13.0 NATURAL DRAUGHT COOLING TOWER

This specification is intended to cover design and construction of One (1) no. of Natural Draft Cooling Tower (NDCT) as detailed hereinafter for this project.

The scope shall include design, engineering, construction of natural draft reinforced concrete hyperbolic cooling tower complete as required for safe and trouble free continuous commercial operation.

It is not intended to specify completely herein, all details of design and construction of cooling tower. However, the design and construction shall conform in all respects to high standards of engineering, design and workmanship and be capable of performing in continuous operation. All drainings and documents shall be approved by before commencement of work at site.

The provisions of this specification are general in nature and cover broad aspects. This specification outlines the minimum requirements. However, it would be absolute responsibility of the bidder to collect, interpret, analyze all necessary information / data for the successful design and construction of the cooling tower. Structural safety and successful operation of the tower shall be the total responsibility of the bidder notwithstanding the approval of the owner.

13.1 System Description

The natural draught cooling tower will be located inside the plant boundary and will be used for cooling the hot circulating water returning from the condenser and various other heat exchangers. The circulation of water will be maintained by Circulating Water (CW) Pumps and Auxiliary Cooling Water (ACW) pumps located inside C.W. pump house.

The hot circulating water reaching the cooling tower will be raised to the top of the hot water distribution system of the tower. The hot water distribution pipes inside the Tower shall be fitted with spray nozzles to distribute the hot water evenly over the PVC fill located immediately below. The hot water cools by evaporation as it drains through the PVC fill into the cooling tower basin.

The cooled water will be collected in a circular basin located under the cooling tower. The basin shall have a central partition, such that any half of the basin can be cleaned/ repaired while the other half is in use.

Water from the cold water basins will flow through RCC channel to the sump of the C.W. pump house.

The supplier should preferably be in a position to take up maintenance/ overhauling work as and when desired by UPRVUNL during whole life of operation of the plant, on service contract and/or piecemeal basis.

13.2 Detailed Scope of Civil Works

- Excavation and backfilling for columns foundation and substructure below cold water basin level.

- R.C. foundation raft & Cold water Basin, R.C. Shell, R.C. support framework for fill support.

- Hot water distribution duct.

  Painting of concrete surfaces shall be as per requirements mentioned elsewhere in this Chapter.

- Providing and installation of access doors in the shell of cooling tower including the necessary fittings and appliances on Tower Shell. The access doors shall be of heavy duty MS doors duly painted with 3 coats of epoxy paints.

- Main access RC staircase outside the tower up to Hot water Duct top, internal RC walkways and platforms all with necessary galvanized MS pipe handrails.

- Cold water channel outlet into gravity tunnel.

- De-sludging arrangement for each compartment of cold water basin.

- Provision of permanent access ladder up to top of tower manufactured in galvanized mild steel with adequate back-guards and landing platforms. The ladder shall comply with all applicable regulations.

- Provision of peripheral drainage around cooling tower as mentioned elsewhere in this Chapter.

- Necessary site clearing and grading all round the tower in accordance with specifications and drawings.

- Water fill test of cold water basin, cold water outlet channel and tunnel.

- Hydro test of Hot water Duct.

- Supply and erection of all base plates, foundation plates, anchor bolts, sleeves, nuts, fasteners, embedded parts and any other likewise material required for all electrical and mechanical equipment and accessories to complete the work.

- Rock anchors will not be considered for foundations in any case.

- Preparation and supply of all working drawings required for the work:

- Piling, excavation, dewatering, shoring and shuttering, backfilling around under ground structures and disposal of surplus soil outside the plant boundary / to the designated dump yard.

- Any other works not mentioned herein, but sufficiently implied and are necessary for completion and proper functioning of the cooling tower.

13.3 Hot Water Distribution System

The distribution troughs/pipes shall be independently supported from the structures

The structural design of the water distribution system shall also consider the following loadings, combined as appropriate.

a) Self weight.

b) Hydraulic pressure during normal operations, including pressure surges.

c) Hydraulic pressures due to mal-operation of tower or supply pumps

Seismic loading on the water distribution system shall also be considered.

The water distribution system shall be provided with adequate pressure surge relief facilities to prevent pressure loadings in excess of values used in the design. If such facilities are not provided, a further increase in loading shall be considered in the design. The pressure level to be considered shall not be less than 1.5 times the design pressure.

The design of water distribution system and its supports shall be capable of accommodating all thermal stresses and movements due to changes in inlet water temperature, outlet water temperature and ambient temperature.

If open basin system of distribution is provided, the basin shall be provided with removable type covers made of pre-cast concrete.

Ready accessibility to the different parts like isolation valves etc. shall be provided and as required necessary platform/walkway and ladder shall be provided for this purpose.

13.4 Louvre & Casing

The louvers and casing may be made of concrete. Concrete casing wall shall be supported from the basin through reinforced concrete. Hinged access door with platforms shall be provided for entry into the tower at suitable locations.

13.5 Cooling Tower Basin & Outlet Sumps

Cooling tower basin, shall be supplied/constructed along with all civil parts, base plates, anchor bolts, nuts, and other accessories, pipe sleeves, inserts, etc. and as required to complete the work in all respects.

The work shall include excavation/back-filling as necessary, all concrete/steel work, cold water outlet sump & sludge pit for each basin, water-proofing and all other works.

The basin shall be partitioned into two individual chambers such that one section can be taken out for maintenance /de-sludging while the other section is in operation.

13.6 Civil and Allied Works

The civil design and construction of the cooling tower shall be in accordance with the technical specifications furnished in relevant Chapters of this Volume.

The Cooling Tower shell, ring beams, diagonal columns at base supporting the ring beam below shell, cold water basin, fill support frame work, hot water distribution duct, cold water channel, louver etc. shall be cast-in-situ RCC construction.

13.7 Civil Design Basis

13.7.1 Loading

The following loads shall be considered for the design of cooling towers:

a) Dead loads

b) Wind loads

c) Earthquake forces

d) Loads due to temperature and shrinkage effects. Temperature effects due to solar radiation shall also be considered.

e) Construction load

f) Foundation settlement etc.

g) Any other load likely to come on cooling tower.

13.7.1.1 Dead Load

For assessing the self weight of the structure, the specific weight of the concrete shall be taken as 2500 kg/m3. All other dead loads shall be assessed in accordance with relevant codal provision. Dead load shall include the self weight of structure, weight of fill material, weight due to plugging/chocking of fills, weight of falling water, weight of hot water pipe, weight of water in hot water channel and distribution system including the self weight of channel and distribution system, weight of drift eliminators etc.

Secondary stresses, if any, due to permanent fixtures on the shell shall also be considered. In addition, live load on the supporting structure due to maintenance activities related to fills /ducts/distribution system shall be considered.

13.7.1.2 Wind Load

The wind pressure on the tower shall be assessed on theoretical basis as well as with the help of Model tests in a wind tunnel of turbulent boundary layer.

All the theoretical methods outlined hereunder for estimating wind load on cooling tower shell shall be valid only if the towers spaced at clear distance of greater than 0.5 times the base diameter at the finished graded ground level. The theoretical method outlined herein forms the basis only for assessing lowest limit of wind forces and shell structure interaction.

For conducting model tests, bidders should survey the whole terrain and make their own assessment of likely critical wind forces & wind structure interaction. It would be the responsibility of the contractor to collect necessary meteorological data duly vetted from the recognized govt. agencies/institutions. After collection of necessary meteorological data, most critical wind speed, wind pressure distribution and other necessary parameter shall be determined by the bidder and get the same vetted by the above agency/appropriate agency(s). Then with the help of physical model tests in a wind tunnel, offering appropriate aerodynamic similitude, the contractor shall obtain the most critical forces, stresses etc. with cooling tower at various levels and locations. Such model test shall also include all adjacent topographical features, buildings, and other structures which are likely to influence the wind load pattern on the tower significantly. The model test shall be carried out in a well reputed institute/testing laboratory after obtaining prior approval from the Owner. The testing agency selected by the contractor shall have requisite experience and should have successfully carried out tests in the past for at least one cooling tower of similar capacity. The model tests shall be duly witnessed and approved by the Owner/consultant. The model test results shall be made available before final approval of the design.

The complete cooling tower shall be designed for all possible wind directions and on the basis of worst load conditions as obtained from Model test and theoretical methods. Under the theoretical method, the circumferential net wind pressure distribution and wind pressure coefficient (p1) for the tower shell (without meridional ribs) shall be obtained from the “Criteria for structural design of Reinforced concrete Nature Draft Cooling Towers IS: 11504-1985.

The above circumferential wind pressure coefficient (p1) shall be increased by multiplying it by 1.43 to account for turbulence in the incident wind and load intensification due to turbulence induced by the adjacent cooling tower or the other structures of significant dimensions. Therefore, the actual design circumferential net wind pressure coefficient (p) shall be computed as p=1.43(p1), where (p1) is the wind pressure coefficient as per IS: 11504-1985.Enhancement factor 1.43 is considered to take the interference effect of adjacent structures of significant dimensions into account.10% increment shall be considered for imperfection in construction as per IS:11504.This factor shall be increased further by 10% during foundation design in absence of model test results. If the model is for C/L of shell, wind load shall be appropriately augmented to cater to the increase in diameter of the shell(O.D).

This design net pressure coefficient (p) and the distribution along the circumference of tower shall be used at all heights of the tower. The above design net pressure coefficient (p) shall include the effect of internal suction.

In order to compute the quasi-static design wind pressure at a given height along the circumference of the tower, the net design pressure coefficient (p) shall be multiplied by the wind pressure acting at that height [P(z)]. For details, reference shall be made to “Criteria for Wind Resistant Design of Structures and Equipments” and as given below.

The wind pressure at a given height [P(z)] shall be computed as per the stipulations of IS: 875 (Part 3)-1987. For computing the design wind pressure at a given height the basic wind speed (Vb) shall be taken as Vb=47m/sec at 10.0 meters height above mean ground level. For computing design wind

speed (Vz) at a height z, the risk co-efficient `K1' shall be considered as per IS: 875 (Part 3)-1987 . For coefficient `K2', Terrain category `1' and class 'C' as per table 2 of IS: 875 (Part-3) – 1987 (Latest) shall be considered. Coefficient `K3' shall be determined by taking into account nearby plant site and other features of the station & topography. The wind direction for design purposes shall be the one which would induce the worst load conditions. However, coefficient `K3' shall not be less than one (1) under any circumstances. The wind pressure at a given height shall be computed theoretically in accordance to the IS Codal position given as under:

$Pz = 0.6\ Vz^2\ N/m^2$

The bidder shall also compute the wind pressure (pz) along the wind direction by Gust Factor (GF) or Gust effective factor method (GEF). Method for estimating the wind load on the tower and other elements, shall be based on IS: 875 (Part-3)-1987. While calculating the gust factor, the term 'b' shall be taken as the diameter of the throat in Fig. 10 of IS: 875 (Part-3)-1987.

Design of the tower shall satisfy quasi-static method & GEF method. Dynamic effects on the tower due to wind action shall also be investigated to ascertain the wind induced oscillation such as ovalling and excitation along and across the wind direction. Bidder shall carry out detailed analysis for the tower and consider the worst combination of static & dynamic effects.

In case the bidder proposes to adopt aerodynamic rough surface such as provision of meridional ribs in the cooling tower shell, the pressure coefficients as given in the VGB-BTR KUHLTUMRE GERMAN SPECIFICATIONS (latest) (structural design of cooling towers) shall be permitted. The provisions of BTR may be adopted for choosing the value of circumferential wind pressure coefficient (p1) only. The wind pressure coefficient (p1), as obtained from BTR after accounting for internal suction shall be multiplied by a factor of 1.43 to arrive at the net design pressure coefficient (p). The bidder shall furnish authorized English Translation of VGB-BTR KUHLTURME GERMAN SPECIFICATIONS (latest) for the review of the Owner. All other stipulations as specified in these specifications shall be met with.

Entire analysis and designs adopted shall be fully supported with authenticated literatures/documents along with relevant references where the same has been successfully implemented.

13.7.1.3 Earthquake Forces :

The seismic analysis shall be carried out in accordance with IS:1893 (all latest parts) by modal analysis for the hyperbolic cooling towers or any other method as approved by the Owner. The earthquake analysis of the shell and its support columns including the foundations shall be carried out by response spectrum method. For the fill supporting structures (RCC frames) response spectrum method is permitted. The modulus of elasticity for concrete shall be obtained from IS: 456-2000 Clause 6.2.3.1 with an Age Factor of 1.0. All the analysis shall be carried out as per the theory of elasticity.

Entire analysis and designs adopted shall be fully supported with authenticated literatures/documents along with relevant reference where the same has been successfully implemented.

13.7.1.4 Loads due to temperature effects

Stresses due to temperature effects :

The cooling tower shell shall be designed for stress due to axi-symmetric temperature distribution corresponding to external ambient temperature variation from 4°C to 50°C. However, the detailed analysis of actual thermal gradient by considering temperatures inside the tower and external ambient temperatures shall be carried out furnishing detailed references and justification for the same.

The shell shall also be checked for thermal stresses arising due to partial operation of the tower in case the operational philosophy so demands. The analysis for the stresses resulting from non-axi-symmetric temperature loading shall be carried out. In such non-symmetric temperature loading, the calculation shall be based upon the operating specification. Besides, the shell shall also be designed for one sided solar radiation effect. Nevertheless an effective temperature difference of at least 250 C across the shell thickness constant over the height and follow a sine functions along half the circumference shall be considered.

Entire analysis and designs adopted shall be fully supported with authenticated literatures / documents along with relevant references where the same has been successfully implemented.

13.7.1.5 Construction Load

The method of construction and the type of formwork to be used shall be decided by the bidder in advance and should be enclosed in the bids submitted. Construction loadings that may occur during execution of work shall be considered in the design of the cooling tower structure. Factors causing temporary loading may include the following depending upon the method of construction.

a) Barrowing of concrete

b) Scaffolding and formwork

c) Loads produced by anchoring devices of climbing scaffolds.

d) Hoist fixings

e) Storage of materials on scaffolding

f) Temporary access

g) Tower crane fixings

h) Works temporarily omitted for access purposes.

Any other load such as foundation settlement, etc.

All loads likely to act on cooling tower but not specified herein shall also be considered for the design of cooling tower structures.

In case different degrees of subsoil stiffness exist, effect of the same shall be taken into account. In such a case, for computing settlements, load distributing capacity of the shell may be considered. Differential settlement between adjacent sections of foundation shall be considered under most unfavourable load combination.

13.7.1.6 Load Combination

Following minimum load combinations shall be considered for the design of cooling towers structures.

a) DL + WL + SL

b) DL + Se L

c) DL + TL

d) DL + WL + TL + SL

e) DL + Se L + TL + SL

f) 1.0 DL + 1.5 WL

g) 0.9 DL +1.5 WL

h) 0.9 DL-1.5WL

Where,

DL	=	Dead Load
WL	=	Wind Load
SL	=	Settlement Load
Se L	=	Seismic Load
TL	=	Thermal Load

In addition to above, construction loads shall be duly accounted for. Under TL various types of thermal loads, as described above, shall be considered separately. Besides above load combination, other load combinations as per relevant IS codes shall also be followed.

13.7.2 **Tower Design Consideration**

13.7.2.1 General

- The complete cooling tower, including the shell, columns, ring beam and foundation, shall be structurally analyzed using a proven finite element modeling technique or an approved alternative method including validation of software used for analysis. For elastic analysis, concrete may be assumed to be un-cracked, homogenous and isotropic. The design geometric profile, thickness variation and support conditions of shell shall be considered in the structural analysis.

- Analysis based on a recognized bending theory of the elastic shells shall be adopted for the design of the tower and supporting structures.

Regardless of analysis method adopted, the equilibrium checks of internal forces and external loads shall be performed.

- Geometric imperfections, if exceed the permissible limit, then the analysis of shell shall take into account of such imperfections and resubmitted for Owner's approval.

- Boundary conditions shall be realistic and based on actual configuration. The magnitude of the calculated displacements should be within limits of the applied theory.

- A detailed dynamic analysis shall be carried out for complete tower for seismic forces by response spectrum method. Cooling tower shall also be designed for cross wind oscillations (wind induced vibration) if the fundamental natural frequency of the tower is less than or equal to 1 Hz. Frequency calculation for free vibration analysis shall also be furnished by bidder during detailed engineering.

13.7.2.2 Size and Shape

- The base diameter, air intake opening height, tower height and throat diameter shall be determined by thermal design consideration by the contractor and submitted to Owner for approval.

- As the range of possible hyperbolic shell shapes is infinite, the same shall generally conform to the following major proportions, which have been extensively adopted in cooling tower constructions.

  H/D = 1.2 to 1.55

  Where H is the total tower height above basin sill level

  Hb/H = 0.75 to 0.85

  Hb is the vertical distance from the throat to basin sill level and 'D' is the base diameter at basin sill level.

- However, other proven profiles may be permitted subject to approval from the Owner. Bidders shall submit along with the offer complete details of the profile, in case the profile is not within the limits stated above, and the names of the sites where such shell profiles have been successfully constructed. Notwithstanding what is stated above, the Owner reserves the right to accept / reject the shell profile.

13.7.2.3 Tower Shell Boundary Conditions

A. Shell Analysis and Design

The following boundary conditions shall be assumed for the design of cooling tower shell :

a) At Upper Edge

The top edge of the shell shall be gradually thickened to form a ring beam to guard against possible instability of the top of the shell due to

high velocity wind gusts. Top edge shall be considered as a free edge in the analysis.

b) At Lower Edge

The lower edge of the shell shall be thickened to form a lower ring beam. The thickness transition from shell to lower ring beam shall be smooth and shall be considered as an integral part of the shell. The lower boundary of the shell shall be considered as elastically supported by discrete columns.

The influence of both support structure flexibility and foundation settlement shall be considered in the analysis and design of cooling tower shell. The shell analysis should include following information at 10o plan angle and of not more than 0.05 of the shell height.

i) Meridional and circumferential direct stress resultants and the tangential shear stress resultants.

ii) Meridional and circumferential bending moments.

iii) Displacements normal to the shell mid-surface.

B. Buckling of Tower Shells

Critical dynamic pressure (wind pressure) at buckling shall be calculated from BS: 4485 Part-4:1996.

Buckling of Cooling Tower shell be checked as per Finite Element Analysis using software such as NISA 2, Ansys etc. The factor of safety for snap through buckling shall be more than 5. This requires non linear analysis including simulation of opening in the model. Alternatively, bifurcation buckling factor can be calculated using linear eigen value analysis with modulus of elasticity E=0.8Ec, to account for cracked section, with factor of safety more than 7.

Besides above, a buckling analysis with wind forces should be made using the theoretical tower geometry and boundary conditions, including the influence of dead weight, by the method of buckling stress state (BSS) approach in accordance with the provisions of VGB/BS 4485.

- The buckling safety factor shall be at least 5.0 for load combinations of dead load + wind load.

- When imperfections in the shell geometry are larger than specified tolerances, the analysis should be rechecked to account for such imperfections and ensure that the desired buckling capacity remains.

C. Opening in Shells

- Opening through the shells should be avoided as far as possible. They should be of smallest required dimensions and shall be shaped such that stress concentration is minimized at the boundary of the opening. Should thickening of the edges be necessary, it shall be smoothly tempered back to the shell thickness.

- Openings shall be provided with additional edge reinforcement of a minimum cross sectional area at each edge equal to 75% of the reinforcement intercepted by the openings in the direction parallel to the edges. In addition diagonal reinforcement shall be provided at each corner as close as possible. The total cross-sectional area in cm2 of this reinforcement shall be 0.5d, at each corner where'd' is the shell thickness in cm.

- No horizontal thrust due to the inlet piping shall be transmitted to the shell.

D. Minimum Thickness of Shell

The thickness of the shell shall be minimum 300 mm or more as per design.

E. Minimum Reinforcement in Shell Spacing and Placement

- The reinforcement used shall be cold worked steel high strength deformed bars of grade Fe 415/500 conforming to IS: 1786 – latest. All reinforcement steel shall be corrosion resistant steel/HCRM. The minimum reinforcement to be provided shall be as follows:

- Top one third portion of shell: 0.4% of concrete cross-sectional area along circumferential direction and 0.35% of concrete cross sectional area along meridional direction.

- Remaining two-third portion: 0.35% of concrete cross-sectional area in both meridional and circumferential directions.

- Minimum bar diameter shall be 10 mm in transverse direction and 12 mm in meridional direction.

- Spacing of reinforcing bars should not exceed 200 mm in circumferential direction and 250 mm in meridional direction.

- The two layers of reinforcing meshes shall be adequately joined by S-hook over the total shell surface. At least two S-hooks in each square metre area of shell surface shall be provided. The hooks shall be of minimum 8 mm diameter bars.

- The concrete cover shall be 50 mm minimum. However, the clear cover shall not be less than 1.5 times diameter of bars. The relevant provisions of IS: 2210 – Criteria for the design of reinforced concrete shell structures and folded plates and IS: 2204 – Code of Practice for construction of reinforced concrete shell roof shall also be deemed to be applicable. All other design criteria for the cooling tower shell which are not specified above shall be in accordance with BS: 4485 Part 4 and BTR.

F. Provision of meridional ribs in Cooling Tower Shell

Meridional ribs in the cooling tower shell may be provided subject to the following conditions:

a) Minimum thickness of shell excluding ribs shall not be less than 300 mm.

b) Coefficients for pressure distribution around the cooling tower circumference including suction may be taken as per VGB-BTR KUCHLTURMEN SPECIFICATIONS (latest). All other factors including load intensification factors shall be as specified elsewhere in these specifications.

c) Shell buckling and strength shall be checked as per clause-9.02.03 B above without considering the effect of ribs.

d) All other stipulations as specified in these specifications shall be met with.

e) Bidder shall furnish an authorized English translation of the VGB-BTR KUCHLTURMEN GERMAN SPECIFICATIONS (Latest) during detailed engineering stage.

13.7.2.4 Raker Columns

Inclination of the column shall closely match the meridional slope at the shell so that the load transfer to foundation takes place through predominantly axial force in columns. Raker columns shall be designed for the most critical forces transferred to an individual raker column from superstructure considering various load combinations as specified in this document.

For selecting effective length of the raker columns, following restraints shall be considered:

a) In case columns restrained at both the ends, the effective length shall be 0.8 and 0.6 times the length of the column radially and tangentially respectively.

b) In case columns are restrained at one end only, the effective length of columns shall be 0.9 and 0.7 times the length of columns radially and tangentially respectively.

c) The columns shall be designed based on working stress method except for the forces from DL + 1.5 WL which shall be designed as per limit state of strength method of IS: 456.

d) The minimum size of raker column section shall be 1200 mm diameter or more as per design

e) The size of pedestals shall be such that it will have minimum 200 mm clear projection from the raker column.

13.7.2.5 Crack Width Control

Under working stress method the maximum crack width of tower shell, lintels, raker columns, cold water basin and fill support structure shall be controlled up to 0.1 mm on basis of formulas as per IS:456-2000 and relevant British codes.

Fill support structures and Drift Eliminators shall be designed as per the load combinations specified in this document. Appropriate Live Loads and imposed loads shall also be considered in addition. The design shall confirm to limit state method as per IS: 456. For fill support structure, the design shall be done considering the weight of fills, falling water, plugging/scaling load and the live load due to the maintenance activities.

13.2.7.6 Pre-stressed Concrete Members

Design, construction and workmanship of pre-stressed concrete, members shall be in accordance with IS: 1343 (Latest revision). Steel wire for pre-stressing shall conform to IS: 1785 (Part 1) (latest edition) or IS: 6003 (latest edition). Crack width control shall be limited to 0.1 mm.

Particular attention shall be paid to achieve an effective bond of the wires in pre-tensioned concrete units. For this purpose, indented wire shall be used. Wires shall be corrosive resistant. Concrete and grout used shall be sulphate resistant.

The bidder shall furnish a write-up for the method to be used for pre-stressed concrete structures.

13.7.2.7 Liquid Retaining Structures

a) The cold water basin including sludge pits, cold water channels, shall be designed as per IS: 456 (latest) with crack width control of 0.1 mm for outer face of the wall and inside face of the wall shall be designed as per IS 3370.

The structures shall be designed for the following conditions:

i) Water filled inside up to maximum level and no earth outside.

ii) Earth pressure with surcharge load of 2.5 t/m2, as applicable, and with/without ground water table at 1.0m below finished ground level outside and no water inside.

b) The basin and associated structures shall be checked against uplift for basin empty condition. Stability shall be checked during construction stage as well as maintenance stage. The factor of safety shall be as per IS: 3370.

c) Loads during construction, erection and maintenance stage shall also be considered.

d) Temperature fluctuations from operation shall be obtained from the design data. Hot water temperature inside and cold air temperature outside shall be considered.

e) Basin floor slab shall be designed to rest on piles or raft/mat foundation including fill-pack support structures. The stiffness of the subsoil shall be taken into account. The founding level of the raft/mat shall be either on virgin ground level or shall be placed at higher level only after scooping out filled up soil up to virgin ground and then filling back with well compacted sand (80% of relative density) up to the founding level of the raft/mat. The bidder shall ascertain the safe bearing capacity of the stratum at the founding level and may adopt the same subject to Owner's approval.

f) Minimum thickness of basin slab shall be 300 mm with minimum reinforcement 0.35% of gross sectional area in both the directions. Reinforcement shall be placed in two layers, top and bottom surface. The effect of provision of flap valves/pressure release valves shall not be considered in the design of CW basin. In the space underneath the basin floor slab a layer of at least 100 mm thick PCC of mix 1:3:6 shall be provided.

g) All reinforcements used shall be corrosion resistant steel/HCRM.

h) The basin floor shall be cast in alternate bays in chequered pattern with sides not exceeding 4.5 meter

i) No pressure relieve valve to be used at basin floor.

13.7.2.8 Water Distribution System

The structural design of the water distribution system shall consider the worst combination of following loads :

a) Self weight, other imposed loads and live load.

b) Hydraulic pressures during normal operations including pressure surges.

c) Hydraulic pressure due to mal-operation of the tower or supply pumps.

- The water distribution system shall be provided with adequate pressure surge relief facilities to prevent pressure loading in excess of values used in the design. If such facilities are not provided, a further increase in loading shall be considered in the design. For the structural design the pressure level to be considered shall not be less than 1.5 times the design pressure.

- The design of water distribution system and its supports shall be capable of accommodating all thermal stresses and movements due to changes in inlet water temperature and ambient temperature.

- The possibility of vibrations being imposed on the distribution system shall be investigated in the design. Seismic loading on the water distribution system shall also be taken into account.

- The design shall be carried out based on uncracked section as per IS: 3370 under normal operating conditions. Strength check for worst loading including malfunctioning shall be carried out with stress limitations as per IS: 3370. The construction shall be completely water tight without the use of fillets, sealing compounds etc. The method of construction shall be such so as to avoid excessive rise in temperature of concrete due to release of heat of hydration.

- Hot water distribution basin/trough/channel at top shall be covered by removable precast concrete slab to prevent direct exposure from sunlight. Corners of pre-cast concrete slabs shall be protected by angles. Lifting lugs shall also be provided for handling of concrete slabs.

- Basin channel wall shall be designed for a minimum surcharge load of 25 KN/Sqm. Paving shall be provided all round cold water basin.

13.7.2.9 Platforms, Walkways, Stairways, Staircases, Internal Grillage etc.

These shall be designed as per working stress method IS: 456-2000 and IS: 800. The crack width in all RCC structures shall be limited to 0.1 mm. A minimum live load of 500 kq/sqm shall be considered for the design of all platforms, walkways, staircases etc. in addition to their own weight.

Platforms shall be minimum 1.2 M wide and walkways shall have 1.5 M wide.

13.7.2.10 Steel Structures

All structural steel members shall conform to IS: 2062 (GR-A). These structures shall be designed, fabricated and erected as per IS: 800 and other relevant Indian Standard codes for structural steel work. All steel structures shall be coated with anticorrosive system.

13.7.2.11 Slide Gates and Screens

Slide Gates and Screens, as per IS: 5620 conforming to IS: 2062 Gr. A, shall be designed for worst combination of operating and maintenance condition. All steel components shall be coated with anti-corrosive paint system. However, all guides of slide gates and screens shall be of stainless steel of Grade AISI 316L.

13.7.3 **Foundations**

Data specification sheet and Soil Report (By EPC Contractor) shall be referred to for selecting allowable bearing pressure to be considered in designing the foundation and in selecting depth of foundation. Cooling tower foundation is to be designed as strip foundation considering appropriate modulus of subgrade reaction. However, the bidder has to select suitable type of foundation compatible with the soil strata and calculated settlement of structure and foundation system. The bidder shall have to furnish conceptual design indicating type of foundation, general arrangement drawing for super structure, basin, pipe supports, pits, founding level etc. including settlement criteria complete with a design basis report with the offer.

The design of the cooling tower foundation structures shall be based on IS: 456 as per working stress method for worst load combination as per clause 9.01.06 In case of load combination DL + 1.5 WL, the limit state method as per IS: 456 shall be adopted.

Foundation shall be checked for safety against overturning, sliding and uplift. The minimum factors of safety for overturning, sliding and hydrostatic uplift shall be 1.5, 1.5 and 1.25 respectively.

While checking stability of the structures, neglect favourably acting loads from water fill, soil cover beyond the edge of the foundation. Ground water table shall be considered at 1.0m below Plant Finished Grade Level for design of foundations and all underground structures.

Minimum grade of concrete shall be M25 for foundation resting over 100mm thick PCC (1:3:6) layer. Clear cover shall not be less than 50mm.

Pile foundation shall be provided as per final approved soil investigation report. It is to be noted that part of cooling tower may have to be installed over existing abandoned ash pond. In that case special care has to be taken in selecting the type of pile, length & capacity of pile including any other special requirement for foundation system including basin as per specific recommendation of final approved soil report. Bidder must visit the site and assess the extent of existing adandoned ash pond area falling within proposed cooling tower before sumissitting his offer. It is to be noted that nothing extra shall be payable to the Contractor by UPRVUNL due to any variation in data assumed during preparation of his offer and execution stage.

Generally net tension should be avoided in the foundations/piles for the shell support foundation unless specifically permitted by the Owner.

While accounting for over burden of the soil for checking the foundation against up-lift, dead weight of the soil directly above the pile cap or ring raft, as the case may be, shall only be considered, neglecting the weight of soil in the cone of up-lift above the foundation.

The foundation structures will be subjected to following loading and extreme load combination case shall be considered for design.

1. Most critical forces transferred from superstructure for the various load combinations.

2. Uplift forces

3. Loading due to foundation settlement

4. Concentrated local loading from column nodes

5. Thermally induced local loading where supply culverts pass through the foundation structures without structural isolation.

6. Surcharge of 2.5 t/sq.m.

CW basin surcharge load shall also be considered in addition to the other relevant loads for the design.

13.7.4 Fill Support Structures and Other Structures

The self weight of the pack support structures shall be based on the weight of the packing including weight of standing, running and dripping water, other operation and plugging/chocking (debris/scaling) loads, etc. in accordance with manufacturer's data. In addition, a live load of 100 kg/m2 shall also be considered for the design of supporting structures.

For other structures like walkways, platforms, etc. a live load of 500 kg/sq.m shall be considered. Hand railings shall be designed for horizontal load of 60 kg/m2.

Wind deflector walls and any other structural elements shall be designed for a horizontal wind load of 80 kq/sqm or as per manufacturer's recommendations, whichever is higher. Thermal loading shall be as per manufacturer's recommendations. Earthquake loading shall be considered based on criteria given for cooling tower. Response spectrum analysis shall be considered.

Design of RCC members shall be based on IS: 456:2000 with limiting crack width of 0.1 mm.

The cold water basin slab/raft shall form the common foundation for the pack support structures. The foundation shall be designed for the most critical forces transferred from CW basin & fill supporting structures including loads introduced by constructional equipments and crane deployed for fill supporting structure or shell erection.

13.7.5 Requirements for Concrete and Reinforcement

All concrete work for the cooling tower shall comply with the requirements given in technical specification for Cement Concrete (Plain & reinforced)

Ordinary Portland cement Grade 53 complying with IS:12269 shall be used in concrete works for all structures and foundations. For PCC, paving and plinth protection works, OPC Grade 43 shall be used.

Fine and coarse aggregate to be used in cement shall comply with IS-383.

Structural concrete shall be of design mix complying with the relevant provisions of IS codes or any International Code of Practice as approved by the Owner.

Durability of the concrete shall conform to severe exposure category as per Table 3 of IS: 456 except noted specifically otherwise.

Plain mild steel reinforcing bar shall conform to IS: 432 grade I quality and high yield strength deform bars (TMT) shall conform to IS: 1786 (Fe-500).

All reinforcements used in RCC structure shall be corrosion resistant. Column reinforcing bars shall be carefully anchored in the shell and foundation. The anchoring length shall not be less than 80 times the diameter of the bars.

All foundations structures shall be provided on all sides with a minimum reinforcement of 0.12% of gross cross-sectional area distributed over top and bottom faces.

The minimum grade of concrete of structural components of cooling towers shall be as follows in accordance with IS: 456.

a)	Shell and Raker Columns	:	M-30 grade
b)	Pre-cast pre-stressed elements	:	M-30 grade
c)	All other RCC concrete	:	M-30 grade
d)	PCC encasement concrete except piles	:	M-25 grade
e)	Piles (with OPC/PPC/PFC)	:	M-30 grade
f)	Tower foundation	:	M-30 grade
g)	Mud mat/lean concrete PCC	:	M-10 grade

Coarse and fine aggregates shall be specially selected to ensure that they are not susceptible to alkali/chloride attack or prone to disintegration at high temperatures. In particular limestone aggregates shall never be used. The maximum size of coarse aggregate shall not be larger than 1/8th narrowest dimension between reinforcement bars not more than 20 mm.

Washing and screening of coarse and fine aggregates to remove fines, dirt or other deleterious materials shall be carried out by approved means as directed by the Engineer-in-charge.

The water cement ratio by weight shall be 0.45 maximum including free moisture in the aggregates, and slump should be suitably decided to provide good quality concrete work.

13.7.6 Admixtures

Admixtures may be permitted to be used in accordance with relevant IS codes to modify the rate of hardening or setting, to improve workability or as an aid to control concrete quality and protection to reinforcement bars against corrosion. The Owner reserves the right to direct the contractor to conduct laboratory tests or use test data, or other satisfactory reference before granting approval. The cost of all tests conducted shall be borne by the contractor. The admixture shall be used in strict accordance with the manufacturer's directions and/or as directed by the Owner. No extra payment will be made to the contractor on account of using admixtures.

Particular attention must be given to concrete placement because of the thin wall section and the presence of reinforcing steel. Consolidation of concrete shall be by vibration. Removal of air and water at the form surface shall be by vibration and rodding. Particular attention shall be paid to accurately shape the corners at all openings.

Point of discharge of the concrete in to the forms be 1500 mm max. above the concrete surface. Concrete shall be deposited in approximately level layers not greater than 400 mm deep unless permitted otherwise.

Concrete in the cooling tower shell in each lift shall be so laid that the no. of vertical or inclined construction joints are minimized to the extent possible. Horizontal construction joints shall be maintained at uniform spacing throughout the height of the cooling tower as per the directions of the Owner.

Special attention shall be paid to proper curing of vertical faces of the cooling tower shell so that these do not remain dry. All thin walled structural members shall be protected by means of curing agents. It is recommended to use a curing agent for the cooling tower shell providing additional protection like a single transparent cooling with a material based on vinyl mixed polymer. Inside face of the shell should be protected by a second pigmented coating of the same base material. Any other method of curing, if permitted by the Owner may be used.

Sampling and testing of concrete shall be carried out as stated in Technical Specification elsewhere and as per relevant Indian Standard Codes. However, following minimum tests shall be carried out, irrespective of whatever stated otherwise:

Test of compressive strength

Columns – 1 Set of 3 cubes per column

Shell-2 sets of 3 cubes per climbing section

13.7.7 Cover to Reinforcement

Unless indicated otherwise the clear concrete cover for reinforcement shall be as per IS Codes.

The correct cover shall be maintained by cement mortar spacers/cubes or other approved means, reinforcement for footing/pile caps, grade beam, and slabs on sub-grade shall be supported on pre-cast concrete cover block as approved by Engineer-in-charge. The use of pebbles or stones as cover blocks shall not be permitted.

The 28 days crushing strength of cement mortar cubes/pre-cast concrete cover blocks shall be at least equal to the specified strength of concrete in which the cubes / blocks are embedded.

The minimum clear distance between reinforcing bars shall be in accordance with IS:456 (latest edition) or as specified elsewhere in this specification.

All lapping of reinforcement bars in the cooling tower shell shall be by lapping as per relevant codal provisions. Prior approval of the Owner shall be taken for deciding the method of lapping the reinforcement bars in the shell.

13.7.8 Checking of shell geometry

The form work for shell shall be capable of adjusting to shell profile and thickness accurately, and rigidly braced to prevent deflection or movement during concreting.

The form work shall be rigid, shape preserving , tight fitting and easy to construct so as to ensure smooth concrete surfaces, no geometrical discontinuities and achieve a high degree of dimensional accuracy.

Check for absolute positions may be carried out from ground stations arranged at not more than 10 degree plan angle apart. Readings of horizontal radius shall be taken at every lift.

The shell shall be constructed within the dimensional tolerances as stipulated in clause 7.3 of IS: 11504. If the permissible dimensional tolerance are exceeded, the Owner will instruct the contractor, in writing, to stop construction of the shell. The Contractor shall then examine the situation and submit a report to the Owner who may require the contractor to demonstrate by calculations that the structural integrity of the shell will not be impaired as a result of the imperfections. The calculations shall be submitted to the Owner, for approval, before construction will be permitted to proceed.

If in the opinion of the Owner the calculations show that the integrity of the shell could be threatened, the Contractor will be required to submit to the Owner detailed arrangement and supporting calculations to set right the shell geometry for approval, before construction will be permitted to proceed.

The cost of carrying out the calculation, any remedial work required and idle time or any delays to the construction programme as a result of dimensional tolerances being exceeded will be borne by the contractor.

Adjustment to the tower shell line on the basis of the survey results shall be made gradually; limiting the maximum change of direction from the existing vertical shell profile to be not more than an angular change of 10 mm measured over 1m of height. Any such adjustment shall be made with full knowledge and consent of the Owner.

The contractor shall carry out an as-built-survey of each lift of the shell. The results of these checks will be recorded on a suitably developed drawing of the shell from which it will be possible to locate the survey check point. A copy of these results will be presented to the Owner prior to commencing the next shell pour.

The contractor's shell construction procedures shall include for providing the Owner with the facilities and a reasonable time period as may be required to carry out an independent check of the completed works.

Suitable communication system such as telephone, wireless equipments, etc. shall be provided by the contractor so that the communications are possible at different elevations of the tower from the ground during construction.

All piling work shall be carried out by specialist subcontractor approved by the Owner. Initial pile load test shall be carried out for at least 3 sets of piles for direct compression and lateral load.

Since the effective action of the piles will depend on the adopted method of construction, the contractor shall guarantee that the piles, as constructed by the sub-contractor, shall effectively transmit the maximum loads which can be imposed on the foundation soil and corresponding maximum deflections.

13.7.9 **General Requirements**

a) The basin slab shall be divided into two equal parts by a partition wall designed to withstand full hydrostatic pressure, with one side empty. The basin construction joints shall be made watertight by injection of chemical grout through nipples. The basin construction shall be tested for water tightness, in accordance with IS: 3370 (Part I) (Latest edition). The cost of the test and any rectification and re-test if required is deemed to be included in the contractor's quoted price. Any cost of filling and emptying of the basin and to rectify defects shall also be borne by the contractor.

b) PVC water stops shall be provided at all construction/ expansion joints of water retaining structures. 230 mm (min) wide and 10 mm (min) thick approved quality PVC water stop with central bulb shall be used where expansion joints are envisaged.

c) The basin floor of each compartment shall be provided with a slope of not less than 1 in 120 towards sump for dewatering. From sump, the water will be drained by C.I. drain pipe, embedded below the basin floor, into a drain chamber outside the tower basin or as per the arrangements described elsewhere in the tender document. Suitable sluice gates (rising spindle type) conforming to IS: 3042 or sluice valves shall be provided in the drain chamber or any other arrangement specified elsewhere in the tender document. Suitable operating platform with access ladders for operating the gates or valves and pipes, shall be provided in the drain box.

d) A 250 mm high sill shall separate the pond floor from the tower outlet.

e) Uniform surface on the top of basin floor shall be provided. In case undulated surface is observed, a top of layer of minimum 25 mm thick 1.3 mix mortar to be provided to achieve uniform surface.

f) Fill will be of film type supported on RCC beam. Film fill should be characterized by reduced air pressure losses, and shall not susceptible to clogging. Design and facing of the film fill shall be such as to expose high air/water surface with minimum air pressure drop.

g) The sluice gates shall be structural steel with anti-corrosive coating specified elsewhere. Number of sluice gates and removable screen shall be two (2) per tower. Proper rubber seal shall be provided so as to avoid any leakage of water. The rubber seal provided for the sluice gates be tested in accordance with the relevant Indian Standard Code. Sluice gates shall be checked for water tightness and smooth operation in dry and wet conditions. Suitable facilities, as approved by the Owner, shall be provided for handling of sluice gates and screens.

h) Lean concrete below foundations, cold water basin, other liquid retaining structures and all underground structures, unless noted otherwise shall be at least 100 mm thick.

i) The R.C.C. structure of the Cooling Tower shall be painted on the exterior surface with two (2) coats of water proof cement paint of approved make and colour .

The interior surface of the Cooling Tower structure and the interior face of the Cooling Tower Basin, fill supporting beams, columns and bracings, raker columns etc. which are in contact with water / moisture shall be painted with one coat of primer and two coats water proof bituminous paint conforming to IS:3384 and IS:9862 respectively.

j) Unless noted otherwise all concrete surface which are in contact with the earth shall be applied with anticorrosive coat system.

k) Water proofing and plasticizer admixtures conforming to relevant IS codes may be added as per manufacturer's instruction to the concrete subject to approval of the Owner.

l) The tower shall be provided with two numbers external RC staircase, leading to a heavy duty door giving access to the distribution system. Staircase shall be minimum 1000 mm wide (clear), with landings of minimum width of 1000 mm at not more than 2500 mm height intervals unless approved otherwise. The stair shall have risers not exceeding 125 mm and treads 250 mm minimum. Anti-skid nosing at each step shall be provided.

m) Minimum size of all doors shall be 2100 mm high (clear) and 1200 mm wide (clear). The door shall be of steel with anti-corrosive coating of polyurethane as specified elsewhere. However, FRP material or equivalent may also be used subject to approval of the Owner. The door shall be air tight when closed.

n) The hand railing on both sides of the staircase shall be galvanized with three rails of 32 mm NB pipes conforming to medium class as per IS:1239, and posts conforming to medium class as per IS:1239 of 32 mm dia galvanized pipes spaced not more than 1.2 m centers. The top hand rail shall be at 1000 mm above the steps with an intermediate

member at 550 mm height. The posts and runners shall be welded construction with round corners. Complete hand rail shall be applied with anticorrosive coating system as specified elsewhere. All galvanization works shall have 610 gm/sqm of deposit.

o) Approved walkways and platforms shall be provided inside the tower at distribution pipe level. These walkways and platforms shall provide safe and clear access to all sprayers and all distribution pipes. The clear width of walkway shall be 1.5m and clear head room shall not be less than 2 m. Radial gaps of 12 mm wide shall be provided at intervals in the walkways for discontinuity.

A reinforced concrete platform of 1500 mm clear width shall be provided around the tower valves. Other walkways shall be at least 600 mm wide with 50 mm (minimum) safety kerbs along each edge. Access ways shall be clear of all obstructions such as distribution pipe support beams, drift eliminator support beams etc. The walkways shall be provided with transverse slots or other opening which will permit the free passage of air and water.

p) Hot double dip galvanized handrails as described above shall be provided on all sides where there is a risk of falling through the fill.

q) Reinforced concrete platforms 1.2 m clear width all around the tower circumference shall be provided on the tower for fixing of aviation warning light at levels specified elsewhere. 12 mm wide radial gaps shall be provided in the platform at suitable intervals for discontinuity. Adequate MS embedment shall be provided in each side of platform to facilitate maintenance of tower shell.

Two (2) diametrically opposite galvanized MS caged ladders, 600 mm wide, made out of 6 mm, x 10 mm flats for full height of the tower shall be provided as per IS: 3696.

r) MS rung ladders shall be hot dip galvanized ladder shall be 600 mm wide fabricated out of 60 mm x 10 mm flats with 20 mm dia. rungs at 300 mm centers. Stays shall be provided at every 2.25 m intervals connecting the ladder with the concrete shell. Upto throat level these ladders shall be on the exterior surface of the cooling tower and shall be continued along the inside surface of the tower up to the top of the tower.

Galvanised MS Safety cage shall be provided for all ladders and shall be fabricated out of 5 nos. verticals of 50 mm x 6 mm flats with 50 mm x 6 mm flat straps at 800mm centers.

A RCC landing of size not less than 750 mm x 1500 mm, with galvanized handrails and galvanized steel door to be provided at the throat for interchange. Intermediate landings of reinforced concrete of size not less than 750 mm x 1500 mm shall be provided at every 8 to 10 m height of the ladder.

Some of these landing levels shall be suitably adjusted to give access to aviation warning beacons for maintenance. Handrails as described above shall be provided on all platforms. The ladder leading

to the top platform shall have approach from ground via the RCC staircase.

s) In order to provide approach for maintenance of shell (inside & outside faces), all platforms shall have 20 mm wide radial openings in the platform floor at locations approved by Owner. Adequate numbers of 75 mm internal diameter puddle flanged C.I. pipes shall be embedded in this platform for passing ropes during maintenance of tower shell.

t) All exposed structural steel work used in cooling towers shall be hot double dip galvanized unless it is coated with a separate anti-corrosive coating system. The minimum coating shall be 610 gm/sq.m and shall comply with relevant IS codes. Galvanizing shall be checked and tested in accordance with IS: 2629.Galvanization shall be followed by the application of an etching primer and anticorrosive hibuild epoxy coating system of DFT 260 microns. 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 AISI 304 or equivalent.

u) Mix proportion in Cement-sand mortar for brick masonry work shall be 1:6 for 250 mm thick brickwork and cement-sand mortar (1:6) shall be used for 125 mm and 75 mm thick brickwork.Thickness of 1:6 cement-sand plaster on brick masonry shall be 18 mm for outside, 12 mm for inside and thickness of 1:4 cement-sand plaster shall be 6 mm for ceiling.

v) Materials for precast concrete components including joint fixing, lifting hooks and other exposed steel components shall conform to technical specification and other points mention in the document.

13.7.10 Grating

Steel gratings, where required, shall be fabricated out of steel flats with minimum thickness of 6 mm. Thickness of fabricated grating shall be 32 mm with flats so arranged as to have a maximum opening of 25 mm or less. Treads for staircases, where needed, shall be of similar grating construction but provided with toe flats of 6 mm thick, and non-skid nosing in an approved manner extending up to 100 mm above the walkway surface. All steel gratings shall be galvanized and applied with anticorrosive coating specified elsewhere.

13.7.11 Paving

The finished ground level shall be paved for 3.0m width all round the outer edge of the cold water basin. The paving shall consist of 150 thick RCC slab of M-20 grade over soling. The minimum reinforcement shall be 10 mm dia spaced 150 mm center to center both ways top and bottom. The RCC slab shall be overlaid 100 mm thick M-10 PCC mat and 300 mm well compacted sand layer. All around peripheral RCC drain leading to drain chamber shall be suitably provided.

13.7.12 Fittings and fixtures

a) Complete system of Lightning protection, Aviation warning lights and Access ladder to be provided as per Clause 7.5 of IS 11504 (latest).

13.8 Drawings, Data and Calculation to be submitted by Bidder :

For list of drawings, data and calculation to be submitted by Bidder before and after award of Contract refer Chapter-18 of Volume-III of this specification.

13.9 Codes and Standards

The design and construction of the cooling tower as specified hereinafter shall comply with the requirements of all applicable latest Indian/British/American Standards and Codes of Practice. The latest editions of the following standards and publications shall be followed in particular:

- BS 4485 Water Cooling Tower (Part 1 thru' 4)
- Cooling Tower Institute of USA, Bulletin ATC-105: "Acceptance Test Procedure for Water Cooling Tower."
- PTC-23: ASME Performance Test Code for Atmospheric Water Cooling Equipment.
- IS: 11504: Criteria for Structural Design of Reinforced Concrete Natural Draught Cooling Towers.
- American Society of Testing Materials
- The materials of various components such as PVC, plain and reinforced concrete, bars and steel wires for concrete reinforcement etc. shall be in accordance with relevant Indian Standards or else to applicable American Standards.

In case of any contradiction between the aforesaid Standards and stipulations as per this specification, the stipulations of this specification shall prevail.

a)