Interim Specification for expansion joint” issued by

MOST circular No. RW/NH – 34059/1/96 – S & R dated 30th November 2000 and 20th **February** 2001, IRC Codes and MORTH Specification for Roads and Bridges and Sound Engineering practices.

Any modification to the design and drawings submitted by the Contractor, if suggested by the Engineer, shall be incorporated without any reservations. The design and drawings including changes approved by the Engineer shall form basis of execution and the Contractor shall undertake all necessary action for ensuring execution of work on that basis.

For design, manufacture, testing and supply of strip seal/modular strip seal expansion joints, following will be followed in order of preferences:

i. Details in this chapter and elsewhere in tender documents.
ii. "Revised Interim Specifications for expansion joints" issued by MOST circular v No. RW/NH – 34059/1/96/ S & R dated. 30.11.2000 and 20th February 2001
iii. IRC Codes and MORTH specifications for Roads and bridges published by Indian Road Congress.
iv. Sound Engineering Practice (Decision of Engineer will be final in this case) which shall include specialized literature as decided by Engineer-in-Charge.

17.34.2 Building Expansion Joints

Specialised expansion joints consisting of extruded aluminium frame assemblies of suitable profile to receive free floating cover plate of required shape and profile / or elastomer suited to building applications shall be used. These will be provided for covering the structural gap at expansion joints along the horizontal faces of slabs and beams, vertical faces of retaining walls, etc. Necessary block-outs as per the manufacturer's recommendations shall be provided in the structure which shall be filled in the approved manner after placing the expansion joints.

The base of the expansion joint assembly shall be fixed onto the concrete base using anchor fasteners (not exposed to top surface) as per manufacturer's specifications. The joint shall have, and anti-skid serrated top plate with a free-floating central plate. All aluminium in contact with concrete shall have zinc chromate finish. The joint assembly shall be capable of accommodating the specified movement without loss of cover and shall include all the necessary accessories, sealant etc as per manufacture's drawings. The joint fixing shall be carried out either by the main contractor under the supervision of supplier/manufacturing agency of approved expansion joint. The expansion joint cover assemblies shall withstand a minimum 500lb point load without damage or permanent deformation. The joint should be watertight and test on same if required on direction of Engineer shall be conducted without any extra payment for same.

17.34.3 Specification for Strip Seal Expansion Joint

Expansion joint type described here-after is the "strip seal" type, but alternate designs can be proposed for concerned organisation approval (e.g. elastomeric omega-shape cover joint, or any other suitable joint type)

a. Components:

Strip seal expansion joint shall comprise the following items:

i. Edge beam:

This shall be either extruded or hot rolled steel section or cold rolled cellular steel section with suitable profile to mechanically lock the sealing element in place throughout the normal movement cycle. Further the configuration shall be such that the section has a minimum thickness of 10mm all along its cross section (flanges and web). The minimum height of the edge beam section shall be 80mm.The minimum cross-sectional area of the edge beam shall be 1500mm ^2.

ii. Anchorage:

Edge beams shall be anchored to the deck by reinforcing bars or bolts or anchor plates cast in concrete or a combination of anchor plate and reinforcing bars. Anchor bars studs or bolts shall engage the main structural reinforcement of the deck and in case of anchor plates or loops, this

shall be achieved by passing transverse bars through the loops or plates.

The minimum thickness of anchor plate shall be 12mm. Total cross-sectional area of bar on each side of the joint shall not be less than 1600mm Sq. per meter length of the joint and the centre to centre spacing shall not exceed 250mm. The ultimate resistance of anchoress shall not be less than 600 kN/m in any direction.

17.34.4 Material

a. The steel for edge beams shall conform to any of the steel grade corresponding to RST 37-2 or 37-3 (DIN), ASTM A36 or A588, CAN/CSA Standard G40.21 Grade 300W or equivalent.
b. Anchorage steel shall conform to IS:2062 or equivalent.
c. All steel sections shall be protected against corrosion by hot dip galvanizing or any other approved anticorrosive coating with a minimum thickness of 100 micron.
d. Chloroprene of strip seal element shall conform to Clause 915.1 of IRC:83 (Part-II). The properties of chloroprene shall be as specified in Table-1.

17.34.5 Fabrication (Pre-installation)

a. The strip seal joint system and all its component parts including anchorages shall be supplied by the manufacturer /system supplier.
b. 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 to be installed, the gap dimension shall be preset.
c. Each strip seal expansion joint system shall be fabricated as a single entity unless stage construction or excessive length prohibits monolithic fabrication. It shall fit the full width of the structure as indicated on the approved drawing. The system shall be pre-set by the manufacturer prior to transportation. Pre-setting shall be done in accordance with the joint opening indicated on the drawing.
d. The finally assembled joint shall then be clamped and transported to the work site.

17.34.6 Table- strip seal element specification

Sealing element is made of chloroprene and must be extruded section. The working movement range of the sealing element shall be at 70mm.

Property	**Specified Value**
Hardness*	63+ /-5 Shore A
DIN 53505	55 +/- 5 Shore A
ASTM D 2240 (Modified)	.
Tensile Strength*	Min 11 MPa
DIN 53504	Min 13 .8Mpa
ASTM D 412	
Elongation at fracture*	Min 350 per cent
DIN 53504	Min 250 per cent
ASTM D 412	
Tear Propagation Strength	Min 10 N/mm
Longitudinal	Min 10 N/mm
Transverse	Min 25 per cent
Shock elasticity	Min 220 Cu.mm
Abrasion	
Residual Compressive Strain (22h/70 deg C/30 per cent Strain))	Max 28 per cent

Aging in hot air	
(14days/70 deg C)	
Change in hardness	Max + 7 Shore A
Change in tensile strength	Max –20 per cent
Change in elongation at fracture	-20 per cent
Ageing in Ozone	
(24 h/50 pphm/25 deg	
C/20 per cent elongation)	No cracks
Swelling behaviour in Oil (168h/25 deg. C)	
ASTM Oil No. 1	
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	Max –35 deg C

Only one set of specification viz. ASTM or DIN shall be followed depending on the source of supply.

a. Each strip seal expansion joint system shall be fabricated as a single entity unless stage construction or excessive length prohibits monolithic fabrication. It shall fit the full width of the structure as indicated on the approved drawing. The system shall be pre-set by the manufacturer prior to transportation. Presetting shall be done in accordance with the joint opening indicated on the drawing.

b. The finally assembled joint shall then be clamped and transported to the work site.

17.34.7 Handling and Storage

a. For transportation and storage, auxiliary brackets shall be provided to hold the joint assembly together.

b. The manufacturer/supplier 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.

17.34.8 Supply/Installation:

Components of expansion joint such as edge beam and strip seal shall be imported from the specified foreign manufacturer / collaborator to ensure quality and performance. The joint shall be supplied and installed only by the MOST approved manufacturer. Contractor shall furnish a warranty of trouble-free performance for at least ten years and free rectification of defects / replacement, if any, during this period.

The joints shall be installed by the manufacturer/supplier (only MOST Approved) or their authorised representative who will ensure compliance to the manufacture's instructions for installation.

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 rigid and firm.

Immediately prior to placing the joint, the pre-setting shall be inspected. Should the actual temperature of the structure be different from the temperature provided for pre-setting, correction of the pre-setting 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 level and finally aligned and the anchorage steel 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 M40 grade. Good compaction and careful curing of concrete is particularly important. After the concrete has cured, the movable installation brackets and shuttering still in place shall be removed.

The neoprene seal shall be field installed in continuous length spanning the entire roadway width. To ensure proper fit of seal and enhance the ease of installation dirt, spatter or standing water shall be removed from the steel cavity using a brush, scrapper or compressed air. The seal shall be installed without any damage to the seal by suitable hand method or machine tools.

The deck surfacing shall be finished flush with the top of the steel sections. 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.

17.34.9 Acceptance Criteria:

a. All steel elements shall be finished with corrosion protection system.
b. For neoprene seal, the acceptance test shall conform to the requirements stipulated in Table-1. The manufacturer/supplier shall produce a test certificate, accordingly, conducted in a recognized laboratory, in India or abroad.
c. The manufacturer shall produce test certificates indicating that anchorage system had been tested in recognized laboratory to determine optimum configuration of anchorage assembly under dynamic loading.
d. Prior to acceptance 25 percent of the completed and installed joints, subject to a minimum of one joint, shall be subjected to water tightness test. Water shall be continuously pounded along the entire length for a minimum period of 4 hours for a depth of 25mm above the highest point of deck. The width of ponding shall be at least 50mm beyond the anchorage block of the joint on either side. The depth of water shall not fall below 25mm anytime during the test. A close inspection of the underside of the joint shall not reveal any leakage.
e. As strip seal type of joint is specialized in nature, generally of the proprietary type, the manufacturer shall be required to produce evidence of satisfactory performance of this type of joint.

17.34.10 Test and Standards of Acceptance:

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria. The manufacturer/supplier shall furnish the requisite certificates from the recognized testing laboratory of India or abroad.

17.34.11 WATERBARS / WATERSTOPS

Where waterbars are required, the joints shall incorporate PVC water bar such as "Fixostop" or approved equivalent (conforming to IS: 12200). The water bars shall be complete with all the necessary moulded or prefabricated intersection pieces assembled with bends and butt joints in running lengths made by welding in an electrically heated jig. The fabrication drawing made by the manufacturer shall be submitted by the Contractor for approval of the Engineer

Jointing and fixing of waterbars shall be carried out strictly in accordance with the manufacturer's instructions which should be enumerated in a detailed method statement and submitted for approval / comments of the Engineer-in-Charge. The following types of waterstops are proposed to be used in the Work.

i. 'FIXOSTOP' Type 230 KD or equivalent – To be used at construction joint in base slab
ii. 'FIXOSTOP' Type 230 KV or equivalent – To be used at expansion joint in base slab
iii. 'FIXOSTOP' Type 240 RS or equivalent – To be used at construction joint in between wall and base slab
iv. 'FIXOSTOP' Type 240 H or equivalent – To be used at expansion joint in base slab

Water bars shall be of approved and appropriate type obtained from approved manufacturers.

The water bars shall be installed so that they are securely held in their correct position during the placing and compacting of the concrete. Necessary supporting devices to prevent sagging of the water bars shall be provided.

Where reinforcement is present adjacent to water bars, adequate clearance shall be left between the reinforcement and water bars to facilitate compaction of the concrete.

Double headed nails maybe used in the edge of the Water bar outside the line of the external grooves for fixing purposes, but no other holes shall be permitted through the water bar.

A representative of the manufacturer shall be present at site during the operations of installing, jointing and embedment of water stop. He shall monitor and certify that the work is being carried out strictly as per specifications and recommended practices.

17.35 SPECIFICATION FOR OMEGA TYPE EXPANSION JOINT

Expansion joint type described here-after is the "OMEGA TYPE EXPANSION JOINT".

17.35.1 Material.

a. Anchorage:
The steel plate shall conform to IS: 2062 or equivalent. The bolt and nutshell be anchored to the deck by welding to the main reinforcement. Steel plate used for shall be 8 mm thick hot dip galvanized. The centre-to-centre spacing of bolts shall not exceed 400 mm.

b. Corrosion Protection:
All steel section shall be protected against corrosion by hot dip galvanising or any other approved anticorrosive coating with a minimum thickness of 100micron.

c. Joint Seal:
i. The sealing element shall be a preformed chloroprene with high tear strength, insensitive to soil, gasoline and ozone. It shall have high resistance to ageing and ensure water tightness. The seal should be vulcanised in a single operation for the full length of the joint required for carriageway, kerbs and footpaths, if any. The seal shall cater for a horizontal movement up to 100mmand vertical movement of 3mm.
ii. The physical properties of chloroprene sealing element shall conform to the following :

17.35.2 Elastomeric Seal:

It shall be performed extruded Omega type section of Elastomeric Seal of such a shape as to promote self-removal of foreign material during normal service operations. Elastomer of joint seal shall conform to clause 915.1 of IRC:83 (Part-II) and satisfy the properties stipulated in IRC SP 69 which shall be as specified in Cl 9.1.6.1 (c) – (i) above.

17.35.3 Handling and Storage:

a. The expansion joint material shall be handled with care and stored under cover.
b. All joint material and assemblies shall be protected from damage and assemblies shall be supported to maintain true shape and alignment during transportation and storage.

17.35.4 Installation:

a. The expansion joint shall be installed by the manufacturer/supplier or their authorities representative, who will ensure compliance of installation procedure and instructions.
b. The dimension of the joint recess edge beam above deck slab and the width of the gap shall conform to the approved drawing.

c. Bolts shall be welded to the main reinforcement in the edge beam deck maintaining the level and alignment of the joint.

d. Concreting of pocket/recess edge shall be done with great care using proper mix conforming to same grade as that of the deck concrete but no less than M30 grade in any case. The water-cement ratio shall not be more than 0.40. If needed, suitable admixtures may be used to achieve the workability. The width of pocket shall not be less than 300mm on either side of the joint. Care shall also be taken to ensure efficient bonding between already cast/existing deck concrete and the concrete in the joint recess edge beam.

e. At the time of installation, joint shall be clean and dry and free from spalls and irregularities, which might impair a proper joint seal.

f. Concrete or metal surfaces shall be clean, free of rust, laitance, oils, dirt, dust or other deleterious materials.

g. The joint seal shall be compressed to the specified thickness for the rated joint opening and ambient temperature at the time of installation, which shall be between +05 to +35 degree C.

h. The joint seal shall be installed without damage to the seal. Loose fitting or open joints shall not be permitted.

17.35.5 Acceptance Criteria:

a. All steel elements shall be furnished with corrosion protection system.

b. For the joint seal the acceptance test shall conform to the requirements stipulated in para 9.1.6.1 (c) above. The manufacturer/supplier of this type of joint shall produce a test certificate to this effect conducted in a recognized laboratory in India or abroad.

c. Prior to acceptance 25% of the completed and installed joints, subject to a minimum of one joint, shall be subjected to water tightness test. Water shall be continuously ponded along the entire length for a minimum period of 4 hours for a depth of 25mm above the highest point of deck. The width of ponding shall be at-least 50mm beyond the anchorage block of the joint on either side. The depth of water shall not fall below 25mm any time during the test. A close inspection of the underside of the joint shall not reveal any leakage.

17.35.6 Tests and Standards of Acceptance:

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria. The manufacturer/supplier shall furnish the requisite from the recognized testing laboratory of India or abroad.

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

17.35.7 Rates:

The contract unit rate shall include the cost of all materials, labour, equipment's, cost of testing including cost of test samples and other incidental charges for fixing the joints complete in all respects as per specifications.

17.35.8 Specification for Compression Seal Expansion Joint

Expansion joint type described here-after is the "Compression seal" type, but alternate designs can be proposed for the Engineer's approval (e.g. elastomeric omega-shape cover joint, or any other suitable joint type)

Compression seal joint shall consist of steel armoured nosing at two edges of the joint gap suitably anchored to the deck concrete and a preformed chloroprene elastomer or closed cell foam joint sealer compressed and fixed into the joint gap with special adhesive binder.

17.35.9 Material

a. Steel Nosing

The steel nosing shall be of angle section ISA 100 x 100 conforming to weldable structural steel as per IS:2062. The thickness of legs shall not be less than 12mm. The top face of the angle shall be provided with Bleeder holes of 12mm diameter spaced at maximum 100mm centre so as to ensure that there are no voided in the concrete beneath the angle.

b. Anchorage

The anchorage steel shall conform to IS:2062 or equivalent. The steel nosing shall be anchored to the deck by reinforcing bars or anchor plates cast in concrete or a combination of anchor plates and reinforcing bars. Anchor plates and anchor loops, this shall be achieved by passing transverse bars through the loops or plates. The minimum thickness of anchor plates shall be 12mm. Total cross-sectional area of bars on each side of the joint shall not be less than 1600sq mm per m length of the joint and the centre to centre spacing shall not exceed 250mm. The ultimate resistance of each anchorage shall not be less than 600 KN/m in any direction.

c. Corrosion Protection

All steel section shall be protected against corrosion by hot dip galvanizing or any other approved anticorrosive coating with a minimum thickness of 100micron.

d. Joint Seal

i. The sealing element shall be a preformed continuous chloroprene or closed cell foam seal with high tear strength, insensitive to soil, gasoline and ozone. It shall have high resistance to ageing and ensure water tightness. The seal should be vulcanized in a single operation for the full length of the joint required for carriageway, kerbs and footpaths, if any. The seal shall cater for a horizontal movement up to 40mm and vertical movement of 3mm.

ii. The physical properties of chloroprene/closed cell foam sealing element shall conform to the following :

- Chloroprene Seal : It shall be preformed extruded multi-web cellular section of chloroprene of such a shape as to promote self removal of foreign material during normal service operations. Chloroprene of joint seal shall conform to clause 915.1 of IRC :83 (Part-II) and satisfy the properties stipulated in Table 2 strip seal element specifications of these specifications except in respect of the working movement range of the sealing element which shall be as specified above.
- Closed Cell Foam Seal : It shall be of preformed non-extruded non cellular section made from low density closed cell, cross linked ethylene vinyl acetate, polyethylene copolymer that is physically brown using nitrogen. The material shall possess properties as indicated in the Table below.

S. No.	**Property**	**Special Value**
(I)	Density	41.7 – 51.3 kg/cum
(ii)	Compression set on 25mm	50% compression samples (ASTM D 3575) for 22 hours at 23^0 C, 2-hour recovery; 13% set.
(iii)	Working temperature	-70 to +700C.
(iv)	Water Temperature absorptions (total Immersion for 3 months) (ASTM3575)	0.09766 kg/sqm
(vi)	Tensile strength	0.8 Mpa
(vii)	Elongation at break (ASTM D 3575)	195 +/-20%

17.35.10 Lubricant cum Adhesive

This type and application of material used in bonding the preformed joint seal to the steel nosing and concrete shall be as recommended by the manufacturer/supplier of the seal system.

17.35.11 Handling and Storage

a. The expansion joint material shall be handled with care and stored under cover.
b. All joint material and assemblies shall be protected from damage and assemblies shall be supported to maintain true shape and alignment during transportation and storage.

17.35.12 Mode of Measurement

The measurement for expansion joints as a finished work shall be in running meters nearest to a centimetre.

17.35.13 Rates

The contract unit rate shall include the cost of all materials (including cast–in-situ concrete), labour, equipment's, cost of testing including cost of test samples and other incidental charges for fixing the joints complete in all respects as per specifications.

17.35.14 Wearing coat

Asphaltic Wearing Coat

Wearing coat shall be provided as indicated on drawings. It shall consist of the following:

i. A coat of mastic asphalt 6mm thick with prime coat over the top of deck before the wearing coat is laid. The prime coat of mastic asphalt shall be 30% straight run 30/40 penetration grade bitumen and 50% light solvent (benzol) to be laid over the deck slab. The insulation layer of 6 mm thick mastic asphalt with 75% limestone dust filler and 25% of 30/40 penetration grade bitumen shall be laid at 375-degree F with broom over the prime coat.
ii. A layer of asphaltic concrete wearing coat of thickness varying from 25 mm to 60 mm to be laid in single layer.

17.35.15 Concrete Wearing Coat

Scope

The work shall consist of laying cement concrete layer of required thickness as indicated on the drawings, It shall not be laid monolithic with the slab.

Materials

Materials shall conform to ISI and / or IRC specifications.

Construction Operation

a. For Weather and seasonal limitations shall be as per IRC Standards.
b. The surface shall be thoroughly swept and scraped clean and made free of dust and other foreign matter. It shall be conditioned to the specified levels, grade and cross fall (camber) as directed by Engineer.
c. Construction operations such as preparation of mix, laying of concrete, steel reinforcement shall conform to respective specifications in the relevant Chapters.
d. Curing of wearing coat earlier than what is generally specified may be resorted to, so as to avoid formation of shrinkage cracks in hot weather.
e. All carriageway and footpath surfaces shall have non-skid characteristics.

17.36 RAILINGS

17.36.1 General

Prefabricated railing as per approved details shall be erected at site Fixing arrangements with deck shall be carefully designed and incorporated.

Railing on bridge shall not be constructed until the cantering or form work for the span has been released and the span is self-supporting. For concrete and steel, specifications of the items of controlled concrete and reinforcement mentioned under relevant specifications shall be applicable.

Railing shall be carefully erected true to line and grade. Posts shall be vertical with a tolerance not exceeding 6 mm in 3 m. The pockets left for posts shall be filled up with non-shrinkable mortar. All edges and corners shall be straight and finished to true line and level. Forms shall either be of single width boards/ plates or shall be lined with suitable materials duly approved by Engineer. Form joints in plain surface will not be permitted. All mouldings, panel work and level strips shall be constructed according to the details shown on drawings.

17.36.2 Metal Railings

General

All complete steel/ aluminium railing elements, terminal sections, posts, and other fittings shall be of shape, size and designation of approved material and make as given in the item of work or as directed by Engineer. In case of steel railing all these elements shall be painted with an approved paint. If straightening is necessary, it shall be done by methods approved by Engineer.

Aluminium sections shall be of approved quality, designation and free from scratches, stains and discoloration.

The Contractor shall take every precaution against damage of the components during fixing in position.

Damaged galvanised surfaces shall be cleaned and regalvanised. Special care shall be taken to prevent staining of all products rust, mortar, etc. before it is put into use.

17.36.3 Fixing

The railing shall be carefully adjusted prior to fixing in place to ensure proper matching at abutting joints, correct alignment and camber throughout their length.

Fixing shall be strictly as per fixing details shown on drawing or as directed by Engineer.

If sections are not galvanised, railing shall be given one shop coat of paint, and three coats of paint after erection.

All necessary holes, chases, etc., required in fixing shall be made by the contractor and made good after installation, without any extra charge.

17.37 CINDER

General

Cinder to be used for filling in floors shall be obtained from furnace of steam boilers using coal fuel only. It shall be clean and free from clay dirt, wood ashes or other deleterious matter. It shall pass through IS Sieve designation 3.35 mm with at least 50% of it passing through IS Sieve designation 1.70 mm. Cinder obtained from brick kilns shall not be used. At site of work, the cinder shall be protected from dirt collecting on it and could be used for filling in drops only.

17.38 SEALANTS

General

Joint sealing compounds shall seal joints in concrete against the passage of water, prevent the ingress of grit or other foreign material and protect the joint filler. The compound shall have good extensibility and adhesion to concrete surfaces and shall be resistant to flow and weathering.

Approved Sealant where specified on the drawings shall be provided strictly in accordance with the manufacturer's written instructions, such joints shall be formed to the correct dimensions, thoroughly cleaned and treated with recommended primer strictly in accordance with the manufacturer's written instructions prior to sealing. Wherever width of gap to be sealed is wide enough to necessitate the use of backer rod, the same shall be provided at no extra cost. The contractor shall use only competent personnel experienced in the application of sealant for such work.

Where specified in the drawings, silicon/ polurithane/ polysuphide based sealants shall be of an approved manufacture. The treatment of the joint and the use of sealing compound shall be strictly in accordance with the manufacturer's written instructions. The entire work shall be carried out as per IS:3414, IS:6509, IS:11433.

Sealants shall be as follows:

Silicon sealant shall be one-part gungrade type with minimum movement capability of 25% and elongation at break of 450% confirming to BS 5889 or TTS 001543A. This Sealant shall be of approved colour and shall be non-staining to the parent concrete surface.

17.38.1 Ancillary Materials

The Contractor shall provide all ancillary materials such as cleaning solutions, epoxy mortar, primer, tool cleaner, bond breaker type, filler boards, back up material, backing rods, polyethylene foam, masking tapes, sealant slot former etc.

17.38.2 Primer

Primer for sealants shall only be as recommended by the sealant manufacturer, Primer shall have been tested for compatibility and durability with the sealant to be used and on samples of the surfaces to be selected.

17.39 BACKDROP MATERIAL

Backdrop material shall be an expanded polyethylene of nominal density 35 kg/cum as recommended by the sealant manufacturer. It shall be of non-absorbent and non-staining material compatible with the sealant used. Tube or rod stock shall be rolled into the joint cavity.

17.40 BOND-PREVENTIVE MATERIALS

Bond-preventive materials shall be pressure-sensitive adhesive polyethylene tape or aluminium foil.

17.41 EQUIPMENT

The Contractor shall inter alia provide the following plant and equipment for the work.

T-paddle, follower plate, solid barrel gun, plastic nozzle, wire brush, heavy duty 500 rpm electric drill, palette knife, masking tape and paint brush for priming etc.

17.42 WORKING LIFE

Care shall be taken to ensure that material with adequate shell life is provided. Material whose shell life is over shall not be used in the works and shall be removed from the site forthwith. Depending on the storage, temperature and humidity, only one unit shall be drawn from the storage.

17.43 CURING PERIOD

No portion of the work where sealant has been applied shall be allowed to be submerged or be wetted by any liquid for a period of 7 days after application of the sealant. This period may be modified depending on the temperature and humidity prevalent at the time.

17.44 ENVIRONMENTAL REQUIREMENTS

The ambient temperature shall be within the limits as given by the manufacturer, when the sealants are applied. The work shall not be carried out in a dusty atmosphere or when it is raining or when the humidity is high.

Sealants shall not be applied when the ambient temperature is below 4-degree C. When the ambient temperature is below 10 degree C but greater than 4 degree C, the sealant containers shall be stored for some hours at 21 degree C, to ease mixing and application.

17.45 DELIVERY AND STORAGE

Materials shall be delivered to the job site in the manufacturer's original unopened containers.

The containers shall include the following information on the label.:

a. Name of supplier,
b. Name of material,
c. Formula,
d. Lot number,
e. Colour
f. Date of manufacture,
g. Mixing instructions
h. Shell life and
i. Curing time

Materials shall be carefully handled and stored to prevent contamination of foreign materials to exposure to temperatures exceeding 35-degree C.

17.46 JOINTS

The effective width to depth ratio shall be as per the table given below unless directed otherwise by the Engineer.

Surface	Joint Width	Joint Depth	
		Minimum	Maximum
For Concrete Masonry or Stone	6mm	6mm	6mm
	Over 6mm up to 12mm	6mm	Equal to Width
	Over 12mm	Half of the width	Half of the width

17.47 SURFACE PREPARATION

General

The surface of joints to be sealed shall be clean, dry, sound and free of all release agents, water repellents, laitance, oil, grease, dirt, chalk, particles of mortar, dust, loose rust, loose mill scale and other foreign substances. Oil and grease shall be removed with solvent and the surfaces shall be wiped with clean clothes.

17.48 CONCRETE AND MASONRY SURFACES

Where surfaces have been treated with curing compounds, oil or other such materials, the materials shall be removed by sandblasting or wire brushing, Litance, efflorescence and loose mortar shall be removed from the joint cavity. The surfaces/edges shall be repaired with epoxy mortar to give smooth and even surfaces to correct lines and levels with a uniform gap for the length to be sealed.

17.49 APPLICATION

17.49.1 Masking Tape

Masking tape shall be placed on the finished surface on one or both sides of a joint cavity to protect adjacent finished surfaces from primer or compound smears. The masking tape shall be removed within 10 minutes after the joint shall be filled and tolled.

17.49.2 Bond-preventive materials

Bond-preventive materials shall be installed on the bottom of the joint cavity and other surfaces to prevent the sealant from adhering to the surfaces covered by the bond-preventive materials. The

materials shall be carefully applied to avoid contamination of adjoining surfaces or breaking bond with surfaces other than those covered by the bond-preventive materials.

17.49.3 Backstops

The back or bottom of joints constructed deeper than specified shall be packed tightly with an approved backstop material to provide a joint of the depth specified.

17.49.4 Primer

The primer shall be used in accordance with the manufacturer's instructions. The primer shall be applied to the joint surfaces to be sealed only and not spill over or be applied to surfaces adjacent to the joints.

17.50 APPLICATION OF SEALANT

The sealant shall be gun-applied with a nozzle of proper size to fit the width of the joint indicated and shall be forced into grooves with sufficient pressure to expel air and fill the groove solidly. The sealant shall be uniformly smooth and free of wrinkles.

The plastic nozzles shall be inserted on the gun and cut to appropriate size. The sealant shall be gunned into joints using an even trigger pressure. The nozzle shall be cleaned occasionally.

The sealant shall be pressed into joints with a wet spatula and tooled within five minutes of application. The jointly shall be tooled slightly concave after the sealant is installed. The tolled joint shall present a smooth and professional joint giving the desired finish and shape. The masking tape shall be removed immediately after tooling.

Application equipment shall be cleaned with a tool cleaner, recommended by the manufacturer, after wearing PVC or rubber gloves and whist the sealant is still in an uncured state.

17.51 CLEANING

The surfaces adjoining the sealed joints shall be cleaned of smears and other soiling resulting from the sealing application as the work progresses. Sealant adhering to, porous surfaces shall be left until is just cured and then removed by abrasion or other mechanical means.

17.52 FIRE PROOFING OF STEEL STRUCTURES

17.52.1 Scope

This specification covers the general requirements of materials and the method of application for internal protection of platform structural steel girder (in a limited length) and steel door where high voltage cable is crossing from track girder to off- road station building, against fire by vermiculite cementitious coating.

17.52.2 Materials

All materials to be used shall conform to the requirements of respective UL codes / IS codes. Sample and test results for all the materials shall be submitted to the Engineer and got approved by him in writing before execution of work. Acceptance criteria of commonly used materials is given below.

17.52.3 Vermiculite Cementitious Coating

Branded product with base as Vermiculite mixed with ordinary portland cement shall have a max loose dry density of 400kg/m3 while in moulded condition, density shall not exceed 800kg/m3. Sulphate content in the branded product shall not exceed 1%, when the sulphate content is expressed as sulphur trioxide.

17.52.4 Reinforcement

Welded wire fabric to be used as reinforcement shall conform to IS:1566 and shall be of approved type. Mesh size shall be 50mm x 50mm and thickness of wire shall be 3mm.

17.52.5 Attachments

a. Tie wire

Tie wire shall be of mild steel not thinnerahan 16SWG.

b. Nuts

Nuts shall be made of mild steel and shall conform to IS:1367 and IS:2585 of required size as recommended by manufacturer.

17.52.6 Surface Preparation

Surface cleaning, Welding nuts and application of primer

All steel surface to be in contact with the fire proofing coating materials shall be cleaned of all oil/grease, loose rust/scales/dust by using detergent and wire brushing.

M-16 or of required size as recommended by manufacturer nuts shall be welded with all the steel members to be fire proofed. Maximum spacing of nuts shall be 400mm centre to centre in both directions. Nuts shall be welded to the steel surface in shop. Epoxy zinc phosphate primer polyamid as specified in table of painting specification or as recommended by manufacturer's shall be also applied to the MS nuts and effected surfaces of the members due to welding after cleaning.

17.52.7 Placement of reinforcement

Reinforcement shall be placed in the middle of coated material thickness. It shall be bent confirming with outlines of finished encasement and rigidly secured in place by tie wire with all the nuts. Minimum lap at ends and sides shall be 100mm and lapped wire fabric shall be tied firmly.

Application

a. Application of fire proofing material coating shall be carried out by skilled and experienced operators.

b. Before start of application, zone which is not to be fireproofed shall be covered with polythene/ tarpaulin to protect them against damage.

c. For vertical webs of steel girder, the coating materials shall be applied in horizontal bands working upwards from the bottom. All outside edges of the fire proofing shall be chamfered by 20mm.

d. Thickness of fireproof coating shall be established by measuring it with electrometer. The fire proofing material, after application shall be cured by keeping it in moist condition for a period of at least 14 days or else the surface shall be coated with a membrane of approved curing compound. Brand name, name of manufacturers, test results and method of application shall be submitted to and got approved from the Engineer prior to procurement of curing compound.

17.52.8 Approach Working Platform &Scaffolding

The contractor shall arrange all approaches, scaffoldings, stairways, ladder, working platform etc. for carrying out the entire works safely. The working area shall be neatly maintained, and all the facilities required by Engineer for proper supervision of the work shall be provided. In case, any special precaution is needed for the safety of the structure till the completion of application, the contractor shall make and provide all such arrangement to the complete satisfaction of the Engineer and shall remove the same after completion of works.

Specific Requirement

17.52.9 Vermiculite Cementitious Coating

Design Requirement

a. Vermiculite cementitious coating shall restrict the temperature of structure, below the maximum permissible temperature of 538 C for structural steel members, for a minimum time period of 2 hours and also it shall not fail till the end of the specified period.

b. The coating shall be non-corrosive to the steel members & shall not be affected by environmental conditions. It shall also be asbestos free.

c. The coating materials shall be durable and easily repairable.

d. Application procedure of the coating shall be easy, non hazardous and also shall not interfere with working of the adjoining areas.

e. The contractor shall submit coating thickness based on test results for structural steel sections to be fire proofed for review/approval of the Engineer for the offered branded product as per UL-1709 when tested on W10 x 49 steel I-beam.

Application

a. Vermiculite cementitious coating shall be mixed with water on a clean platform or in a clean mixing box or in a suitable mixer as per manufacturer's specifications. Water cement shall be adjusted so that vermiculite cementitious coating adheres properly to steel surface and does not sag or slide upon application.

b. Primer compatible with the vermiculite cement coating as recommended by the manufacturer's shall be applied over the steel surface after cleaning the shop primer if required as per the manufacturer's specifications.

c. Mixed vermiculite cementitious coating shall generally be applied, over the steel surface with the help of spray gun except for small area and inaccessible location, where application with conventional hand tools shall be permitted. Mixed vermiculite shall be used within the pot life specified by the manufacturer. Under no circumstances rebound material shall be used.

d. The full specified thickness shall be developed in three successive coats. rendering coat, floating coat, finishing coat and thickness of each coat shall be as manufacture's requirement.

Each successive layer shall only be applied after the preceding layer has developed its initial set and is also properly scratched with steel brush to developed proper bond. If the application is interrupted and does not satisfy successive layers criteria, the coating shall be cut back to the steel surface/preceding layer with a trowel at an inclined angle. Exposed surface of this coating shall be thoroughly wetted before resuming the work.

e. Application of mixed vermiculite shall not be carried out if the air temperature or the temperature of the surface to be fire proofed 4 C or less. Provision shall be made for adequate ventilation during and after application, until the coating is dry.

17.52.10 Finishing and Joint Sealing

Fireproof coating shall be finished with 2 coats of microporous exterior topcoat as recommended by manufacturer, compatible to cement surfaces of approved make and colour conforming to IS: specifications.

17.53 TEST

The contractor shall submit the certificate of test results for the vermiculite cementitious coating over structural member from a laboratory, approved by the Engineer. Test shall be performed as per the requirements laid down in UL-1709 for 2 hours duration when tested on W10 x 49 I-beam.

17.54 MEASUREMENT

Measurement for fire proofing coating of 2hrs shall be in Sqm based on the net surface of structural steel on which it is applied.

Approved Manufacturers/ Supplier

All materials and products shall conform to the relevant standard specification, IS codes and other relevant codes etc. and shall be of approved makes and design.

17.55 POLYCARBONATE ROOF/WALL PANELS

The multi-cell polycarbonate panel to be used for Roofing/Wall Panels should have the following specifications:

a. Two side Co-extrusion for UV rays protection

b. Panels have to be joined together by protected polycarbonate connector/aluminium connector/any other mechanism that makes joint perfectly water tight.
c. Year warranty
d. Thermal Insulation >/=1.50 W/m^2.K Acoustic Insulation >/=20dB
e. Linear Thermal Expansion=.065mm/m degree C Temperature Range (-20 degree to 120 degree C) Fire Reaction BS1d0 or better as per EN 13501

17.56 FLY ASH BASED PRODUCTS:

Fly ash-based products such as Mechanized Autoclaved Sand Lime Fly ash Bricks/ Fly Ash Lime Gypsum Bricks/Autoclaved Aerated Concrete (AAC) Blocks have to be used in all construction activities.

17.57 ROOF TOP (SOLAR)

The roof top solar PV system shall be mandatorily implemented at depots and stations with the specifications as below.

a. Hot dip galvanized MS mounting structures (with 1000 gm/m2 zinc mass coating) may be used for mounting the modules/ panels/arrays. Each structure should have angle of inclination as per the site conditions to take maximum irradiation. However, to accommodate more capacity the angle inclination may be reduced until the plant meets the specified performance ratio requirements.
b. The Mounting structure shall be so designed to withstand the speed for the wind zone of the location where a PV system is proposed to be installed (like Bangaluru-wind speed of 180kM/hour). It may be ensured that the design has been certified by a recognized Lab/ Institution in this regard and submit wind loading calculation sheet to NCRTC. Suitable fastening arrangement such as clamping should be provided to secure the installation against the specific wind speed.
c. The mounting structure steel shall be as per latest IS 2062 and as per Contract condition.
d. Structural material shall be corrosion resistant and electrolytically compatible with the materials used in the module frame, its fasteners, nuts and bolts. Aluminium structures also can be used which can withstand the wind speed of respective wind zone. Necessary protection towards rusting need to be provided either by coating or iodization.
e. The fasteners used should be made up of stainless steel. The structures shall be designed to allow easy replacement of any module. The array structure shall be so designed that it will occupy minimum space without sacrificing the output from the SPV panels. Installation of solar structure should not damage the roof in any way. If any concrete or foundation is required, it should be preferably precast type.
b. f) The bidder needs to take care of the load bearing capacity of the roof and need arrange suitable structures based on the quality of roof.
a. The total load of the structure (when installed with PV modules) on the terrace should be less than 80 kg/m2.

17.58 TEMPORARY GROUND ANCHOR

The temporary ground anchors installed to support the diaphragm wall or secant piles shall be as follows:

General

This specification deals with temporary ground anchors and shall be read in conjunction with the conditions of contract and the Specification for Excavation. A temporary ground anchor means wherein the contractor proposes to use ground anchors as part of his Temporary Works. A ground anchor is a structural element installed in soil or rock that is used to transmit an applied tensile load

(as a result of horizontal earth pressure) into the ground. The Contractor shall comply fully with the requirements of this specification in the design, erection and installation of ground anchors.

Where works are ordered to be performed by the Contractor but are not specified in this specification, the Contractor must carry them out with full diligence and expedience as are expected for works of this nature and shall comply with the relevant clauses of the codes – IS14448, IS10270, FHWA recommendations, BS 8081, ACI440.6, IS456 and PTI recommendations for prestressed rock and soil anchors (2004).

This contract to be carried out by specialised agency which has capability in following:

1. to design and supply the anchor
2. to assemble, install, grout and stress the anchor.

There can be one specialized agency for both above and there can be two separate specialized agencies for each of the activities. However, each of the specialized agency must have completed at least one project in India of similar material, nature and job application.

17.58.1 Reference Standards

IS14448, IS10270, FHWA recommendations, BS 8081, ACI440.3, ACI440.6, IS456 and PTI recommendations for prestressed rock and soil anchors (2004).

17.58.2 Design By Specialised Contractor

The Contractor shall include in the submission, for the Engineer's review, his proposed design of ground anchor with Assembly drawings. Unit rates of ground anchors shall be based on the allowable anchor forces required for the safe and adequate performance. The Contractor's submission of calculations and shop drawings shall include the following information:

a. Anchor layout
b. Anchor design details
c. Anchor structural and geotechnical design capacity
d. Grade and properties of the tendon material
e. Percent of tendon ultimate load at working load
f. Grout - cement type, strength, additives
g. Anchor load, length, and bond diameter
h. Anchor free stressing length and de-bonding details
i. Initial lock-off load of anchor
j. Anchor bond length or fixed length design details
k. Endorsement by the Contractor's Professional Engineer
l. Any other information required by the Engineer in his review of the Contractor's design.

The Contractor's design calculations and specifications shall comply fully with the relevant recommendations of reference codes. In matters not specifically covered by the reference codes and the Engineer's specifications, the Contractor's design shall be in accordance with accepted principles of good engineering practice. It shall be the Contractor's responsibility to clearly itemise those matters.

The review of the Contractor's design by the Engineer does not in any way absolve or reduce the duties and responsibilities of the Contractor to ensure the safety and adequacy of his works.

Method Statement for Construction Operations

Prior to commencement of works, the Contractor shall submit to the Engineer a detailed method statements, for the installation of ground anchors. For the purpose of this Clause, a method statements shall be a document containing

a. A detailed construction sequences
b. Proposed drilling method
c. Proposed installation method
d. Proposed grouting, stressing method and equipment

e. Material and plant requirements at each construction stage.
f. Shop drawings.
g. Methods of testing.

The Engineer shall inform the Contractor in writing within 14 days after receipt of the Contractor's method statement either

a. that the Contractor's proposed methods have the consent of the Engineer; or
b. in what respect, in the opinion of the Engineer, the proposed methods fail to meet the requirements of the contract

17.58.3 Inspection & Testing

The Engineer shall inspect the installation of anchors and will monitor anchor stressing acceptance tests to ensure that the Contractor's anchor design and construction method will produce the suitable anchorage system in the soil/rock conditions encountered on site.

The testing of concrete and grout shall be in accordance with the provisions for works concrete in the General Concrete Specification.

17.59 COMPLIANCE INSPECTION

The Engineer shall carry out inspection to ensure that the Contractor follows the approved shop drawings and good engineering practice.

17.59.1 Acceptability

Acceptance test shall be carried out on all temporary ground anchors; in accordance to EN1537:1999. Failure of any anchor to meet acceptance test criteria will result in rejection of the anchor in question. Consistent failure of a given anchor type require reassessment of the anchor design and installation practices.

Materials

17.59.2 General Requirements

Tendons

The temporary ground anchor should be a grouted multi-strand system that is post-tensioned prior to excavation.

The requirements listed in the following clauses shall apply, wherever relevant, to materials used in all anchors. The handling, storage and use of materials shall comply with manufacturers' instructions.

Post-tensioned tendons shall comply with the following:

a. Hybrid GFRP/Steel system with minimum system ultimate tensile strength of 250 kN
b. FRP bar shall be solid round bar of 19mm dia conforming to ASTM D2583, nominal c/s area 284sqmm, Ultimate tensile load of min 300 KN, modulus of elasticity of 50 GPa and ultimate strain of 2.11%.
c. Stressing tail of not more than 2 metres to be made of high tensile steel strand with a diameter of 15.2mm and minimum ultimate tensile stress of 1860 MPa, a modulus of elasticity of 195 GPa, maximum relaxation of 2.5% and c/s area of 140mm2; conforming to IS14268/1995 class 2.
d. PT steel strand and GFRP bar to be connected with a steel coupler. Usage of glue or grout for bonding of the couplers with FRP profile is not permitted. The steel connection should not be more than 350mm in length.
e. In case of GFRP tendon longer than 11.8m, steel coupler to be used. The steel connection should not be more than 350mm in length.

A manufacturer's certificate shall be submitted to the Engineer containing all the relevant information as mentioned above. A full system ultimate loading (FRP+Coupler+PT Strand) to be submitted for at least 5 samples per lot.

GFRP material is cuttable or breakable in nature, with coherent inert properties, and so can be left inside the ground. Since both the free length and bond length of the temporary ground anchor is made of GFRP, it doesn't need to be removed from the ground once redundant.

17.59.3 Cement Grout

Grout shall consist of ordinary Portland cement OPC43/OPC53 grade or more obtained from approved manufacturer/supplier.

Admixtures shall comply with the requirements of BS 5075: Part 1: 1982 and BS 5075: Part 3: 1985 and shall only be used with the prior agreement of the Engineer.

Grout cubes of 100mm size shall be prepared and cured in accordance with BS 1881: Part 3: 1970, and the strength of grout cubes shall be tested in accordance with BS 1881 : Part 4 : 1970. The grout shall have a minimum compressive strength measured on 100mm cubes 20 N/mm2 at 3 days and 35 N/mm2 at 28 days. Collection of grouts shall be from the grout overflowing from the drillhole unless otherwise agreed by the Engineer.

Admixture, if used, shall be provided at the Contractor's own expense. Admixtures shall impart to the grout the properties of low water content, good flow ability, minimum bleeding and controlled expansion. Its formulation shall contain no chlorides or other chemicals in quantities that may have harmful effects on the cement or prestressing steel. The Contractor shall submit to the Engineer the manufacturer's literature indicating the type of admixture and the manufacturer's recommendations for mixing the admixture with the grout. All admixtures shall be used in accordance with the instructions of the manufacturer.

17.60 PLASTICS

17.60.1 PVC Pipe – UNBONDED LENGTH

A PVC sleeve encasing individual tendon shall be used as part of the corrosion The PVC tube shall be conforming to DIN 8074 & DIN 8075 and IRC:18-2000. The ends of the sleeve shall be sealed with neutral mastic.

17.60.2 Corrosion Protection

Being GFRP (an inert material) used for anchor, no specific corrosion protection is required for tendons.

17.60.3 System Components

General

The anchor shall be designed to provide an ultimate load holding capacity of not less than specified.

Free And Fixed Anchor Length

The free anchor length is the distance between the anchor head and the proximal end of the grout. The fixed anchor length is the length of anchorage over which the tensile load is capable of being transmitted to the surrounding ground. The fixed anchor length shall not be less than 3m for all anchors subjected to acceptance tests.

Spacers & Centralizers

Spacers shall be provided on multi-tendon anchors to ensure separation between the individual components, and to ensure individual tendons are positioned uniformly over the cross-section of the drill hole. Centralisers shall be provided on multi-tendon anchors to ensure separation between the individual components, and to ensure individual tendons are positioned uniformly over the cross-section of the drill hole.

Anchor Head Components

The anchor head components which retain the force in the stressed tendon shall comply with the requirements of BS 4447: 1973.

The anchor head shall be designed so as not to induce secondary stresses in the tendon. Wedges should be fitted between anchor head and support plinth, unless the anchor head permits compensation for angular deviations of the tendon from the axial position.

The anchor head design for temporary anchorages shall permit in-service tests to be made as long as such tests are required.

Equipment

All stressing equipment must be used in accordance with the specifications of the manufacturer and Clause 9 of BS 8081:1989 and must at all times be maintained in good condition.

The pumps, jacks and all tensioning equipment shall be calibrated. All calibrations must be conducted by an approved laboratory with the necessary equipment and must be certified. The calibrations shall be carried out no longer than 3 months prior to using the equipment on site. If any incident occurs during transportation, handling or tensioning which may have caused damage, the equipment must be recalibrated.

Anchor stressing shall be in the manner specified in the approved shop drawings and approved method statement. Stressing shall not be carried out until the grout has reached its specific strength.

All equipment used for fabrication, handling and placing shall be such that it will not damage the anchor tendons.

The grouting equipment shall be capable of continuous mechanical mixing to produce a grout free of lumps and undispersed cement. A manifold system with a series of valves and calibrated pressure gauge with a capacity of 10 N/mm2 shall permit continuous circulation and pumping of grouting with accurate control of grout pressure.

Stressing equipment shall be capable of applying at least the specified test load to the anchor tendon. A calibrated pressure gauge indicating the hydraulic jack pressure should, as a minimum requirement, comply with class 2 of BS 1780. They should be supplied with a calibration certificate and shall read to an accuracy of at least ±3% of the load applied.

17.61 ANCHOR FABRICATION

Anchors shall be either shop fabricated, or field fabricated in accordance with approved shop drawings, using personnel trained and qualified in this type of work.

17.61.1 Drilling

Holes for anchors may be formed by drilling method. The drilling method used shall be subjected to the agreement of the Engineer. Full temporary casing shall be installed to maintain a clean and open shaft and prevent wash out of fines outside the casing in all holes. Grouting shall be carried out with the temporary casing inside the hole and after fresh grout emerge from the hole, then only the temporary casing can be slowly retrieved while grouting continues. Any alternative method shall be approved by the Engineer.

Drill holes for ground anchors shall be provided in accordance with the Drawings. The drill hole entry point shall be positioned within a tolerance of ±75mm. Deviation in alignment shall not exceed 1 in 30.

The Contractor shall keep a record of all drilling procedures and times, which shall be made available to the Engineer.

17.61.2 Anchor Installation

The installation of the tendons shall be supervised by suitably qualified personnel familiar with this type of work. All equipment used for handling and insertion of the anchor shall be such that it will not damage the anchor tendon and corrosion protection.

Grout tubes shall be flushed with water or compressed air to ensure that they are clear.

The anchor bonded lengths as indicated in the approved design submissions shall be considered the minimum bonded lengths and shall be located within the specified bond zone of the anchorage stratum.

The Contractor shall maintain a record showing the anchor type, length, position and installation date for each anchor.

17.61.3 Anchor Testing

a. Suitability Test

As per EN1537

b. Pull Out Test

As per EN1537

c. Performance Test

100% anchors will be stressed up to 125% of working load during installation and then reduced to lock-off load of 110% of pre-load (no incremental loading or hold time); such that all anchors will be subjected to performance test during installation.

18 NOT USED

19 MECHANICAL, ELECTRICAL & PLUMBING WORKS

19.1 GENERAL

19.1.1 The Contractor shall only use the approved materials as indicated in the Employer's Requirements duly approved by the Engineer.

19.1.2 The Contractor shall develop the design and select equipment based on technical specification and on sound, proven and reliable engineering practices. The broad design / selection criteria shall be submitted with technical support data in the technical proposal. Detailed calculations shall be submitted to the Engineer during the design process for review and approval.

19.1.3 The Contractor shall ensure the correct selection of the make meeting the design specifications and application duty. The technical submission made by the Contractor shall clearly indicate deviation or improvements if any, for specifications. Before placing order for procurement, the Engineer may ask for the sample of proposed make to be verified for its suitability to the specifications and application duty. However, in case the Engineer considers that the make/model proposed by the Contractor does not meet the requirement, the Contractor will be required to propose an alternative make acceptable to the Engineer. The decision of the Engineer in this regard shall be final and binding on both parties.

19.1.4 Vendor approval policy

a. It shall be obligatory for the Contractor to obtain Notice of 'No Objection' from the Engineer for the vendors identified / selected for all items of work, even if the name of the vendor is specified in the tender and the works to be done including purchase of materials and equipment in accordance with the Standards specified in the Contract.

b. While selecting the Vendor, due care is to be taken to ensure that the vendor is capable in providing good "after sales services" in during two years Defect Liability Period (DLP) and subsequently during the life of the item / equipment, thereafter.

19.1.5 Vendor Approval and Selection Procedure

a. The contractor shall submit the Vendor proposal for all the equipment / systems to be supplied in the contract in accordance with the tender requirement for obtaining "No-Objection" from the Engineer. The contractor shall submit the proposal for the vendor after ensuring that the proposal meets the specifications in line with the quality and safety standards of the proposed makes. The proposed product should be a proven one. The Contractor shall also stand full guarantee to his proposal and if at any stage it is found that the material is not suitable or meeting the tender requirement, the contractor shall replace the material and provide the material from the alternate vendor after approval from Employer without any additional cost to Employer. The alternate makes can be used only after an approval has been accorded by the Employer, whose decision will be final in the matter.

b. The approval of vendor for any equipment / product shall be done in two stages :-

i. Stage-I

Assessment of capability of proposed Vendor to supply a particular equipment or product, with quality and performance requirements, as required by Specifications as well as other contract conditions. The proposed product should be a proven product in service for at least 3 years in similar working environment or as specified in contract specifications.

Assessment of the financial and functional strength of the Vendor to supply the requisite quantity of equipment and product as per delivery schedule acceptable to the contractor and the Engineer to deliver the project in time.

ii. Stage-II

Stage-II called as Technical Approval Stage, selection of Equipment or product from the equipment / products / model being manufactured / supplied by the approved vendor will be done. This stage includes thorough technical assessments about the conformance of the offered equipment / product / model to the Specifications and other requirements of the contract.

c. Before placing the order for procurement, the sample of approved make shall be verified for its suitability to the specification and application. In case the Engineer, (whose decision will be final and binding on both parties) considers that the make / model proposed by the contractor does not meet the tender requirement, the contractor will be required to propose an alternative make acceptable to the Engineer.

d. To obtain Vendor Approval, the Contractor must submit the request with the following minimum documents along with duly filled with Vendor Approval Checklist.

i. Company Profile and Experience of the Vendor

ii. Clause wise compliance of the relevant Specifications.

iii. Details of supplies / orders executed in last five years for the type of equipment / product offered. Supplies / orders executed for Elevated/Underground Metro / Suburban / Railway Systems shall be specifically mentioned.

iv. Details of the facilities available at the Works / Manufacturing Unit where the proposed equipment / product shall be manufactured.

v. ISO 9000 Certification for the Works / Manufacturing Unit where the proposed equipment / product shall be manufactured (The Works / Manufacturing Unit where the proposed equipment / product shall be manufactured must have ISO 9000 Certification)

vi. Proof regarding compliance to Manufacturer's Qualifications. The offered products must be proven in service in similar environment i.e Metro / Railways or Airport.

vii. Audited Financial Statements of the Vendor for the last three years.

viii. Type test certificates / Performance certificate from accredited laboratories for the proposed type of equipment / products as specified in contract specifications to establish the technical capability of the vendor (In case, specific requirements are mentioned in the relevant sections of Specifications with regard to type testing, same shall also be complied additionally).

ix. The vendor shall not have been blacklisted by any Govt. Agency in India during last 5 years.

e. Undertaking for submission of tripartite warranty Agreement duly signed by the authorized signatory of the supplier / vendor and Contractor to the Engineer / Employer within 30 days after signing of subcontract / vendor agreement between the Contractor and the subcontractor / vendor.

f. Any other item as required by Employer / the Engineer, the Contractor must be included/certified in the check list, that the vendor Proposal is complete and all the above documents are available in the Vendor Proposal. In addition, the Contractor must check / certify compliance to the Specifications before forwarding the same.

g. Incomplete Vendor Proposal shall not be treated as a submission and will be returned. For all the proposed vendors, the contractor shall submit details of Major subcomponents / system which is outsourced / "bought out" item for the proposed main equipment vendor. The Employer (if required) may ask details for granting specific vendor approval for the source of sub-component, which shall be submitted along with the vendor proposal for the main equipment / system.

h. The contractor shall submit along with the vendor proposal the commitment for Reliability, Availability and Maintainability requirements in terms of MTBF (Mean Time Between failure), FRPCPY (Failure Rate Per Cent Per Year) and MTTR (Mean time to Repair), etc. from the manufacturer of the proposed equipment / major subcomponent. These proposed / committed parameters shall be reviewed during the Defect Liability Period (DLP).

i. If it is found that the parameters are not being complied, then the Contractor / vendor shall be bound to either replace the complete equipment / sub system OR carry out necessary modifications in the equipment / sub-system to meet the performance parameters.

j. The Engineer shall issue "No-Objection" to the Vendor Proposal (received complete with all the documents mentioned above) after detailed scrutiny.

k. It may be noted that Approval of Vendors shall only be done by the Employer / the Engineer after the award of the work. Vendor submissions shall not be evaluated during the tender evaluation. Conditional Tender offers received from Tenderers with particular Vendors for supply of equipment / products will not be evaluated during evaluation and will be dealt with after award of the work.

l. For obtaining "No-Objection" on the Vendor Proposal, the Contractor must submit technical submission accompanied with the calculations / other technical documents to justify the selection of any particular model of equipment / product, detailed technical features / parameters of the selected product, type test certificates as specified in contract specifications from the accredited laboratories for the offered products, any other document required by the Engineer.

m. It may further be noted that Employer / Engineer shall be under no obligation to accept equipment / products manufactured by the successful Tenderer, unless it meets the entire criterion mentioned above.

n. In addition to the above, the following shall also be ensured for the Vendor Approval and Selection: -

   i. Proven Design:

      The Contractor shall develop the design based on the contract specifications and on sound proven and reliable engineering practices. The broad design details shall be submitted with technical support data in the technical bid. Detailed calculations shall be submitted to the Engineer during the "design process" stage for review and approval.

   ii. Systems and Sub-Systems

      - Manufacturer shall have at least 5 years' experience of design and manufacturing of similar system. Proposed systems from the proposed manufacturing unit shall have been in use and have established their satisfactory performance and reliability for 3 years in minimum in metro / railways or Airport.
      - All sub-systems, equipment and major components etc. (hereinafter referred as 'sub-systems') shall be state-of-art and of proven design.
      - Proposed Systems/ sub-systems shall have been in use and have established their satisfactory performance and reliability on at least Two mass rapid transit systems (including Metro/ Railways or Airports) in revenue service over a period of three years or more either outside the country of origin or on an average in two

different countries.

o. Systems / Sub-systems / components used in other MRTS in India do not get automatically qualified for use unless specifically approved by the Engineer for this project. If required by the Engineer, Contractor shall provide certificate of satisfactory performance for a period of five years or more from the Metro(MRTS) operators /Suburban / Railway, where similar System/ Sub-systems of a different rating are already proven in service as per the above criteria then the supply shall be based on such subsystems. All 'sub systems' shall be procured from the approved vendors and sourced from only such manufacturing units those have supplied the sub-systems that fulfil the proven design requirements as above.

p. The Engineer/Employer may ask the Contractor/ vendor to get the equipment, components and parts to be incorporated in the metro(MRTS) / Suburban / Railway system, tested in certified laboratories (designated by the Govt. of India) to check for any kind of embedded malware / trojans / cyber threat and for adherence to Indian standards. The Contractor and the vendor shall be required to get the test conducted without any extra cost to Employer, and submit its report. Contractor / Vendor shall inform the dates and location of test at least 15/30 days in advance to the Engineer.

q. For sourcing the equipment from indigenous manufacturing facilities, following conditions shall be complied: -

   i. In case the vendor uses his own facilities for indigenization after part supply of equipment from the approved manufacturing unit, no change in design, component type / make, quality standards, manufacture procedure, etc. shall be made without specific approval of the Engineer.

   ii. In case OEM wants to use manufacturing facilities in India (other than his own) for items for which the OEM has been approved, it shall enter into an agreement with such selected Indian equipment manufacturer and obtain prior approval from Employer. No change in composition, rating, type, model no., manufacturing process, quality standards, design, etc. and make of the components used in assemblies/sub-assemblies of such equipment as manufactured by the approved parent vendor, shall be made without specific approval of the Engineer.

   iii. In both the cases (i) and (ii) above, the first article manufactured indigenously shall be Type tested as per relevant standards before starting bulk manufacturing. The Approved parent vendor shall also submit Triparty warranty agreement as per Annexure-B, for ensuring that full technical support is extended to Employer / contractor during project execution and also during DLP and 5 years beyond DLP.

   iv. In case OEM wishes to change/make/type specifications, etc. of any subcomponents for supplies to be sourced from Indian facility, specific prior approval of the Engineer shall be obtained for changes made, model, specification, etc. Responsibility for obtaining such prior approval shall rest solely with the contractor.

r. For obtaining "No-Objection" of subcontractor for the electrical works, the contractor shall submit subcontractor's proposal in accordance with the (Checklist for the Subcontractor Proposal for Electrical Contracts). However, in case the proposed subcontractor is also a supplier of the equipment / material then the vendor proposal in accordance with the above procedure shall also be submitted for obtaining "No-Objection".

s. Payment against the delivery/installation/completion/testing & Commissioning of MEP items, as per "Section 9 and shall be as per site progress and as approved by the Engineer.

t. The Contractor to submit PO Copy /Invoice of Each item to verify Correct selection / procurement of Vendor / material is made by the Contractor. The Contractor shall take prior approval before delivery of items at site.

19.1.6 In case the Contractor has to use systems or sub-system(s) that do not fulfil the above said criteria, then the Contractor shall furnish sufficient information to prove the basic soundness and reliability of the offered systems and sub-system(s) for review of the Engineer. The Engineer's decision on Contractor's proposal shall be final and binding.

19.2 CODES AND STANDARDS

A list of Indian and International Codes and Standards in conjunction with the MEP materials and equipment is confirmed in this Section, Technical Specifications. The latest prevailing version of Codes and Standards shall be used by the Contractor.

20 ARCHITECTURE

20.1 GENERAL

20.1.1 The Contractor shall only use the approved materials as indicated in the Employer's Requirements or as similar approved by the Engineer.

20.1.2 The Contractor shall ensure material selection and complies with the design specifications and application duty requirement. Before placing a procurement order, a sample shall be provided to the Engineer for consent.

20.1.3 Only new materials and equipment shall be used for the Works. All materials and equipment furnished by the Contractor shall be subject to review and consent of the Engineer. Any materials which, in the opinion of the Engineer, have lower quality than the approved makes shall be immediately removed from the project and no payment shall be claimed or shall be made to the Contractor.

20.1.4 As and when required, the Contractor shall send materials for testing by an independent institute/laboratory as decided by the Engineer.

20.1.5 The manufacturers list given in Appendix C is for reference only. Alternatives materials and equipment from other manufacturers may be considered, depending on full compliance to Employer's Requirements and as approved the engineer. Please note that the Engineer's Decision in this regard shall be final and be adding to the Contractor.

20.2 CODES AND STANDARDS

A list of Indian and International Codes and Standards in conjunction with the Architectural materials and equipment is stated in this Section, Technical Specifications. However, the latest version of standards shall be considered by the Contractor as decided by the Engineer during design and execution stage as per requirement.

20.3 MASONRY WORKS INCLUDING MULLIONS, TIE BEAMS, LINTELS, ETC.

20.3.1 General

This section specifies the requirements for the furnishing and erection of Masonry works.

20.3.2 Products

a. Fine and Coarse Sand
b. Fine and Coarse Aggregate
c. Ordinary Portland Cement (OPC)
d. Aerated and Solid concrete Masonry Units nominal dimensions of 200(w) x 400(l) x 200/150/200mm (t)
e. Reinforcement Bars for supporting mullions, tie beams, lintels, etc

20.3.3 Execution

The Contractor shall prepare technical specifications for the execution of Masonry works including Mullions, Tie Beams, Lintels, etc and submit it to the Engineer for its review and consent prior to commencement of works.

20.3.4 Quality Assurance

All works shall be performed by the Contractor employing trained personnel with a minimum 10 years proven experience.

20.4 FLOORING WORKS

20.4.1 General

This Section specifies the requirements for the supply and installation of floor finish materials and related accessories.

20.4.2 Quality Assurance

All works shall be performed by the Contractor employing trained personnel with a minimum 10 years proven experience.

20.4.3 Detailed Design Drawings and Shop Drawings

Detailed design drawings shall be submitted for review.

20.4.4 Maintenance Data

Maintenance data of floor finish materials shall be provided.

20.4.5 Products

Colour and texture shall be in accordance with the Material Finish and the Colour Co-ordination Schedule;

a. Granolithic Flooring / Hardenite/Hardcrete Flooring
b. Raised Access Floor
c. Vitrified Tiles
d. Granite Flooring
e. Epoxy Flooring
f. Interlocking Paver blocks
g. Yellow Tactile Tiles
h. Concrete cobbles
i. Concrete kerb stone
j. Kota
k. Foam concrete

20.4.6 Execution

The Contractor shall prepare technical specifications for the execution of flooring works and submit it to the Engineer for review and consent prior to start of work.

20.5 WALL FINISHES

20.5.1 General

This Section specifies the requirements for the supply and installation of wall finish materials and related accessories. Equivalent specifications may be presented to the Engineer for review.

20.5.2 Quality Assurance

All works shall be performed by the Contractor employing trained personnel with a minimum 10 years proven experience.

20.5.3 Detailed Design Drawings and Shop Drawings

a. Detailed design drawings and shop drawings shall be submitted for review.
b. Detail design drawings and shop drawings shall clearly indicate materials and largescale details for head, jamb, mullions and sill, profile of components, elevations of units, anchorage details, location of isolation coating, operating hardware, description of related components, exposed finishes, fasteners, etc.

20.5.4 Maintenance Data

Maintenance data of wall finish materials shall be provided.

20.5.5 Products

a. Granite Facia, 20 mm thick
b. Granite Flooring/Coping, 30mm thick
c. Ceramic Tile Cladding, 8mm thick
d. Vitrified Tile Cladding, 10mm thick
e. Toughened, Laminated, Fire Rated Glass works
f. Mirror 6mm thick
g. Granite counter tops, 30mm thick

20.5.6 Finishes

a. Acrylic Emulsion Paint
b. Enamel Paint
c. Texture Paint
d. Anti-Dust Epoxy Paint
e. Fire Retardant Paint
f. Cement Sand Render / Plaster
g. Anti-rust primer

20.5.7 Execution

The Contractor shall prepare technical specifications for the materials, accessories and execution of wall finishes works and submit it to the Engineer for review and consent prior to start of works.

20.6 DOORS & IRON MONGERY

20.6.1 General

This Section specifies the requirements for the supply and installation of steel doors frames, ironmongery, etc all complete.

20.6.2 Quality Assurance

All works shall be performed by the Contractor employing trained personnel with a minimum 10 years proven experience.

20.6.3 Submittals

a. Contractor's shop drawings shall be submitted for review and consent to the Engineer before start of manufacture and shall indicate the elevations, jamb and head details for frame type, hardware reinforcing, preparation for finish hardware and anchoring of frames and special features.
b. The metal thickness of doors and frames shall be indicated along with sizes and methods of anchorage.
c. The manufacturer, type and series of doors and frames shall be identified and listed on the Contractor's drawings and referred to door schedule on Drawings.

20.6.4 Coordination

a. Where indicated on the Drawings, provision shall be made in doors and frames for specified lock set and door alarms, including cut-off and raceways as required. This Work shall be coordinated with the electrical requirements specified.
b. Provisions shall be made for opening in doors to accommodate louvers, Glass panels.

20.6.5 Materials

a. Compact Laminated doors
b. Pressed Steel Doors
c. Fire Rated Doors

20.6.6 Fabrication

a. Steel doors and frames shall be completely shop fabricated in accordance with ASTM specifications and NFPA 80.

b. Fire rated doors and frames shall be completely shop fabricated in accordance with requirements of Underwriter's Laboratories.
c. Doors and frames shall be reinforced, mitred, drilled and tapped to receive finish hardware.
d. Doors and frames shall be fully welded, with no visible seams or joints on faces or vertical edges and reinforcing channels.
e. Welded corners shall be ground to a flat plane, filled with metallic paste filler, sanded to uniformly smooth finish and primed.
f. An identification plate should be affixed to the inside of frame indicating: nomenclature of door / door type, fire rating period, hardware type, etc

20.6.7 Execution

The Contractor shall prepare technical specifications for the materials and accessories and submit it to the Engineer for review and consent prior to start of work.

20.7 WINDOWS

20.7.1 General

The work specified in this Section consist of providing windows and frames with insect screens, complete with 6mm thick toughened glass, window sash locks, etc.

20.7.2 Submittals

The Contractor will provide the Engineer with a schedule of windows indicating their size, type, location, etc along with detail shop drawings for review and consent before start of manufacture.

20.7.3 Execution

Contractor shall prepare technical specifications for the execution of Windows and submit it to the Engineer for review and consent prior to installation works.

20.8 STEEL AND METAL WORKS

20.8.1 General

This Section specifies the requirements for the supply and installation of preformed metal cladding (roofing, wall) system and accessories in accordance with the Drawings.

20.8.2 Quality Assurance

a. All Work shall be performed by the Contractor employing trained personnel with a minimum ten years proven experience.
b. The Contractor shall supply a certificate of compliance from the manufacturer for cladding coating and stainless-steel fasteners.

20.8.3 Materials

a. Profile shall be detailed on the drawings. Colour shall be in accordance with the Material Finish and Colour Co-ordination Schedule.
b. Metal cladding profile shall be indicated on the drawings.
c. Insulation for roofing, fibre glass blanket insulation laminated on one side with single sided aluminium foil vapor barrier shall be used.

20.8.4 Fabrication

Metal cladding shall be fabricated in single length sheets to suit various support conditions and to manufacturer's recommendations and to comply with the Drawings.

20.8.5 Execution

The Contractor shall prepare technical specifications for the materials, accessories and execution of the materials and submit it to the Engineer for its review and consent prior to start of work.

20.9 WATERPROOFING WORKS

20.9.1 General

The Work specified in this section consists of all works associated with waterproofing to be detailed on the Contractor's design drawings

20.9.2 Quality Assurance

All works shall be performed by the Contractor employing trained personnel with a minimum 10 years proven experience.

20.9.3 Submittals

The Contractor will provide the Engineer with a schedule of materials proposed along with location detail, performance data sheet of materials proposed for review and consent before start of works.

20.9.4 Materials

a. Silicon Water Repellent Coating
b. Membrane Roof Water Proofing
c. Liquid Applied Water Proofing

20.9.5 Execution

The Contractor shall prepare technical specifications for the materials, accessories, etc and submit it to the Engineer for review and consent prior to start of work.

20.10 PAINTING & POLISHING

20.10.1 General

This Section specifies the requirements for painting of all items in accordance with the Material Finish and Colour Co-ordination Schedule.

20.10.2 Quality Assurance

a. All Work shall be performed by the Contractor employing trained personnel with a minimum ten years proven experience.
b. All paint materials and applications shall be subject to review by qualified inspectors appointed by the Engineer which may include manufacturer's representatives.

20.10.3 References and Standards

All materials shall be to Indian and ASTM standards

20.10.4 Submittals

a. Manufacturer's specifications and instructions for each application shall be submitted for review
b. A Contract Schedule showing manufacturer, supplier paint type, coats, colour, locations and phasing/coordination shall be submitted.

20.10.5 Coordination

Painting shall be coordinated with work of other trades and applications pre-arranged according to the Contract Schedule.

20.10.6 Materials

a. Paint thinners, solvents and fillers shall be of excellent quality and shall match the specified products for each application.
b. First class new brushes shall be used for all applications. Rollers and spraying equipment where permitted, must be reviewed by the Engineer.
c. All materials shall be to ASTM Standards.
d. The paints and thinners shall have low VOC content and shall be IGBC/GRIHA compliant

Colouration must be performed on factor approved equipment for perfect match with approved samples submitted.

20.10.7 Execution

The Contractor shall prepare technical specifications for the materials, accessories and execution of the materials and submit it to the Engineer for review and consent prior to start of work.

20.11 FALSE CEILING

20.11.1 General

This Section specifies the design, fabrication, supply and installation of false ceiling including related accessories.

20.11.2 Quality Assurance

20.11.3 All works shall be performed by Contractor's certified trained personnel. Submittals

a. Detailed design drawings / shop drawings shall clearly indicate the reflected ceiling plans, all materials, thickness, finishes, connections, joints, method of anchorage etc.
b. Crucial dimensions shall be confirmed by site measurement.
c. Sample module showing basic construction and assembly, treatment at walls, recessed fixtures, splices and finishes etc. shall be submitted for Engineer review and consent.
d. Trap doors should be clearly indicated in the drawings and shop drawing indicating their fixing and opening system should be submitted for review and consent prior to start of works.

20.11.4 Materials

Installed ceilings should be able to withstand wind load up to Indian standard.

a. Calcium Silicate Board
b. Metal (MS/GI)

20.11.5 Execution

The Contractor shall prepare technical specifications for the materials, accessories and execution of the materials and submit it to the Engineer for review and consent prior to start of work.

20.12 MISCELLANEOUS WORKS

a. Powder Coatings
b. Sanitaryware including Fittings and Fixtures station wide
c. Expansion Joints/Movement Joints
d. Architectural Expansion Joint System
e. Tensile Roof Fabric
f. Rolling Shutters
g. Synthetic Acrylic (Solid Surface)
h. Galvalume/Zincalume/Galvanized Roof Sheeting
i. Landscaping, Horticulture, Site clearances and Development

20.13 ANTI-GRAFFITI COATINGS

20.13.1 General

This Section specifies requirements for the supply and application of Anti-Graffiti Coatings, for use on all masonry and concrete surfaces, either as indicated on the drawings, or as subsequently scheduled and agree with the Engineer. Products will be required to protect horizontal areas, walkways etc. for removal of dirt and grime as well as concrete wall or column surfaces against graffiti.

20.13.2 Quality Assurance

a. All works shall be performed by the Contractor employing trained personnel with a minimum 10 years proven experience.
b. Anti-Graffiti materials shall be from one supplier only.
c. The properties of the Anti-Graffiti material shall be listed by the supplier, who will provide details of the required method and rate of application.
d. Surface preparation shall be in accordance with the manufacturer's instructions.

20.13.3 Submittals

Samples of each coating system material.

a. Manufacturer's printed data, including procedures for mixing, thinning, applying and precautions which shall be observe during the application shall be provided.

b. Schedules indicating those surfaces which are to be coated with Anti-Graffiti Coating shall be prepared and approved by the Engineer.

20.13.4 Execution

The Contractor shall prepare technical specifications for the materials, accessories and execution of the materials and submit it to the Engineer for its review and consent prior to start of work.

20.14 CHEMICAL RESISTANT COATINGS

20.14.1 General

This Section specifies the requirements for the supply and installation of chemical resistant coatings.

20.14.2 Quality Assurance

20.14.3 All works shall be performed by Contractor's certified trained personnel Execution.

The Contractor shall prepare technical specifications for the materials, accessories and execution of the materials and submit it to the Engineer for review and consent prior to start of work.

20.15 WATER REPELLENT COATINGS

20.15.1 General

This Section specifies the requirements for the supply and installation of water repellent coatings.

20.15.2 Quality Assurance

a. All works shall be performed by the Contractor employing trained personnel with a minimum 10 years proven experience.

b. Mock-up

i. Water repellent coating shall be applied to approximately 20 square meter area of surface to be treated.

ii. Verification shall be made that surface is coated with sufficient water repellent coating to effectively repel moisture; and

iii. Verification shall be made that application of water repellent coating will produce no surface stains.

20.15.3 Submittals

Prior to commencement of application, the Contractor shall submit the coating manufacturer's literature, specifications and application instruction to the Engineer for review and consent.

20.15.4 Project Site Conditions

a. Plant and vegetation, which might be affected by water repellent coating fumes or alkalinity of material, shall be protected by suitable methods.

b. Water repellent coating shall not be applied where dust is being generated.

20.15.5 Materials

a. Water repellent coating shall be a solvent-based coating of acrylic resins and volatile hydrocarbon solvents, water clear.

b. Water repellent coating shall impart little or no perceptible seen.

c. Coating containing tars or polysulfide polymers shall not be used for this application.

20.15.6 Execution

The Contractor shall prepare technical specifications for the materials, accessories and execution of the materials and submit it to the Engineer for review and consent prior to start of work.

20.16 ROOF SHEETING

20.16.1 General

This Section specifies the minimum requirements for the supply and installation of Roof Sheets and accessories in accordance with the Drawings

20.16.2 Quality Assurance

20.16.3 All works shall be performed by Contractor's certified trained personnel.

a. Galvanized Roof Sheeting
b. Galvalume Roof Sheeting
c. Zincalume Roof Sheeting
d. Multiwall Polycarbonate for Skylight

20.16.4 Execution

The Contractor shall prepare technical specifications for the materials, accessories and execution of the materials and submit it to the Engineer for its review and consent prior to start of work.

20.17 LIST OF MATERIALS

The list will apply to all Public & Non-public areas, station entrances, FOBs and System Rooms. For the use of items as 'applicable" installation is subject to location and environmental conditions / system requirements.

a. Wall Materials

Acceptable	Not acceptable
• **Monolithic materials** • Concrete with sealers (with sufficient surface texture to conceal minor soiling and damage without complicating maintenance procedures or constituting a hazard to clothing or skin of patrons).	**Monolithic materials** • Rough concrete (within 3 m of floor immediately adjacent to public circulation and flow areas) • Plaster • Exposed steel • Glass (only acceptable at elevator housing walls and other special conditions as required for safety and security and approved by IE. • Curtain wall assemblies.
Unit Materials • Unglazed and glazed ceramic mosaic tile • Ceramic facing veneers • Glazed and unglazed brick • Cast Terra cotta block units • Vitrified Tile • Natural Granite • Natural Marble • Precast Concrete • Sand stone • Porcelain enamel steel panel - non-combustible assembly • Crystallized glass panels • Concrete masonry units - non-public areas only in underground stations. • Reinforced cast-in-situ concrete for underground works and shafts. • Structural glaze faced concrete masonry units • Acoustic board **Acceptable for use over 3 m above floor** • Rough or textured concrete • Acoustic panels - in passageway areas only	**Unit Materials** • Gypsum board (acceptable for 2-hour rated enclosure at smoke exhaust duct where passing through ancillary space) • Plastics • Wood • Glass

Surface Applied Finishes • Clear sealer - on concrete surfaces or concrete masonry units. • Rendered block work with finish	**Surface Applied Finishes** • Vinyl wall covering • Paint • Epoxy coatings.

b. Floor Materials –finish to provide Slip resistant surface.

Acceptable	Not acceptable
Monolithic materials • Concrete - with appropriate finish to provide slip- resistant surface in ancillary areas. • Hardened finish where shown Acid-resistant applied coating	**Monolithic materials** • Bituminous toppings • Synthetic resin toppings Resinous Terrazzo Tile
Unit Materials • Natural granite. • Manufactured Granite • Vitrified Tile • Unglazed ceramic tile • Vinyl Tile - Non-Public areas only. • Kota Stone • Paver Blocks	**Unit Materials** • Resilient tile and sheet products - in public areas • Wood products • Marble • Mosaic tile. • Glazed Ceramic tile.

c. Ceiling Materials

Acceptable	Not acceptable
Monolithic materials • Smooth concrete • Acoustic Materials (vermiculite plaster, etc.) sprayed onto mechanically fastened expanded metal lath. expanded metal lath.	Cement Plaster
Unit Materials • Non-corrosive linear metal panels with applied coating or natural brushed finish with wrapped acoustical material • Non-corrosive metal panels with applied coating or natural brushed finish with large perforations with wrapped acoustical material • Rigid, cellular glass blocks. • Calcium silicate board • Acoustic mineral fibre board ceiling	**Unit Materials** • Acoustic tile (ceramic and mineral, glass and wood fibre) • Gypsum board • Suspended plaster systems • Wood
	Surface Applied Finishes • Gypsum Plaster

d. Door Materials

Acceptable	**Not acceptable**
• Flush hollow metal doors and frames: ➢ Public areas - alkyd enamel finish ➢ Non-public areas - alkyd enamel finish. • Wire glass at doors with vision panels • Laminated safety glass at elevator, glazed doors and hoist ways • Stainless steel overhead rolling grilles. • Stainless steel service gates. • Stainless steel doors. • Toughened Glass doors	• Fluor polymer finished doors and frames • PVC doors • Wooden, particle board doors • Anodized aluminum doors and frames • All upward acting sectional doors • All non-tempered, non-safety glass

e. Smoke Exhaust duct cladding Materials

Acceptable	Not acceptable
• Non-corrosive metal - natural brushed finish • Non-corrosive metal with fire rated applied coating.	• High polished stainless-steel ceiling or smoke exhausts duct cladding.

f. Canopy Materials

Acceptable	Not acceptable
• Steel deck, factory-finished baked enamel • Non-corrosive metal-natural brushed finish • Silicone or Teflon-coated fibreglass (where out of reach of vandals). • Steel, factory finished aliphatic polyurethane coated.	• Ordinary glass • Uncoated fabric • Ordinary plastics

g. Handrails Materials

Acceptable	Not acceptable
• Steel with factory finished aliphatic polyurethane coats • Stainless steel, public areas • Painted galvanized steel • Stainless steel welded wire mesh screen	• Aluminum • Uncoated steel • Uncoated galvanized steel

Structural Steel Works

20.18 STRUCTURAL STEEL

a. All structural components other than purlins and side cladding runners shall be made from Hot Rolled Sections and plates with Grade-B0 (with mandatory impact testing) having a minimum yield stress of 250 MPa conforming to IS:2062. Minimum metal thickness for Hot Rolled sections shall be 6mm. Such steel shall be procured from approved manufacturers.

b. Whenever high strength steel is specified, it shall be conforming to IS: 8500.

c. All steel tubes shall be hot finished seamless steel tubes (HFG) of the specified strength and as approved by the Engineer and shall conform to IS: 1161. Tubes made by other processes, and which have been subjected to cold working, shall be regarded as hot finished if they have subsequently been heat treated and are supplied in the normalized condition.

d. Purlins and side cladding runners only shall be made from cold formed sections and shall conform to ASTM A570 Gr 50 with minimum yield strength of 345 MPa. Minimum metal thickness for cold formed sections shall be 3.15mm UNLESS SPECIFICALLY PERMITTED by Engineer-in-charge/Structural Consultants.

20.19 STEEL SUPPLIED BY THE CONTRACTOR

a. The Contractor shall furnish to the Engineer all mill orders covering the material ordered by him for this project and also the test reports received from the Mills for his approval and information. It is not intended that all the steel materials to be supplied by the Contractor for the work shall be specially purchased from the rolling mills. The Contractor's stock material may be used, provided the mill test reports identified with the materials, satisfactorily demonstrate the specified grade and quality. The Engineer shall have the right to test random samples to prove authenticity of the test certificates produced by the Contractor, at the Contractor 's cost.

b. All steel materials supplied by the Contractor shall be in a sound condition, of recent manufacture, free from defects, loose mill scale, slag intrusions, laminations, pitting, flaky rust, etc. and be of full weight and thickness specified.

c. Wherever the Contractor, in order to accommodate his other materials in stock, desires to substitute structural steels or plates for the sizes shown on drawings, such substitutions shall be made only after authorization in writing by the Engineer.

d. The Engineer may direct that substitution be made, when he considers such substitutions is necessary.

20.20 THREADED FASTENERS

a. Technical supply conditions for bolts and nuts shall comply with IS: 1367. Unless specified otherwise all field connections shall be bolted with high strength bolts of property Class 8.8. Unless specified otherwise, the bolts and nuts shall be hexagonal.

b. All anchor bolts and nuts shall be of property Class 4.6 (Grade-B) of IS: 1367 and shall conform to IS: 5624. All nuts shall be hexagonal and shall conform to property class compatible with the property class of the bolt used.

c. Plain washers shall conform to IS: 5369, unless otherwise specified. One washer shall be supplied with each bolt and, in case of special types of bolts, more than one washer as needed for the purpose shall be supplied. An additional double coil helical spring washer, conforming to IS: 6755, shall be provided for bolts carrying dynamic or fluctuating loads and those in direct tension.

20.21 ELECTRODES

Electrodes used for metal are welding of mild steel shall be heavy coated type electrodes conforming to IS: 814 (Part I & II) and shall be of the best quality approved by the Engineer. All electrodes/ wires / flux shall be kept under dry conditions. Any electrode I wires /flux damaged by moisture shall not be used unless it is guaranteed by the manufacturer that, when it is properly dried, there will be no detrimental effect. Any electrode, which has part of its flux coating broken away or is otherwise damaged, shall be rejected. Any electrode /wires/ flux older than six (6) months from the date of manufacture shall not be used. Batch certificates for electrodes/ wires /flux shall be submitted by the Contractor. Welding consumables for Manual metal arc welding shall conform to IRS-M-28, Wire and Flux combination for Submerged Arc welding to IRS-M- 39 and filler wires for CO2 welding to ROSO/ M & C, Specification. Threaded Fasteners

20.22 HANDLING AND STORAGE

a. Proper storage of steel (sections and fabricated members) at the job site shall be the responsibility of the Contractor.

b. Structural steel shall be stored out of mud and dirt. Proper drainage of the storage area shall be provided. These shall be protected from damage or soiling by adjacent construction operations.

c. Fabricated steel shall not be handled until the paint has thoroughly dried. Care shall be taken to avoid paint abrasions and other damage. Steel work shall be transported in such a way so as not to over stress the fabricated sections. All pieces bent or otherwise damaged shall be rejected and shall be replaced by the contractor at his own cost.

d. Checking and inspection of fabricated structural steel work by the Engineer shall be done at various stages of completion of fabrication work. The contractor is required to ensure that fabricated steel work is properly stacked such that all joints of all members are either visible or accessible for inspection at all stages of inspection work. Care should also be taken to ensure that fabricated members are not subjected to stresses due to defective stacking.

20.23 FABRICATION

a. All fabrication work shall be done in accordance with IS: 800, read in conjunction with relevant codes mentioned therein.

b. Fabrication shall be done in workshops approved by Engineer, unless specifically permitted by Engineer that fabrication can be done at site. Under such circumstances work shall be done on a specially designed and constructed platform. Location, size, specification and construction of such a platform shall have prior approval of Engineer. Loads associated with such platforms shall be provided to Engineer.

c. Mild steel rolled sections and plates shall be cut by shearing/machining and grinding the surfaces to true sizes and shapes. Gas cutting of mild steel may be permitted by the Engineer, provided that every cut face and edge is smoothened by grinding operation. Prior approval of Engineer must be obtained for using gas-cutting techniques either by mechanized gas cutters or manually operated gas cutters. While, using gas-cutting methods, proper allowance must be made for grinding to bring the cut piece to exact required dimensions.

d. Extensive use of templates shall be made in doing fabrication work. Templates shall be clean and should have true surfaces prepared for every successive use.

e. Reinforcements for the structural steel members if required shall be included. In case actual members are used as templates for similar pieces, it will be at the discretion of the Engineer to decide whether such pieces are fit to be incorporated in the finished structure. Jigs and manipulators shall be used, where practicable, and shall be designed to facilitate welding and to ensure that all welds are easily accessible to the operators.

f. All material shall be straight and free from twist and bends unless required to be curvilinear in from. If necessary the material shall be straightened and I or flattened I straightened by pressure. Heating of rolled sections and plates for purpose of straightening shall not be permitted.

g. Curvilinear members shall be formed by bending with the help of pneumatic press. Final shaping, to a very limited extent, however, may be done by local heat application. This shall be done only on receiving approval from the Engineer.

h. Holes

All holes shall be made at right angles to the surface of the member. Holes shall be clean cut without any torn or jagged edges. Holes shall be done by drilling. Punching shall not be resorted to, unless previously approved by the Engineer. In any case, punching of holes in materials having a thickness in excess of the connector diameter, or, for materials thicker than 16 mm, the hole shall be punched 3 mm less in diameter than the required size and then reamed to the full size. Holes shall not be formed or enlarged by burning or gas cutting under any circumstances.

20.24 WELDING

a. In general, only Automatic submerged arc welding will be used for fabrication. Subject to approval of Engineer, Metal inert gas welding may be done for short length where access to the location of the weld does not permit submerged arc welding. The welding and the welded work shall conform to IS: 816, unless otherwise specified. As much work as possible shall be welded in shops and the layout and sequence of operations shall be so arranged as to eliminate distortion and shrinkage stresses. Unless otherwise specified all weld shall be for full contact for all sides.

b. Electrodes for shielded-arc manual welds shall comply with the requirements of IS:814 and shall be amenable to radiographic tests and shall be of approved make. The electrodes for manual arc welding shall be suitable for use in the position and type of work, as laid down in the above specifications and as recommended by the manufacturers. Electrodes

classification group 1 or 2 as given in IS: 814 shall be used for welding steel conforming to IS: 2062. Electrodes shall conform to IS-1442 for steel conforming to IS: 8500. Joints in materials above 20 mm thick, and, all important connections shall be made with low hydrogen electrodes Electrode flux covering shall be sound and unbroken. Broken or damaged coating shall cause the electrodes to be discarded. Covered electrodes for manual arc-welding shall be properly stored in an oven prior to use in a manner recommended by the Manufacturer and only an hour's quota shall be issued to each welder from the oven.

c. Electrodes larger than 5 mm diameter shall not be used for root-runs in butt-weld.

d. Welding plant and accessories shall have capacity adequate for the welding procedure laid down and shall satisfy appropriate standards and be of approved make and quality, the Contractor shall maintain all welding plant in good working order. All the electrical plant in connection with the welding operation shall be properly and adequately earthed and adequate means of measuring the current shall be provided.

e. All welds shall be made only by welders and welding operators who have been properly trained and previously qualified by tests to perform the type of work required as prescribed in the relevant applicable standards.

f. All welds shall be free from defects like blow holes, slag inclusions, lack of penetration, undercutting, cracks etc. All welds shall be cleaned of slag or flux and show uniform sections, smoothness of weld metal, feather edges without overlap and freedom from porosity.

g. Fusion faces and surfaces adjacent to the joint for a distance of at least 50 mm on either side shall be absolutely free from grease, paint, loose scales, moisture or any other substance which might interfere with welding or adversely affect the quality of the weld. Joint surfaces shall be smooth, uniform and free from fins, tears, laminations etc. Preparation of fusion faces shall be done in accordance with the approved fabrication drawings by shearing, chipping, machining or machine flame cutting except that shearing shall not be used for thickness over 8 mm.

h. In the fabrication of cover-plated beams and built up members all shop splices in each component part shall be made before such component part is welded to other parts of the member. Wherever weld reinforcement interferes with proper fit-up between components to be assembled for welding, these welds shall be ground flush prior to assembly.

i. Members to be joined by fillet welding shall be brought and held as close together as possible and in no event shall be separated by more than 3 mm. If the separation is 1.5 mm or greater, the fillet weld size shall be increased by the amount of separation. This shall only apply in the case of continuous welds. The fit-up of joints at contact surfaces which are not completely sealed by welds shall be close enough to exclude water after painting.

j. The separation between fraying surfaces of lap joints and butt joints with backing plate shall not exceed 1.5 mm. Abutting parts to be butt welded shall be carefully aligned and the correct root gap maintained throughout the welding operation. Misalignments greater than 25 percent of the thickness of the thinner plate or 3 mm whichever is smaller shall be corrected and in making the correction the parts shall not be drawn into a slope sharper than 2 degrees (1 in 27.5).

k. Welding procedures recommended by appropriate welding standards and known to provide satisfactory welds shall be followed. A welding procedure shall be prepared by the Contractor and submitted to the Engineer for approval before start of welding.

l. Approval of the welding procedure by the Engineer shall not relieve the Contractor of his responsibility for correct and sound welding without undue distortion in the finished structure.

m. Voltage and current (and polarity if direct current is used) shall be set according to the recommendations of the Manufacturer of the electrode being used, and suitable to thickness of material, joint form etc. The work shall be positioned for flat welding wherever practicable and overhead weld shall be avoided.

n. No welding shall be done when the surface of the members is wet, nor during periods of high wind unless the welding operator and the work are properly protected. In joints connected by fillet welds, the minimum sizes of single run fillet welds or first runs and minimum full sizes of fillet welds shall conform to the requirements of IS: 816 and IS: 823. Fillet welds larger than 8 mm shall be made with two or more passes.

o. All 'full penetration butt welds ' made by manual arc-welding, except when produced with the aid of backing material or welded in flat position, from both sides in square- edge material, not over 8 mm thick with root opening not less than one-half the thickness of the thinner part joined, shall have the root of the initial layer gouged out on the back side before welding is started from that side, and shall be so welded as to secure sound metal and complete fusion throughout the entire cross section.

p. Butt welds shall be terminated at the ends of a joint in a manner that will ensure their soundness. Where abutting parts are 20 mm or more in thickness, run-on and run-off plates with similar edge preparation end having a width not less than the thickness of the thicker part joined shall be used. These extension pieces shall be removed upon completion of the weld and the ends of the weld made smooth and flush with the abutting parts. Where the abutting parts are thinner than 20 mm the extension pieces may be omitted but the ends of the butt welds shall then be chipped or gouged out to sound metal and side welded to fill up the ends to the required reinforcement.

q. Each layer of a multiple layer weld except root and surface runs may be moderately peeled with light blows from a blunt tool. Care shall be exercised to prevent scaling or flaking of weld and base metal from over-peeling.

r. Before commencing fabrication of a member or structure in which welding is likely to result in distortion and/or locked up stresses, a complete programme of fabrication, assembly and welding shall be made and submitted to the Engineer for his approval. Such a programme shall, include, besides other appropriate details, full particulars in regard to the following

s. Proposed pre-bending of components such as flanges and pre-setting of joints to offset expected distortion.

   i. Make up of sub-assemblies proposed to be welded before incorporation in final assembly.

   ii. Proposed joint forms, classification of wire and flux or covered electrodes, welding process including fitting and welding sequence with directions in which freedom of movement is to be allowed.

   iii. Proposed number, spacing and type of strong details of jigs and fixtures for maintaining proper fit up and alignment during welding.

   iv. Any other special features like assembling similar members back-to-back or stress relief.

Suggestive Minimum Preheating of Metals

Thickness of Thickest Part at point of Welding Applicable Codes	**Minimum Preheat & Inter-pass Temperature**			
	Other than low-hydrogen welding electrodes		**Low Hydrogen welding electrodes**	
	IS:226 Steel or IS:2062 Steel	**IS:961 Steel**	**IS:226 Steel or IS:2062 Steel**	**IS:961 Steel**
Upto 20 mm incl.	None	Welding with this process not allowed	None	
Over 20 mm to 40 mm incl.			10°C	
Over 40 mm to 63 mm	110°C			110°C

Thickness of Thickest Part at point of Welding Applicable Codes	Minimum Preheat & Inter-pass Temperature			
	Other than low-hydrogen welding electrodes		Low Hydrogen welding electrodes	
	IS:226 Steel or IS:2062 Steel	IS:961 Steel	IS:226 Steel or IS:2062 Steel	IS:961 Steel
incl.				
Over 63 mm incl.	150°C		110°C	150°C

Minimum preheat temperature for metal thickness up to 50 mm shall be 100°C

t. If so desired by the Engineer, mock up welding shall be carried out at the Contractor 's cost to establish the efficacy of the proposed programme, with any modification suggested by the Engineer in limiting distortion or/and residual stress to acceptable levels. Such modifications will not relieve the Contractor of any of his responsibilities.

u. The ends of butt joints shall be welded so as to provide full throat thickness. This may be done by the use of extension pieces, cross-runs or other approved means. The weld face shall, at all places, be deposited projecting the surface of the parent metal. Where a flush surface is required, the surplus metal shall be dressed off. Splices and butt joints of compression members, depending on contact for stress-transmission, shall be accurately machined over the whole section. In column bases, the ends of shafts together with the attached gussets, angles. Channels etc., after bolting and/or welding together as the case may be, shall be accurately machined so that the parts connected butt over the entire surface of contact. Care shall be taken that connecting angles or channels are fixed with such accuracy that they are not reduced in thickness by machining by more than 0.8mm.

v. The minimum leg length of a fillet weld as deposited shall be not less than the specified size. In no case shall a concave weld be deposited, unless specifically permitted. Where permitted, the leg length shall be increased above that specified length, so that the resultant throat thickness is as great as would have been obtained by the deposition of a flat-faced weld of the specified leg length.

w. After making each run of welding, all slag shall be thoroughly removed and the surface cleaned. The weld metal, as deposited (including tack welds), shall be free from-cracks, slag inclusions, porosity, cavities and other deposition faults. The weld metal shall be properly fused with the parent metal without under cutting or overlapping at the toes of the weld. The surface of the weld shall have a uniform consistent contour and regular appearance.

20.25 INSPECTION OF WELDS

a. All welds shall be inspected for flaws by any of the methods described in these specifications, and as per IS: 822. The choice of the method to be adopted shall be determined by the Engineer.

b. The Contractor shall arrange for all tests as called for in the schedule of quantities, at his own cost.

c. In case the tests uncover defective work, such tests shall be at the Contractor 's cost and the Contractor shall correct such defects at his own cost, and prove the soundness of rectified work.

d. The correction of defective welds shall be carried out as directed by the Engineer without damaging the parent metal. When a crack in the weld is removed, magnetic particle inspection or any other equally positive means as prescribed by the Engineer shall be used to ensure that the whole of the crack and material up to 25 mm beyond each end of the crack has been removed. Cost of all such tests and operations incidental to correction shall be to the Contractor 's account.

20.26 FABRICATION TOLERANCES

Unless otherwise shown on drawings, the fabrication tolerances shall generally be as detailed hereunder.

a. Straightness

The dimensional and weight tolerance for rolled shapes shall be in accordance with IS:1852 for indigenous steel and equivalent applicable codes for imported steel. The acceptable limits for straightness (sweep and camber) for rolled or fabricated members shall be: Struts and columns: L/1000 or 10 mm whichever is smaller for all other members not primarily in compression such as purlins, beams, bracings& web members of trusses and latticed girders: L/500 or 15 mm whichever is smaller. Where Lis the length of finished member, or such lesser length as the Engineer may specify

b. Twists

A limit for twist (prior to erection) in:-

Box Girder and heavy columns L/1500

Other members L/1000

The twist of the member between any two sections shall be measured with the web vertical sections.

c. Camber

Tolerance in specified camber of structural members shall be+ 3 mm

d. Length

Tolerance in specified length shall be as follows:

Type of Member	Tolerance
A column finished for contact bearing	+1 mm
Other members (e.g. beams) under 10 m	+ 0 and -3 mm
Other members (e.g. beams) 10 m long and over	+ 0 and -5 mm

e. Square-Ness at End of Members

Beam to beam and beam to column connections where the abutting parts are to be jointed by butt welds, permissible deviation from the square-ness of the end is:

Beams up to 600 mm in depth	1.5 mm
Beams over 600 mm in depth	1.5 mm every 600 mm depth upto a max 3 mm

Where abutting parts are to be jointed by bolting through cleats or end plates, the connections require closer tolerance. Permissible deviation from square ness of the end is:

Beams up to 600 mm in depth	1.0 mm
Beams over 600 mm in depth	max of 1.5 mm

f. Butt Joints

i. For full bearing, two abutting ends of columns shall first be aligned to within 1 in 1000 of their combined length and then the following conditions shall be met.

ii. Over at least 80% of the bearing surface the clearance between the surfaces does not exceed 0.1 mm.

iii. Over the remainder of the surfaces the clearance between the surfaces does not exceed 0.3 mm. Where web stiffeners are designed for full bearing on either the top flange or bottom flange or both, at least half the stiffener shall be in positive contact with the flange. The remainder of the contact face could have a max. gap of 0.25 mm.

g. Depth of Member :

Acceptable deviation from the specified overall depth is:

Fordepthsof900mmandunder	+/- 3 mm
For depths over 900 mm and under 1800 mm	+/- 5 mm
For Depths of 1800 mm andover	+ 8 mm : - 5mm

h. Web Plates

i. Acceptable deviation from flatness in girder webs in the length between the stiffeners or in a length equal to the girder depth shall be 11150th of the total web depth.

ii. Flange Plates

iii. Limit for combined warp-age and tilt on the flanges of a built up member is 1/200 of the total width of flange or 1.5 mm whichever is smaller measured with respect to centre-line of flange.

iv. Lateral deviation between centre-line of web plate and centre-line of flange plate at contact surfaces, in the case of built up sections shall not exceed 3 mm.

i. Inspection

The Contractor shall give due notice to the Engineer in advance of the materials or workmanship getting ready for inspection.

i. All rejected material shall be promptly removed from the shop and replaced with new material for the Engineer's approval / inspection. The fact that certain material has been accepted at the Contractor 's shop shall not invalidate final rejection at site by the Engineer, if it fails to be in proper condition or has fabrication in-accuracies which prevent proper assembly . No materials shall be painted or dispatched to site without inspection and approval by the Engineer unless, such inspection is waived in writing by the Engineer.

ii. Shop inspection by the Engineer or his authorized representative, or, submission of test certificates and acceptance thereof by the Engineer, shall not relieve the Contractor from the responsibility of furnishing material conforming to the requirements of these specifications. Nor shall it invalidate any claim, which the Engineer may make because of defective or unsatisfactory material and/or workmanship.

iii. The Contractor shall provide all the testing and inspection services and facilities for shop work except where otherwise specified. For fabrication work carried out in the field, the same standard of supervision and quality control shall be maintained as in shop fabricated work. Inspection and testing shall be conducted in a manner satisfactory to the Engineer.

20.27 TESTING

a. Material Testing.

If mill test reports are not available for any steel materials, the same shall be got tested by the Contractor to the satisfaction of Engineer to demonstrate conformity with the relevant specification.

b. Tests on Welds

i. Magnetic Particle Test

Only where the Engineer requires that flaw-detection of welds be done by 'Magnetic Particle Test', in such cases the tests are to be done in accordance with IS: 3703. If heat treatment is performed, the completed weld shall be examined after the heat treatment. All defects shall be repaired and re-tested. Magnetic particle tests shall be carried out using alternating current. Direct current may be used with the explicit written permission of the Engineer.

ii. Dye Penetration Test

Where welds are required to be examined by dye penetration inspection method, such tests shall be carried out in accordance with IS: 3658.

iii. Radiographic Inspection

Whether instructed by Engineer, or not, all 'Butt' welds shall be fully inspected by radiographic examination method. Such examination shall be done in accordance with the recommendations of IS: 1182.

20.28 TEST FAILURE

At any stage, in the event of any material or work failing to meet an inspection or test requirement, which is not overseen by the Engineer, the Contractor shall notify the Engineer immediately. The Contractor must obtain permission from the Engineer before repair is undertaken. The quality control procedures to be followed to ensure satisfactory repair shall be subject to approval by the Engineer. The Engineer has the right to specify additional inspection or testing as he deems necessary, and the additional cost of such testing shall be borne by the Contractor. The Contractor shall maintain records of all inspection and testing which shall be made available to the Engineer on demand.

20.29 SHOP MATCHING

Some steel work, particularly columns along with tie beams, bracings etc. may have to be shop assembled to ensure satisfactory fabrication. If the Engineer so desires, he may order such assembly at shop for verification. The Contractor shall comply with such instructions without claiming any extra cost.

20.30 SHOP ASSEMBLY

The steelwork shall be temporarily shop assembled, as necessary, so that the accuracy of fit may be checked before dispatch. The parts shall be shop assembled with a sufficient number of parallel drifts to bring and keep the parts in place.

Since parts drilled or punched, with templates having steel bushes shall be similar and, as such, interchangeable, such steelwork may be shop erected in part only, as agreed by the Engineer.

20.31 ASSEMBLY

a. All parts assembled for bolting shall be in close contact over the whole surface.

b. The component parts shall be so assembled that they are neither twisted nor otherwise damaged. Specified cambers, if any, shall beprovided.

c. All parts of bolted and welded members shall be held firmly in position by means of jigs or clamps while bolting or welding. No drifting of holes shall be permitted, except to draw the parts together and no drift used shall be larger than the nominal diameter of the bolt. Drifting done during assembling shall not distort the metal or enlarge the holes.

d. Trial assemblies shall be carried out at the fabrication stage to ensure accuracy of workmanship, and these checks shall be witnessed by the Engineer/ Authorised inspecting agency. Such trial assemblies shall be at the cost of the contractor.

20.32 FIELD BOLTS

a. Requirements stipulated under bolting shall apply for field bolts also. Field bolts nuts and washers shall be furnished by the Contractor in excess of the nominal numbers required. He shall supply the full number of bolts, nuts and washers and other necessary fittings required completing the work, together with the additional bolts, nuts and washers totalling to 10% of the requirement subject to minimum of 10 Nos.

b. At the time of assembly, the surfaces in contact shall be free of paint or any other applied finish, oil, dirt, loose rust, loose scale, burrs and other defects which would prevent solid seating of the parts or would interfere with the development of friction between them.

c. If any other surface condition, including a machined surface, is specified, it shall be the responsibility of the Contractor to work within the slip factor specified for the particular case.

d. Each bolt and nut shall be assembled with washers of appropriate shape, quality and number in cases where plane parallel surfaces are involved. Such washers shall be placed under the bolt head or the nut, whichever is to be rotated during the tightening operation. The rotated nut or bolt head shall be tightened against a surface normal to the bolt axis, and the appropriate tapered washer shall be, used when the surfaces are not parallel. The angle between the bolt axis and the surface under the non-rotating component (i.e. the bolt head or the nut) shall be 90 + 3 degree. For angles outside these limits, a tapered washer shall be placed under the non-rotating component. Tapered washers shall be correctly positioned.

e. 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. Nut 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.

f. If, after final tightening, a nut or bolt is slackened off for any reason, the bolt, nut and washer or washers shall be discarded and not used again.

20.33 MARKING OF MEMBERS

a. After checking and inspection, all members shall be marked for identification during erection. This mark shall correspond to distinguishing marks on approved erection drawings and shall be legibly painted and stamped on it. The erection mark shall be stamped with a metal dye with figures at least 20 mm high and to such optimum depth as to be clearly visible, even after a member is galvanized.

b. All erection marks shall be on the outer surface of all sections and near one end, but clear of boltholes. The marking shall be so stamped that they are easily discernible when sorting out members. The stamped marking shall be encircled boldly by a distinguishable paint to facilitate easy location. Erection marks on like pieces shall be at identical location. Members having lengths of 7.0 m or more shall have the erection mark at both ends.

c. Each fabricated member, whether assembled prior to dispatch or not so assembled, shall bear an erection mark, which will help to identify the member and its position in respect of the whole structure, to facilitate re-erection at site. This erection mark shall be incorporated in the shop detail and erection drawings.

20.34 ERRORS

Any error in shop work which prevents proper assembling and fitting up of parts in the field by moderate use of drift pins or moderate amount of reaming will be classified by the Engineer as defective workmanship. All charges incurred by the Engineer either directly or indirectly because of the poor workmanship will be deducted from the amount due to the Contractor before payment is made. The amount of such deduction will consist of the sum total of the costs of labour direct or indirect, material, plant, transportation, equipment rental and overhead expenses. In case the Engineer chooses to reject the material because of poor workmanship, the cost of all handling and returning the material to the Contractor, if he so desires, shall entirely be to the Contractor 's account. All the replacement materials shall be supplied free and in all such cases, the cost of handling, transport and delivery to site shall be borne by the Contractor.

20.35 ERECTION

a. Erection of structural steel fabricated components shall be done generally in accordance with provisions of IS: 800.

b. Before starting of erection work, the contractor shall ensure the fulfilment of the following activities :

i. The contractor shall submit, for examination by the Engineer, detailed particulars of his proposed methods of erection of the superstructure steelwork, together with complete calculations relating to strength and deflection. If the erection scheme necessitates the attachment of strength steelwork to the permanent steel work, the contractor shall submit, for approval of the Engineer, the methods he proposes for making good the permanent steelwork after removing the temporary work. The contractor shall also submit the design and fabrication drawings including detailed calculations of temporary nose, counter weight, all temporary support, staging, braces etc. required for safe erection, for approval of the Engineer.

ii. The contractor shall provide all construction and transport equipment, tools, tackle, and consumables, materials, labour and supervision required for the erection of the structural steel work.

iii. Handling, assembling, bolting, welding and satisfactory installation of all fabricated structural steel materials in proper location, according to approved erection drawings and/or as directed by the Engineer.

iv. Setting out, aligning, plumbing, levelling, bolting, welding and securely fixing the fabricated steel structures in accordance with the erection scheme, or as directed by the Engineer.

20.36 QUALITY CONTROL AND TESTING REQUIREMENTS

a. Quality Control through established testing norms of the welded structural steelwork as per quality requirements or Engineer in charge.

i. The Contractor shall submit the following:

- Proposed overall schedule for documentation of shop drawings, plan/procedures and records, submission of procedure of fabrication.
- The contractor shall himself inspect all materials and shop work to satisfy the specified tolerance limits and Quality norms before the same are inspected by Engineer.

ii. The contractor shall through appropriate planning and continuous measurements in the workshop and the erection at site, ensure that the tolerance are strictly adhered to.

b. Fabricating agency shall have in house facilities for all testing of weld.

c. Visual Examination

The contractor shall conduct visual examination and measurement of the external dimensions of welds for all joints. Before examining the welded joints, areas close to it on both sides of the weld for a width not less than 20 mm shall be cleaned of slag and other impurities. Examination shall be done by a magnifying glass which has a magnification power of ten (10) and measuring instrument which has an accuracy of +0.1 mm or by weld gauges. Welded joints shall be examined from both sides. The contractor shall examine the following during the visual checks.

i. Correctness and shape of the welded joints

ii. Incomplete penetration of weld metal.

iii. Influx

iv. Burns
v. Unwelded craters
vi. Undercuts
vii. Cracks in welded spots and heat affected zones
viii. Porosity in welds and spot welds
ix. Compression in welded joints as a result of electrode impact while carrying out contact welding
x. Displacement of welded element

The contractor shall, document all data as per sound practices.

d. In order to exercise proper control of the quality of the welding, Contractor shall enforce methods of control as tabulated below:

Purpose	Control subjects	Methods of control
1	2	3
i) Control of welding materials and basic metal quality	Quality control of electrodes welding wire, flux and protective gases. Checking of quality and Weldability of the basic metal and welded members	Weldability test to determine the technological properties of materials. Mechanical test of weld metal. metal graphical investigations of welds macro-structure and microstructure. Checking of weld metal resistance for intracrystalline corrosion. Study if weld metal solidity by physical control methods
(ii) Checking of welders qualifications	Welding of specimens for quality determination	Mechanical tests, metal graphical investigation & checking of welded joints by physical control methods Checking of assembly quality & centering of welded members
(iii) Control of welded joint quality	Control of assembly accuracy and technological welding process	Checking of welding equipment conditions. Checking correctness of welding procedure. Visual examination of welds

e. Mechanical Test

The Contractor shall carry out various mechanical tests to determine weld-ability, metal alloy ability, and nature of break, correct size and type of electrodes, degree of pre-heat and post-heat treatment. The type, scope and sample of various mechanical tests shall be determined in agreement with the purchaser. The number of tests conducted shall depend on the result obtained to satisfy the Engineer that the correct type and size of electrode, degree of pre-heating and post-heating and weld-ability of metal are being followed.

f. Dye Penetration Test

All welds (100 %) shall be tested by "Dye Penetration test" as per current practices.

g. Radiography Test

Radiography test shall be conducted by the contractor to determine gas inclusion (blow holes, hollows) slag inclusion, shallow welds and cracks for 100 % lengths all butt joints. Before conducting the examination, the welded joints shall be cleaned of slag and scales and visually examined. The welds shall be marked into separate portions depending on the length of photograph. The length of photograph shall be such as to ensure that there are no distortions and shall reveal the defect correctly. The length shall not be more than 0.75 of the focal distance and the width of the photograph would depend on the width of the welded joint plus 20 mm on either side of the weld. The cassette with film shall be protected by sheet of lead or equivalent of proper thickness against incidental, diffused and secondary radiation.

The direction of the ray with relation to the film shall be as specified hereunder.

Welds of butt joints without edge slopes with edge processing shall be examined by central ray directed at right angles to the weld.

In special cases examination of welds with inclined rays directed along edge slopes may be permitted by the Engineer/ Authorised inspecting agency.

Lap joints shall be examined by directing rays at 45 degree to the bottom plate. Welds in T-joints, without any edge preparation shall be examined by rays directed at 45 degree to the weld. Angle welds in lap and tee-joints shall be examined by the rays in opposite direction, i.e., the film will be on the side of the weld. Weld in angle joints shall be checked by directing ray along the bisector of the angle between the welded elements. Opposite direction of the ray and location of the film may also be permitted by the Employer.

h. Ultrasonic Test

Ultrasonic test shall be conducted by the contractor to detect gas inclusion (pores), slag inclusion, shallow welds, cracks, lamination and friability etc for the fillet joints. Prior to starting of ultrasonic test, the welded joint shall be thoroughly cleaned of slag and other material. Surface of the basic metal adjacent to welded joint on both sides shall be mechanically cleaned by the grinder or a metal brush to provide the contact of the whole ultrasonic probe surface with surface of basic metal. The width of the clean surface shall be as directed by the Engineer/ Authorised inspecting agency. The welded joint then shall be covered with a thin coat of transformer oil, turbine or machine oil to ensure acoustic contact. The joints so treated shall be marked and the marks shall be entered into the documentation, subsequent to this, ultrasonic test shall be carried out as directed by the Engineer. Unless otherwise directed by the Engineer 10% of welds shall be subjected to ultrasonic testing. Engineer may at his discretion vary the frequency of such tests depending on the performance record of earlier tests.

i. Magnetic particle Test

Based on other test results, or considerations that raises doubts on welded joints at important locations in the structure, the Engineer may call for Magnetic Particle Tests of joints. The Contractor shall comply with such requirements, and arrange for such tests at his own cost.

20.37 PAINTING OF PRE-ENGINEERED STRUCTURAL STEEL WORK

a. Paint

i. All paint delivered to the fabrication shop shall be ready mixed, in original sealed containers, as packed by the paint manufacturers. Addition of thinners shall not be permitted.

ii. Opened containers of Paint shall be stirred frequently to keep the pigment in suspension

b. Storage of Paints

i. All paints shall be stored strictly in accordance with the requirements laid down by the paint manufacturers . The storage area shall be well ventilated and protected from

sparks, flame, direct exposure to sun or excessive heat, preferably located in an isolated room or in a separate building.

ii. All paint containers shall be clearly labeled to show paint identification, date of manufacture, batch number, order number and special instructions in legible form. The containers shall be opened only at the time of use. Paints that have liveried, gelled or otherwise deteriorated during storage, shall not be used. Paints, for which the shelf life specified by the supplier has expired, shall not be used without inspection and approval by the Engineer.

c. ExecutionPaint System

In general, except where specified otherwise in approved shop drawings Sand blasting of steel surfaces shall be carried out in accordance with IS:1477.

Painting work shall be carried out as follows:

DESCRIPTION	**GENERAL SURFACE**	
Fabrication Shop	**External Surfaces**	**Internal Surfaces**
Surface Treatment	Abrasive blast cleaning to minimum SA-2.5 SIS-055900 near -white blast cleaning	Abrasive blast cleaning to minimum SA-2.5 SIS-055900 near - white blast cleaning
1st Under-Coat	Inorganic zinc silicate primer (self-curing solvent type) OFT - 75µm shall be Berger Zinc Anode 304 MZ or approved equivalent. The primer should be applied by spray only.	Epoxy zinc phosphate primer polyamide cured OFT-35µm
2nd Under-Coat	Epoxy zinc phosphate primer polyamide cured OFT-35µm shall be Berger Epilux 610 Primer or approved equivalent. The primer should be applied by spray or brush only.	Epoxy zinc phosphate primer polyamide cured OFT-35µm shall be Berger Epilux 610 Primer or approved equivalent. The primer should be applied by sprayor brush only.
3rd Under-Coat	Epoxy zinc phosphate primer polyamide cured OFT-35µm shall be Berger Epilux 610 Primer or approved equivalent. The primer should be applied by spray or brush only.	Polyamide cured coal tar epoxy coating OFT 100µm
4th Under-Coat	Epoxy high build micaceous iron oxide coating polyamide cured OFT-90µm shall be Berger Epilux 4 High Build MOI or equivalent. The primer should be applied by spray or brush only	Polyamide cured coal tar epoxy coating OFT -100µm
Erection Site	**External Surfaces**	**Internal Surfaces**
Intermediate Coat	Acrylic polyurethane finish aliphatic isocyanate cured OFT-30µm shall be Berger thane or approved equivalent applied by spray or brush in approved colour.	**NA**
Finish Coat	Acrylic polyurethane finish aliphatic isocyanate cured OFT-30µm shall be Berger thane or approved equivalent applied by spray or brush in approved colour.	**NA**

INTERNAL SURFACE = Internal surface are those which will become inaccessible after fabrication and are not prone to humidity and moisture from the atmosphere.

EXTERNAL SURFACE = All other surfaces which are prone to humidity and moisture from the atmosphere.

The following precautions must be taken:

i. After abrasive blast cleaning, the first undercoat (primer coat) should be applied well before surface deterioration.

ii. At least EPOXY MIO coating application should be completed before giving any long over coating interval for external surface.

iii. At least up to one coat of coal tar epoxy shall be completed before giving any long over coating interval for internal surface.

iv. Over coating intervals, application parameters shall conform to manufacturer 's instruction manual.

v. The OFT (Dry film thickness) shall be measured after completion of each coat.

d. Surface Preparation

i. General: All surfaces shall be cleaned of loose substances and foreign materials. e. g. dirt. Rust, scale, oil, grease, welding flux etc so that the prime coat adheres to the original metal surface. The work shall be carried out in accordance with IS: 1477 (1971) (Part I). Any oil. Grease, dust or foreign matter deposited on the surface after preparation shall be removed and care shall be taken to ensure that the surface is not contaminated with acids, alkalis or other corrosive chemicals. The primer coat shall he applied immediately after the surface preparation is completed.

ii. Before the application of any paint the surfaces to be treated shall be thoroughly cleaned freed from all scale, loose paint, rust and other deleterious matters. Oil and grease shall be removed from the surface by washing with solvents or with a detergent solution before blast cleaning operation of metal polish with metal pellets. If any traces of oil or grease remain after blasting they shall be removed by solvent cleaning and the area will be re-blasted thereafter.

iii. All welding areas shall be given special attention for removal of weld flux slag, weld metal splatter, weld head oxides, weld flux fumes, silvers and other foreign objects before blasting. If deemed necessary by the Engineer, acid washing and subsequent washing with clean water shall be used.

iv. Any rough seams will have to be ground and must be inspected and approved by the Engineer before application of the coatings.

v. All structural steel to be painted shall be cleaned. Blast cleaning in accordance with SA1/2 Near- White Blast cleaning (equivalent Swedish Standard SIS 055900). For SA 2 1/2 the profile should be in the range of 40-70 microns and shall be measured with comparator Mill scale, rust and foreign matter shall be removed to the extent that the only traces remaining are light stains in the form of spots or stripes. Finally the surface shall be cleaned with a vacuum cleaner or clean dry compressed air.

vi. The blast cleaning shall produce a surface roughness complying with the one specified by the paint manufacturer for the primer concerned. If, cleaned surfaces are rusted or are contaminated with foreign material before painting is accomplished they shall be re- cleaned by the Contractor at his own expenses.

vii. The surface shall be cleaned by impingement of abrasive materials, such as grit of cast iron, malleable iron, steel or synthetic material, at high velocity created by clean and dry compressed air blast. Prior to application of the blast, heavy deposits of oil and grease shall be removed by solvent cleaning and excessive surface scale removed by hand tool or power tool cleaning.

e. Mixing and Thinning

i. All ingredients in a paint container shall be thoroughly mixed to break-up lumps and disperse pigments, before use and during application , to maintain homogeneity. All pigmented paints shall be strained after mixing to remove skins and other undesirable matters.

ii. Dry pigments, pastes, tinting pastes and colours shall be mixed and/or made into paint so that all dry powders get wetted by vehicles and lumps and particles are uniformly dispersed.

iii. Additives that are received separate such as curing agents, catalysts, hardeners etc. shall be added to the paint as per the manufacturer's instructions. These shall be promptly used within the pot life specified by the manufacturers and unused paint thereafter shall be discarded.

iv. Thinners shall not be used unless essential for proper application of the paint. Where thinners are used, they shall be added during the mixing process and the type and quantity of thinner shall be in accordance with the instructions of paint manufacturer

f. Paint Application

i. Paint shall be applied in accordance with the manufacturer recommendations, as supplemented by these Specifications. The work shall generally follow IS:1477- (Part II).

ii. Prior approval of the Engineer shall be taken in respect of all primers and/or paints before their use in the works.

iii. Paint shall generally be applied by brushing except that spraying may be use for finish coats only when brushing may damage the prime coats. Roller coat or other method of paint application shall not be used unless specifically authorized .

iv. Spraying paint shall not be adopted on red lead or zinc rich paints. Daubers may be used only when no other method is practicable for proper application in difficult accessible areas.

v. Paint shall not be applied when the ambient temperature is 10°C and below. For paints which dry by chemical reaction the temperature requirements specified by the manufacturer shall be met with. Also, paint shall not be applied in rain, wind, fog or at relative humidity of 80% and above or when the surface temperature is below dew point, resulting in condensation of moisture. Any wet paint exposed to damaging weather conditions shall be inspected after drying and the damaged area repainted after removal of the paint.

vi. Each coat of paint shall be continuous, free of pores and of even film thickness without thin spots. The film thickness shall not be so great as to detrimentally affect either the appearance or the service life of the paint.

vii. Each coat of paint shall be allowed to dry sufficiently before application of the next coat, to avoid damages such as lifting or loss of adhesion. Undercoats having glossy surface shall be roughened by mild sand papering to improve adhesion of subsequent coats. Successive coats of same colour shall be tinted. Whenever practical, to produce contrasts and help in identifying the progress of the work.

g. Brush Application

i. Proper brushes shall be selected for a specific work piece. Round or oval brushes which conform to IS: 487 are better suited for irregular surfaces, whereas flat brushes which conform to IS: 384 are convenient for large flat areas. The width of flat brushes shall not generally exceed 125mm.

ii. Paint shall be applied in short strokes depositing a uniform amount of paint in each stroke followed by brushing the paint into all surface irregularities, crevices and corners and finally smoothening or levelling the paint film with long and light strokes at about right angles to the first short strokes. All runs and sags shall be brushed out. The brush marks left in the applied paint shall be as few as practicable.

h. Spray Application

i. The spraying equipment shall be compatible with the paint material and provided with necessary gauges and controls. The equipment shall be cleaned of dirt, dried paint, foreign matter and solvent before use.

ii. The paint shall be applied by holding the gun perpendicular to the surface at a suitable distance and moved in a pattern so as to ensure deposition of a uniform wet layer of paint. All runs and sags shall be brushed out immediately. Areas not accessible to spray shall be painted by brush or dauber.

iii. Water trap acceptable to Engineer/ Authorised inspecting agency shall he furnished and installed on all equipment used in spray painting.

i. Shop Painting

i. The painting system specified in Table shall be followed. Surfaces, which will be inaccessible after field assembly, shall receive the full-specified protective treatment before assembly .

ii. Surfaces in contact during shop assembly shall not be painted. Surfaces which can not be painted but require protection shall be given a rust inhibitive grease conforming to IS:958-1975 or solvent deposited compound conforming to IS: 1153 (1975) or IS: 1674 (1960) or treated as specified in the drawing.

iii. Surface to be in contact with concrete shall not be painted.

iv. The shop coats shall be continuous over all edges, including ends meant for jointing at site by bolting, except where the paint could be detrimental to bolting. In such cases, no paint shall be applied within 50mm, and the unprotected surface shall be given a coat of corrosion inhibitive compound.

v. The unpainted area shall be cleaned prior to welding. The welded joint shall be cleaned and deluged, and immediately after covered by the same paint as has been used for the remaining surface.

j. Protection of Paintwork

i. The Contractor shall provide measures as necessary to prevent damage to the work and to other property or persons from all cleaning and painting operations. Paint or paint stains which result in other unsightly appearance on surfaces not designated to be painted shall be removed or obliterated by the contractor at his cost.

ii. All painted surfaces that in the opinion of the Engineer/ Authorised inspecting agency are damaged in anyway, shall be repaired by the contractor at his cost with materials and to a condition equal to that of the requirements specified in these specifications.

iii. Upon painted surfaces that in the opinion of any other work that would cause dust, grease or foreign materials to be deposited upon the painted surfaces, the painted surfaces shall be thoroughly cleaned.

iv. The areas for high-strength bolts shall be protected by masking tape against undercoat application at the fabrication shop. Immediately prior to erection any rust in the paint area shall be removed by power wire brushing to a standard equivalent to SA3.

v. Contractor shall make provision for requisite site painting to all fabricated steelwork, as per requirements of related specifications of the painting.

k. Repair of Paint Defects:
All damage to the previous paint shall be repaired. All loose paints shall be removed back to firm edge. Surface irregularities and contaminants shall be removed. Hard, glossy surfaces may require abrading to obtain a suitable surface for painting. Surfaces, which are to be over coated and which have become contaminated shall be either be solvent cleaned in accordance with SSPC-SP-1 "Solvent Cleaning" or high pressure fresh water washed and if required, a suitable detergent may be used.

l. Inspection :
Testing :The final paint shall be free from obvious defects and shall be tested by the contractor as follows :
Film Thickness: All dry-film thickness limits as specified shall be strictly adhered to. It is recommended that, in order to achieve the specified dry-film thickness, frequent checks of ET-film thickness are to be carried during the paint application with wet-film thickness gauges such as the Alcolmeter wheel or comb type wheel gauge. The dry film thickness of individual coats and of the total coating system shall be checked at random over an area representative of the total work. A minimum of 5 readings shall be taken for each 10 m2 of coated surface. For a surface area less than 10m2a minimum of 3 readings shall be taken. Additional readings shall be taken if there have been any changes in application of equipment, spray nozzle size, thinning of paint, etc.
Inspection: The application work is to be inspected at all stages and finished paint work shall have the correct shade, degree of gloss and evenness and be free from defects such as cracks, holidays, runs sags, wrinkles, patches, brush or roller marks, or other defects that may be detrimental to the quality of the coating. Prior to acceptance of the paintwork, a final inspection shall be made

20.38 PRE-COATED STEEL SHEETING FOR ROOFS AND WALLS

a. Scope Of Work
Coated steel profiled sheet of approved colour shall be installed at roof and side cladding on steel framing or on any other material at any other location as directed by the Engineer, and shall be executed as per the details shown on the "Good for Construction" and approved shop drawings and as per specialist manufacturers recommendation, complete in all respects. The work shall be executed in flat, tapered, curved form both in plan and section as required.

b. Materials
The base material of sheet shall be polyester coated high tensile cold rolled steel as per AS 1397, coating class AZ 150 (min. 150 gm/m2 zinc aluminium alloy coating mass, total of both sides) in 0.455 Base Metal Thickness (0.62mm Total Coating Thickness (TCT))aluminium zinc alloy (ALUMINUM 55% AND ZINC 43.45 %& SI-ZINCALUME 1.6%) and having a minimum yield strength not less than 300Mpa.

c. Coating
Exterior coating shall be silicone modified polyester (SMP) with 30-50% silicone content (min.) or Super Polyester XRW quality paint coat of approved colour and 35 microns total thickness consisting of 20 microns top coat over 5-micron polyester back coat and a 5 micron primer coats on both surfaces including side and end laps. The sheet coating conforming to general requirements of AS/NZS 2728 Type-4 / IS:15965 Class-3 durability and Gloss value.

d. Sheeting Profile

e. Standing seam profile sheeting shall have 400mm effective cover width, 3nos stiffeners symmetrically spaced 100-115mm c/c parallel to 65mm deep rib, fixed to every purlin by means of structural grade Aluminium clip with UPVC thermal pad at bottom of the clip to reduce or eliminate thermal bridging effect. Standard seam sheet fixing

Providing, bending to required curved profile and fixing single skin high-rib colour coated profiled standing seam sheeting (with provision for fixing solar panel, lighting arrester, earth strips, fall arrester, ladder, walkway etc.,) with 0.55mm Base Metal Thickness (0.62mm TCT) high tensile Zincalume steel with standing seam joint at support spacing of 1m. The Standing seam profile sheeting shall have 400mm effective cover width, 3nos stiffeners symmetrically spaced (100mm c/c) parallel to 65mm deep rib, fixed to every purlin by means of structural grade Aluminium clip with UPVC thermal pad at bottom of the clip to reduce or eliminate thermal bridging effect. The base metal sheet shall be high tensile cold-rolled steel as per AS 1397. The panel overlapping shall be mechanically field seamed using electric seamer tool to achieve increased weather durability and greater resistance to wind uplift. The profile should be suitable for flat, curved or tapered shapes to achieve various Architectural requirements. The steel sheet shall have a minimum yield strength of 300Mpa, metallic coated with Zinc-Aluminium alloy (55% ALUMINUM, 43.4% ZINC & 1.6% SI-ZINCALUME), AZ150 (minimum 150gm/m2 total on both sides). The sheet shall have Silicon Modified Polyester Coating (SMP, minimum silicon content 30%-50%) or Super durable Polyester XRW quality paint of approved colour. The coating shall be as per AS/NZS-2728: 1997 (Category-3) the total thickness of 35microns, comprising of exterior coat of SMP or Super Durable Polyester XRW over 5micron Polyester back coat cover over 5micron primer coat on both surfaces. The sheet conforms to general requirement of AS/NZS 2728 type-4 / IS 15965 class 3 durability and gloss value.

The Aluminium clip shall be fastened with 40micron zinc coated or 25micron zinc-tin alloy coated, Hex head, self-drilled screw as per AS 3566-2002 Class 3 fasteners of approved make as per the requirement considering the profile shape and design load. The fastener size shall be calculated as per the design or manufacturers recommendations.

The sheets shall be laid starting from the eaves or from bottom upward in case of cladding (IS 3007). The sheets shall be laid from the end of the building away from prevailing wind so that exposed edges face down wind.

Fastener, Aluminium Clip, other important items and erection procedure shall be got approved by The Engineer. All the supporting members are straight, level, plumb and true (according to AISC) before starting erection, sheeting shall be fixed according to approved shop drawings. Sheet shall be protected with Guard Film on both sides. Guard film shall be removed after erection of sheeting and before handing over the sheeting to client.

The Contractor shall carry out and complete the works in every respect in accordance with approved drawings and directions and to the satisfaction of the Engineer.

f. Scope includes fixing of sheeting at all elevation levels & heights including aligning and levelling. Shop Drawings and Approvals

Shop drawings shall be prepared for all sheeting work by the contractor and show the entire installation system including purlin layout, sheet layout, sizes and colour, fixing details etc. Shop drawings shall be submitted to the Engineer for his approval.

The Contractor shall submit catalogues, design calculations for sheet profile confirming safe distributed load capacity, samples of all items to be used and samples of workmanship for approval of the Engineer-in-Charge.

g. Accessories

The specification for capping, flashing and trims materials shall be same as that for sheeting and shall be factory formed to required shape and profile based on shop drawings.

Roofing accessories like flashings (straight or crimp curved), capping etc. shall be provided from similar coating as used for sheets and shall be fixed by means of self- drilling self-tapping screws with EPDM washer seals.

h. Tolerances
Length : +0-10 mm
Cover width : + or -6mm

i. Structural Stability and Guarantee against Rusting/Corrosion
The Contractor shall provide design calculations for sheeting taking into account wind loads, seismic and other code requirements and guarantee structural stability.
The contractor shall also give guarantee for the sheets against rusting/corrosion, leakages through laps and fasteners, colour fading etc. for a period of ten years.

20.39 RAIN WATER GUTTER

Rain water gutters shall be fabricated out of 3.15 mm thick galvanized M.S. Sheets. All arrangements for incorporating outlets for rainwater down take pipes shall be incorporated in the fabrication, as per approved drawings and instructions. Gutters shall be Hot-dip galvanized and painted as per painting specifications of structural steel work. Thickness of galvanized coating shall not be less than 50 microns. Connections between each section shall be made water-tight by site seal welding.

20.40 ALUMINIUM LOUVERS

The work for provision of Aluminium Louver pre powder coated for ventilation shall be for easy escape of hot air which accumulates at the roof of work shop shed to normalize the ambient temperature in depot shed and result the comfortable feeling of environment for workmen and normal working of machinery & plants. The work shall comprise :

i. Design, Fabrication, supply, modification, installation testing and commissioning as per drawing and BOQ.
ii. Louver shall consist extruded section of aluminium 4"x1" rectangular pipe frame, c-channel 2½" x ½ " with metal framework of 3mm thick sheets, 1.5mm thick S-type louvers as per drawing enclosed.
iii. Louver bracket/frame shall be permanently fastened to the existing structure without damage.
iv. Any additional support and angle etc. required shall be aluminum and pure polyester pre powder coated before fabrication/installation.
v. All friction parts, fastenings or any part remaining, as machined / unpainted shall be coated with a product to protect them from corrosion until the unit is commissioned.
vi. The paint (if required) shall be done by two coat of epoxy/polyester paint and one coat of epoxy primer.
vii. The contractor shall arrange free of cost supply of resources, scaffolding, materials, tools, plant, transportation and manpower for fabrication and installation of the Louver.
viii. The contractor shall arrange free of cost all material, equipment and accessories even if not particularly mentioned, necessary to achieve a complete installation in perfect operating condition.
ix. The quantity specified in BOQ is approximate and is likely to vary as per site requirement and performance at the same rate as accepted by competent authority.

Note:

a. Before taking up mass production of louvers, contractor will offer one sample to the DMRC engineer for inspection and approval.
b. Before taking up fitment of louvers on a large scale, contractor will set up a mock up free of cost at site and will offer it to DMRC engineer for inspection and approval.

20.41 POLYCARBONATE SHEETS FOR ROOF LIGHTING

a. General

This section covers the requirements of providing, erecting and fixing of polycarbonate sheets of approved colour and approved transparency on roofs for the purpose of lighting. Sheets shall be procured from established and approved manufacturers .

b. Material

i. Material to be used on roofs shall not be less than 3.0 mm thick, and shall be profiled to exactly match the profile of pre-coated metal sheets to be used for general roof and side claddings.

ii. Sheets shall be supplied in maximum lengths that can be transported and erected without causing damage to the sheets, but in any case the lengths shall not be less than 10.0 m.

iii. Material shall be free from scratches and other surface damages. These shall be stored in sheltered places and stacked with intermediate layers of soft puffed plastic sheets. Stacks shall be covered with and wrapped around with polyethylene sheets to prevent dust accumulation on the sheets.

iv. Material shall be U-V treated and shall be of tested quality. The contractor shall ensure that the manufacturer provides with the test certificates for the following properties:

Test	Procedure	Results
Flammability		
Self-ignition	ASTM 1929-3	570 °C
Smoke density	ASTM D 2843	54%
Burning extent	ASTM D 635	less than 1.0
Weathering		
Weathering evaluation Concentrated	ASTMD4364-84	Successful exposure to Sunlight radiation
Colour change	ASTM D 2244	Not more than 3 units after 60 60 months
Light transmission	ASTM D 1003	Shall not decrease more than 10 points after 60 months
-Ditto-	-Ditto-	Shall not decrease by more than 6% after 10 years
Heat exposure	300°F / 25 mins	No darkening effect
Water penetration	ASTM E 331	No penetration
Impact	ASTM E 822-81	Repels hail storm of 25 mm at Velocity of 21m/sec
Expansion/contraction		Linear thermal change of 0.065 mm Im 1°c
U-V Filtration	Australian Standard No. 1067	Transmission less than 0.1%
Modulus of Elasticity	DIN 53457	24000 kg / sq cm

c. Submittal

Contractor shall submit test reports from manufacturer on all tests.

The contractor shall also submit a guarantee that the performance of the sheets supplied by him shall meet with the requirements of the test certificates to be produced by him.

d. Installation

Sheets shall be installed in sequence as shown in approved shop drawings, and fixed to purlins with polymer coated, galvanized, hexagon headed self-drilling, self tapping screws. Side laps shall be as per manufacturers specification. End laps shall be 225 mm. Joints with metal sheets shall be sealed with Butyl-based adhesive . The edges shall be sealed with silicone sealant as per manufacturers specification, and then covered with butyl- based adhesive tapes.

e. Measurement

Contractors quoted rates for sheeting work shall include all materials, tools, plants, all accessories including fasteners, adhesives , sealants , tapes etc. and labour, all temporary works complete to the requirement of these specifications and instructions

Work shall be measured and paid for on the actual net area of clear opening, excluding all overlaps at sides and ends.

20.42 TOUGHENED GLASS FOR WINDOWS

a. General

This section covers the requirements of providing, erecting and fixing of 6mm thick glass (toughened) of approved color and approved transparency on windows and north lights for the purpose of lighting. Glass shall be procured from established and approved manufacturers .

b. Submittal

Contractor shall submit test reports from manufacturer on all tests.

The contractor shall also submit a guarantee that the performance of the toughened glass supplied by him shall meet with the requirements of the test certificates to be produced by him.

c. Measurement

Contractors quoted rates for glass work shall include all materials, tools, plants, all accessories including fasteners, adhesives , sealants, tapes etc. and labor, all temporary works complete to the requirement of these specifications and instructions

Work shall be measured and paid for on the actual net area of clear opening, excluding all overlaps at sides and ends.

21 GLASS FIBER REINFORCED CONCRETE - ENVELOPES

21.1 INTRODUCTION

21.1.1 Scope

This specification covers the requirements for the manufacture, curing and testing of GRC products applied in this project. It gives detailed requirements for grades of GRC manufactured by three different methods:

- 'Spray' Grades 18 and 18P
- 'Premix' Grades 10 and 10P
- 'Premix' Grades 8 and 8P

'P' refers to the use of acrylic thermoplastic polymer emulsion in the GRC mix design.

The specification covers mixes with and without polymers. Selection of the applicable grade should be made by the producer in consideration of the engineering design of the product. This choice should then be approved by the purchaser.

21.1.2 References

- Indian Standards and Codes
- ASTM C 150 - Standard Specification for Portland Cement

- ASTM C947 - Standard Test Method for Flexural Properties of Thin-Section Glass-Fiber-Reinforced Concrete (Using Simple Beam With Third-Point Loading)
- ASTM E 84 - Standard Test Method for Surface Burning Characteristics of Building Materials.
- ASTM G 23 - Standard Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Non-metallic Materials.

21.2 CONSTITUENT MATERIALS

21.2.1 Alkali-resistant glass fiber

Glass fibre shall be an alkali-resistant continuous filament fibre developed and formulated to have high strength retention in hydraulic cement environments. The producer shall provide certification from the supplier to show that the glass fibre conforms to approved National Standard.

21.2.2 Cement

Cement shall be supplied by a manufacturer of assessed capability, made to recognized national standard and supported by suitable certification. Cement shall be correctly stored and kept dry to avoid deterioration.

21.2.3 Fine aggregates

Fine aggregate or sand shall be washed and dried to remove soluble matter and permit accurate control of the water/cement ratio. The particle shape should be round or irregular and should have a smooth surface without honeycombing. For spray GRC, the maximum particle size shall be 1.2mm; for premix GRC, the maximum particle size shall be 2.4mm. In both cases the fine fraction, i.e. sand passing a 150 micron sieve, shall be less than 10% of the total weight of sand.

Silica sands are widely used and should conform to the specification in Table 1.

Sands with a higher moisture content may be used provided the moisture content is known and the mix design is altered accordingly.

Sands other than silica sands may be used but the producer should provide evidence of their suitability. Soft building sands must not be used.

Table 1: Specification for silica sand

Silica Content	> 96%
Moisture Content	< 2%
Loss-on-ignition	< 0.5%

21.2.4 Water

Water shall be clean and free from deleterious matter, see BS EN 1008 / NBC / equivalent IS standards, Mixing water for concrete.

21.2.5 Admixtures

Admixtures are permitted and their use is encouraged as they can enhance the properties of GRC. They should always be used strictly in accordance with the suppliers' recommendations and the producer must ensure that their use has no adverse effect on the product.

Calcium chloride-based admixtures must not be used if the GRC component contains steel reinforcement, fixing sockets or other cast-in devices.

21.2.6 Acrylic polymers

Acrylic thermoplastic polymer dispersions should be used in accordance with the manufacturers' instructions and should conform to the specification in Table 2.

Polymers with properties outside the above specification may be used with the agreement of the purchaser and adequate test results.

Table 2: Specification for polymer curing aid.

Silica Content	> 96%
Compound Type	Aqueous thermoplastic polymer dispersion
Polymer Type	Acrylic based
Solids	45 55 %
Appearance	Milky white, creamy, free from lumps
Minimum film-formation temperature	7 – 12 °C
Ultraviolet resistance	Good
Alkali resistance	Good

21.2.7 Pigments

Powder pigments or dispersions may be used to produce coloured GRC. The pigments should conform to international or national standards. The purchaser should recognize that color variation may occur and must agree an acceptable range of variation with the producer.

21.2.8 Steel Framing Materials

Steel frame system shall be a welded prefabricated frame produced in accordance with approved shop drawings, fabricated to meet design loads, wind loads, handling and erection loads.

21.2.9 Other component materials

Other component materials (e.g. silica fume, metakaolin, fly ash, reinforcing fillers, admixtures, meshes), may be added to modify the properties of the mix. They must be used in accordance with the supplier's instruction and the producer must demonstrate that their use will not adversely affect the properties of the GRC

21.2.10 Panel physical properties

- Matrix: Portland cement, sand, and polymer
- Shell thickness: 15 mm nominal
- Edge thickness: 25 mm minimum
- Density: 2145 kg/m³
- Weight: 32-37 kg/m²
- Glass fiber: 4% minimum
- Color: As specified by the engineer
- Surface: Lightly sandblasted or smooth if paint ready
- Flexural Strength: 1,860 psi (12.8 MPa)
- Tensile Strength: 1260 psi (8.7 MPa)
- Compressive Strength: 4,000 psi (27.6 MPa)
- Coefficient of Linear Thermal Expansion (ASTM D696): 13.6 x 10-6 mm/mm/ºC
- Hardness (Abrasion): 0.37%
- Thermal Conductivity: 4.3 Btu in/h/ft²/ºF (0.62 W/m²)
- Surface Burning Characteristics (ASTM E84):

- Flame Spread: 0
- Smoke Development: 0

21.3 COMPOSITION OF GRC

21.3.1 Mix design [Grades 8, 10 & 18]

It is the responsibility of the producer to select a suitable mix design for the product. The mix design must be such that the mechanical properties of the GRC in Section 8 of this Specification are achieved and that these requirements are consistent with the engineering design of the product.

The mix designs in Table 3 is intended as a guide indicating typical figures; designs falling outside these guidelines may be acceptable but should be scrutinized before use.

Table 3: Guide mix designs [Grades 8, 10 & 18]

Premix Grade	Grade 8	Grade 8P
Description	General purpose premix	
Aggregate/ Cement ration	0.5-1.50	0.5-1.50
Water / Cement ratio	0.30-0.40	0.30-0.40
Glass Fibre content (% by weight of total mix)	2.0-3.0%	2.0-3.0%
Polymer Solids content (% by weight of cement)	Nil	4-7%
Extreme dimensional variations mm/m	0.6-1.2	0.6-1.2
Water Absorption	5-11%	5-11%
Minimum bulk dry density Kg/m^3	1800	1800
Minimum bulk wet density Kg/m^3	2000	2000

Premix Grade	Grade 10	Grade 10P
Description	Sprayed premix or High quality cast premix	
Aggregate/ Cement ration	0.5-1.50	0.5-1.50
Water / Cement ratio	0.30-0.38	0.30-0.38
Glass Fibre content (% by weight of total mix)	2.0-3.5%	2.0-3.5%
Polymer Solids content (% by weight of cement)	Nil	4-7%
Extreme dimensional variations mm/m	0.6-1.2	0.6-1.2
Water Absorption	5-11%	5-11%
Minimum bulk dry density Kg/m^3	1800	1800
Minimum bulk wet density Kg/m^3	2000	2000

Premix Grade	Grade 18	Grade 18P
Description	Direct sprayed GRC	
Aggregate/ Cement ration	0.5-1.50	0.5-1.50
Water / Cement ratio	0.30-0.38	0.30-0.38
Glass Fibre content (% by weight of total mix)	4.0-5.5%	4.0-5.5%
Polymer Solids content (% by weight of cement)	Nil	4-7%
Extreme dimensional variations mm/m	0.6-1.2	0.6-1.2
Water Absorption	5-11%	5-11%
Minimum bulk dry density Kg/m^3	1800	1800
Minimum bulk wet density Kg/m^3	2000	2000

21.4 MANUFACTURE

GRC products manufactured only by premix and spray production methods are covered in this Specification.

21.4.1 Manufacture by simultaneous spray

a. Weighing/batching

Dry ingredients shall be batched by weight using calibrated weighing equipment capable of an accuracy of ± 2% of the stated batch weight. Liquids should be weighed, volume batched or automatically dispensed. The producer must demonstrate that the method employed will give an accuracy of ± 2%.

b. Mixing

The cementitious slurry should be mixed in a suitable mixer in accordance with the manufacturer's instructions and using the stated mix design. The producer must demonstrate that this type of mixing system is to be used. The consistency of the mix should be tested by measuring the slump in accordance with GRCA's Methods of Testing GRC Part 5 or applicable national standards.

c. Spraying

Spraying should be carried out using specialist equipment that allows the simultaneous deposition of known quantities of cementitious slurry and chopped glass fiber. Before starting production, the spray equipment must be calibrated to ensure that the specified glass fiber percentage is achieved. Calibration to measure the deposition rates of the glass fiber and cementitious slurry should be carried out using 'bag and bucket tests' in accordance with GRCA's Methods of Testing GRC Part 4 or applicable national standards.

These tests should be carried out for each pump at the beginning of each shift, after any alteration of the equipment controls and after any unsatisfactory 'wash out' test results (Section 7.1).

If the equipment used gives continuous readings of glass and slurry output these tests need not be carried out.

A mist coat without fibre may be sprayed; this coat should be as thin [~1mm] as practicable and should be followed immediately by the first GRC spray.

When a facing coat is used this may be sprayed or poured. This coat may be allowed to stiffen but the first GRC coat must be applied before initial set takes place. Typical thickness is 3-5mm depending on subsequent treatment e.g. grit blasting or acid etching.

The GRC materials must be sprayed and built up in thin layers of 3-4mm until the required thickness is achieved. The sprayed GRC should be compacted by a hand roller before spraying the next layer. After the final layer has been sprayed the thickness of the GRC must be checked using a template or depth gauge and compared to the design thickness.

Unless specifically stated in the agreed product manufacturing specification, the design thickness should be considered as a minimum and no part of the component should be below this thickness. Over-thickness will be permitted and is to be expected particularly at corners or areas with a deep profile. It will not be permitted if:

Any flat areas exceed the design thickness by 4mm.

The weight of the component exceeds the maximum design weight as specified by the engineer.

After checking the thickness, any areas of under thickness should be re-sprayed and areas of over thickness removed and the material discarded. The specified finish to the ' back' of the unit should be applied using a float or roller.

21.4.2 Manufacture by premix

a. Weighing/batching

Dry ingredients should be matched by weight using calibrated weighing equipment capable of an accuracy of ± 2% of the stated batch weight. Liquids should be weighed, volume batched or automatically dispensed. The GRC manufacturer should demonstrate that the method employed will give an accuracy of ± 2%.

b. Mixing

The GRC should be mixed in a two-stage or other suitable mixer. The producer must demonstrate that the equipment is suitable for manufacturing premix GRC.

First the cementitious slurry should be mixed at high speed in an intensive shear mixer or other approved mixer. The slurry is then transferred to a second mixer or the mixing action of the shear mixer adapted so that the AR glass fibre is blended uniformly into the slurry.

The AR glass fibre may be added manually or automatically as chopped fibres or automatically as AR glass fibre roving using a fibre chopper.

c. Cast Premix

The premixed GRC material should be pumped or carried in a holding vessel to the filling station. The material should then be poured or pumped into the mould ensuring that the method of filling expels the air from the product and planes of weakness are avoided. Compaction may be by internal or external vibration or by the use of a 'self-compacting' mix. The producer must ensure that the method chosen is consistent with the required surface finish and mechanical properties.

d. Sprayed Premix

The premixed GRC material may also be sprayed onto or into moulds using specialist sprayed premix equipment. A facing coat or a mist coat may be sprayed first. The GRC material should be sprayed in layers 4-6mm and compacted by roller before spraying the next layer. The thickness should be checked as in 4.1.3

21.4.3 Storage before demoulding

Filled moulds must be stored at temperatures between 5°C and 40°C. 'P' grades must be stored at a temperature higher than the MFFT but below 40°C.

Moulds must be stored on a level surface and supported in such a manner that they will not bow or twist.

Once the initial set has taken place the mould shall be covered with polythene of 500 gauge or above and should not be moved until demoulding.

21.4.4 Demoulding [inc. lifting and fixing]

The GRC component must not be demoulded until it has gained sufficient strength to be removed from the mould and transported without being over-stressed. The time required will be temperature dependent.

Demoulding must be carried out in such a manner that no damage occurs to the component. Unique demoulding, lifting and fixings sockets must be embedded in the component. All embedded items should be of a suitable material [preferably austenitic stainless steel or non-ferrous] and encapsulated in a block of GRC; size and procedures to be used should be agreed with the engineer before starting production.

21.4.5 Curing

a. Moist curing (for non-polymer grades)

GRC components should be cured at controlled temperature and humidity. Ideally this should be for seven days at 20°C and 95% RH. This is not always practical and alternative curing regimes are satisfactory providing the producer demonstrates that the procedure:

i Enables the component to achieve the physical properties given in Section 8.

ii Ensures that excess shrinkage caused by a too rapid drying of the product does not occur.

iii The curing method is acceptable to the purchaser and engineer.

b. Curing of polymer grades

Components produced using polymer grades of GRC should be loosely covered overnight and should be dry cured after demoulding. Moist curing can be detrimental. Temperature above 35°C or below 5°C should be avoided for the first two days after manufacture.

Products should not be exposed to drying winds or excessive heat for a minimum of two days.

21.4.6 Storage, handling and transport

GRC components must be stored, handled and transported in such a way that:

a. **No** part of the component is overstressed.

b. Bowing or twisting is not induced in the component.

c. No damage is caused to any part of the component, particularly edges and corners.

d. No permanent staining or discoloration is caused either by the storage conditions or the stacking/protection material.

e. For large components, the method of handling, storage, loading and transporting shall be agreed with the engineer.

21.5 QUALITY CONTROL AND ASSURANCE

21.5.1 Quality management system

The manufacturer should demonstrate that a quality assurance system is operated. This shall comply with ISO 9001 or similar.

21.6 SAMPLING

21.6.1 Sampling and Test Boards

Tests may be carried out on coupons cut from the GRC components themselves but this is not normally practical. It is acceptable to produce a Test Board for testing. This shall be manufactured, demoulded and cured in the same manner as the component it represents. Its quality should be the same as the component, as far as possible.

However, due to testing equipment restraints, the thickness should be limited to 12mm. Test Boards must be large enough for sufficient coupons to be cut to meet the testing requirements; 500 x 800mm is proposed so that with spray processes, any directional effects can be identified.

21.6.2 Frequency

The frequency of production of Test Boards shall be not less than 1 board per day per mixer/pump, for both spray and premix processes. Spray process Test Boards not tested shall be kept for a minimum of one year for any future testing requirements.

21.7 TESTING

The following tests shall be carried out and the required properties shall be as shown in Tables 3, 4 and 5.

21.7.1 AR Glass fiber content

The AR glass fiber content shall be determined in accordance with approved national standards. With spray processes, the test shall be carried out once per day per spray station as a minimum.

21.7.2 Limit of proportionality [LOP] and modulus of rupture [MOR]

The LOP and MOR shall be determined at 7 and/or 14 and/or 28 days in accordance with approved national standards. 7 and 14 day results shall only be acceptable if they already exceed design requirements.

Additional information such as % Strain to LOP, % Strain to MOR and Young's Modulus provided by modern test equipment should be recorded for information only.

The minimum LOP and MOR testing frequency shall be:

Spray: Twice per week per spray station or every 10 tons of GRC produced, whichever is the greater.

Premix: Once per week per mixer or every 10 tons of GRC produced, whichever is the greater.

These frequencies are an absolute minimum and individual manufacturers may elect to test more frequently, as they feel appropriate.

Table 4: Characteristic Values

GRADE	8 or 8P	10 or 10P	18 or 18P
Characteristic LOP*	5	6	7
Characteristic MOR*	8	10	18

*A minimum of 40 Test Board Mean shall be analysed in the calculation of the Characteristic Values.

21.7.3 Bulk density, water absorption and apparent porosity

These properties shall be determined in accordance with approved national standards. All of these tests shall be carried out a minimum of once per month.

21.7.4 Other tests

Other tests of GRC may be carried out when required by the purchaser, including extreme dimensional variation tests BS EN 1170-7, full scale load tests of products and components, fire tests, performance testing of cast-in fixings etc. These tests should be supervised by the Engineer.

21.8 COMPLIANCE

21.8.1 General

The constituent materials should comply with the requirements of Section 2 and the composition of the GRC shall comply with Section 3. The GRC should be produced and cured in accordance with Section 4. It should be sampled at a frequency complying with Section 6 and tested in accordance with Section 7. It should meet the requirements of Section 8.

21.8.2 Minimum values for compliance

Table 5 indicates minimum LOP and MOR values using in-process inspection results as a guideline for initial compliance only. To conform to this specification, the manufacturer must also be able to demonstrate via their testing regime and documentation that analysis shows Characteristic Values as shown in Table 4. This analysis must form part of their Quality Assurance procedures to be allowable.

If other properties, e.g. density or porosity, are considered to be critical for an application, compliance values and testing frequency should be agreed between the purchaser and the producer.

21.9 NON COMPLIANCE

21.9.1 Failure to comply

If any single test board fails to meet any of the compliance requirements, the GRC at risk shall be that produced between the previous complying test board and the next complying test board.

Where testing is not carried out on a daily basis retained sample boards (see 6.2) may be tested to determine the extent of the non-compliant product.

21.9.2 Action in the event of non-compliance

a. The action to be taken over GRC products that do not comply with this specification should be determined with due regard to the technical consequences of adopting remedial measures or replacing the rejected products.

b. In estimating the quality of the sub-standard GRC and in determining the action to be taken, the following should be established wherever possible.

c. The validity of the testing shall be confirmed by checking that the sampling, testing and calculations have been carried out in accordance with this specification.

d. That the raw materials and mix proportions used in the GRC under investigation comply with both the specifications and/or with those agreed between purchaser and producer.

e. That the curing regime adopted before testing complies with the recommendations in this Specification. Re-testing of test boards may be appropriate when it is considered that the storage conditions of the product might result in improved properties because of extended curing.

f. The effect of any reduction in GRC properties on the strength and durability of the product.

g. Three points should be considered:

   i The safety factors adopted in the design.

   ii The thickness of GRC produced compared to the design thickness.

   iii LOP/MOR strengths required by engineering calculations

Table 5: Minimum strengths

GRADE	8 or 8P	10 or 10P	18 or 18P
LOP MPa			
Mean of 4 consecutive test board means	7.25	8.00	8.00
Minimum for individual test board mean	5.75	6.00	6.00
MOR MPa			
Mean of 4 consecutive test board means	9.50	12.00	21.00
Minimum for individual test board mean	7.50	8.50	15.00

22 TERRACOTTA CLAY TILE RAINSCREEN ASSEMBLY

22.1 PART 1 GENERAL

22.1.1 SECTION INCLUDES

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

B. Ventilated Rain-screen Facades Assembly consisting of double-leaf, through body color terracotta clay tiles, aluminum support system, clips, gaskets and related accessories.

C. Engineering design and performance requirements for terracotta rain-screen assemblies.

22.1.2 RELATED REQUIREMENTS

A. Section 03 3000 - Cast-In-Place Concrete: Structural concrete.

B. Section 04 2200 - Concrete Unit Masonry: Single-wythe CMU.

C. Section 05 1200 - Structural Steel Framing: Structural steel building frame.

D. Section 05 4000 - Cold-Formed Metal Framing: Stud wall framing system.

E. Section 06 1600 – Sheathing: Exterior gypsum board sheathing.

F. Section 07 2100 – Thermal Insulation: Rigid/ Semi Rigid Insulation.

G. Section 07 2500 – Weather Barriers: Water-resistive barriers, drainage materials, and flexible flashing.

H. Section 07 6200 – Sheet Metal Flashing and Trim: Flashings and trims.

22.1.3 REFERENCE STANDARDS

A. ASTM C67 - Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile; 2013a.

B. ASTM C484 - Standard Test Method for Thermal Shock Resistance of Glazed Ceramic Tile; 1999(2009). Applicable for glazed tiles only

C. ASTM C 126 Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick and Solid Masonry Units. Applicable for glazed tiles only

22.1.4 ADMINISTRATIVE REQUIREMENTS

A. Pre-installation Meeting: Convene one week before starting work of this section.

1. Conduct pre-installation meeting at site attended by Owner, Architect, Manufacturer's Technical Representative, and other trade contractors.
2. Coordinate building framing in relation to terracotta rainscreen assembly.
3. Coordinate window, door and louver, and other openings and penetrations of terracotta rainscreen assembly.
4. Coordinate terracotta rainscreen assembly with rain drainage work, flashing, trim, and construction of other adjoining work to provide a leak proof, and secure installation.

5. Coordinate construction of mock-up, sequence of construction, coordination with substrate preparation, materials approved for use, compatibility of materials, coordination with installation of adjacent and covering materials, and details of construction.
6. Coordinate shop drawings, construction and installation such that manufacturing can proceed without impact to the general schedule and not be contingent upon field dimensions.

22.1.5 ACTION SUBMITTALS

A. Product Data: For each rainscreen assembly component indicated include construction details, material descriptions, dimensions of individual components and profiles, and finishes.

B. LEED Submittals:

1. Product Data for Credit MR 4.1 and Credit MR 4.2: For clay products having recycled content, documentation indicating percentages by weight of postconsumer and pre-consumer recycled content. Include statement indicating cost for each product having recycled content.
2. Product Data for Credit MR 5: For products clay products that have been extracted, harvested or recovered, as well an manufactured within 500 miles of the project site for a minimum of 10% or 20%, based on cost.

C. Shop Drawings: Submit drawings for a complete terracotta rainscreen assembly

1. Include plans, elevations, sections, and attachment details. Show and include adjacent Work and interface between terracotta rainscreen assembly and adjacent Work including termination and transitions of weather barrier, exterior glazed aluminum curtain walls, sub-girt support system, and flashings required. Include all adjacent Work by others.
    a. Distinguish among factory, shop, and field assembled work.
    b. Identify special shapes required and indicate their locations on the building.
2. Include details for assembly expansion and contraction and for drainage of moisture occurring within the assembly to the exterior.
3. Indicate adjacent structure locations by actual field dimensions.
4. Indicate terracotta rainscreen assembly dimensions, including joints and allowable tolerances.
5. Include details of each vertical and horizontal intersection of each terracotta rainscreen assembly with other systems and materials, showing the following:
    a. Anchorage to building structure.
    b. Expansion provisions and maximum allowable movement.
    c. Building movement, deflection, and creep provisions and maximum allowable movement.
    d. Terracotta clay tile cladding.
    e. Flashing and drainage.
    f. Insulation.

D. Professional Engineer's Analysis: Submit complete structural analysis and calculations performed by a Professional Engineer licensed in the State of the Project location.

E. Delegated-Design Submittal: For terracotta rainscreen assembly indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by a qualified professional engineer responsible for their preparation.

1. Provide calculations for loadings and stresses of framing, fastening and attachments.

F. Samples:

1. Samples for Initial Selection: For each type of terracotta tile indicated.
    a. Provide samples of tiles, trim, and accessories for the purpose of color selection.

2. Samples for Verification: For each type of component indicted provide three samples.
   a. Terracotta Clay Tiles: 4 x 8 inches minimum of a standard color.
   b. Trim and Closures: 12 inches long minimum for each color and shape.
   c. Support Structure: 12-inch long minimum, including gaskets and clips.
3. Samples for color development: For each custom color indicated.
   a. provide three laboratory samples in a size of 3x3”

G. Tile Replacement Procedure

Tile replacement procedure should not impact the tile or tile-system performance. Gluing tiles into a modified system is prohibited. Terracotta clay tile elements must be individually removable. Replacement tiles must be installed without modifying tile or support system. Provide manufactures standard replacement procedure as part of the submittal package.

22.1.6 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Submit coordination drawings on which the following items are shown and coordinated with the terracotta tiles and aluminum support system, drawn to scale, using input from installers of the items involved:
   1. Backing structure, sheathing, weather barrier, and continuous insulation.
   2. Wall-mounted items including doors, glazed assemblies, louvers and lighting fixtures.
   3. Penetrations of assembly by pipes and utilities.

B. Design Test Reports: Submit copies of test reports performed in accordance to part 1.3 of this section and supporting the requirements of part 2.4 of this section.
   1. Test reports shall be performed by independent, accredited testing laboratories, and shall bear the seal of a registered professional engineer.

C. Warranties: Provide unexecuted specimen warranty documents for each warranty as required in specification article 1.13.

22.1.7 CLOSEOUT SUBMITTALS

A. Maintenance Data: For terracotta rainscreen assembly to include in maintenance manuals.

22.1.8 QUALITY ASSURANCE

A. Material Source Limitations: Obtain terracotta clay tiles, aluminum support system, clips, gaskets and related accessories from a single source manufacturer.

B. Manufacturer’s Qualifications: Terracotta clay tile and aluminum support system manufacturers who have been in business for a minimum of ten (10) years and are experienced in the design and manufacturing of terracotta rainscreen assemblies.

C. Installer Qualifications: Engage an experienced contractor (erector) to install the terracotta rainscreen system who has experience specializing in the installation of rainscreen systems.
   1. Contractor must be approved by manufacturer specified as supplier of the terracotta rainscreen system and obtain written certification from manufacturer that installer is approved for installation of the specified system.
   2. Successful contractor must obtain all components of rainscreen system from a single manufacturer. Any secondary products that are required which cannot be supplied by the specified manufacturer must be recommended by primary manufacturer.
   3. Fabricator/Installer shall submit work experience and evidence of adequate financial responsibility. Architect reserves the right to inspect fabrication facilities in determining qualifications.

D. Professional Engineer Qualifications: Licensed structural engineer in the state where the project is located and experienced in design of complete terracotta rainscreen assembly of the types specified in this section with minimum five (5) years’ experience and minimum three (3) completed projects of similar scale and scope as this Project within the past five (5) years.

22.1.9 MOCK-UP

A. Mockup: Build mockup in size and location directed by Architect. Show details of terracotta rainscreen assembly. Demonstrate methods and details of installation. Show details of horizontal and vertical joints, penetrations, doors, windows, louvers, pipe openings, inside and outside corners, top and bottom of wall. Including support system, insulation, weather barrier, and backing structure.

B. Approval of mockup does not relieve Contractor of responsibility to comply with all requirements of contract documents.

C. Approved mock-up may remain as part of the completed Work.

22.1.10 DELIVERY, STORAGE, AND HANDLING

A. Deliver components, terracotta tiles, and other manufactured items so as not to be damaged or deformed. Package terracotta tile for protection during transportation and handling.

B. Unload, store, and erect aluminum framing system and terracotta tiles in a manner to prevent bending, warping, twisting, and surface damage.

C. Stack terracotta tiles on platforms or pallets, covered with suitable weather-tight and ventilated covering. Store tiles to ensure dryness, with positive slope for drainage of water. Do not store tiles in contact with other materials that might cause staining, cracking, or other surface damage.

22.1.11 PROJECT CONDITIONS

A. Weather Limitations: Proceed with installation only when existing and forecasted weather conditions permit work to be performed according to manufacturer's written instructions and warranty requirements.

B. Maintain environmental conditions (temperature, humidity, and ventilation) within limits recommended by manufacturer for optimum results. Do not install products under environmental conditions outside manufacturer’s absolute limits.

22.1.12 FIELD CONDITIONS

A. Weather Limitations: Proceed with installation only when existing and forecasted weather conditions permit installation to be performed according to manufacturer's written instructions and warranty requirements.

B. Field Measurements: Verify locations of structural members and wall opening dimensions before terracotta rain screen installation.

22.1.13 WARRANTY

A. Manufacturer’s Warranty: Provide manufacturer’s standard material warranty in which the manufacturer warrants that the rain screen aluminum support system and terracotta clay tiles shall be free from defects for a period of (5) five years due to faulty workmanship.

B. Installer’s Warranty: Installer's 3 year warranty covering rain screen assembly installation.

C. Warranties shall commence on date of substantial completion.

22.1.14 ATTIC STOCK

A. Manufacturer to provide minimum 1% attic stock material of each type in projects maximum length.

B. Manufacturer to provide minimum 1% extra material for installation process.

22.2 PART 2 PRODUCTS

22.2.1 ASSEMBLY DESCRIPTION

A. Terracotta Rain screen Assembly - Completely integrated exterior wall assembly comprising of:

1. Base Wall System – Steel Stud, Concrete Masonry Unit, or Cast-In- Place Concrete. Building components must be designed to accommodate imposed loads from the support system and terracotta tile, so their deflection under imposed loading will not cause deflection of support system exceeding specified tolerances.
2. Weather Resistive Membrane: Comply with all applicable building codes and regulations for air and water infiltration and exfiltration.
3. Aluminum Support System: Aluminum girt system, carrier tracks with gaskets, and tile clips to support terracotta clay tiles and drain rainwater.
4. Insulation: Comply with all applicable building codes and regulations for thermal insulation.
5. Terracotta Clay Tile Elements: Double-leaf, back ventilated, through body color terracotta clay tile elements, with self-draining open joint system.

22.2.2 DESIGN AND PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer licensed in the state where the project is located to provide complete structural analysis and calculations.

B. General Performance: Terracotta rainscreen assemblies shall comply with performance requirements without failure due to defective manufacture, fabrication, installation, or other defects in construction.

1. Terracotta rain screen assemblies shall withstand movements of supporting structure including, but not limited to, story drift, twist, column shortening, long-term creep, and deflection from uniformly distributed and concentrated live loads.
2. Failures include the following:
   a. Thermal stresses transferring to building structure.
   b. Terracotta tile element breakage.
   c. Noise or vibration created by wind and thermal and structural movements.
   d. Loosening or weakening of fasteners, attachments, and other components.

C. Design Criteria.

1. Perpendicular to the plane of the building structure, net deflection of the aluminum support members shall not exceed L/175 of span. A span is defined as the distance between centerline of anchor to building fastening. For cantilever, span is defined as two times the distance between last anchor to the building fastening centerline and the cantilever end.
2. The system shall have a design load of positive and negative pressure to meet local building codes.
3. At connection points of aluminum support framing members to anchors, combined movement of anchor relative to building, and framing member relative to anchor, shall not exceed 0.063 inch in any direction.
4. At 1.5 times design pressure loads for aluminum support framing members, there shall be no failure or gross permanent distortion of framing members, anchors, or connections. At connection points of framing members to anchors, combined movement of anchor relative to the building, and framing member relative to anchor shall not exceed 0.125 inch set after load is removed.

D. Movement.

1. Design, fabricate, and install system to withstand building, seismic, and thermal movements including deflections, temperature change without buckling, distortion, joint failure, or undue stress on system components, anchors, or permanent deformation of any kind.

a. Provide for a thermal movement over and ambient temperature range of 120 degrees F, and a surface temperature of 180 degrees F.

22.2.3 MANUFACTURERS

1. Manufacturers are subject to full compliance with specification requirements, and shall be submitted for approval as follows.
   a. Manufacturers not listed above must submit for approval ten (10) days prior to bid date.
   b. Submittals must show evidence of compliance with this specification and the drawings.
   c. Submittals must provide proof of manufacture and successful performance of the rain screen principle for systems of similar size and complexity.
   d. Manufacturer shall provide a reference list of at least 25 projects, including names, addresses, and phone numbers where large tiles and baguettes have been used.
   e. No substitutions will be permitted after the bid date of this project.

22.2.4 TILE ELEMENTS

A. Double-leaf, back ventilated, extruded through body color terracotta clay tile elements with horizontal shiplap joints.
   1. Length: 1200mm
   2. Height: 300mm
   3. Thickness: 28 mm, approximately.
   4. Weight: approximately 55 Kg/sqm.
   5. Profile(s): Provide the following profiles as indicated on the drawings:
      a. [Insert selected profile(s)].
   6. Color(s): Provide the following colors as indicated on the drawings:
      a. Color: As per Engineer approval
   7. Orientation: Horizontal

B. Finishes:
   1. Provide tiles in natural finish manufactured from high quality clays to prevent the formation of pores (more than 1.0 mm in diameter) in the clay body for preventing problems in connection with freeze and thaw.
   2. Finish: Natural

C. Tile Tolerances:
   1. Width: Deviation of the tile length from nominal dimensions (cuts) shall not exceed +/- 1.0 mm.
   2. Height: Deviation of the tile height up to 200mm shall not exceed 2.0mm, 400 mm shall not exceed +/- 2.5 mm, and up to 600 mm +/- 3.0 mm.
   3. Thickness: Deviation of tile thickness shall not exceed +/- 1.5 mm.
   4. Diagonal Flatness: Deviation of the tile flatness shall not exceed 0.25% of diagonal measurement.
   5. Straightness: Deviation shall not exceed 0.25% of total module size.

D. Tile Testing:

Provide material test report to demonstrate performance of clay products.

   1. Water Absorption: Test according to ASTM C 67 using 24-hour submersion and 5 hours boiling (separate sets of specimens, minimum 5 specimens each).
      a. Absorption by submersion shall not exceed 5 percent average, 6 percent individual specimen.
      b. Absorption by boiling shall not exceed: 7 percent average, 8 percent individual specimen.

2. Freezing and Thawing: Test according to ASTM C 67(minimum 5 specimens). No specimen shall lose more than 0.5 percent of its original dry weight. No specimen shall crack, crumble or fracture. Specimens shall conform to approved color range samples before and after testing.
3. Breaking Load: Test according to ASTM C 67 (minimum 5 specimens). Supports shall be actual hardware used for this project. Apply load at mid-point between supports. Report shall include breaking load, calculated section modulus at mid-span and calculated breaking stress. Modulus of Rupture in average shall not be lower than 2500lb/in². Minimum 5 specimens.
4. Thermal Shock Resistance: Test according to ASTM C 484 for glazed tiles. Minimum of 5 specimens. Specimens shall pass two cycles. Applicable only for glazed tiles.
5. Efflorescence: Test according to ASTM C 67. Minimum 10 specimens. Specimens to be rated "Not Effervesced".

22.2.5 RAINSCREEN SUPPORT SYSTEM

A. General: Aluminum girt system, carrier tracks with gaskets, and tile clips to support terracotta clay tiles and drain rainwater.
   1. System designed to accommodate thermal movement.
   2. System designed for terracotta clay tile elements to be removed individually, without breakage, notching, glue fixing or disruption to adjacent tiles.
   3. Tile clips must be concealed.
   4. Wet sealants will not be permitted.

B. Horizontal Tile System Components:
   1. Aluminum horizontal 'T' shaped sub-girts.
   2. Aluminum adjustable wall brackets.
   3. Extruded aluminum vertical carrier tracks with EPDM gaskets.
   4. Zinc cast tile clips.
   5. Vertical joint spacer profile black

C. Vertical Tile System Components:
   1. Extruded aluminum 'T' shaped horizontal brackets.
   2. Extruded aluminum horizontal 'T' shaped carrier tracks with EPDM gaskets.
   3. Adjustable aluminum tile clips.

D. Fasteners:
   1. Provide manufacturer recommended fasteners for specified substrates and project conditions. Use only stainless steel fasteners in exposed areas and wet zones.

E. Finishes:
   1. Provide technical anodized aluminum finish (class II) on aluminum framing members.

22.2.6 FABRICATION

A. Manufacture aluminum support system for terracotta clay tiles and hardware in conformance with approved shop drawings so that tolerances are not exceeded.
B. Fabricate aluminum components and terracotta clay tiles to the sizes, profiles, colors and textures per manufacturer's standards.
C. Aluminum components shall be furnished with a technical anodized industrial coating.
D. Aluminum support system and tiles clips must be designed so that terracotta clay tiles can be removed independent of other tiles.

22.2.7 ASSEMBLY PERFORMANCE TESTING

A. Water Penetration: No uncontrolled water penetration shall occur beyond the plane of the back of the terracotta clay tile that is not contained or drained back to the exterior. "Controlled" water or condensation shall drain harmlessly to the exterior of the work without "wetting" adjacent surfaces or insulation and not visible in the final surrounding conditions.

1. Provisions shall be made to drain rainwater to the exterior face of the work, including any water entering the joints and/or condensation occurring with the work. The wall shall be designed to collect and remove all secondary water from the surrounding conditions.

22.3 PART 3 EXECUTION

22.3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances, terracotta clay tile rain screen assembly supports, and other conditions affecting performance of work.
   1. Examine wall framing to verify that girts, angles, channels, studs, and other structural support members and anchorage have been installed within alignment tolerances as specified.
   2. Examine wall sheathing to verify that sheathing joints are supported by framing or blocking and that installation is within flatness tolerances as specified.
   3. Examine weather barrier to verify that installation is seamless and all penetrations have been sealed.
   4. Examine rough-ins for components and systems penetrating terracotta clay tiles to verify actual locations of penetrations relative to seam locations of tiles before installation

B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

22.3.2 INSTALLATION

A. Install aluminum support system and terracotta clay tile elements in accordance with manufacturer's instructions and approved shop drawings, within specified erection tolerances.

B. Establish level lines for tile coursing and positioning of support rails.

C. Attach aluminum support framing with engineered fasteners and anchors to accomplish performance requirements at spacing recommended by manufacturer in accordance with lateral loads and system dead load requirements.

D. Coordinate flashing and sheet metal work to provide weather tight conditions at wall terminations.

E. Starting at bottom of wall, attach terracotta clay tiles to aluminum carrier tracks with tile clips in accordance with manufacturer's instructions.

F. Provide for temperature expansion/contraction movement of terracotta clay tile elements at wall penetrations and wall mounted equipment in accordance with system manufacturer's product data and design calculations.

G. Install components so that in their final location and position they are not twisted, out of plane, or exceed manufacturer's specified tolerances. Terracotta clay tile elements must be individually removable without damage or tile and system modification. Provide manufactures standard procedure as part of the submittal package.

H. Remove damaged work and replace with new, undamaged components.

22.3.3 ERECTION TOLERANCES

A. Installation Tolerances: Align terracotta clay tile elements within installed tolerance of 1/4 inch in 20 feet (6 mm in 6 m) at location lines as indicated and within 1/8-inch (3-mm) offset of adjoining faces and of alignment of matching profiles.

22.3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a manufacturer-authorized service representative to inspect terracotta clay tile rainscreen assembly installation. Report results in writing.

B. Remove and replace rainscreen assembly components where inspections indicate that they do not comply with specified requirements.

C. Additional inspections, at Contractor's expense, will be performed to determine compliance of replaced or additional work with specified requirements.

22.3.5 CLEANING

A. On completion of terracotta clay tile rainscreen assembly installation, clean finished surfaces as recommended by manufacturer. Maintain in a clean condition during construction.

B. Protect aluminum components and terracotta clay tile elements from damage for the duration of construction.

C. Replace any components that have been damaged.

23 ALUMINUM WORK.

23.1 ALUMINIUM LOUVERS (PLATFORM) (E/F/G/H/I/J)

Supply and fixing of Hunter Douglas® Aerobrise 300 or Equivalent, Half Fin fixed louver consists of 'V shaped' louver fin skin with crowning manufactured out of 1.0 mm thick enameled corrosion resistance aluminum Alloy AA3005/AA3105 and formed on high-speed high precision DALLAN COMBI multi stage roll forming system. The roll formed fin profile is mechanically fixed between 5 mm thick aluminum extruded press plate and 2.7 mm aluminum extruded assembly channel. The nylon end caps shall be provided on both sides of the fins.

The louver fin skin & shall be coil coated finish suitable for exterior applications. The coil is coated on a continuous paint line double baked and shall be stove enameled and finished with Luxacote or equivalent, a patented special three layered coating system (consisting of first a conversion layer of thickness 800-2000mg/Sq.M., a polyurethane basecoat of 16-20 microns, and a special top coat of polyamide particles of 8-12 microns thick to provide excellent abrasion and damage resistance) in a continuous coil coating process of the approved colour on the exposed side and the reverse side with epoxy.

Paint performance criteria:

- Coating thickness shall be 24 to 32 µm and determined by ECCA T1.
- Colour difference shall be <0.70 unit and determined by ECCA T3
- Pencil hardness shall be > H and determined by ECCA T3
- Corrosion resistance shall be 3 Years under creep < 2mm (Outdoor exposure) and determined by ECCA T19
- U V Ray Resistance shall be determined by ECCA T19 No crack / flacking/blistering/chalking for minimum period of 5 Years. Colour change shall be < 5 units, gloss loss < 50%
- Humidity Resistance as per ISO 6270, 1000 Hours blistering < B2S2
- Salt /Acetic Acid Spray Test shall be as per ASTM G85, 1000 Hrs. under creep <2mm

The fin is fixed to substructure (which should be paid separately as extra item) with Installation bracket and necessary screws. The factory assembled louver fins of 300mm projection and as per the length shall be fixed mechanically to installation frame of Aluminium/MS provided by others with total projection of 316mm from the installation frame. The louver Fins shall be provided in 300mm module (variable depend upon site requirement) in varying lengths as per site requirements subject to a maximum of 5Mtrs. The installation frame shall be mechanically fixed to a structure 150mm distance from the fin panel edges and a c/c maximum distance of 2100mm in between subject to wind load. The erected installation frame shall be aligned within the tolerances of ± span/1000 of plumb line and level with a non-cumulative tolerance of a maximum of 2 mm.

23.2 ALUMINIUM LOUVERS (PLATFORM) (A/B/C/D)

Supply and Installation of Hunter Douglas®DoubleFin Aerobrise 400 or equivalent plain Louver Fixed System consists of extruded aluminium square shaft & butterfly clamps covered with aluminium metal cover skin on top & bottom sides, 'V' shaped aluminium fin skin with crowning manufactured out of 0.7mm pre coated aluminium alloy AA 3005/AA 3105 fixed on both sides of square shaft, Sliding U – Profile, Fixation Disk, Fin Suspension, end cap & end cap screws, and accessories for fixed system. The module of fin for fixed system is 400mm and the length of the fin shall be determined based on the wind load calculation and deflection. The fins are formed on high-speed high precision DALLAN COMBI multi stage roll forming system and factory assembled Aerobrise 400mm or equivalent fin will be fixed on both ends to suitable Installation frames of MS sections/Aluminium (which should be paid separately as extra item) provided by others. The installation frame shall be fixed mechanically to concrete structure with MS or Aluminium brackets. The erected substructure shall be aligned with in the tolerances of span/1000 of plumb line and level with a non-cumulative tolerance of a maximum of 2 mm. The louver Fin skin shall be coil coated in PVDF finish or suitable for exterior applications.

The louver fin skin & shall be coil coated finish suitable for exterior applications. The coil is coated on a continuous paint line double baked and shall be stove enamelled and finished with Luxacote or equivalent, a patented special three layered coating system (consisting of first a conversion layer of thickness 800-2000mg/Sq.M., a polyurethane basecoat of 16-20 microns, and a special top coat of polyamide particles of 8-12 microns thick to provide excellent abrasion and damage resistance) in a continuous coil coating process of the approved colour on the exposed side and the reverse side with epoxy.

Paint performance criteria:

- Coating thickness shall be 24 to 32 µm and determined by ECCA T1.
- Colour difference shall be <0.70 unit and determined by ECCA T3
- Pencil hardness shall be > H and determined by ECCA T3
- Corrosion resistance shall be 3 Years under creep < 2mm (Outdoor exposure) and determined by ECCA T19
- U V Ray Resistance shall be determined by ECCA T19 No crack / flacking/blistering/chalking for minimum period of 5 Years. Colour change shall be < 5 units, gloss loss < 50%
- Humidity Resistance as per ISO 6270, 1000 Hours blistering < B2S2
- Salt /Acetic Acid Spray Test shall be as per ASTM G85, 1000 Hrs. under creep <2mm

23.3 WINDOW FIXED GLAZING

Providing, fabricating and installing in position, pure polyester powder coated aluminium doors, windows, curtain walling, skylights, partitions, grilles, glazing with extruded aluminium sections and profiles complete in all respects in straight or faceted profiles including arched angular in elevation including sub frames in tubular aluminium (having mill finish), outer frames, architraves, beading, wool pile 6mm thick clear float glass (if required), gaskets, all complete.

23.4 ALUMINUM FOR RAIN PROTECTION

Supply & Installation of Luxalon SL-4 84Ror equivalent Perforated panel Sun Louvers manufactured by Hunter Douglas India Pvt. Ltd.or equivalent Of approved colour Grey consisting of panel 84 mm wide x 16mm deep x 0.6mm thick with round edges panel length up to 6mtrs coil coated on a continuous paint line double baked and roll formed from enamelled corrosion Resistance Aluminium Alloy M3005 (Al.Mg.) for higher strength and good Roll forming Characteristics.Panel shall be clipped to baked enamelledAluminium SL4 panel stringer of 33mm wide and 96mm deep x 0.95m m thick and a standard length of 5mtrs made of double baked enamelledAluminium Alloy AA5O50(Al.Mg.) black with cut-outs to hold the panel in a module of 96mm c/c at a distance of 1mtr.

The carrier shall be fixed to a suitable structure (which should be paid separately as extra item) by means of rigid fixing details.

PAINT FINISH: 84R Panels shall have Luxacoat® or equivalent exterior paint finish which will be of 3 layers.

Mode of Measurements: Measurements shall be Length and Breadth of the facia without any deductions for any openings.

24 BUILDING WORKS

24.1 GENERAL REQUIREMENTS

24.1.1 Preambles to Outline Construction Specification

25.1.1.1 General

a. For convenience, this document contains references to a variety of international standards which are included as indicative information only
Wherever practical Indian Standards [IS], Codes of Practice, etc. shall be utilized and take precedence

b. The document and the individual clauses contained within it have been included for general and outline purposes only; - and, in consequence: -
- The contents are to be accepted as indicative only; and are to be reviewed, amended and developed, as deemed appropriate, to suit the formulated designs and site-specific requirements.
- The contents as included, are to be considered as limited in extent and overall scope; and shall be developed and expanded to specify the entirety and detail of the works.
- Items included in this, Outline Document may or may not be finally incorporated into the Contractor's working specification.

25.1.1.2 Technical

a. The final Specification document shall be structured to clearly address both the Material and the Workmanship [including Protection] aspects of the works.

b. Emphasis shall be placed on the Contractor and all Sub-contractors to abide by the requirement to take all appropriate site dimensions, as deemed necessary to undertake and complete the works.

c. Equal emphasis is to be placed on the Contractor and all Sub-contractors, as considered appropriate, to abide by the requirement to prepare and submit shop drawings for approval by the Engineer, prior to commencement of any specialist works.

d. It shall be made abundantly clear that the Contractor and all appropriate Sub-contractors / Suppliers shall be duty bound to furnish the Employer's Representative with a sufficient quantity of samples, mock-ups and process and the continuance of the works at no additional cost to the Employer.

e. Wherever deemed appropriate, materials and workmanship shall be in strict accordance with manufacturer's recommendations.

f. In all given circumstances, sufficient due care and attention shall be paid to prevent electrolytic corrosion between dissimilar materials and metals, in particular.

g. Similarly, all necessary precautions shall be taken to ensure adequate corrosion protection for all exposed and hidden elements.

25.1.1.3 General Requirements Materials

The Contractor will note the requirement to use materials available in India as far as possible. These materials must meet the requirements of the relevant Indian Standard (IS), or, where appropriate an equivalent International Standard.

25.1.1.4 Compliance with Specification

The Contractor shall comply fully with the requirements of the following specifications in regard to quality of materials, submission of samples for approval prior to commencement of installation work and methods and procedure of installation.

All proprietary materials or processes submitted by the Contractor and approved by the Engineer shall be used or carried out strictly in accordance with the manufacturer's instructions and recommendations and also to comply with this Specification.

Where one or more proprietary materials or processes are named in this specification for Architectural and Building Works as acceptable materials or workmanship the Contractor shall still be responsible to ensure that these materials or workmanship comply with the requirements described in this Specification. In particular all materials shall comply with appropriate requirements for fire resistance.

Where materials are proposed by the Contractor for any part of the Works that require certain tests and where no previous test certificates have been issued by any competent authorities or approved testing laboratory, the Contractor shall at his own cost, submit the material for the appropriate test at an approved laboratory.

25.1.1.5 Materials

Cement and water for mortar shall be as specified under Section 3 "Concrete: Plain & Reinforced".

Lime shall be approved hydrated lime or quick lime to BS 890 delivered to site in sealed bags bearing the manufacturer's name or brand. Lime shall be prepared to the appropriate requirements of BS 5628, and shall be soaked in water for not less than 16 hours before use.

Sand shall be clean and sharp, free from salts, loam and organic matter, complying with the requirements of BS 1199/1200, as appropriate and be well graded from 5mm down.

Plasticisers shall comply with BS 4887. Integral waterproofing agents for mortar may be either powder additive or equal approved mixed in accordance with the manufacturer's instructions.

a. FLY ASH BASED PRODUCTS :

Fly ash-based products such as Mechanized Autoclaved Sand Lime Fly ash Bricks/ Fly Ash Lime Gypsum Bricks/Autoclaved Aerated Concrete (AAC) Blocks have to be used in all construction activities.

Bricks shall be facings from an approved kiln, machine pressed, well burnt, hard, square, or uniform shape, colour and size with all sharp clean arises and free from all defects. Samples shall be submitted to the Engineer and approved before placing an order.

Concrete blocks shall be obtained from an approved manufacturer. Concrete blocks shall be hollow with a minimum average compressive strength of 7.0N/mm2.

Materials for precast concrete lintels shall be as specified under Section 3 "Concrete: Plain & Reinforced."

Horizontal wall reinforcement shall be galvanized steel mesh reinforcement, 22 gauge. Steel bar reinforcement shall be as specified under Section 3 "Concrete: Plain & Reinforced."

Movement joint filler shall be as approved by the Designer; [Engineer], sealer shall be coloured silicone sealant to the approval of the Engineer.

b. Mortar

Mortar shall comprise one-part cement, one part lime, and six parts sand, thoroughly mixed with just sufficient water to provide workability.

Plasticisers may only be used with the approval of the Engineer and shall be added strictly in accordance with the manufacturer's instructions.

Mixing of mortar shall be done by mechanical batch mixer or by hand on a clean, watertight platform of adequate size. All constituent materials shall be accurately gauged.

Mortar shall be used within one hour of mixing. Mortar that has started to set shall not be used. De tempering of hardened or partly hardened mortar will not be permitted.

c. Blockwork Generally

Blockwork shall, unless otherwise described, be built in stretcher bond of hollow cellular or solid blockwork.

Blocks shall be well wetted before lying and kept wet until laid.

Hollow blocks shall be grouted solid with mortar where required by the Design.

Blocks shall be laid in true and regular courses on a full bed of mortar of 10mm average thickness, exclusive of any key in the jointing surfaces of the blocks. Sufficient mortar shall be used in bedding and jointing to ensure that all keys are solidly filled.

All horizontal joints shall be properly level. The vertical joints shall be properly lined, and quoins, jambs and other angles plumbed as the work proceeds. All walls shall be plumbed vertical.

Standard size blocks shall be used wherever possible. Broken blocks shall not be used except where required for bonding purposes. Walls and partitions shall be bonded to one another at angles and junctions.

Joints on faces of block walls which are to be rendered or plastered shall be raked out for a depth of 10mm as the work proceeds.

Walls shall be carried up regularly without leaving any part more than one metre lower than another unless the permission of the Engineer is first obtained. Work which is left at different levels shall be racked back.

Before commencing any blockwork, the Contractor shall confer with other trades to ensure that all pipes, ducts, conduits, sleeves, bolts, frame lugs, etc. or any other materials necessary to be installed in the blockwork at the time it is built have been fixed or provided for.

Fire pots around ducts, cable trays, waterpipes, drains and the like shall be of an approved intumescent material.

d. Blockwork Reinforcement

Blockwork shall be reinforced to BS 5628.

Mesh wall reinforcement is to be built in at every second course. Mesh shall be 100mm wide for 150mm blockwork and 150mm wide for 200mm blockwork.

Where shown on the Drawings, the block units are to be vertically reinforced through the core of the block units with high yield steel bars, securely tied to the starter bars left projecting from concrete structure. The core of block unit is to be grouted solid around bar with mortar or with a lean mix concrete with 10mm maximum aggregate.

e. Movement Joints

Movement joints shall be sealed by an approved sealer applied in strict accordance with the manufacturer's instructions. The surface of the concrete or blockwork to which the sealer is to adhere shall be straight and cleaned of all filler material, dirt, oil, grease and other matter. The sealer shall be applied by methods recommended by the manufacturer so that the sealer 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.

f. Precast Concrete Units

Precast concrete units shall be cast, reinforced, handled and erected all as specified under Section 3 "Concrete: Plain & Reinforced."

25 VENDOR APPROVAL

All materials and products shall conform to the M&W Specifications, BIS Codes and other relevant codes. Contractor shall propose minimum 2 vendors from the suggested list for Engineer's approval. Engineer may approve or reject the proposed vendor and / or ask contractor to use any specific vendor out of the suggested list. The decision of Engineer in this respect shall be final and biding.

For Appendix A, the list of approved makes for products and materials is given below. No further

approval is required to be taken for usage of these makes.

The manufacturers of products/materials should have been supplied to other Indian Metros (MRTS) / Suburban / Railways with a proof of client certificate.

For Appendix B - Deleted
For Appendix C - Deleted

Appendix A – Civil/Structural Material/Manufacturer Product List

S. No.	Material / Product	Manufacturer's Name
1	Cement	OPC: ACC, UltraTech, Bharati cement, Ambuja, JK Lakshmi, JSW, JK Cement, PSC: Dalmia, JSW, Birla Gold
2	Reinforcement Bars	VIZAG STEEL (RINL), TATA Steel, SAIL, JSW, JINDAL (STEEL & POWER),
3	Epoxy	FOSROC, SIKA, Qualcrete, Fairmate, BASF, CHRYSO, Berger, MC-Bauchmie, MAPEI, Durabuild
4 (a)	Expansion Joints for Viaduct	Prequalified Manufacturers as per RDSO's latest approved list with proper approval of Engineer / Employer
4 (b)	Expansion Joints for Building	MYK Schomburg, Migua, CS, Sanfield, Inpro, 3R Joints & Seals, VR Engineers, Greensboro Polychem, MC-Bauchemie, Asian Paints, ECMAS
5	Admixtures	FOSROC, SIKA, Fairmate, BASF, MC-Bauchemie, Pidilite, CHRYSO, MYK Schomburg.
6	Pile Testing	CIMEC, Spectro, Bureau Veritas, ADS Labstech, ATL, Avantech, Geodynamics, AIMIL, Cengers, CBRI, EMC India, Pile Dynamic, Composites Combine Technocrats, CEG test House, Synergy Testing House, Unique Engineering services, Axis testing solutions, Pile tech solutions (PLEASE NOTE THAT NABL ISO/IEC:17025 ACCREDITION IS MANDATORY)
7	Anchor Fastener	HILTI, FISCHER, BIT, TRUTEK, FOSROC, Mungo, Minova, UIP, Wuerth (Please note that ETA Certification is mandatory for using/supplying fasteners for load bearing structural members)
8	Structural Steel	TATA, SAIL, ESSAR, Jindal Steel & Power Ltd., JSW
9	Pre- stressing Strand (LRPC)	TATA SSL Ltd, USHA Martin,
10	Bearings	Prequalified Manufactures as per RDSO's latest approved list with proper approval of Engineer / Employer
11	Horizontal Tie Bars/Shear Bars	MacAlloy, Dextra, BB Bars System, BBV Systems, Euroalloy
12	HDPE Sheathing	Rex, Gwalior Polypipes Ltd, Kataria Sheathing, Tirupati, Dynamic Prestress, JK Prestressing

S. No.	Material / Product	Manufacturer's Name
13	Formwork Release Agent	FOSROC, MBT,MC Bauchemie, CHRYSO, BASF, Fairmate, Durabuild, Adoadditives, MYK Schomburg, Thermax, STP, MAPEI, Asian Labs,
14	Prestressing System	Freyssinet, BBR, VSL, Dynamic, Kellick Nixon, Tensacciai (India Ltd.), JK Prestressing, Usha Martin, VSIL.
15	Reinforcement Couplers	Dextra, Halfen Moment, Sanfield,
16	Hollow Sections, Pipes	TATA, Surya Pipes, JSW, Jindal Steel and Power ltd, APL Appolo,
17	Drainage Pipes	Tirupati Plastomatics, Duraline, REX, STIPL,
18	Polyurethane Paints	Berger, Asian, Nerolac, Nippon,
19	Non Shrink Grout	FOSROC, SIKA, BASF, MBT, CHRYSO, Fairmate, MYK Schomburg, ECMAS, CAC, Asian Paints, BERGER, Ado Additives, MC-Bauchemie, Asian Labs, MAPEI, Ultracon Buildtech
20	Bonding Coat	CICO, FOSROC, Sunanda, BASF, CHRYSO, MYK Schomburg, Minova, Fairmate, SIKA, BERGER, Ultracon, Thermax, ECMAS, Asian Paints, Asian Labs, Ado Additives, MAPEI, MC-Bauchemie, Durabuild
21	Polysuphide Sealant	DON, Pidilite, BASF, FOSROC, CHRYSO, SIKA, Fairmate, Durabuild, Asian Paints, MYK Schomburg, Ultracon, MC-Bauchemie, Buildtech
22	Steel Structural Fasteners	All RDSO Approved Vendors only.
23	Corrosion Protection Paints	Berger, Johnson Nicholson, Nerolac, Asian Paints, Fosroc, Shalimar, Universal Paint, DON, INM Nuvent Paints, CHRYSO,
24	Micro Silica/Silica fumes/Mineral additives	Sika Elkem, FOSROC, MAPEI, Corniche, Star Silica, CICO, CAC, BASF, Buildtech, Ashtech, Alccofine.
25	Fire Resistant Paint	Akzo Nobel, PPG, Jotun, Sunanda, Berger Paints
26	Integral Crystalline Waterproofing Method	Penetron, XYPEX, SIKA, DON
27	Water stopper/ Bar	Kanta Rubber, Greenstreak, Duron, Sunanda, Wall Grip, Asian Paints, FOSROC, Maruti, CHRYSO, DON
28	Liquid Polymer membrane waterproofing	BASF, MAPEI, MYK Schomburg, Pidilite, ECMAS, Durabuild, Asian Paints, DON, BERGER, FOSROC, Ado Additives, MC-Bauchemie, Thermax, Asian Labs, CHRYSO, Ultracon, Buildtech

S. No.	Material / Product	Manufacturer's Name
29	Curing Compound	Clean Tech Concure, Vista, FOSROC, CHRYSO, CICO, DON, Durabuild, BERGER, Fibrex, Ado Additives, SIKA, Fairmate, MYK Schomburg, Ultracon, ECMAS, Asian Labs, Asian Paints, MC-Bauchemie, MAPEI, Buildtech,
30	Polycarbonate Sheets	GallinaAcroplus, Coxwell, Poly U, Fabic, Lexan, DANPALON, GE Plastics,
31	Fly Ash	Thermal Plants, Ashcrete, Ultra Pozz, Star Pozz, Ashtech, Jaycee Build Corp LLP, SUPERPOZZ P500
32	Pre-Coated Profiled Metal Sheeting	TATA Blue Scope,JSW, Essar Steel, Super Disco Ispat, Aditya Profiles
33	Fly Ash Block/ AAC Block	Siporex, Ascolite, J.K. Laxmi, Ashtech, UNICRETE
34	Water proofing additives / chemicals	Sika, FOSROC, Kunal Conchem, Concrete Additives Chemicals, MAPEI, Normet. BASF, Ultratech Cement.
35	Rock Bolts/Swellex Bolts	Geo Constech, DSI, Atlas Copco, FIREP International, Minova
36	Concrete Sealer	CICO, Sika, BASF, Concrete Additives Chemicals, MAPEI, Ultratech Cement.
37	Silicon Water Repellent Coating	STP, Sika, BASF, Concrete Additives Chemicals, MAPEI, Normet, Fosroc
38	Polymer	WALLGRIP, TRISHUL, Fairmate, Shubham Minerals, Goldy Minerals, GeoPolymer

APPENDIX B – Deleted.

APPENDIX C – Deleted.