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Research Article

Wind effect on Hyperbolic RCC Cooling Tower

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Abstract

R/C cooling towers are used for many kinds of industrial and power plants. These are huge structures and also show thin shell structures. The present paper deals with effect of wind analysis of hyperbolic cooling towers having variation in the height and thickness. The existing cooling towers are chosen from Bellary thermal Power station (BTPS) as case study. For the other models of cooling towers, the dimensions and thickness of the shell are varied with respect to reference tower. The cooling towers are analyzed by Staad. ProV8i having boundary conditions considered are Top end free and Bottom end is fixed. The Material properties of the cooling towers are young's modulus 2.1 Mpa, Poisson Ratio 0.15 and density of RCC 25 kN/m3. Wind loads on these cooling towers have been calculated in the form of pressure by using design wind pressure co efficient given in IS 11504-1985 code & design wind pressure at different levels as per IS 875 (Part 3)-1987 code. Displacement in X, Y and Z directions, maximum and minimum principal stress at top and bottom are obtained. The variation in displacement v/s thickness, maximum and minimum principal stress is plotted graphically.

Keywords: *Cooling tower, Displacement, Principal Stress, and Wind Load.*

1. Introduction

Wind forms the major external applied loading in the design of cooling tower and it also provides the most common means of determining degree of lateral strength required by towers. Cooling towers constitute very important Structure in the power generation systems they also contribute to environment protection. The hyperbolic cooling towers are used in nuclear power plants, thermal power plants, chemical and other industrial plants. From the structural point of view they are high rise reinforced concrete structures in the form of doubly curved thin walled shells of complex geometry and so is their analysis and design. The in-plane membrane actions primarily resist the applied forces and bending plays the secondary role in these special structures. In the absence of earthquake loading, wind constitutes the main loading for the design of natural draught cooling towers.

The static and dynamic analysis of hyperbolic cooling tower. The study includes the comparison between two existing cooling towers of different element types and varying mesh ratio is adopted and also deflection pattern, maximum principal stresses and von mises stress is compared in the analysis (Sachin Kulkarni and Prof A. V. Kulkarni, 2014). The effect of wind loading on analysis of natural draught hyperbolic cooling tower emphasize on effect of wind on Natural draught hyperbolic cooling tower. The slenderness of the columns and the large dimensions of the shell make these structures vulnerable to earthquake and wind disturbances (Tejas G. Gaikwad *et al*, 2014). Response of Natural Draught Cooling Towers to Wind loads. This paper deals with the study of five cooling towers of 122m, 177m, and 200m, high above ground level with different throat height to total height ratio's, throat diameter to base diameter ratio's and diameter to thickness ratio's. The results of the analysis include membrane forces, meridional force and hoop force and bending moments (G. Murali, 2012). Finite Element Analysis for Structural Response of RCC Cooling Tower Shell Considering alternative supporting systems. The comparison has been made of the self-weight loading, static wind loading and pseudo static seismic activities the loads are calculated as per the recommendation of relevant IS codes (Esmaeil Asadzadeh *et al*, 2012).

2. Geometry of Cooling Towers

The geometry of the Hyperboloid revolution

$$\frac{R_0^2}{a_0^2} - \frac{Y^2}{b^2} = 1 \qquad (1)$$

In which R_0 is the horizontal radius at any vertical coordinate, Y with the origin of coordinates being defined by the center of the tower throat, a_0 is the radius of the throat, and b is some characteristic dimension of the hyperboloid.

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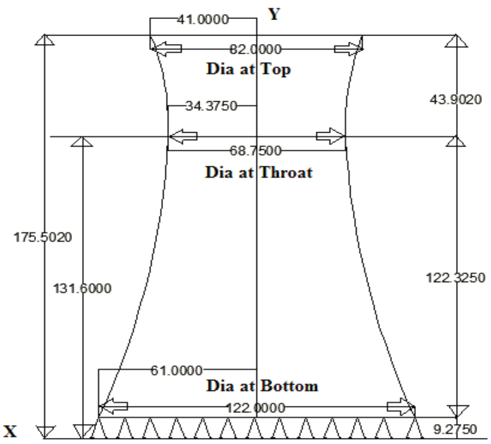

Fig.1 Geometry of existing Cooling Tower

Table 1 represents geometric details of the cooling towers i.e. total height, diameters at various levels etc.

Table 1 Geometric Details of Cooling Towers

S. No	Description	Symbols	Parametric values		
			CT1	CT2	CT3
1	Total height	H	143.5m	157.85m	175.50m
2	Height of throat	H_{thr}	107.75m	118.525 m	131.60m
3	Diameter at top	D_t	63.6m	69.96m	82.00m
4	Diameter at bottom	D_b	110m	121.00m	122.00m
5	Diameter at throat level	Dthr	61.00m	67.10m	68.075m
6	Column height	H_c	9.20m	10.12m	9.275m
7	(H_c/H) ratio		0.750	0.750	0.750
8	(D_{thr}/D_b) ratio		0.554	0.554	0.563

CT1 and CT3 are the existing cooling towers and CT2 is intermediate cooling tower between two existing cooling towers. The thickness is varied from 200mm, 300mm, 400mm and 500mm. The material properties of cooling towers are young's modulus 2.1Mpa, Poisson Ratio 0.15 and Density of RCC 25kN/m^3. The boundary conditions are top end free and bottom end is fixed. The following Fig.2 shows nodes in model, meshing and boundary conditions applied to model from front view, isometric view and bottom view and Fig.3 represents the application of wind loading to the model from front view, isometric view and bottom view.

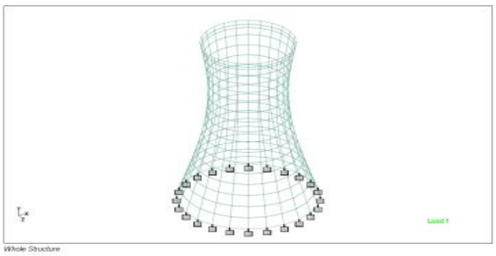

Fig.2 Nodes, Meshing and Boundary Conditions (Isometric View)

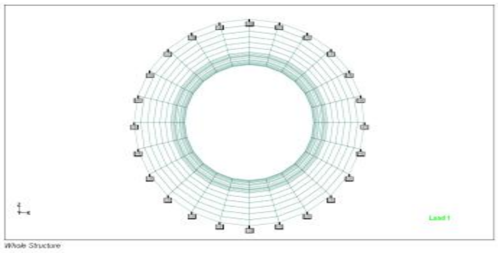

Fig.3 Nodes, Meshing and Boundary Conditions (Bottom View)

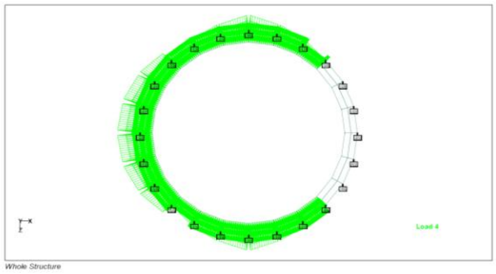

Fig.4 Application of Wind Load (Bottom View)

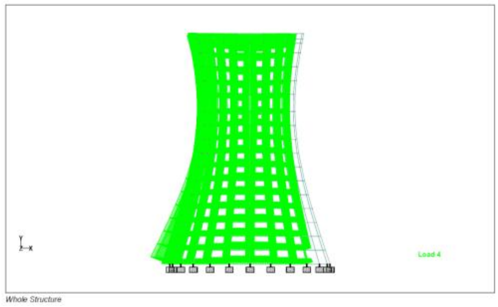

Fig.5 Application of Wind Load (Front View)

The wind pressures on cooling towers at a given height [p_z] are 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 (V_b) will be taken as V_b =39 m/s at 9.2m height above mean ground level. For computing design wind speed (V_z) at a height z, the risk coefficient $k_1 k_1$ =1.06 will be considered. For coefficient k_2 terrain category 2 as per table 2 IS: 875 (part-3)-1987 will be considered. The wind direction for design purpose will be the one which would induces worst load condition. Coefficient k_3 will be 1 for the Tower under consideration. The wind pressure at a given height will be computed theoretically in accordance with the IS codal provision given as under

$$p_z = 0.6V_z^{\ 2} \quad (2)$$

Where $V_z = V_b k_1 k_2 k_3$ (3)

In which p_z is the horizontal radius at any vertical coordinate, Y with the origin of coordinates being defined by the center of the tower throat, a_0 is the radius of the throat, and b is some characteristic dimension of the hyperboloid.

Wind loads on these cooling towers have been calculated in the form of pressure by using design wind pressure co efficient given in IS 11504-1985 code.

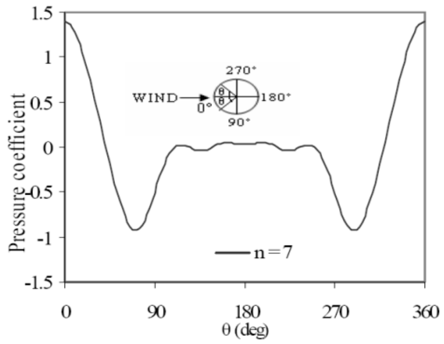

Fig.6 Circumferential Pressure Distribution as per IS code

The circumferential pressure distribution can be represented by a Fourier cosine series of the form as given below:

$$p' = \sum_{n=0}^{7} f_n \cos n\theta \qquad (4)$$

$$= f_0 + f_1 \cos n\theta + f_2 \cos 2\theta + \ldots\ldots + f_7 \cos 7\theta \qquad (5)$$

Where

p' = pressure coefficient

n = harmonic constant

θ = horizontal angle measured from the windward meridian

f_n = harmonic constant

Values of *Fn* for various values of *n* are tabulated below:

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

The actual design wind pressure on the shell is obtained by multiplying the basic wind pressure as given in IS: 875-1964· by the coefficient P' obtained above.

3. Tabulation and Results

3.1 Displacement

Variation of Displacement for Wind Load in X, Y and Z direction for different thickness is presented in **Table2**, **Table3**, and **Table4** and plotted graphically in **Fig.7**, **Fig.8** and **Fig.9** respectively. The variation of displacement in Y and Z direction is similar.

Table 2 Displacement due to Wind Load in X Direction in (mm)

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cower Tower3
200	1.8	2.639	2.371
300	1.081	1.619	1.456
400	0.737	1.117	1.018
500	0.538	0.825	0.762

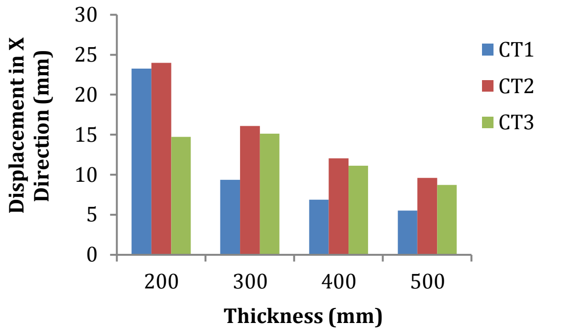

Fig.7 Variation of Displacement for Wind Load in X direction for different thickness

Table 3 Displacement due to Wind Load in Y Direction in (mm)

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cower Tower3
200	1.8	2.639	2.371
300	1.081	1.619	1.456
400	0.737	1.117	1.018
500	0.538	0.825	0.762

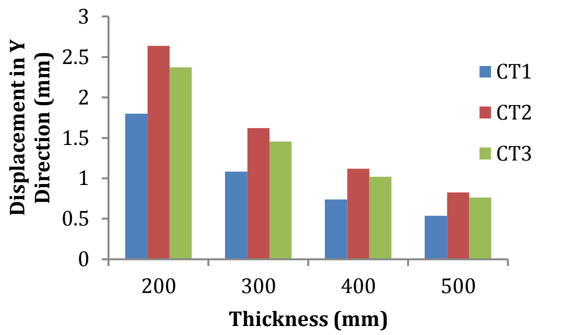

Fig.8 Variation of Displacement for Wind Load in Y direction for different thickness

Table 4 Displacement due to Wind Load in Z Direction in (mm)

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cower Tower3
200	23.851	27.112	15.854
300	10.211	17.836	15.361
400	7.445	13.071	11.204
500	5.79	10.154	8.738

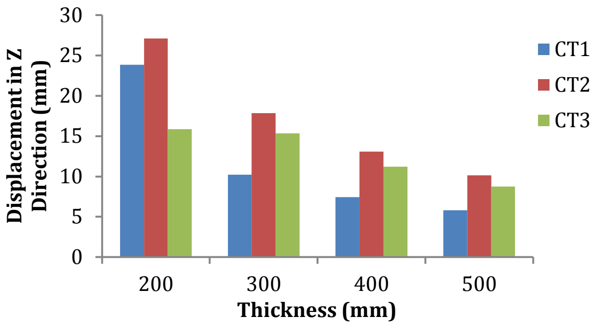

Fig.9 Variation of Displacement for Wind Load in Z direction for different thickness

3.2 Principal Stress

The maximum and minimum principal stress at top due to wind load is presented in **Table 5** and **Table 6** is plotted graphically in **Fig.10** and **Fig. 11** and also maximum and minimum principal stress at bottom due to wind load is presented in **Table 7** and **Table 8** plotted graphically in **Fig. 12** and **Fig. 13.** It is observed that as the thickness and height increases principal stress decreases.

Table 5 Max Principal Stress at Top

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cower Tower3
200	1.044	1.621	1.17
300	0.686	1.063	0.779
400	0.509	0.787	0.583
500	0.403	0.623	0.465

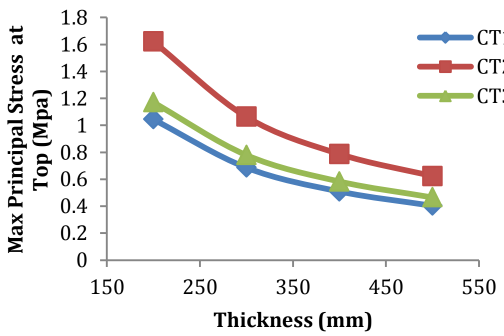

Fig.10 Variation of Principal Stress due to Wind Load for different thickness

Table 6 Min Principal Stress at Top

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cower Tower3
200	-0.381	-0.449	-0.423
300	-0.259	-0.308	-0.288
400	-0.19	-0.232	-0.209
500	-0.15	-0.188	-0.181

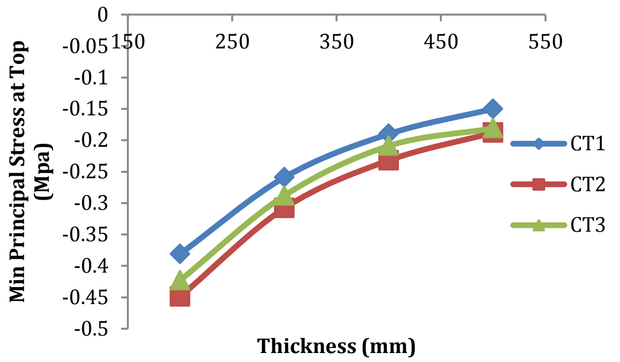

Fig.11 Variation of Principal Stress due to Wind Load for different thickness

Table 7 Max Principal Stress at Bottom

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cower Tower3
200	0.025	0.051	0.102
300	0.025	0.041	0.109
400	0.022	0.037	0.103
500	0.018	0.037	0.086

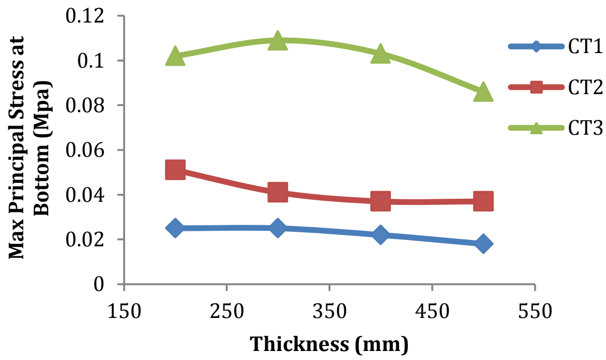

Fig.12 Variation of Principal Stress due to Wind Load for different thickness

Table 8 Min Principal Stress at Bottom

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cower Tower3
200	-0.744	-1.127	-1.091
300	-0.513	-0.768	-0.729
400	-0.395	-0.589	-0.548
500	-0.323	-0.479	-0.438

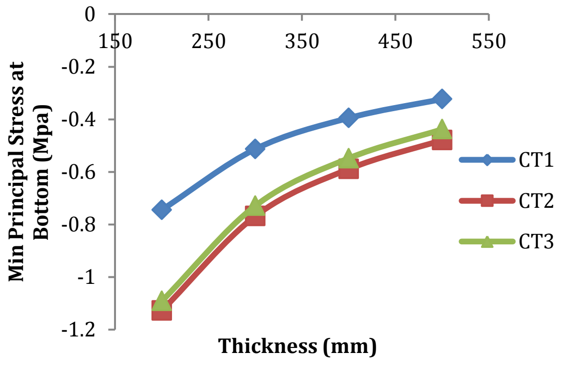

Fig.13 Variation of Principal Stress due to Wind Load for different thickness

Conclusions

From the variation of displacement in X, Y and Z directions with thickness and variation of max and min principal stress at top and bottom, it is evident that

1) Due to wind loading as the thickness and height increases displacement goes on decreasing. Displacement in CT2 is maximum than CT1 and CT3.
2) The Distortion is minimum at bottom part of shell due to fixed base (i.e. fixity), & maximum at top part of shell.
3) Principal stress due to wind loading goes on decreasing with increase in its thickness and height.

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