RESPONSE STUDY OF NATURAL DRAFT HYPERBOLIC COOLING TOWERS UNDER WIND LOADS: A REVIEW

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Abstract:Basically, cooling tower is a devise which extract waste heat from industry or plant building to the atmospherethrough cooling of water stream at a lower temperature. As these are very huge thin shell structures, they basically subjected toits self-weight and the dynamic loads as an earthquake load and wind load. Recent devastative occurred earthquakes havevulnerable effects on cooling towers and played vital role of them in safety and performance of power plants during and after astrong ground motion. The cooling tower has been analyzed for the wind load as well as the seismic load by using the finiteelement analysis of ANSYS version by assuming its bottom end fixed and top end free to displace. As a part of analysis, coolingtower of height 143.50 mt is taken of having different column supporting systems i.e. H-frame, V-frame, I-frame, A-frame. Theeffect of wind load on the cooling tower is considered by defining design wind pressure coefficients given in IS: 11504-1985 alongwith the pressure distribution at various height as per given in IS: 875-PartIII-1987. Seismic load is carried out by applying 0.5gin accordance with the IS: 1893-2016. For the purpose of comparison, maximum principle stresses, shear stresses anddeformation of tower are derived from the analysis.

IndexTerms **- Hyperbolic cooling tower, ANSYS WORKBENCH, I-frame, H-frame Support, Wind load, Throat location, Stiffeners.**

I. INTRODUCTION

Cooling tower is a heat rejection device, which extracts waste heat to the atmosphere though the cooling of a water stream to a lower temperature. Common applications for cooling towers are providing cooled water for air-conditioning, manufacturing and electrical power generation. R/C cooling towers are subjected to its self weight and the dynamic load such as an earthquake motion and a wind effects. Especially, dynamic analyses of these structures are important factor to design R/C cooling tower structures. Especially, dynamic analyses of these structures are important factor to design R/C cooling tower structures. The structures have huge surfaces of concrete with increasing its constructional height and also, R/C shell structure is usually placed on the supporting columns to take a cold air into it. R/C cooling tower represents the combinations of R/C shell and R/C column structures. The progressive nature of the corrosion-induced deterioration, understanding the root cause, the consequences and associated costs was essential. As such, a condition evaluation was conducted. The total weight of the tower and the static pressure on each column also was determined. Utilizing the collected data, the tower was recreated using a three-dimensional structural engineering computer program. The software included model generation, static, dynamic and linear analyses. Dynamicbehavior of R/C cooling tower shell under an earthquake loading is analysed by use of FEM. The most common sight, especially in power plants and nuclear plants, is hyperboloid-shaped cooling towers. The hyperboloid shape impacts the strength of the entire structure. Since cooling towers are supposed to cool the working fluid down to a low temperature, they release vapours into the atmosphere through the opening at the top of the tower. Therefore, these towers have to be sufficiently tall (they can be as tall as 200 meters), or else the released vapour may cause fogging or recirculation. To support such a high structure, it is extremely important that the base is considerably consolidated and spread over a large area so that it can support the tall, heavy structure above it. This is why cooling towers have a large, circular base.

Why hyperbolic shape preferred?

Hyperbolic shape helps in facilitating aerodynamic lift and ensures faster and more efficient diffusion in to the atmosphere. There are also some other reasons behind the usage of this shape. For example, a wide base not only provides strength to the whole structure, but also offers ample space for the installation of machinery. From a logistical standpoint, this shape is easier to build, as it employs a lattice of straight beams to erect the tower. Also, this type of structure is more resistant to external naturalforces than straight buildings.

All cooling towers are designed to remove waste heat fromwater and transfer it to the atmosphere, but there are a lotof ways to accomplish this task. Cooling towers can becategorized in a number of different ways, because thereare so many differences between cooling towers. For ourpurposes, we will cover three kinds of cooling towersbased on how air and water flow (counter flow, cross flow,and hyperbolic) and two types based on how the air ismoved (mechanical and natural draft).

Geometry of Cooling Towers:

The geometry of the Hyperboloid revolution,

$$\frac{R_0^2}{{a_0}^2} - \frac{y^2}{b^2} = 1$$

In which is the horizontal radius at any vertical coordinate, Y with the origin of coordinates being defined by the center of the tower throat, is the radius of the throat, and b is some characteristic dimension of the hyperboloid.

Load calculation:

Other than self-weight, the external applied loads thataffect the cooling tower are dead loads, wind loads, effectof adjacent structures, imposed loads, foundationsettlement loads, constructional loads, and thermal loads.The predominant forces acting on the cooling tower willresult from wind or seismic loading. The reinforcementdesign of cooling tower is often controlled by the netdifference between the tension due to wind load andcompression due to dead load.

Wind force forms the major external applied loading in thedesign of cooling towers, and it also provides the mostcommon means of determining the degree of lateralstrength required by the towers. Wind load is calculated aspressure acting on each plate. Both vertical andcircumferential variation if wind pressure is considered.The vertical variation if wind pressure is given by IS 875 – part 3 – 1987. And circumferential variation of windpressure is given by IS 11504 – 1985.

Vertical Wind pressure distribution:

IS 875 (Part 3) – 1987 determines wind pressures based onpeak wind speed of 3 second gust with a return period of50 years. The zones of basic wind seed at 10 m aboveground at speeds of 33, 39, 44, 50 and 55 m/s are shown inthe code on a wind map of the country. The design windspeed is calculated by considering the factors k1, k2, k3related to probable life of structure, terrain, localtopography and size of structure separately, and theircombines effect is determined by multiplying the factors,the design wind pressure at any height above mean groundlevel shall be obtained by the following relationshipbetween wind pressure and wind velocity:

$$P_z = 0.6\, V_z^2$$

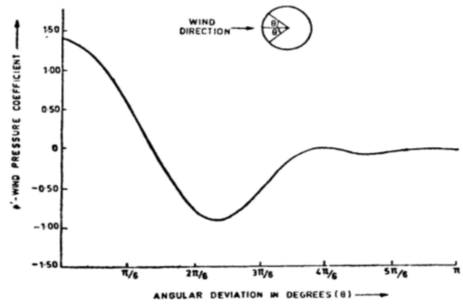
Where
P_z = design wind velocity in N/m²at height z, and
v_z= design wind velocity in m/s at height z.

Design Wind Speed (Vz) is The basic wind speed (Vb) forany site shall be modified to include the effects of risklevel, terrain roughness, height and size of structure andlocal topography to get design wind velocity at any height (Vz) for the chosen structure.

$$V_z = V_b . k_1 . k_2 . k_3$$

Vz = design wind speed at any height z in m/s;
k1 = probability factor (risk coefficient),
k2 = terrain, height and structure size factor and
k3 = topography factor.

Circumferential wind pressure distribution:



IS 11504 – 1987 gives the coefficient for circumferentialvariation of wind pressure in hyperbolic cooling towers. Asper the code (clause 5.1.3 and 6.2 - A- 2), the windpressure distribution on the outside of the shell is assumedto be symmetrical about the center line in the direction ofwind.

For practical design these values may be increased by 10percent to take into account geometrical imperfections. Thewind pressure coefficient distribution around the shell isdefined by the following graphCircumferential Wind Pressure Coefficient DistributionThe distribution shall be used at all heights of the towerand includes an allowance for internal suction.

$$p' = \sum_{n=0}^{7} Fn. \cos n\theta$$

P'= design wind pressure coefficient,
Fn = Fourier coefficient of nth term, and
θ = angular position measured from the incident winddirection in degrees.

Values of $F_n$for various values of n are tabulated below:

N	Fn
0	-0.00071
1	+0.24611
2	+0.62296
3	+0.48833
4	+0.10756
5	-0.09579
6	-0.01142
7	+0.04551

With various values of Fn from the table, circumferentialwind distribution coefficient for each 2.5° angle differenceis calculatedvariation of the coefficient (p') in thestructure's cross section. The coefficient is maximum atincident 0° and it slowly reduces below 0 and attainsnegative maximum (Suction) around 75°.

Circumferential variation of wind pressure:

The actual design wind pressure on the shell is obtained bymultiplying the basic wind pressure as given in IS: 875 bythe coefficient p'. Hence individual values of pressureacting on all 2880 plates are calculated.

Dynamic effects of wind:

As per IS 875 (Part 3) – 1987, Clause 7.1 Flexible slenderstructures and structural elements shall be investigated toascertain the importance of wind induced oscillations orexcitations along and across the direction of wind. Ingeneral, the following guidelines may be used forexamining the problems of wind induced oscillations:

 Buildings and closed structures with a height tominimum lateral dimension ratio of more than about 5.0, or

 Buildings and structures whose natural frequency in thefirst mode is less than 1.0 Hz. (Natural frequency is (1/T),whereas the fundamental time period (T) may either beestablished by experimental observations on similarbuildings or calculated by any rational method of analysis)Any building or structure which satisfies either of theabove two criteria shall be examined for dynamic effects ofwind. If preliminary studies indicate that wind- inducedoscillations are likely to be significant, investigationsshould be pursued with the aid of analytical methods or, ifnecessary, by means of wind tunnel tests on models.

Effect of adjacent structures:

For taller and larger cooling towers the effect of adjacentstructures in wind load plays a vital role, and hence it isimportant to derive the wind pressure distribution on thestructure from wind tunnel experiments. Also for towersbuilt at closer spacing, it is suggested to determine windpressure distribution by model tests in a wind tunneloffering appropriate aerodynamic similitude. Such modelsshall include all adjacent topographical features, buildingsand other structures which are likely to influence the windload pattern on the tower significantly. This effect is notconsidered in this project.

CONCLUSION

The base diameter, air intake opening height, tower height and throat diameter are determined by thermal considerations. Hence optimizing the location of throat is highly necessary in structural and economic considerations.

 Circumferential and meridional variation of both SX andSY shows that location of throat influences the stressesinduced in cooling tower shell significantly.

 Variation of SX along height shows that the effect ofthroat variation is much in the bottom of the cooling tower and it gradually reduces to zero as we go to the top ofcooling tower.

 Economical design with respect to SX would be to havea relatively lower throat and at the same time whose meridional reinforcement requirement at bottom is close tominimum reinforcement requirement. This gives additionalbenefit due to lower SX above shell mid-height.

 Hoop stresses are highly affected by changes in throatlocation mainly at throat level. Hoop stress variation issuch that, higher throat location is not economical inincident face of cooling tower. Whereas very low throatlocation is not economical on the suction face.

 The effect of throat variation is significant at throat thanit is at bottom and top of cooling tower. At top level bothincident face and suction face are subjected to higher hoopstresses. This implies the significance of providing anupper ring beam.

 The range provided for throat location in the towerdesign considerations given by IS11504 can be used fortowers of height less than 100m. For taller towers,optimization of throat location is required as it plays a vitalpart in the structural safety and economy.

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