Wind forces on the chimney system shall be determined based on site specific wind design criteria provided elsewhere in this document.

The chimney and its components shall be designed to resist the most onerous forces resulting from all the possible combinations of the various loadings.

**5.03.03 Wind Shield**

The wind shield shall be designed for vertical loading, cross wind loading, seismic loading, circumferential wind loading, thermal gradients etc. The load calculation and load combinations shall be as detailed in IS 4998. The wind shield shall be analysed for cases with and without flue liner loads.

Forces/stresses in the wind shield due to eccentricity effects of local loadings, insolations effects, rotation of chimney foundations, construction tolerances and moments of second order shall also be considered.

Seismic response of the chimney shall be computed by the response spectrum method. Dynamic modulus of Elasticity shall be considered for calculating natural frequencies of the chimney. At least, the first five modes of vibrations shall be used for this analysis.

The across wind analysis of the chimney shall be carried out as per the provisions of IS 4998. Across wind loads shall be combined with co-existing along wind loads.

The effect of the openings/cut-outs in the chimney shell shall be duly considered in the design of the windshield. The minimum thickness of shell shall not be less than 500mm.

The minimum vertical reinforcement shall be 0.3% of the concrete area. The maximum spacing of the reinforcement bars shall not be more than 250 mm on each face. The minimum circumferential reinforcement shall be 0.2% of the concrete area. The maximum spacing of the reinforcement bars shall not be more than 200 mm on each face. The circumferential reinforcement in the top 3 meters of the windshield shall be twice that required from design forces. The clear cover to reinforcement shall be 50 mm.

There shall be a continuous ring of concrete shell without any opening for a height of atleast 5m below the soffit of flue duct openings.

There shall not be any reverse (outward) slope in the inside face of chimney shell. Where there is a sudden change in slope/ profile of the shell, the circumferential reinforcement shall be increased to twice the requirement as per the design in a circumferential band extending atleast 3m above and below such slope/profile change level.

The diameter of the reinforcing bar for the main vertical reinforcement of shell shall not be less than 25mm for a shell height up to the top level of flue duct opening.

Shell thickness between any two 10m reference levels shall not vary more than 150mm.

The minimum thickness of shell/closure wall at beam support recess/ opening locations shall be 100mm.

Grade of concrete for chimney shell, and other super structure shall be minimum M30. Only OPC cement shall be used for Chimney shell and other super structure.

The final design shall be checked & verified by 'Wind Tunnel Test' and shall be conducted at a reputed institution. Dynamic interference effects due to additional chimney(s)/NDCTS's and other tall structures located upto distance of 20 times diameter at 2/3rd height of subject chimney in the area or in the future expansion stage of the project, as envisaged by the owner at the time testing, shall be determined along with the other topographical features of the local area through model test.

**5.03.04 Flue Liners**

The flue gas parameters & various operating conditions for selection of flue liner material, material specification for flue liner and the criteria of flue gas exit velocity for sizing the flue liner shall be as specified elsewhere in the specification.

For flue liner with base metal as mild steel, the thickness of the base metal shall be determined from structural considerations. The thickness of any clad metal/coating/block lining etc. provided on the base metal shall not be considered for computing the structural strength of flue liner. The minimum thickness of the mild steel base metal shall, however, not be less than that specified elsewhere in the specification.

Two manholes placed diametrically opposite shall also be provided in each flue at all internal platform levels.

The supporting/restraining arrangements of the liners should be such that expansion of the liners longitudinally or circumferentially is not restrained.

**5.03.05 Internal Platforms**

The platforms shall be designed for dead, imposed (live), erection work and other possible loadings and temperatures effects. These platforms shall provide support and lateral restraint to the steel liners and provide access for inspections and maintenance. Forces imposed on the floors due to lateral restraint of flues shall be enhanced aptly for impact effects. These platforms shall also be designed suitably for the liner erection works. The platform shall be made up of chequered floor panels supported on grid of structural steel beams. All beams shall have bolted connections. The maximum permissible deflection in main steel girders supporting flue liner shall be span/1000.

**5.03.06 Internal Staircase**

The staircase shall have a clear passage way width of not less than 800 mm and a clear headroom of not less than 2100 mm. The riser height shall not be more than 175 mm and tread width shall not be less than 225 mm.

**5.03.07 Foundation**

The chimney foundation shall be designed as per limit state method as per IS 4998 for the most critical combination of forces and moments, resulting from all possible combinations of the various loadings from the chimney system during all stages of constructions. The effect of water table shall be considered and the foundation shall be checked for overturning for minimum and maximum vertical loads. There should be no uplift under any portion of the foundation/piles for any loading condition. Since chimney is a wind sensitive structure no allowance shall be made in the load carrying capacity of the bearing strata / piles under any load case/combination with wind. The foundation diameter to depth ratio shall not exceed 12. The diameter of the reinforcing bar for the main radial and tangential reinforcement for the foundation shall not be less than 25mm. The spacing of radial steel at the outer edge of the foundation shall not be more than 250mm. Grade of concrete for foundation shall be minimum M 30.

**5.03.08 Thermal insulation (Applicable in case of Titanium / C-276 Flue Liner)**

The insulation shall be semi-rigid, resin bonded type, in the form of slabs and shall conform to IS: 8183. Blanket type insulation shall not be used. The density of insulation shall not be less than 64 kg/cu.m for resin bonded glass wool insulation and 100 kg/cu.m for resin bonded rock wool. The coefficient of thermal conductivity of insulation shall not be more than 0.52mW/cm/$^{o}$C at a mean temperature of 100$^{o}$C.

The insulation thickness shall not be less than 100 mm, in any case, and shall be provided in two layers with the second layer of insulation covering the joints of the first layer. The insulation

shall be wrapped on the outer-most surface with galvanised wire mesh using MS galvanised pins and speed washer.

5.03.09 **Chimney Painting**

(i) All exposed steel surfaces (including exterior surface of mild steel flue liner in case the design does not envisage provision of thermal insulation on the exterior surface of flue liner) except surfaces of steel wind strakes shall be painted as specified in corrosion protection clause of this specification.

(ii) All steel parts embedded in concrete like Strake embedment assembly including bolts, nuts, washers, pipe sleeves and insert plate shall be galvanized as per IS:4736. The minimum weight for galvanizing shall be 610 g/sq.m and shall comply with relevant IS Codes.

(iii) The inside surface of chimney shell above roof, horizontal surface of shell at top, underside of concrete roof slab, etc shall be painted with epoxy phenolic coating system having total 220 microns DFT.

a) All concrete surfaces shall be provided with two component transparent polyamide cured epoxy sealer coating (having solid by volume minimum 40% ±2%) of minimum 50 micron DFT to be applied over cleaned surface in multiple coats. Surface to be coated shall be absolutely dry, clean and dust free.

b) Sealer coat shall be followed with the application of Intermediate coat of epoxy phenolic coating (solid by volume minimum 63%) of minimum 100 micron DFT. This coat shall be applied after an interval of minimum 24 hours (from the application of primer coat) by airless spray technique.

c) Intermediate coat shall be followed with the application of finish coat of two-pack aliphatic Isocyanate cured acrylic finish paint (solid by volume minimum 55% ±2%) with Gloss retention (SSPC Paint Spec No 36, ASTM D 4587, D 2244, D 523) of Level 2 (after minimum 1000 hours exposure, Gloss loss less than 30 and colour change less than 2.0 $\Delta$E) and minimum 70 micron DFT. This coat shall be applied after an interval of minimum 10 hours and within six (6) months (from the completion of Intermediate coat), Colour and shade of the coat shall be as approved by the Employer.

(iv) The entire external surface of chimney shell shall be painted with epoxy phenolic coating as specified in (iii) above in alternate bands of 'signal red' and 'bright white' colours.

**5.03.10 Rack and Pinion Elevator**

A rack and pinion elevator, with a load carrying capacity of 400 kg (min) (passenger cum goods), cabin floor size of 1100 mm x 1000 mm (min.) and an operating speed of 40 m/min. (approx.), shall be provided for travel from the grade level to the top of the chimney. A landing platform shall be provided at all access/ platform levels. The elevator shall be of a proven and approved make. Enclosure shall be fabricated from tubular steel and expanded metal or wire mesh, 2.1 m high (Approx.).

A Safety device comprising of an over speed governor in constant mesh with the rack by means of a flame hardened steel pinion shall be provided to protect the cab against over speed during the cab downward motion and the same shall actuate the brake mechanism and stop the down ward motion gradually. The lift shall be installed using anchor fasteners. The electrical requirement of the system shall conform to the main electrical specification. Drive motor shall be of S3 duty class with CDF of 25% and maximum number of 120 starts per hour in 55 degree Celsius ambient temperature. The motor shall be provided with internal 220V AC single phase space heaters or an alternate heating system. The elevator shall be supplied, installed, painted, tested, commissioned etc. complete with all mandatory spares (as specified in Part-F of this specification) and operation maintenance manual.

**5.04.00 RAW WATER RESERVOIR**

**5.04.01 Scope**

The scope of work for Raw water reservoir generally involves design, preparation of general arrangement drawings, construction drawings, supply of labour, materials and construction of all civil and structural works like site clearance, site leveling & grading, excavation, filling, construction of earthen embankment, providing sand filters, sand chimney, sand blanket in embankment, cut-off trench, mechanical compaction, slope protection, HDPE lining, PCC lining, non woven geotextile, Inlet and Outlet Structures, RCC spillways, supplying & laying of MS pipes and associated Civil Works, road works, construction of drains along the reservoir boundary etc. and other ancillary works associated with the completion of reservoir as per directions of the Engineer.

Disposal of surplus excavated material in NTPC Land outside plant boundary(including dressing the top surface) and compacting the same by mechanical means in layers(not exceeding 300mm thickness, higher layer thickness upto 500mm in case of compaction using special type of equipment such as vibratory roller etc.) to minimum 85% Standard Proctor Denisty at optimum moisture content in case of soil and/ or to 85% of original volume in case of boulders , clearing grass and vegetation, levelling is in bidder's scope.

**5.04.02 General Requirements**

Raw water reservoir shall have gross usable capacity as indicated in the tender drawing.

**5.04.03 Design Requirement**

Sizing of the reservoir shall be such so as to utilize the maximum allocated area for the reservoir as per the layout drawing of the plant and as directed by the Owner. Bottom 500 mm (minimum) depth of water shall be treated as dead storage for settlement of any silt etc. The dead storage shall be over and above the total required capacity of the reservoir. The reservoir shall be provided with a free board as per requirements of IS 10635, but in no case, the same shall be less than 1500mm.

Earthen embankment shall be designed as an earthen dam as per IS: 12169 with internal drainage system i.e. sand chimney and sand blanket of 500mm (min.) thickness shall be provided inside the embankment. Slope stability of embankment shall be analyzed as per IS: 7894. However, the minimum slope of embankment shall be 1V:2.5H with a berm of 3.0m at every 6.0m interval. The founding level of embankment shall be at least 300mm below natural ground level. The top soil shall be stripped to a minimum depth of 300mm. However, the stripping depth, if required, shall be increased to the required level as per actual conditions to totally remove all vegetations, organic matters, roots, soft spots, etc.

The whole area of reservoir bed shall be graded & leveled by cutting and filling.

Wherever filling is required at the bed of the reservoir, area shall be stripped first and then embankment filling shall be done in layers of 300mm compacted thickness and compacted to minimum 90% of maximum dry density (Standard Proctor) by mechanical means at optimum moisture content.

Minimum top width of embankment shall be 6.0m with provision of single lane WBM road including black topping all around on top of embankment. WBM road shall be constructed in accordance with IRC: 19 (latest edition). On downstream slope of the embankment, rip-rap shall be provided from toe up to or higher level than the HFL. Turfing shall be provided from embankment top to rip-rap/HFL level. Rock-toe with toe drain shall be provided at the toe (bottom) of the embankment all around the reservoir. Toe drain shall be of adequate capacity to be constructed in RCC grade M30. An approach ramp of minimum 6m width and min. 1V:8H slope shall be provided for access to the top of reservoir embankment along with single lane WBM road including black topping. The side slope of ramp embankment shall be minimum 1V:2.5H and shall be provided with rip-rap/turfing (as required) on side slopes.

In order to arrest the seepage/percolation losses through reservoir bed/embankment, 1mm thick high density polyethylene (HDPE) liner shall be provided at entire bed and upstream side slopes. HDPE liner shall be laid on the prepared soil bed which is free from any sharp objects, roots or any other organic materials. HDPE liner shall be anchored in PCC filled trench at the edge of top of embankment. HDPE liner shall be protected by providing non woven geotextile and 75 thick PCC lining.

Suitable underdrainage system consisting of Pressure Relief Valves (PRV) shall be provided below the HDPE liner in the reservoir bed to counter uplift forces on HDPE liner occurring when the reservoir is empty and ground water table in the vicinity is above the reservoir bed level. PRVs shall conform to IS 4558.

**5.04.04** **Earthen Embankment**

**Material for Filling**

Material to be used for embankment filling shall be of approved quality excavated from inside the reservoir/plant area or brought from borrow area arranged by the Contractor. Material used for embankment filling shall not be organic soils, peat, cohesionless soil, sand dust, expansive soils and chemically aggressive soils. They shall be clean and free from shingle, salts, organic roots and sod, lumps, concrete or any other foreign substances. Fill shall be placed in horizontal layers not exceeding 300 mm compacted thicknesses. Compaction shall be done to achieve minimum 95% standard Proctor density by mechanical means.

Filling shall be accurately finished to line, slope, cross-section and grade as shown on the approved drawings. Finished surface shall be free of irregularities and depressions and shall be within (+/-) 20mm of the specified level.

When the borrow area is located contiguous to the embankment alignment then it must be ensured that the borrow area shall not be opened within a distance of 5 times the height of embankment contiguous to the heel or the toe of the embankment or 25 metre whichever is more.

The required approach roads and haul roads shall be constructed and maintained by the Bidder. The Bidder shall divert the existing roads, nallah/drain if any which are in the Raw Water Reservoir area at his own cost before the start of work.

Frequency of sampling and testing including the methods for conducting the tests are as given in Table-1. The testing frequencies set forth are desirable minimum and Engineer shall have the full authority to carry out or call for tests as frequently as he may deem necessary to satisfy himself that the materials and works comply with the appropriate specifications.

Following Acceptance Criteria shall be followed:

a. All individual samples collected and tested should pass without any deviation when only one set of sample is tested.

b. For re-test of any sample, two additional samples shall be collected and tested, and both should pass without any deviation.

c. Where a large number of samples are tested for a particular test then 9 samples out of every 10 consecutive samples tested shall meet the specification requirement.

**5.04.05** **DELETED**

**5.04.06** **Graded Coarse Aggregate Filters**

Graded coarse aggregate shall be used in filters below rip-rap and rock-toe as per IS 8237. The coarse aggregate material shall consist of durable well graded broken rock of hard stone. The materials shall range in the size from 10mm to 75mm and shall satisfy the filter criteria.

The rock material used in the aggregate filters shall satisfy the following condition:

a) Specific gravity shall not be less than 2.50.
(As per IS 1122)

b) Sulphate soundness less than 10% loss of weight after 5 (Five) cycles
(As per IS 1126)

c) Aggregate Impact value shall not exceed 30%
(As per IS 2386)

d) Water absorption shall not exceed 2.5%
(As per IS 2386)

a) In slake durability test (as per IS 10050), the percentage retained after two ten (10) minutes cycles shall be more than 85%.

**5.04.07** **DELETED**

**5.04.08** **HDPE Liner**

The proposed lining system consisting of High Density Polyethylene (HDPE) membrane shall form the water-tight barrier to prevent seepage/leakage. Bidder shall examine in detail the prevailing conditions and provide a liner system to meet the above requirement.

The specification as outlined hereunder shall be treated as bare minimum. However, bidder shall offer the system to meet the site specific requirements and shall provide complete details in the offer. In case bidder deems it necessary to provide additional measures over and above what has been specified, he may do so at the quoted rate against the schedule of item. Bidder shall guarantee the satisfactory performance of the proposed liner system for a period of five years from the end of defect liability period.

REQUIREMENT OF HDPE MATERIAL

The High Density Polyethylene (HDPE) Liner shall be manufactured out of polyethylene resin. The resin composition and production shall meet the intended purpose as specified above. The natural polyethylene resin without the carbon black shall meet density of 0.932 g/cc or higher and melt index less than 1.0 g/10min. The test methods shall conform to ASTM D 1505 or ASTM D792 or equivalent for density test and ASTM D1238, condition E or equivalent for Melt Index test.

The HDPE liner shall not be less than 6.0 M in width. Carbon Black shall be included in the resin to render it ultra-violet resistant. The Carbon Black content shall be between 2-3 percent as per ASTM D 1603. The surface of liner shall not have striations, roughness, pinholes or bubbles. The liner may be smooth. The liner sheet thickness shall be 1.0MM (40 Mil) with sheet density not less than 0.94 g/cu.cm. The Melt Flow Index shall be less than 1.0 g/10min. The method for testing melt flow index shall be as per ASTM D 1238 or equivalent. The Tensile stress at yield shall not be less than 17.0 N/mm and the yield strain not less than 12%. The strain at break shall not be less than 700%. The Tear Strength as per ASTM D 1004 or equivalent shall not be less than 130 N. The Puncture Resistance as per ASTM D 4833 (or equivalent) shall not be less than 390 N. For all other properties & test methods specified elsewhere in this specifications shall conform to GRI test method GM13 (Latest revision).

Any sealants used shall be of type as per the recommendations of the HDPE manufacturer compatible with the intended use. However, before the use, Owner's approval shall be obtained.

INSTALLATION AND LAYING OF LINING SYSTEM

The HDPE Liner sheet (Geo-membrane rolls) shall be brought to site by trailer/truck or by any suitable transport without damaging the geo-membrane. The geo-membrane rolls shall be stored in such a way that they are protected from puncture, dirt, grease, moisture and heat. In case any material gets damaged, it shall be segregated and stored separately for replacement. All the geo-membrane rolls shall be stored on a prepared smooth surface. The HDPE Liner works shall be executed at site by the supplier of HDPE liner only.

Subgrade (reservoir bed) shall be rolled and compacted and made flat and smooth. The top layer of reservoir bed subgrade shall be compacted with 2 passes of 8 to 10 flat footed roller over rock and soil surface. Any weak and soft spots, if present shall be removed and replaced with compacted fill. All subgrade surface where lining shall be placed should be smooth, free of all foreign and organic matter, sharp objects. Standing water or excess moisture shall not be allowed.

For the purpose of anchoring the geo-membrane, anchor trench shall be excavated to the line, grade and width as shown in the drawings, rounded corners shall be provided in the trench to avoid sharp bends in the geo-membranes.

Geo-membrane shall be laid using a spreader bar assembly attached to a loader bucket or any other method as approved by the Engineer. While laying the geo-membrane precaution shall be taken to avoid any damage to the lining system. Equipment or tools shall not damage the geo-membrane during handling, transportation and laying. Personnel working on the liners shall not smoke or wear shoes that may damage the geo-membrane. The method of unrolling the panels should be such that it should not cause scratches or crimps in the geo-membrane. While unrolling due care shall be taken to ensure that the subgrade is not damaged. In order to prevent uplift by wind, adequate loading by sand bags or similar items that will not damage the geo-membrane shall be placed over the geo-membrane. Continuous loading along the edges of the geo-membrane panels shall be provided in order to minimize the risk of wind flow under the panels.

Geo-membrane shall not be laid when ambient temperature is above 50°C. Placement of geo-membrane shall not be carried during rains or in presence of excessive moisture such as fog, dew, etc. In presence of high winds also laying of geo-membrane shall not be taken up.

Deployment of geo-membrane shall immediately followed by field seaming operation. The field seaming shall be as per manufacturer's recommended process. The field operation shall either be hot shoe fusion type or extraction welding type. Any other process may be acceptable subject to approval of the Owner.

On embankment slopes and other slopes, in general, seams shall be oriented in the general direction of maximum slopes. In other words, the seams shall orient down and not across the slope. In corners and other geometric forms, the number of field seams shall be minimized. At the base, T-seam shall not be closer than 1.5m from the toe of the slope. Seams shall be aligned with the least possible number of wrinkles and fishmouths. If a fishmouth or wrinkle is found, it shall be relieved and cap stripped.

All geo-membrane panels shall have a finished overlap of 100mm (minimum) in case of hot wedge welding and 75mm (minimum) for extrusion welding. Unless approved by the Engineer-in-Charge, cleaning solvents shall not be used.

Bidder shall provide all equipment as approved by the Owner. The equipment shall consist of, but not limited to, hot-wedge welder, Extrusion Welder, high speed side grinder, generator, necessary power grid, Vacuum Box Test Equipment for non-destructive seam testing, Air pressure test equipment for non-destructive seam testing, Field Tensiometer for performing shear and peel tests.

In order to verify that seam conditions are acceptable, field test on seams shall be conducted. Test seams shall be carried out at the outset of each seaming period and at least once every four hours for each seaming instruments and personnel deployed that day. All test seams shall

be made in contact with the subgrade. All welding rods used for extrusion welding shall have the same properties as the resin used in the geo-membrane. The length of test seam sample shall be 3.0 meter in case of hot wedge welding and 1.0 meter in case of extrusion welding. At least five test specimens shall be cut from each end of the test seam. A tensiometer shall be used to test five specimens for shear and five specimens for peel. Each specimen shall be at least 25mm wide with a 100 mm plus width of the seam as grip separation, the seam shall be centered between the clamps. The rate of grip separation shall be 50mm per minute. Average of five specimens test results shall be considered for seam strength properties, four out of five specimens shall pass seam acceptance criteria. Shear and peel test shall result in film Tearing Bond (FTB), as defined in NSF std. 54 or equivalent, which is a failure in ductile mode of one of the bonded area. In case a test seam fails to meet the field seam requirements of the specification, the apparatus for seaming and / or seamer shall not be used until the deficiencies are corrected and a successful test seam results.

All fields seams are over their full length shall be tested non-destructively. The non-destructive test shall be conducted either by vacuum Box Testing Method and /or Air pressure testing Method.

Vacuum Box Testing (VBT)

VBT shall be carried out by bidder as per the procedure outlined hereunder. A vacuum box assembly consisting of a rigid housing with a transparent window and having a soft rubber gasket attached to be bottom, porthole or valve assembly and a vacuum gauge shall be used. A soapy solution in plastic bucket with a mop shall be made available. The excess sheet overlap, if any, shall be properly trimmed away. Then a strip or geo-membrane of length 300 mm shall be wetted by the length of box with the soapy solution. The box shall be place over the wetted area and compressed. Create a vacuum of 0.2kg/sw.cm to 0.35 kg/sq.cm. Care shall be taken to ensure that a leak proof seal is created. Vacuum shall be maintained for sufficient time. For a period of approximately 15 seconds, examine the geo-membrane through the viewing window for presence of any animated soap bubbles. In case no animated bubbles appears after 15 seconds, close the vacuum valve and open the bleed valve. Thereafter, move the box over the next area adjoining the tested area with a minimum 75 mm overlap. Repeat the process as described above.

In case animated soap bubbles appear all such areas shall be marked, repaired and then retested successfully.

In locations where seams cannot be non-destructively tested, the seam shall be spark tested according to the manufacturer's recommendations and directions of the Engineer.

Air Pressure testing (APT)

APT shall be applicable for all double fusion seams, only. Bidder shall furnish all required equipment. An air pump equipped with pressure gauge capable of generating and sustaining a pressure between 1.7 kg/sq.cm and 2.1 kg/sq.cm. The pressure gauge shall be equipped with a sharp hollow needle.

The Bidder shall seal one end of the seam to be tested. Then insert needle or any other approved pressure feed device through the sealed end of the channel created by the double wedge fusion weld. Then energize the air pump to verify the unobstructed passage of air through the channel. Seal the other end of the channel. Then energize the air pump to about 2.1 kg/sq.cm. Close the valve and allow 2 minutes for the injected air to come to equilibrium in the channel and keep the pressure approximately for 5 minutes. In case loss of pressure exceeds 0.28 kg/sq.cm or even pressure does not stabilize, then locate faulty area. The area to be repaired and then retested successfully. In case the test is successful, the air channel should be deflated.

Destructive seam testing shall be carried out as per the recommendations of the manufacturer. One destructive test shall be carried out for every 150 meter length of seam or as directed by the Engineer. Holes in the geo-membrane resulting from obtaining the seam samples shall be

immediately patched and vacuum tested. The sample shall be 300mm wide and 1.0 meter long with the seam centered lengthwise. The sample shall be cut into three equal length pieces. One piece to be given to the Engineer and the other shall be with bidder for testing. Bidder shall test ten 25mm wide specimens, five specimens for shear strength and give for peel strength. To be acceptable, four out of five specimens must pass.

The Owner may send seam samples, at his own discretion, to a laboratory for testing.

In case the sample fails the destructive test, then the Bidder shall cap strip the seam between the failed locations. If the test fails, then process is repeated. Over the length of seam failure, the Bidder shall either cut out the old seam, then reposition the panel and re-seam or add a cap strip.

Bidder shall thoroughly inspect all seams and non-seams areas of the geo-membrane for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Surface of the geo-membrane shall be cleaned at the time of inspection by the Bidder. Each suspect location in seam and non-seam areas shall be further non-destructively tested in presence of Engineer, if so desired. Each location that fails the non-destructive e testing shall be marked and repaired by the Bidder. The defective seams shall be cap stripped or replaced. Small holes shall be repaired by extrusion welding. If the holes are larger than 6mm, if should be patched to the satisfaction of the Engineer. All tears shall be repaired by patch work, where the tear is on a slope or an area susceptible to stress and has a sharp end; the same shall be properly rounded before patching. Blisters, large cuts and undispersed raw materials shall be repaired by patches; Patches shall be done by extrusion welding. The weld area shall be ground not more than 10 minutes prior to welding. It shall be ensured that no more than 10% of the thickness is removed by grinding. Welding shall commence immediately after grinding and must overlap the previous seam by at least 50mm. Re-seaming over an existing seam shall be carried out, if permitted, only after regrinding. Generally, welding shall restart by grinding the existing seam and re-welding a new seam. Patches shall be round or oval in shape, made of the same geo-membrane, and extend a minimum of 150mm beyond the defective areas.

Each repair shall be non-destructively tested to the satisfaction of the Engineer-in-Charge. Repairs that pass the non-destructive tests shall be considered as an acceptable repair. In case the tests fails, the repair shall be repeated and retested until passing test results are obtained. The bidder shall keep daily reports and details of all non-destructive and destructive testing. The report/ documentation shall clearly identify all seams that initially failed the test and include all evidence/ certification from the Engineer that these seams were satisfactorily repaired and successfully retested.

All anchor trenches shall be casted by the bidder. Anchor trench material shall be plain cement concrete. It shall be suitably placed to the size as specified in the drawings without damaging geo-membrane. If damage occurs, it shall be repaired immediately.

For attachments to concrete, stainless steel concrete anchors and epoxy anchors, stainless steel nuts and washers along with stainless steel slotted flat bars (6mm thick) shall be provided at no extra cost to the owner. Bidder shall also provide closed cell neoprene gaskets and associated adhesive with no extra cost to the owner. Bidders shall make their own assessment of the requirements and include all cost in the quoted price of geo-membrane (HDPE Liner).

Wherever pipe penetrations are to be sealed, the geo-membrane shall be formed around the pipes with stainless steel clamps, closed cell neoprene gaskets, etc shall be provided all around the pipe to make it leak proof. The details of the seal generally follow the manufacturer's recommendations subject to the owner's approval. No separate payment shall be made for all pipe penetration sealing works. The bidder shall make his own assessment of the total work and provide for the same in the unit rate quoted for geo-membrane (HDPE Liner).

All quality control measures shall be deployed by the bidder. All tests are required to be carried out at Bidder's own cost during the production of materials as well as during laying operation.

All resins for use in geo-membrane shall conform to the requirements. Each lot shall be sampled with following tests conforming to manufactures specifications.

1. Density : ASTM D 1505
2. Melt Index : ASTM D 1238

All additives are to be tested and approved prior to use with the following testing performed and compared to the manufacture's requirements'.

1. Carbon Black content : ASTM D 1603

Manufacturer's quality Assurance Testing shall conform to the provisions as stipulated here. Full width samples shall be taken as tokens from the end of each roll. The HDPE liner that is to be supplied, quality control testing shall meet following frequency.

| Test | Description | Method | Frequency |
|---|---|---|---|
| 1. | Thickness | ASTM D 5199 | Every roll |
| 2. | Tensile properties | ASTM D 638 | Every 5000 Sq.m. |
| | a. Tensile strength at yield. | | |
| | b. Tensile strength at Break | | |
| | c. Elongation at Yield. | | |
| | d. Elongation at Break. | | |
| 3. | Tear resistance | ASTM D 1004 | Every 5000 Sq.m. |
| 4. | Puncture Resistance | ASTM D 4833 | Every 5000 Sq.m. |
| 5. | Carbon Black Content | ASTM D 1603 | Every 5000 Sq.m. |
| 6. | Dimensional Stability | ASTM D 1204 | Every 5000 Sq.m. |
| 7. | Carbon Black Dispersion | ASTM D 5596 | Every 5000 Sq.m. |
| 8. | Density | ASTM D 1505/D792 | Every 5000 Sq.m |
| 9. | Melt Index | ASTM D 1238 | Every 5000 Sq.m. |
| 10. | Oxidative Induction Time | ASTM D 3895 | Every 5000 Sq.m. |
| 11. | Low Temperature Brittleness | ASTM S 746 | One per resin lot |
| 12. | Environmental Stress resistance | ASTM D 1693 | Every 5000 Sq.m. |
| 13. | High Pressure Oxidative Induction Time | ASTM D 5885 | Every 5000 Sq. m. |

14. Oven Aging at 85 Deg C – High Pressure OIT (min. ave.)- % retained after 90 days – ASTM D 5885 - Every 15000 Sq. m. and each formulation

15. UV Resistance – High Pressure OIT (min. ave.)- % retained after 1600 hrs – ASTM D 5885 - Every 15000 Sq. m. and each formulation

Welding rod samples shall be tested at the frequency of once per 25 rolls of welding rod. Following tests shall be performed on the samples.

1. Thickness/diameter as per ASTM D751 : ASTM D 751
2. Density as per ASTM D 1505 : ASTM D 1505
3. Melt Index as per ASTM D 1238 : ASTM D 1238
4. Carbon black content as per ASTM D 1603 : ASTM D 1603

All the reference to ASTM codes shall be tested as the base requirement. Other International codes of practices, which are equivalent to the above ASTM, shall also be acceptable to the owner subject to prior approval.

Results of all the tests shall be furnished to the owner for his review. Owner or his authorized representative reserve the right to inspect the testing facilities and witness the tests as and when desired.

Owner or his authorized representative reserve the right to retest some or all the parameters of HDPE liner at NTPC identified 3rd party testing laboratory anytime during the execution of contract. Sample shall be selected from site randomly jointly by NTPC and contractor. Cost of all testing shall be borne by the contractor. In case the sample does not meet the requirement of Technical Specifications, then owner reserve the rights to reject the HDPE liner lot from which the sample is selected.

Precautions to be taken for HDPE liner laying:

1. After the construction of reservoir embankment, the slopes shall be dressed properly and shall be free from any gravel or sharp rock pieces. The slopes & bed of reservoir shall be free from any gravel or sharp rock pieces which can puncture the HDPE liner.
2. After the bed preparation, HDPE liner roll shall be unrolled one at a time. The liner shall be adequately loaded with the sand bags and shall be immediately welded with the adjacent liner roll.
3. Once the welding of previous liner rolls is completed then only the next roll shall be unrolled.
4. The loading of HDPE liner shall be continuous at the edges and in a dense grid of 1mX1m at over the liner area.
5. Liner shall not be left open without adequate loading and it shall be pressed properly (in order to take out air pockets which causes undulation) before welding.
6. Anchoring of HDPE liner at reservoir top shall be done as per the construction drawing.
7. Non-Woven geotextile & over that 75 thick PCC M20 layer shall also be placed over HDPE liner to get finished surface.
8. In the reservoir bed, 300mm thick layer of specified soil shall be provided in rocky surface. Bed shall not consist of gravels and sharp rock pieces.
9. The welding of HDPE liner rolls shall be carried out simultaneously. Large number of rolls should not be left un-welded to avoid tearing off of liner.

**5.04.09** **PCC Lining**

75mm thick Plain Cement Concrete of grade M-20 (design mix) shall be provided over non-woven geotextile laid over HDPE liner at all levels on the inner surface of reservoir embankment (upstream side slope) and reservoir bed with graded stone chips (12.5 mm nominal size).

Synthetic Polyester triangular fibre of length 12mm,effective diameter 10-40 microns and specific gravity of 1.34 to 1.40 shall be mixed in Plain Cement Concrete of grade by using 125gms of synthetic Polyester triangular fibre for 50 Kg cement used as per directions of Engineer.

**Placing**

After the slope & bed of reservoir has been dressed to line and HDPE liner has been provided over the compacted earth/soil, the entire upstream slope surface & bed shall then be covered with non woven geotextile followed by placing of 75 thick PCC lining. The PCC lining shall be

free from impurities like particles of stone, lime and other foreign materials visible to the naked eye on the surface and shall be of uniform texture. On completion of PCC lining, the surface presented by the lining shall be even throughout, free from irregularities.

**5.04.10** **Non-Woven Geotextile**

This specification covers the technical requirements for the Manufacturing and Installation of the nonwoven geotextile. All materials meet or exceed the requirements of this specification, and all work will be performed in accordance with the procedures provided in these specifications.

**Submittals**

A. Prior to material delivery to project site, the contractor shall provide the engineer with a written certification or manufacturers quality control data which displays that the geotextile meets or exceeds minimum average roll values (MARV) specified herein.

B. The contractor shall submit, if required by the engineer, manufacturer's quality control manual for the geotextile to be delivered to the site.

**Geotextile**

A. Geotextile shall be Needle punched Non-woven type.

B. The geotextile shall be manufactured from prime quality virgin polymer.

C. Geotextile shall be with U-V (Ultra-violet) treatment suitable for a temperature range from 0 Deg. C to 50 Deg. C so that the strength and the life of the same is not affected due to exposure to ultraviolet

D. Geotextile shall meet or exceed all material properties as given below.

E. In addition to the above, geotextile shall have good resistance to chemicals and to biological degradation

| | |
|---|---|
| 1. Material for Geotextile filter | 100% Polypropylene |
| 2. Mass per unit area | 250 g/sq.m (ISO 9864) |
| 3.Thickness in mm | 2.2 (min.) (ISO 9863) |
| 4. Tensile strength | 19 kN/m (ISO 10319) |
| 5. Elongation at break | 80/35(md/cd)(ISO 10319) |
| 6. Puncture strength | 2900 N (ISO 12236) |
| 7. Effective opening size | 0.09mm (ISO 12956) |
| 8. Horizontal water flow 20kPa | 13 l/m.h (ISO 11058) |
| Horizontal water flow 200kPa | 3.0 l/m.h (ISO 11058) |
| 9. Vertical water flow 50mm head | 72.0 l/sqm.h (ISO 11058) |
| 10. Width to be supplied | minimum 3.5 m |

**MANUFACTURE**

All rolls of the geotextile shall be identified with permanent marking on the roll or packaging, with the manufacturers name, product identification, roll number and roll dimensions.

**TRANSPORT**

A. Transportation of the geotextile shall be the responsibility of the contractor.

B. During shipment, the geotextile shall be protected from ultraviolet light exposure, precipitation, mud, dirt, dust, puncture, or other damaging or deleterious conditions.

C. Upon delivery at the job site, the contractor shall ensure that the geotextile rolls are handled and stored in accordance with the manufacturer's instructions as to prevent damage.

**INSTALLATION**

A The geotextile shall be handled in such a manner as to ensure that it is not damaged in any way. Any damage to the geotextile to the extent that it is no longer usable as determined by these specifications or by the engineer, the contractor shall replace the geotextile at his own cost.

B The geotextile shall be rolled down the slope in such a manner as to continuously keep the geotextile in tension by self-weight. The geotextile shall be securely anchored in an anchor trench where applicable, or by other approved or specified methods.

C. In the presence of wind, all geotextiles shall be weighted by sandbags or approved equivalent. Such anchors shall be installed during placement and shall remain in place until replaced with cover material.

D. The contractor shall take necessary precautions to prevent damage to adjacent or underlying materials during placement of the geotextile. Any damage to such material occur due to the fault of the contractor, the contractor shall repair the damaged materials at his own cost and to the satisfaction of the engineer.

E. During placement of the geotextile, care shall be taken not to entrap soil, stones or excessive moisture that could hamper subsequent seaming of the geotextile as judged by the engineer.

F. The geotextile shall not be exposed to precipitation prior to being installed and shall not be exposed to direct Sun light for more than 15 days after installation.

G. The geotextile shall be seamed using heat seaming or stitching methods as recommended by the manufacturer and approved by the engineer. Sewn seams shall be made using polymeric thread with chemical resistance equal to or exceeding that of the geotextile. All sewn seams shall be continuous. Seams shall be oriented down slopes perpendicular to grading contours unless otherwise specified. For heat seaming, fusion welding techniques recommended by the manufacturer shall be used.

H. The contractor shall not use heavy equipment to traffic above the geotextile without approved protection.

I. The geotextile shall be covered (as per drawings) as soon as possible after installation and approval. Installed geotextile shall not be left exposed for more than 15 days.

J. Material overlying the geotextile shall be carefully placed to avoid wrinkling or damage to the geotextile.

**5.04.11 Spillways/Over Flow Structures**

Bidder shall suitably design and construct spillways/over flow structures to prevent overtopping of the embankment. The discharge from the spillways/overflow structures shall flow to the nearest nallah or drains with capacity to accommodate it.

**5.04.12 Inlet /Outlet Structures**

Suitable outlet pipes of mild steel (MS) as per IS: 3589 shall be provided. The adequate nos. of outlet pipes (as per design requirement) of suitable diameter and minimum 500mm thick RCC encasement with concrete Grade M20 as per IS 456. Pipes shall be laid as per IS 783.

Inlet structure shall be suitably designed & constructed. Inlet pipes shall be of MS as per IS: 3589 and laying shall be done as per IS 783. The number and diameter of pipes shall be suitably designed to meet the capacity requirement. A minimum 500mm thick RCC

encasement with concrete Grade M20 as per IS: 456 within the embankment shall be provided. To dissipate the turbulence and energy of the falling water suitable energy dissipation devices/system shall be provided.

**5.04.13 Rip-Rap**

Rip-rap shall be hand placed on the slopes of the embankment as per IS: 8237 - "Code of practice for Protection of slope for reservoir embankments". The thickness shall be 300mm and shall be measured normal to slope of the embankment. The rock materials used for rip-rap shall satisfy the quality requirements specified in IS code.

**5.04.14 Rock Toe**

The rock material used for the rock toe shall satisfy the quality requirements. Rock toe shall be formed with rock material consisting of sound, durable and well graded broken rock obtained from approved quarries and shall be of approved quality. The materials shall range in size from 10 to 45 cm. All brush, roots or other perishable materials shall be removed from rock-fill during spreading and disposal off. Contamination of the rock with finer materials from any other zones shall be avoided. Accumulations of soil caused by contamination shall be removed. Rock materials shall not be dumped directly but shall be hand placed in layers.

**5.04.15 D/S Slope Protection Works – Turfing**

The D/S slope of embankment including berms, if any, shall be turf sodded from top of embankment to rip-rap level. Turfing shall consist of at least 5 cm thick grass turf sods of approved variety obtained from the tank beds or river margins for use in this work. The sod shall include a mat of roots and earth at least 5cm thick. Sod containing an excessive amount of obnoxious weed growth shall be excluded. The block of sod shall be laid on the slope in close contact and then tampered firmly in place so as to fill and close the joints between blocks.

**5.04.16 Diversion of Surface & Under Ground Water**

The whole of the works shall be carried out in the dry condition. Water from any source shall be diverted or pumped as required, clear of the works. Bidder shall make all necessary arrangement whatsoever required for keeping the work area dried by diverting and pumping of water, and also provision and operation of all temporary works including pumps, motors, fuel, piping and for the formation of any sumps, drainage channels, flumes, coffer dams and other protective works.

**5.04.17 Rainfall Run-Off**

As part of the work may have to be carried out in wet season, Bidders programme and methods must be capable of dealing with run-off from rainfall on the adjacent catchment area. The associated flow in the nallahs etc. shall be diverted clear of the works by an approved system of bunds and channels. Bidder shall supply, install and operate his own temporary pumping installation.

**5.04.18 Prevention of Pollution**

Arrangement shall be made by the Bidder to prevent pollution of the water in any streams, springs, nallahs and lakes. Arrangements for sprinkling of water in the construction and borrow area to prevent any dust blowing also shall be done by the Bidder. Bidder shall be solely responsible and liable for all damage caused by any pollution that may take place during the execution of the works, and he shall make arrangements, as the Engineer may approve, for preventing pollution but, not withstanding such approval, the entire responsibility for any pollution shall rest with the Bidder

**Table-1**
**Frequency of sampling and testing**

| S.No. | Nature of test/Characteristics | Method of test | No. of samples & frequency of test | Remarks |
|---|---|---|---|---|
| 1 | Suitability of fill material | | One in every 2000 cum for each type and each source of fill materials subject to a minimum of two samples | Test for soil and sand |
| | a) Grain size analysis | IS: 2720 (Part-IV) | | |
| | b) Liquid limit and Plastic limit | IS: 2720 (Part-V) | | |
| | c) Shrinkage limit | IS: 2720 (Part-VI) | One in every 5000 cum for each type and each source of fill material | Test for soil The frequency of test can be increased depending on type of soil |
| | d) Free swell Index | IS: 2720 (Part-XL) | | |
| | e) Chemical Analysis | IS: 2720 | One in every 5000 cum for each type and each source of fill material | Test for soil and sand |
| | i) organic matter | Part-XXIL | | |
| | ii) calcium carbonate | Part-XXIII | | |
| | iii) Ph | Part-XXVI | | |
| | iv) total soluble sulphate | Part-XXVII | | |
| 2. | Standard proctor Test | IS: 2720 (Part-VII) | One in every 2000 cum for each type and each source of fill material | Test for soil for determining optimum moisture content, dry density etc |
| 3. | Moisture content for fill before compaction | IS: 2720 (Part-II) | One in every 2000 cum for each type and each source of fill material | Test for soil |
| 4. | Degree of compaction of fill | | | |
| | a) Dry density by core cutter method or dry density in place for sand displacement method | IS: 2720 (Part-XXIX) | For area filling, one for every 1000 sqm area for each compacted layer | Test for soil |
| | b) Relative density (density Index) | IS: 2720 (Part-XIV) | For area filling, one for every 1000 sqm area for each | Test for soil |

| | | | | |
|---|---|---|---|---|
| | | | compacted layer | |
| | c) Dry Density for proctor needle penetration | Standard practice | Random checks to be carried out for each compacted layer in addition to tests mentioned under IV(a) above | Test for soil |

**5.05.00 ASH HANDLING SYSTEM**

5.05.01 The civil works for Ash handling system shall comprise of bottom ash and fly ash handling systems, which includes Ash slurry pump house and their related sumps/tanks, Ash water pump house, Bottom Ash (BA) slurry transportation pump pit and their related sumps/tanks Slurry trench (In case of SCC system), Transport/instrument Air Compressor house, Conveying air compressor house, Switchgear /Control/RIO rooms, HCSD Pump house, AHP Control room building, Ash classifier, Ash silo, supporting structures and foundations for Bottom ash hopper, Buffer hoppers, dewatering bins, bottom ash overflow tank, Settling tanks and Surge tanks, Seal water tank, Bagging plant Complex, Silo Utility Building complex including development of silo area (i.e. paving, fencing/boundary-wall, access roads, office block and watchman cabin), miscellaneous equipment foundations, trenches, pipe racks, pedestals/thrust blocks for HCSD pipe supports ( inside the plant boundary) including bridges/ culverts for road/rail/drain/nallah as required. For the ballast-less rail track under silo area complex a 4.0m wide area (2.0 m either side of centre line of railway track) shall be left unpaved along the rail track in complete silo area complex same shall be constructed by railway siding agency. RCC peripheral drains, crossing rail track shall be covered with permanent RCC slab (minimum 150 mm thk.) & construction of these RCC drains such that it will not create any hindrance in construction of rail track. Top of paving level in balance silo area complex shall be governed by the top level of rail track in silo area complex. Steel gates of minimum 6.0m width for entry & exit of railway wagons in silo area complex shall be provided in boundary wall/ fencing of silo area complex. For the hindrance free movement of railway rack on the rail track under Silo following shall be provided however necessary approval shall be taken from the railway authority by successful bidder.
*Horizontal clearance: A minimum clearance of 3.5m shall be maintained between centre line of the Railway track to face of the crossing structure.
*Vertical clearance: A minimum vertical clearance of 8.5m shall be maintained between Rail top level and bottom of structure.

5.05.02 Transport air compressor houses, Conveying air compressor houses, Ash slurry Pump House, HCSD Pump house shall have steel shed building with side sheeting and Silo utility building, shall have RCC framed structure, with RCC columns and profiled metal deck sheet roofing (filled with RCC) supported on steel purlins & truss / girders. Other buildings like MCC /switchgear rooms, control room, etc. shall have RCC framed structure with cast-in-situ RCC roof slabs. Bagging plant Complex building shall be closed steel shed. All RCC buildings shall have brick cladding. Crane girders or monorails shall be provided as per requirement and the same shall be of structural steel construction.

5.05.03 The documents and drawings as listed below are to be submitted for the approval of the Employer unless specified otherwise. The list given below is not exhaustive but indicative only.

a) Project design intent document giving the basis of design, which shall cover all the design philosophy aspects, parameters, assumptions, references, loading cases, load combinations, analysis and design of all buildings, structures, facilities etc. shall be furnished for approval, before commencement of detailed engineering.

b) Structural analysis, design calculations and drawings of substructures and super structures for all buildings/structures, facilities like pump houses/shed, compressor houses, sumps / tanks, channels, pipe support structures, culverts/ bridges, pedestals, thrust blocks transformer yards, etc. shall be submitted for approval of the owner.

c) The design and drawings for the equipment and their supporting structures like bottom ash hopper, buffer hopper/collector tanks, surge tank/settling tank, silos/bins, etc. associated with Ash Handling System, shall be submitted to the Owner for information only. However, the structural design criteria and basis of design as mentioned at (a) above, for these structures also shall be approved by the Owner.

d) Top of RCC pedestal of foundation for bottom ash hopper, fly ash silo, other columns etc. shall be 300 mm above paving level or surrounding finished ground level (FGL).

5.05.04 **DELETED**

5.05.05 The Silo utility building complex shall be fenced with chain linked fencing, if placed inside the plant boundary and shall be confined with boundary wall if placed outside plant boundary. Gates shall be provided for rails, truck movement and transformers. The boundary wall shall be of one brick thick of height 2.4 m with a 600 mm high galvanized concertina at top, such that total height is 3.0 m above formation level. The fencing shall be PVC coated G.I. Chain link of minimum 4 mm thickness (including PVC coating) of mesh size 75mm x 75 mm and of height 2.4 m above toe wall. The toe wall shall be 1 brick thick, minimum 200 mm high above paving/formation level and 300 mm below paving/formation level on 75 mm thick PCC (1:4:8) bedding. Entire area in the silo area complex shall be paved and have a peripheral RCC drain of adequate capacity & slopes covered with perforated precast RCC slabs of minimum 150 mm thickness with provision of openable galvanized steel grating covers of 1.0 m at every 4 m interval .The complex shall be provided with a sump for collection of ash water. In addition to the outer confinement, additional fencing with gates should be provided for all transformers in the complex. A watchman cabin with a minimum area of 5 Sq.m shall also be provided in this area.

5.05.06 Pipe supports shall be provided for ash slurry pipes—HCSD–pipes, dry fly ash(FA) pipes including RCC thrust blocks and any other supports required to complete the system. Over-ground pipes shall be supported on RCC pedestals except for FA pipes which shall be on elevated steel trestles. Unless noted otherwise, the top of concrete pedestals shall be minimum 500 mm above surrounding ground level/paving level. Pipes shall be suitably anchored with RCC pedestals to resist lateral and vertical movements as per system requirement. Conveyor Galleries, Trestles, Trasfer points shall be provided for Dry Bottom ash system

5.05.07 **DELETED**

5.05.08 Where the pipes are crossing the road through RCC box culverts, the culvert top generally, shall not be not more than 100 mm above the road top and a hump with slope of 1:35 shall be provided on the road. All other road crossings inside the plant area can be either underground or overhead road crossings with necessary headroom clearance. For any boundary wall crossings, pipe shall be laid through casing pipe / RCC culvert. After laying the pipe, the boundary wall shall be restored. For other water body crossings, such as local Nallah / canal, local water bodies, local drains etc. suitable structural arrangement with 800 mm wide walkway shall be provided. Minimum clearance of the bottom of pipeline for all such locations shall be 1.50 M above the High flood level (HFL). Bidder to take all statutory clearance from concerned authorities for crossing his pipe/trestles over road / rail / culverts / nallah etc. at his own cost and initiative, without any commercial implication to the owner. For any other additional works,

bidder have to make their own assessment too of the quantity/ number of culverts, existing pipe pedestal crossings, nallah crossings etc., based on their site visit before quoting.

5.05.09 All ash handling system pipe crossings with Railway Lines including MGR lines shall be laid by method accepted by concerned railway authorities for existing rail lines & by cast in situ RCC box culvert for future envisaged rail lines. The railway track crossings are to be designed in accordance with railway Standard/RDSO guidelines and all necessary approvals from the concerned Railway authorities shall be obtained by the Bidder, without any financial implications to the owner.

5.05.10 **DELETED**

5.05.11 All liquid retaining structure shall be designed by working stress method as per IS 3370 (Part-1&2):2009. The thickness of base slab in liquid retaining/ carrying structures shall be minimum 150mm. Minimum grade of concrete for liquid retaining structures like Sumps/tanks/drain sumps etc shall be M-30.

5.05.12 For liquid retaining structures, the minimum reinforcement in each direction shall not be less than 0.24% of the gross cross-sectional area.

5.05.13 All liquid retaining structures shall be tested for leak proofness with full water level in accordance with clause no.12 of IS 3370(Part 1):2009 and IS 6494.

5.05.14 All pump houses and other substructures shall be checked for stability as per the following guidelines:

a) Stability of structure against sliding during construction as well as operating conditions for various combinations of applied characteristic loads. In case where dead load provides the restoring moment, only 0.9 times the characteristic dead load shall be considered. Factor of safety against sliding shall not be less than 1.4 under most adverse combination of applied characteristic loads.

b) Stability of structure as a whole against overturning. It shall be ensured that the resisting moment shall be not less than the F.O.S. times the maximum overturning moment. Factor of safety against overturning shall not be less than 1.2 due to characteristic dead load and shall not be less than 1.4 due to characteristic imposed load.

c) Stability of structure against uplift due to the ground water table at finished ground levels during construction and after construction stages. Minimum factor of safety of 1.2 against uplift shall be ensured considering 0.9 times dead weight, empty condition inside and ignoring the superimposed loadings. Inclined wedge action shall be limited to 15 degree with vertical plane. Provision of pressure relief valve / flap valves etc. shall not be permitted to counter the uplift. Also FOS against uplift, to be taken as 1.0 considering the dead weight of structure and soil resting on side projections, if any, in the vertical plane. Inclined wedge action of soil shall not be considered in this case.

5.05.15 **Architectural Features of Ash Handling System Buildings**

a. Building shall have Aluminium and Steel doors/ windows/ rolling shutters / ventilators.
b. Safety norms shall be followed as applicable. The buildings shall be provided for Pump houses, Switch Gear Room, Control Room etc. as per ash handling system requirements.
c. External finish shall be of premium acrylic smooth exterior paint with silicon additives.
d. All the air conditioned rooms shall be provided with hermetically sealed double glazing in windows and false ceiling.
e. Encased staircase shall be provided for double storeyed buildings and cage ladder shall be provided for roof access in single storeyed building.
f. Each building shall have one toilet block with drinking water facility.

**5.06.00 FGD SYSTEM**

5.06.01 The civil works for FGD system shall comprise of civil, structural and architectural works below and above ground level of FGD control room building, slurry re-circulating pumps & oxidation blowers building, tank foundations, absorber tower foundation, MCC building, gypsum dewatering building, transformer foundation, equipment foundations, pipe & cable gallery/ trestles, drainage, sanitation, water supply (from terminal points to various buildings/facilities) and all other civil, structural and architectural works associated with the complete FGD system specified elsewhere in this specification. Bidder may also refer terminal points & exclusions in this regard.

5.06.02 **Buildings for FGD System**

FGD System may comprise of various buildings based on the functional requirement viz. MCC/Control room building, Gypsum dewatering building, re-circulating pumps & oxidation blowers building, Gypsum storage shed etc.

5.06.02.01 **Control building, M. C. C. Buildings**

These shall be steel/RCC framed building with RCC roof and floor. For steel framed building roof /floor shall comprise of RCC slab over profiled metal deck sheets (to be used as permanent shuttering only) over structural beams. Cladding shall be of brickwork/concrete block work with plastering on both sides. Roof shall be provided with roof water proofing treatment, as specified elsewhere in the Technical specification. Suitable arrangement shall be provided so as to prevent ingress of water into the cable trenches inside the building from cable entry locations. All air - conditioned areas, shall be provided with false ceiling system (details specified elsewhere) with under deck insulation.

5.06.02.02 **Not Used**

5.06.02.03 **Gypsum Dewatering Building**

This shall be steel framed building with R. C. C. roof and floor. For steel building roof /floors shall comprise of RCC slab over profiled metal deck sheets (to be used as permanent shuttering only over structural beams). Cladding shall be of single skin metal sheeting or brickwork/concrete block work with plastering on both sides. Roof shall be provided with roof water proofing treatment, as specified elsewhere in the Technical specification

5.06.03 **Booster Fan foundations**:

Fan foundations shall be RCC block foundation directly resting on virgin soil/ pile below Ground level. The vertical faces of this block foundation shall be isolated from adjacent footings by providing minimum 100mm thick polystyrene board of type-1 conforming to IS: 4671 with density 20 kg/cum sandwiched between the vertical face of block foundation and 230 thick brick wall all round.

ii) **Design Concept:**

a) For the foundations of Fans etc. detailed static and dynamic analysis shall be done.

b) Wherever block foundation is adopted by the bidder for FAN foundations, suitable provisions to be ensured by the bidder in their General Arrangement and design to prevent transmission of vibration from these machine foundations to other nearby structures / foundations.

The bidder or his consultant should have adequate prior experience in design of machine foundations and the machines should be in successful operation for at least one year prior to the date of submission of bid.

5.06.04 Pipe and cable gallery/ trestles shall be as per details given in clause no. 5.02.08.

5.06.05 **RCC Floors, Paving & Grade Slab details**

Passages shall be provided inside the FGD area connecting to the outer periphery road to have access to the various facilities/buildings. These passage areas shall be provided with heavy duty paving for movement of heavy vehicles. The top surface of the passages shall be finished with 50 mm thick metallic hardener topping. Heavy duty paving shall also be provided for the areas in the equipment lay down area, unloading & maintenance area, storage area with 50 mm thick metallic hardener topping.

Lightly loaded areas such where no heavy traffic movement is envisaged shall be provided with Normal Duty paving. However, corridors below pipe/cable trestle gallery where no traffic movement is envisaged and in the area over the buried fire water pipes shall be provided with interlocking concrete blocks of minimum M35 grade and minimum 80 mm thickness underlain by 20mm thick layer of sand followed by 200mm thick 63 mm and down aggregate with interstices filled with selected moorum/ non-expansive soil.

All facility/buildings shall be provided with 750 mm wide plinth protection all around. It consists of 50 mm thick P.C.C. M-20 grade with 12 mm maximum size aggregate over 200 mm thick stone soling using 40 mm nominal size rammed, consolidated and grouted with fine sand.

An area of minimum 7.5m width all around the tank foundations and other facilities/buildings shall be paved. This paving shall be beyond the extent of plinth protection. Further, heavy duty paving shall be provided for passages connecting the outer periphery road to have access to the various facilities/buildings.

Wherever multiple FGD facilities are located in a cluster in the areas proposed for FGD, the entire extent of the cluster shall be provided with area paving maintaining minimum 7.5 m width around the facility buildings. Paving shall be extended up to nearest road for easy access to FGD facilities. Any functional requirement of paving for FGD facility not specifically mentioned in this document is also in scope of bidder.

**GRADE SLAB OF BUILDINGS AT GROUND FLOOR**

In buildings, the grade slab shall consist of 150mm thick RCC M25 grade base slab over an under bed as specified below. The under bed for ground floor slab shall consist of 75mm thick 1:4:8 PCC on stone soling of 200mm compacted thick with 63 mm and down aggregate with interstices filled with well graded selected sand/ moorum/ non-expansive soil on compacted and dressed sub - grade. Reinforcement for the slab shall consist of minimum 8mm dia. bars @ 200 mm c/c at top & bottom of the slab in both directions. However, at unloading & maintenance area, gypsum storage shed stone soiling of minimum 400mm thick and grade slab with minimum 10mm dia bars @ 200 mm c/c at top and bottom in both directions shall be provided.

Further, top surface of grade slabs shall be finished with 50mm thick metallic hardener topping.

5.06.08 Bidder shall provide permanent access to all facilities/structures from the nearby existing roads of the Owner.

Roads shall be of concrete as per IRC standards, with minimum thickness of pavement (PQC) as 250mm (in M 35 grade) and DLC of 150 thick (in M 10 grade). Double lane road (width 12m having 7.5m wide pavement & 2.25m wide shoulders on both sides) shall be provided.

**5.07.00 SEWERAGE SYSTEM:**

Complete sewerage system including Sewage Treatment Plant for facilities within the plant is in bidder's scope. Bidder shall provide 'De-centralized Sewage Treatment' units. The capacity of the Decentralized Sewage Treatment' units should be as per the design requirements, subject to minimum combined capacity of 75 Cum/day.

Design of Sewage treatment plant shall be as per CPHEEO manual. Primary, Secondary and Tertiary treatment to be provided. Treated sewage water shall be used for horticulture purpose as per quality requirement of CPHEEO manual.

Cement concrete pipes of class NP-3 as per IS 458 shall be used below ground level for sewage disposal in all areas other than main plant area. However, for pressure pipes and in main plant areas, and under roads spun Cast Iron pipes conforming to IS 1536 of required class shall be used. RCC manholes with CI cover shall be provided at every 30m along the length, at connection points, and at every change of alignment, gradient or diameter of a sewer pipeline. This shall be as per IS 4111.

Sewage pump stations shall be provided as per IS 4111.

Bidder shall have to provide complete arrangement for sewage disposal up to the sewage treatment plant including pumping facilities.

**5.08.00 Plant Storm Water Drainage System**

Complete storm water drainage system of Plant area is in bidder's scope. Storm water drain shall be designed taking into account the finished ground levels of the plant & surrounding area, drainage pattern, intensity of rainfall, etc. These values shall be based on minimum rainfall intensity of 75mm/hr. All RCC drains shall be either RCC Cast-in-Situ or RCC Pre-cast drains. The minimum grade of concrete shall be M25 for RCC Cast-In-Situ drains and M30 for RCC Pre-cast drains.The maximum velocity for RCC open drains shall be limited to 1.8 metre per second. However, minimum velocity of 0.6 metre per second for self - cleansing shall be ensured. Bed slope not milder than 1 in 1000 shall be provided. The inside drain dimension at any point should not be less than 0 .45m (height) x 0.75m (breadth).

Open RCC rectangular section, unless required otherwise due to functioned requirement, shall be provided for all drains. The thickness of side walls and bottom slab of RCC drains shall be minimum 150mm or as per design considerations whichever is higher for drains upto depth of 1m from formation level. For depth of drain more than 1m from formation level, the thickness of side walls and bottom slab of RCC drains shall be minimum 200mm or as per design considerations whichever is higher.

The drains shall be provided on both sides of the double lane roads and single lane roads. The drains shall be provided on one side of the patrol roads along boundary wall. These shall be designed to drain the road surface as well as all the free and covered areas, etc. Box culverts shall be provided at all rail, road and other crossings.
Layout of drain shall be as per layout given in tender drawing "Layout of drain'.

Complete drainage upto outfall point to be completed to avoid flooding in the respective area.

**5.09.00 TRANSFORMER FOUNDATION**

Foundations of transformers shall be designed for seismic and wind loads in addition to other applicable loads. Solid RCC block foundation shall be provided for the main transformer block. Alternatively, transformer shall be supported on a RCC foundation comprising of common raft for rail supporting walls up to rail-cum-road along with pedestals for jacking pad, roller lock etc. Tie beams connecting roller lock pedestals at rail level shall also be provided. Common raft/solid RCC block shall be supported on soil or pile based on requirement specified elsewhere in the specification.

Oil soak pit / oil water separation pit for transformer shall be provided as envisaged elsewhere in the specification.
The oil soak pit shall be provided for each transformer and shall be filled with gravel of size 40mm. The volume of the soak pit shall be sufficient to store one-third (1/3) of the oil volume of transformer/reactor considering only 40% of the volume as available voids between gravel filling. The oil soak pit shall also be provided with a sump at the corner to allow drainage of water/oil from the soak pit. Oil soak pits sump of individual transformers shall be connected to common oil retention /oil water separation pit through hume pipes and manholes.
Separate common oil retention pit/oil water separation pit shall be provided for a group of transformers in transformer yard area of each generation unit of plant.
The Oil-water Separation pit shall be designed for an effective capacity of complete oil of one transformer having highest volume of oil along with 10 minutes of firewater. For calculating effective capacity of oil-water separation pit, effective depth excluding 200 mm freeboard below invert level of inlet pipe shall be considered. Plan area and depth of oil-water separation pit shall be decided based on above consideration.
Oil-water Separation pit shall be provided with five separate chambers interconnected by pipes.
First chamber shall be for collecting oil-water mix from transformers' soak pits in case of fire. After entering into first chamber, oil being the lighter in density floats above the water. The water from lower elevation flows in to subsequent chambers interconnected through galvanized MS pipes. The accumulated oil in the first chamber to be pumped out for subsequent usage or disposal. Water collected in the last chamber to be pumped out for subsequent disposal after treatment. Invert level of inlet Hume pipes (of NP-3 grade and adequate capacity), carrying oil and water from transformers soak pits, shall be designed for gravity flow. Freeboard of 200 mm shall be provided below the invert level of inlet pipes. Invert levels of interconnecting pipes of subsequent chambers shall be decided accordingly.
Arrangement for moving the transformer into place using rail cum road, jacking pads and pulling blocks including inserts, as required, shall be provided along with the transformer/reactor foundations.
RCC Firewall shall also be provided between the transformers wherever required.
300 mm thick PCC M20 encasement all around the Pylon supports inside soak pit for firefighting system shall be provided up to top of gravel filling. However, the supply and erection of Pylon supports with anchor fasteners for HVW spray system are not under the scope of this package. Coarse aggregate filling inside the transformer oil soak pit shall be carried out only after construction/erection of Pylon supports and PCC encasement.

**5.10.00** **Roads**

All roads shall be of rigid pavements unless otherwise specified. Rigid pavements shall be constructed with Geopolymer concrete. Concrete road/pavement or rigid pavement, mentioned in specification, shall mean road /pavement constructed with Geopolymer Concrete. All concrete roads shall be unreinforced jointed plain concrete pavement having dowels in transverse joints and tie bars at longitudinal joints.

A 40mm bitumen mastic wearing course over concrete pavement shall be provided with industrial bitumen of grade 85/25 conforming to IS : 702, prepared by using mastic cooker and laid to required level and slope, including providing antiskid surface with bitumen fine grained hard stone chipping of approved size at the rate of 0.005 precoated cum per 10 sqm and at approximate spacing of 10 cm centre to centre in both directions, pressed into surface protruding 1 mm to 4 mm over mastic surface, including cleaning the surface, removal of debris etc. all complete. (Considering bitumen using 10.2% as per MORTH specification).
This 40mm bitumen mastic wearing course shall be laid after completion of construction activities i.e at the time of handover.

All the road shall again be repaired/made good as per IRC : SP :83 after completion of construction activities i.e at the time of handover.

All service and utility lines like fire water line, sewerage line, electric cables line etc. crossing the road shall be taken through NP3 class RCC Hume pipe. Hume pipe shall be laid before road work so that the road shall not be damaged.

Construction of road work shall be as per priorities given in Tender drawing 'Layout of Road Drawing'.

5.10.00.01 **For road to be constructed with Geopolymer Concrete:**

The design of rigid pavement shall be carried out as per IRC: 58. The effects of design wheel load, maximum tyre inflation pressures, tyre contact area for the vehicle, traffic loads, environmental factors such as temperature changes in the pavement, other factors, like impact, load repetitions, etc., are to be taken. The design traffic load shall be a minimum value of 4 million standard axles. The road shall be designed for 30 years of life and considering a minimum traffic growth rate of 1 per cent per annum. The concrete pavement for roads shall be minimum 250 mm thick slab.

The road construction including its shoulders, base, sub base and concrete pavement shall be as per MORTH. The road base shall be with minimum 150 mm thick dry lean concrete over granular sub base. Dry lean concrete shall be laid by a mechanical paver and compacted by vibratory rollers. Concrete pavement of the road shall be done with fully mechanized paver fitted with electronic sensors for construction techniques. Laying /placing of Concrete DLC and PQC manually with hand-guided means or by semi-mechanized methods may be permitted around BTG area provided acceptance criteria as per MORT&H specification is achieved. Dry lean concrete shall be minimum M10 grade and concrete pavement slab shall be minimum M35 grade concrete pavement shall be provided with 125 micron polythene sheet below it. Concrete pavement shall also be provided with contraction and expansion joint with MS dowel bars and as per Ministry of Road Transport and Highways (MORTH) specification.

The finished top (crest) of all roads shall be 350 mm above the surrounding finished ground level.

All culverts and RCC bridges at crossings of all roads / rail tracks / facilities with drains / nallahs / channels / roads / rail tracks / pipes / other facilities, etc. are to be designed and constructed.

Unless otherwise specified, all roads (excluding access roads to all buildings / facilities / structures, patrol road along boundary wall and road inside the switchyard) shall be double lane roads.

5.10.00.02 Geo-polymer concrete road shall be constructed over soil sub-grade/embankment. Road section shall comprise of Granular Sub base over soil sub-grade, Dry Lean Concrete of M10 Grade (DLC) base and Pavement Quality Concrete of M35 grade (PQC) top layer. Thickness of different layers of pavement section shall be as per design. However, minimum thickness shall be 150 mm for DLC and 250 mm for PQC. Provisions of Clause 5.10.00.01 in respect of design, construction and other requirement shall also be applicable for Geopolymer concrete road. In addition, specific information pertaining to geopolymer concrete is provided in Chapter D-1-8.

5.10.01 **Double Lane Roads**

The double lane roads shall be (12 metre wide) with 7.5 metre wide concrete pavement and 2.25 metre wide raised shoulders on both sides of the roads as given in tender drawing "Details of road" .

5.10.02 **Single Lane Roads**

All access roads to all buildings / facilities / structures, road approaches / connections, access roads to liquid fuel storage areas and other equipment areas where access is necessary from inspection, operation and maintenance point of view and all roads inside the switchyard shall be single lane roads as given in tender drawing "Details of road".

5.10.03 **PATROL ROADS**

All patrol roads along the boundary wall shall be single lane roads with 3.75 metre wide concrete pavement and 1 metre wide shoulders on one side of the road. as given in tender drawing "Details of road".

5.10.04 Intermediate Road

The intermediate lane roads shall be ( 8 meter wide) with 5.5 meter wide concrete pavement and 1.25 meter wide raised shoulders on both sides of the road as given in tender drawing Details of Road.

*Concrete roads anywhere mentioned in specification shall be read as Geo-polymer concrete road.

**5.11.00 DELETED**

**5.12.00 Fuel Oil Handling system**

The civil works are to be provided for following fuel oil handling system areas as mentioned below:

a. Fuel Oil pressurizing pump house.

b. Foundation and dyke wall and all associated works for LDO tanks.

c. Pedestals and foundations to support the interconnecting piping between LDO tanks to the pressurizing pumps as well as piping from tanker unloading area to the Unloading pump house and further on to the LDO tank.

d. Oil water separator pit.

5.12.01 **Fuel Oil Pressurising Pump House**

**Salient Features:**

This building shall be a single storeyed framed superstructure with RCC columns, structural steel roof truss (with rafter and tie level plan bracings), purlins and roof slab. The roof slab shall comprise minimum 40 mm thick (above the crest of metal deck sheet) RCC slab supported on profiled metal deck sheet connected through shear anchor studs. Waterproofing of Roof slab shall be done as per architectural specifications. The building shall be completely covered with 230mm thick brick wall with provisions for fire proof doors, windows, rolling shutters. The basement RCC slab and RCC wall shall be designed as for uplift and external surcharge load as per the design criteria specified elsewhere. All pump foundations shall be designed for both static and dynamic loading. The building shall have separate enclosures for the control room and the switchgear room. All rainwater down comers shall be concealed with brick wall. The minimum floor area of this building shall be as per the equipment layout plan of the bidder/ EPC contractor.

**Design Concept:**

The grade of concrete shall be M 25 for all columns, beams, footing and slabs. The building shall be designed as per IS: 456, IS 800, IS 1893, IS 13920 (for ductility detailing).

5.12.02 **Fuel Oil Storage Tank Foundations**

The Fuel Oil Storage Tank foundations shall be either RCC raft or RCC Ring Beam system with compacted infill. The RCC raft /RCC ring beam shall be supported on virgin soil or pile foundation depending on the load bearing capacity of the soil. The tank bottom base plate shall

be supported on flexible compacted fill comprising 75mm thick Bitumen aggregate mix on top and compacted sand/ soil fill below, compacted in layers of 200mm to minimum 85% relative density as per IS:2720. The bitumen-aggregate mix shall consist of compact crushed stone, screenings, fine gravel, clean coarse sand(river sand ) mixed in hot asphalt (8 to 10 percent by volume) and rolled or compacted. In the GA & detailing of foundation RCC ring wall/ beam it should be ensured that no bearing stress from tank superstructure is transmitted to the concrete surface. The top of flexible compact fill and top of RCC Circular wall shall be atleast 325mm above the surrounding ground surface for effective drainage.

The finished tank grade (Top surface of flexible compact fill) shall be crowned from its outer periphery to its centre at a slope of 1 in 100.

The Tank foundations shall be inside a RCC dyke wall enclosure. The entire area outside the tank foundations and within the surrounding RCC dyke walls shall be paved with concrete. The thickness of concrete paving shall be minimum 100mm.The single layer reinforcement in paving slab shall be min 10 Tor@200c/c. The area paving RCC slab shall be supported on 230mm thick Rubble soling with the internal voids filled with coarse sand. The height of the RCC dyke wall shall be evaluated based on the depth of Oil spillage for full oil volume of one storage Tank in addition to a free board of 300mm. Structural steel cross over ladder shall be provided (min 2 numbers) for each RCC wall dyke enclosure. Operating platforms wherever required as per functional requirement shall be provided.

5.12.03 **DELETED**

5.12.04 **DELETED**

5.12.04 **Oil Water Separator Pit**

The Oil-Water Separator RCC structure (pit) shall be designed as an underground structure. The sizing of the separator shall be based on the total surface run-off from the Fuel Oil Handling area and Hydraulic design for the oil separation. Surcharge load and ground water table up to ground surface shall be considered in addition to other functional loads for structural design of RCC wall for the separator pit.

Drainage trenches with proper bed slopes towards the oil-water separator pit shall be provided around the tank foundation. The entire area outside tank foundation shall have slope towards the drain trenches

Foundation for trestles and pedestal foundations, for supporting the pipes, shall be provided wherever required, at appropriate spacing. At pipe bends, necessary thrust resisting arrangement shall be provided.

The entire fuel Oil Handing area shall be fenced all round with minimum 1.50m high metal fencing with provision for gates at key locations.

Seismic design shall be carried out for the Fuel Oil Storage Tank foundation, Fuel Oil Unloading Pump House & the Oil water separator.

5.12.06 **Architectural Features of Fuel Oil Handling Buildings**

Spaces for Pump Rooms, MCC Rooms, Control Rooms etc. shall be provided as per functional requirement. One Toilet block with drinking water facility shall be provided in each building.

External finishing shall be of Premium Acrylic Smooth Paint with Silicone additives over suitable primer of water proof cement.

**5.13.00 AREA PAVING**

RCC paving of minimum 150 mm thick with M25 grade concrete, over an under bed as specified herein shall be provided for areas mentioned below. RCC paving shall be designed as rigid reinforced concrete pavement for the crane/ vehicular/ equipment movement loads which the paving has to bear. The under bed for paving shall consist of preparation and consolidation of sub-grade to the required level, laying of stone soling of 200mm compacted

thickness for normal duty paving and 400mm compacted thickness for heavy duty paving with 63 mm and down aggregate with interstices filled with selected moorum/ non-expansive soil followed by 75 mm thick 1:4:8 PCC (1 part cement, 4 parts sand and 8 parts stone aggregate) with 40 mm nominal size aggregate. For normal duty paving, reinforcement of the RCC paving shall consist of minimum 8mm diameter bars @ 200 mm c / c in both directions at the centre of the slab. For heavy duty paving/ passage, reinforcement of the RCC paving shall consist of minimum 10mm diameter bars @ 200 mm c / c in both directions at the centre of the slab.

Paving areas shall be provided with the metallic hardener floor finish as specified elsewhere in the specification.

Passages shall be provided inside the main plant block connecting to the outer periphery road to have access to the various facilities/buildings. These passage areas shall be provided with heavy duty paving for movement of heavy vehicles. The top surface of the passages shall be finished with 50 mm thick metallic hardener topping. Heavy duty paving shall also be provided for the areas in the complete Mill bunker building and handling areas for PA/FD/ID fans with 50 mm thick metallic hardener topping.

Ground floor area in the boiler shall be provided with normal duty paving and shall be finished with 50 mm thick metallic hardener topping.

Ground floor area in the ESP envelope shall be provided with normal duty paving with neat cement punning. Wherever paving is envisaged to be provided, RCC paving shall be provided. However, corridors below trestle where no traffic movement is envisaged and in the area over the buried fire water pipes shall be provided with interlocking concrete blocks of minimum M35 grade and minimum 80 mm thickness underlain by 20mm thick layer of sand followed by 200mm thick 63 mm and down aggregate with interstices filled with selected moorum/ non-expansive soil.

All other areas inside the Main plant block shall be provided with normal duty paving without metallic hardener topping.

Suitable open RCC drains shall be provided to dispose off storm water drain. Separate open RCC drains shall be provided to dispose off floor wash and plant effluents into RCC sump pits. Separate RCC sump pits shall be provided for different types of effluents. The paving shall be provided with slope of 1:500 to dispose the surface water/wash water to the nearest drain. All drains/pits shall be provided with Heavy duty electro forged GI grating cover.

Sewer lines (Cast Iron), interconnected by sewer manholes (RCC) at regular intervals (not exceeding 30 meter centre to centre) shall be provided to dispose off sewage from main plant block.

For the purpose of area paving, Main plant block is defined as the entire area enclosed between peripheral roads encompassing the Transformer yard area, Main Plant Building area, Boiler area, ESP area, Chimney area & FGD area.

5.13.01 **Ground Floor Slab of Buildings**

| | |
|---|---|
| | In all buildings including main plant building, the ground floor slab shall consist of minimum 150mm thick RCC M25 grade base slab over an under bed as specified below. The under bed for ground floor slab shall consist of 75mm thick 1:4:8 PCC on stone soling of 200mm compacted thick with 63 mm and down aggregate with interstices filled with well graded selected sand/ moorum/ non-expansive soil on compacted and dressed sub - grade. Reinforcement for the slab shall consist of minimum 8mm diameter bars @ 200 mm c/c at top & bottom of the slab in both directions. However, at passages, unloading & maintenance bays, stone soiling of minimum 400mm thick and minimum 10mm diameter bars @ 200 mm c/c at top and bottom in both directions shall be provided. |
| | Further, top surface of ground floor slabs shall be finished with 50mm thick metallic hardener topping. |
| 5.13.02 | **Civil Works for Fire Detection & Protection System in Ground Floor/ Paving** |
| | Fire water pipes shall be provided with either RCC trench/buried underground/on pedastal. |
| | Fire water trenches shall be open RCC type trench with removable RCC cover. RCC valve pit alongside trenches and RCC fire trenches crossing drains shall also be provided as per requirement. |
| | Interlocking concrete block paving shall be provided over the buried fire water pipes as specified elsewhere in the specification. |
| | At road/ drain crossings, NP3 class hume pipe encased in RCC shall be provided as per requirement at a depth of minimum 1m from FGL for routing of fire water pipes. |
| | In case of rail crossings, NP4 class hume pipe encased in RCC shall be used instead of NP3 class hume pipe. |
| | Each of the outdoor deluge valve and accessories shall be provided with housing comprising of Brick wall and RCC roof. |
| **5.14.00** | **DELETED** |
| **5.15.00** | **DELETED** |
| **5.16.00** | **DELETED** |
| **5.17.00** | **Induced Draft Cooling Towers** |
| | The civil , structural and architectural works for cooling towers are related mainly to following areas, but not limited to: |
| 5.17.00.01 | Cooling Tower Basin |
| | The basin of the cooling tower for collection of cold water shall be made of Reinforced Cement Concrete (RCC M - 30 grade as per IS: 456). The floor of the basin shall be sloped to minimum 1 in 80 towards the sludge drains. The required slope shall be achieved by screed concrete of grade M-15 as per IS:456 having minimum thickness at edge as 25 mm. Drainage arrangement of basin shall be as specified elsewhere in the Technical Specifications. If the cooling tower basin and sludge sump is below ground level, FRP hand railing shall be provided all around the cooling tower basin and sludge sump pit. The bottom 500 mm of hand railing shall also have FRP/PVC wire mesh with opening size of 50mm grid to avoid ingress of leaves, vegetation, and debris into the basin. The basin shall be tested for water tightness as per IS:3370. |
| | Bottom of the lowest level beam shall be at least at free board level. In case, the beams are provided into the water, the same shall be designed for un-cracked section as per IS:3370. |
| | The outlet channel shall be covered on top with removable precast concrete slabs for about 5m length from cooling tower basin and the entire length of cold water outlet channel shall be provided with 32 NB (Medium) G.I pipes. Hot water duct around cooling towers, if placed below ground shall be encased with min. 500mm thick PCC (M20 grade). |

**a) Foundation of Cooling Tower**

The foundation of the Cooling Tower shall be as detailed out elsewhere in the specifications.

**b) Super Structure of Cooling Tower (applicable in case of RCC cooling tower)**

Columns, beams and other structures like tie beams, slabs etc. shall be of reinforced cement concrete of grade M-30 (minimum) as per IS : 456. Uniform concrete grade shall be used for the entire cast-in-situ reinforced concrete superstructure.

The fan deck slab shall be properly sloped so that rain water does not accumulate over the deck slab. The slope shall be 1 : 120 (min.). The slope shall be provided with screed concrete of grade M-15 (minimum) as per IS : 456.. Fan Deck slab and all other over ground platforms shall be provided with FRP handrailing. Suitable arrangement for drainage of rain water to be provided. However, there is no specific requirement of Rain Water down comers.

**c) Cells, Distribution System and Stack (applicable in case of RCC cooling tower)**

Cooling tower cells shall consist of RCC columns, beams and walls. The spacing of columns shall be minimum 4000 mm c/c. Inclined bracings shall not be provided between the columns. Hot water distribution channel shall also be of RCC. Cell division partition walls shall be of precast solid concrete blocks with provision of pilasters for walls, if required. The peripheral wall shall be Cast-in-Situ RCC wall and shall have two layers of reinforcement on either faces in both directions with minimum dia of reinforcement bars as 8 mm and maximum spacing as 150 mm c/c. Minimum thickness of Cast-in-Situ RCC peripheral walls shall be 200 mm.

Hot water channel shall be covered with suitably designed precast / cast - in - situ concrete slab. Wherever flow control valves are located over hot water basin, these shall be placed over precast concrete covers / concrete slab and designed for specified load. The minimum thickness of RCC fan stack shall be 150 mm. The fanstack shall have two layers of reinforcement on either faces in both directions with minimum dia of reinforcement bars as 8mm and maximum spacing as 200mm c/c.

**d) Stairs**

RCC staircase for approach to fan deck for each cooling tower shall be provided. The stairs shall have 1000 mm clear width and FRP hand railing. The riser shall be maximum 175 mm & treads 250 mm (minimum). Edge protection angle (min 35X35X6, made of aluminum) shall be provided to the treads with the lugs.

**e) Steel Structures**

All mild steel parts of structures used in cooling towers shall be hot dip galvanized or seal spray zinc coated as per BS:5493 (for a very long period of maintenance of more than 20 years). The minimum coating for galvanization shall be 610 gm/sq.m and shall comply with relevant IS Codes. Galvanizing shall be checked and tested in accordance with IS: 2629. All welding shall be done before galvanizing. Any site joints required to be carried out after galvanizing shall be either flanged or screwed joints. Nails, nuts, bolts and all components coming in direct contact with water shall be of stainless steel of SS 316.

**f) Water proofing of structures and construction joints**

For water proofing of underground structures including basin slab and hot water distribution channel, water proofing cum plasticizer compound shall be mixed with the concrete. In addition Chemical injection treatment shall be provided for the construction joints of all underground structures.

**g) Expansion Joints**

PVC sealing strips shall be used for all expansion joints where water is retained. The minimum thickness of PVC sealing strip will be 6 mm (minimum) and minimum width 225 mm. The expansion joint shall be as per IS: 3370. At expansion joints, joints filler material with sealing compound on both sides shall be provided throughout the length of the joint.

**h) Grade of concrete**

All RCC associated with induced draught cooling towers including switchgear and control room, unless specified otherwise, shall be design mix (controlled) concrete of grade M 30 of IS: 456. Water - cement ratio shall not exceed 0.45.

Minimum 75 mm thick PCC of grade M-7.5 as per IS: 456 shall be provided as mud mat below foundation unless specified otherwise. The PCC shall extend 75 mm beyond the outer edge of structural concrete.

For water retaining structure minimum 100 mm thick PCC of grade M-10 as per IS:456 shall be provided as mud mat below the bottom slab / raft. The PCC shall extend 100 mm beyond the outer edge of the structural concrete.

**i) Form-Work**

Plywood Form-work shall be used for basin, basin walls, outlet channel and super structures.

**j) Doors (applicable in case of RCC cooling tower)**

FRP door shall be provided in each fan stack at fan deck level. Door height & width as per requirement for equipment movement (clear) shall be provided. However, door size shall be minimum 2100 mm high (clear) & 1200 mm wide (clear). Door shall have locking facility.

**k) Coating**

All concrete surfaces in direct contact with water/ water spray/moist air shall be applied with Moisture Compatible Corrosion Resistant Coating System or its equivalent as specified in Annexure-G. All concrete surfaces subject to water/ water spray/moist air upto and including Fan Deck slab level including basin slab, inner faces of peripheral walls, all faces of cell partition wall, all faces of columns, all faces of beams (both cast in situ and precast), bottom surface of fan deck slab for counter flow tower and both surface of fandeck slab for cross flow tower, inner face of fanstack, all faces of hot water basin (for cross flow tower), etc as applicable shall receive the said coating after cleaning and drying of the concrete surface. The detailed specification of the coating system on concrete surfaces is given in Annexure-G.

External surfaces of Cooling tower peripheral walls and fanstack shall be painted with two or more coats of waterproof cement paint of approved shade, make and color.

**l) Paving**

Paving shall be provided for a minimum clear width of 5.0 m from the outer face of the HW pipes all around the cooling tower basin. Paving shall also be provided in between the hot water pipes and space available between HW pipes and CT basin wall spray catcher. The minimum total width of paving around CT basin shall be atleast 8.5 m from outer edge of the spray catcher or basin wall. Paving shall consist of reinforced concrete base slab laid over 75 mm thick PCC of grade M-10 as per IS:456 sub-base and 200 mm thick stone soling. The sub-base shall be laid on the compacted and suitably prepared sub-grade. The degree of compaction of sub-grade shall be as specified elsewhere in the specification. The thickness of the RCC base slab of grade M - 25 shall be suitably designed considering a superimposed load intensity of 5T /

Sq.m. However the minimum thickness of base slab shall be not less than 150 mm having double layered reinforcement in both directions both top and bottom. The maximum spacing of the reinforcement bars shall be 150mm c/c and minimum dia of reinforcement bars shall be 8mm.

RCC peripheral drain of minimum cross sectional dimensions 300mm X 300mm to dispose storm water shall be provided around area paving and shall be connected to nearest Owner's storm water drain.

RCC paving all around cooling towers shall be connected to the existing road so as to provide approach to both cooling towers and switchgear & control room building as indicated in tender drawing. The clear width of this approach road shall be 5.5M and top of approach road shall be 350 mm above FGL.

**m) Walkways**

Permanent walkways at least 1000mm clear width shall be provided at hot water distribution level and at drift eliminator level for counter flow type cooling towers. The clear working height available above these walkways shall be at least 2.0 meters. The walkway and its supporting structure shall be of RCC M - 30 grade. Suitable RCC guards rails 300 mm high shall also be provided on both sides of these walkways. Over the guard rails FRP hand railing shall be provided. The vertical post of handrail shall be 700 mm high and at an interval of 1500mm c/c. There shall be two levels of horizontal pipes for hand railing spaced equally in vertical plane.

Permanent walkways at least 1000 mm clear width shall also be provided for access to fan and around gear box with FRP gratings of clear opening size not more than 50 MM x 50 mm and grating thickness of 50 mm on RCC supports at fan deck Level.

**05.17.00.02 Design Criteria**

**R.C.C. Structures**

(a) The design of all liquid retaining/conveying structures like of cooling tower like C.W. basin, sump, hot water distribution channel/basin, sludge drain and pits shall be designed by working stress method as outlined in Clause 4.5 of IS 3370 (Part 2) : 2009. These structures shall be designed for following conditions :-

1. Water filled inside upto the designed level and no earth outside.
2. Earth pressure plus 2.0 T / $M^2$ surcharge (Vertical direction) plus ground water table at Finished Graded ground Level (FGL) outside and no water inside.

(b) The design of all structures other than liquid retaining/conveying structures of cooling tower above CW basin slab such as columns, beams, fins, walkways, slabs, cladding/partition wall, fan stack, precast beams etc. as applicable shall be carried out by limit state method as outlined in Clause 4.4 of IS: 3370 (Part 2): 2009. Further, for limiting the crack width, the stress for the reinforcement steel shall be limited to 130 MPa (on all faces) as per clause 4.4.3.1 of IS: 3370 (Part 2): 2009 using the partial safety factor for serviceability condition as per clause 4.4.1.3.

Wherever, the foundation raft of cooling tower is same as CW basin slab, the foundation shall be designed by working stress method as outlined in Clause 4.5 of IS 3370 (Part 2): 2009 (all faces). However, if the cooling tower foundation is not the same as the CW basin slab and a separate foundation for the cooling tower is provided below the CW basin slab due to founding level requirements, the basin slab shall be designed as a structural slab resting on grid of beams taking support from columns or as a flat slab taking support from columns. Arrangement with providing walls between the columns and the periphery to support the structural basin slab is not permitted. The CW basin slab (both faces, including beams at CW basin slab level) shall be designed as structural

slab by working stress method as outlined in Clause 4.5 of IS 3370 (Part 2): 2009 and the structures below CW basin slab shall be designed as per IS:456 (2000). However, the size of the column below CW basin slab upto foundation shall be maintained same as the size of the columns just above CW basin slab.

(c) The design of staircase, switchgear building, control room/RIO room, transformer and trestle foundation, storm water drain shall be as per IS: 456 (2000).

(d) The Cold Water basin shall be checked against uplift for basin empty condition with ground water table at FGL. Stability against uplift shall be ensured both for construction & operating stage with no water inside. The provision of flap valve / pressure release valves is not permitted. The factor of safety against uplift shall be as per IS: 3370.

(e) Fan deck shall also be designed for rolling loads due to movement of equipment during Installation / maintenance operation.

Minimum Clear cover for all RCC structures/elements of cooling towers to meet durability requirements shall conform to severe exposure condition as per IS: 456 (2000).

**Fan Supporting Structures (applicable in case of RCC cooling tower)**

**Static Analysis & Design**

The following load conditions and load combinations shall be considered for the design of the Fan supporting structures.

(a) Machine Load

(b) Load case (a) + unbalance load for the balance of the fan corresponding to G16 as per ISO 1940-1: 2003

(c) Load case (a) + unbalance load corresponding to one blade failure load condition.

The strength design of the Fan supporting structure shall be done for worst loading combinations as stated above.

**Dynamic Analysis**

(a) Free vibration analysis

A free vibration analysis of the fan supporting structure including the intermediate supporting structure for motor, gear box and pillow block (if applicable) shall be carried out to calculate the natural frequency of the fan supporting structure and its fundamental natural frequency shall be at least + 20% away from the operating speed of the fan and motor.

(b) Forced vibration analysis

Forced response analysis shall be carried out on the fan supporting structure including the intermediate structure supporting the motor, gear box and pillow block to calculate the vibration amplitudes for the following unbalance condition: -

1. For unbalance load corresponding to G16 as per ISO 1940-1: 2003
2. For unbalance load corresponding to one blade failure condition.

The amplitude derived shall be within the permissible values as specified by the fan manufacturer or IS: 2974 (Part - IV), whichever is more stringent.

**Mid Bearing Supporting Structure**

The intermediate supporting structure for motor, gear box and pillow block if provided shall be so arranged that it does not cause any torsional moments on the beams / pedestals on which the intermediate support rests. The intermediate supporting structure shall be

orthogonal to the grid of beams on which it rests. The motor shall be supported on a base frame. The concrete block supporting the fan/gear reducer shall be connected to immediate lower level of beam column junctions by means of at least four diagonal columns.

**Fan Stack**

The fan stack shall be made of RCC with minimum 150 mm thickness. With reinforcement provided on both faces in either direction. Design of the fan stack shall be made on the basis of relevant stipulations of IS : 11504 for Natural Draught Cooling Towers. The fanstack shall have two layers of reinforcement on either surfaces in both directions with minimum dia of reinforcement bars as 10mm and maximum spacing as 150mm c/c.

**Steel Structure**

These structures shall be designed, fabricated and erected as per IS: 800 (latest revision).

All mild steel parts or structural steel works used in the cooling towers shall be hot dip - galvanised as per IS: 4759 with 610gm/sq.m. coating or seal spray zinc coated as per BS:5493 (for a very long period of maintenance of more than 20 years). Nails and all components coming in direct contact with water shall be of stainless steel of SS 316 or equivalent.

For all steel structures, other than hot water pipes, sludge pipes and hot water distribution pipes, which are outside cooling tower painting shall be as specified in corrosion protection clause. However, for painting of hot water pipes, sludge pipes and hot water distribution pipes, relevant clause for painting specified elsewhere in the technical specification shall be referred.

The minimum cement content as specified in subsequent clauses of this specification shall be applicable for all structures of cooling towers.

**Test for water tightness**

The water tightness of C.W. basin, outlet channel, CW channel and all other water retaining structures shall be tested for water tightness as per the provisions of IS : 3370.

**5.17.00.03 Stoplog gates and Trash racks for Cooling Tower**

Stoplog gate and trash rack/screen shall be provided in the outlet channel of each cooling tower. The design criteria and material specification for Stoplog gates and Trash racks shall be as specified for Circulating Water Pump House.

**5.18.00 CW SYSTEM, RAW WATER SYSTEM CIVIL WORKS**

**5.18.01 Circulating Water Pump House (CWPH), Raw Water Pump House (RWPH)**

5.18.01.01 A circulating water pump house (CWPH) for housing circulating water pumps and Raw water pump house (RWPH) for housing raw water pumps shall be provided. Separate bays shall be provided for each pump by providing intermediate dividing piers of RCC between the pumps.

a) The pump houses shall be provided with minimum two sets of stop-logs for each opening sizes along with electrically operated hoisting arrangements. Steel embedments required for stop-logs shall be provided for all the bays.

b) All bays of pump houses shall be provided with a removable trash rack including electrically operated hoisting arrangements and cleaning arrangements. Moreover, one spare trash rack for each opening sizes shall

also be supplied. Steel embedments required for trash-racks shall be provided for all the bays.

c) Stop-logs, trash-racks and hoists shall be supplied in accordance with the specifications covered elsewhere.

d) The steel structure shall be provided to carry EOT crane of the CW and Raw Water pump houses. The over ground portion of Raw Water Pump House and CWPH including maintenance bay shall be framed structure of structural steel work with permanently colour coated metal sheeting at roof and side open. However 4m high steel sheet side cladding shall be provided at the top under the roof for protection against rain. At the ground level, brick cladding of 0.9m height above the finished floor level, plastered on both sides shall be provided for all pump houses.

e) The pump house including its forebay shall be of RCC with M-30 grade of concrete conforming to IS 456. The CWPH pump house shall be structurally separated from forebay by providing an expansion joint. The pump house shall be provided with separate maintenance bay

f) For Raw Water Pump House (RWPH), connection shall be provided to meet the flow requirement with all necessary arrangement & precautions. Further, associated structure for & including supply of valves/gates are also to be provided for isolation of the connection.

5.18.01.02 Each pump house shall be provided with a separate maintenance bay for maintenance of various equipment. Length of maintenance bay shall be adequate for one pump maintenance or minimum dimension indicated in the tender drawing, whichever is higher. Hand-rail with 32 NB (medium) pipes shall be provided around the operating floor on the forebay side in the stoplog and trash rack area.

5.18.01.03 **Sump model study for CWPH**

Sump model study for circulating water pump house shall be carried out as specified elsewhere in the specification.

5.18.01.04 **Design requirement for CWPH, RWPH**

Design of substructure shall be divided into two parts, namely,

(a) Stability analysis, and

(b) Structural analysis and design.

For the design of substructure, a surcharge load of 2.0 T / Sq.m shall be assumed at the finished ground level for nearby vehicular movement.

**(a) Stability Analysis**

The Pump House sub structure shall be analyzed and designed for following load combinations: -

1. **Under Operation Stages**

   Maximum load from super structure + equipment load + load from sub structure + no water in the pump chambers + earth pressure at rest from outside with surcharge and maximum ground water pressure.

2. **Condition ( 1 ) + earthquake/ wind**

3. **Under Construction Stages**

   No load from super structure and deck slab, load from sub structure with no water in the pump chambers, pump units not installed, earth pressure at rest from sides with surcharge and maximum ground water pressure.

**4. Condition ( 3 ) + earthquake**

Following stability checks will be made for the above load combinations:

**i) Check for overturning**

Factor of safety against overturning, i.e, the ratio of stabilizing moment to overturning moment shall be as per IS: 456.

For the above condition, uplift due to maximum Ground water table (GWT) acting on the base slab and side pressures on the walls due to earth and ground water shall be considered as destabilizing forces. In order to have no tension condition at tip of the base slab, resultant of all the forces acting on the pump house under different conditions of loading as listed above shall fall within middle one third of the base width provided. Maximum compressive stress at other end of the base slab shall be within the safe bearing capacity of soil / rock.

Under earthquake condition, resultant of all the forces including earthquake force shall fall within middle three fourth of the base width provided. An increase of 25% shall be allowed in the safe bearing capacity of soil when earthquake forces are considered.

**ii) Check for Sliding**

Factor of safety against sliding under static condition, i.e. ratio of horizontal frictional resistance to horizontal sliding force shall be as per IS:456. For this condition, earth pressure at rest and the maximum GWT pressure from sides shall be taken as de - stabilizing forces. Keys shall be provided, if found necessary, to increase the factor of safety against sliding.

To ensure an adequate factor of safety under earthquake condition, the factor of safety against sliding shall not be less than 1.2.

**iii) Check for Uplift**

Right from construction to operating stage, minimum factor of safety against uplift due to ground water shall be 1.2. Installation of pressure release valves shall not be permitted in the base slab (raft) of the pump houses to counter the uplift due to ground water.

**(b) Structural Analysis**

**1) Base Slab**

Base slab of the pump houses shall be designed as a raft foundation supported at locations of piers. Following load cases shall be considered:

i. Maximum water level in the sumps with maximum GWT.

ii. No water in the sumps and maximum GWT.

iii. Alternate bays of sumps filled with water with maximum GWT.

iv. Same as in (iii) above but with minimum water level.

**2) Intermediate Piers**

Intermediate piers shall be designed by working stress method as per IS: 456 ( latest), with limiting crack width of 0.2mm for the worst combination of maximum water pressure on one side and no water in the adjacent sump. These shall be designed as RC walls fixed at base and supported (hinged) at top by the deck slab. Since a breast wall may be provided for stop logs and back wall is provided connecting all the piers at the rear end, additional restraints for the pier due to breast walls and back wall may also be accounted for.

Intermediate piers are also to be checked for the combined action of direct load due to

superstructure and bending due to water pressure from one side.

**3) End Piers**

Design of end piers will be similar to the intermediate piers. The end piers shall be designed for the following conditions:

I. Soil pressure + maximum GWT + surcharge of 2 Ton / Sq.m. at FGL from outside or design surcharge load at floor level with no water in the sumps.

II. Only maximum water level in the sump.

End piers shall be designed by working stress method as per IS: 456 (latest), with limited crack width of 0.2mm on water face and the outside, i.e., earth side shall be designed as cracked section as per IS : 456. Since end piers are fixed at base and supported (hinged) at top by deck slab, there will be negligible yielding of the wall at top. This will give rise to earth pressure at rest and therefore an earth pressure at rest, Ko = (1 - Sin f) is considered where f =angle of internal friction of soil.

End piers shall also be checked for the combined action of direct load due to super structure and bending due to earth pressure with surcharge and ground water pressure.

**4) Back Wall**

Back walls shall be designed as fixed at bottom of the base slab and on two vertical sides by the piers and supported at top by the deck slab. Since back walls are also of the unyielding type, earth pressure at rest, Ko, shall be considered for design.

Back walls shall be designed by working stress method as per IS: 456, with crack width limited to 0.2 mm on water face and as cracked section on outer face as cracked section as per IS : 456.

Following load combinations shall be considered:

i. Soil pressure + maximum GWT + surcharge of 2 T / sq.m. at FGL from outside with no water inside the sump.

ii. Only maximum water level inside the sump.

**5) Operating Floor Slab**

Operating floor slab or deck slab shall be designed for loads of the pumps and other equipment, which may be placed on it. A live load of 1.5 ton / Sq.m. shall be considered on the deck slab. The deck / slab shall have monolithic construction with the piers and shall be designed as a continuous RC slab supported on piers. Design of bottom face shall be by working stress method as per IS: 456, with crack width limited to be 0.2 mm. Floor slab of maintenance bay may be designed as slabs on grade. A live load of 3 T / Sq. m. may be considered for the maintenance bay floor slab. Dynamic analysis shall be carried out to ensure proper separation of natural frequency of the structure and pump operating frequency

5.18.01.05 **C.W. Ducts**

CW ducts shall be concrete encased steel lined ducts. The concrete encasement shall be of minimum 500mm thick with square shape outside. Generally, M20 grade PCC encasement shall be provided. At locations of duct crossing road, rail in transformer yard or any other facility, RCC encasement of grade M25 shall be provided. Minimum two layers of reinforcement (On both faces) of 12 mm diameter bars @ 200 mm c/c shall be provided for RCC encasement of CW Duct. Top of CW duct encasement shall be minimum 1.5 m below finished ground level.

The minimum thickness of steel pipes shall be as follows including corrosion tolerance of 2 mm: