

# Thermal Effect on RCC Hyperbolic Cooling Tower

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**ABSTARCT:** 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 natural draft or hyperbolic cooling tower makes use of the difference in temperature between the ambient air and the hotter air inside the tower. As hot air moves upwards through the tower (because hot air rises), fresh cool air is driven into the tower through an air inlet provided at the bottom. The present paper deals with study of thermal analysis on cooling towers. As a case study cooling towers from Bellary Thermal Power Station (BTPS) are selected. These cooling towers are analysed using software Staad. ProV8i by assuming top end free and fixity at base. The material properties of cooling towers are young's modulus 2.1Mpa, Poisson Ratio 0.15 and Density of RCC 25kN/m<sup>3</sup>. The results of the analysis include displacement in X, Y, Z directions and Maximum Principal Stress is obtained. The variation in Displacement v/s thickness, max principal stress v/s thickness is plotted graphically.

**KEYWORDS:** Cooling tower, Displacement, Maximum Principal Stress, Thermal Load.

## I. INTRODUCTION

Natural Draught cooling towers are most effective measures for cooling of thermal power plants by minimizing the need of water and avoiding thermal pollution of natural water bodies. Thus they are able to balance environmental factors, investments and operating costs with demands of reliable energy supply. The cooling load is determined by the amount of heat that needs to be extracted from a given process or peak comfort cooling demand. The cooling tower must be adequately sized to reject this same amount of heat to the atmosphere.

Cooling towers are used to reject heat through the natural process of evaporation. Warm recirculating water is sent to the cooling tower where a portion of the water is evaporated into the air passing through the tower. As the water evaporates, the air absorbs heat, which lowers the temperature of the remaining water. This process provides significant cooling to the remaining water stream that collects in the tower basin where it can be pumped back into the system to extract more process or building heat, thereby allowing much of the water to be used repeatedly to meet the cooling demand. The amount of heat that can be rejected from the water to the air is directly tied to the relative humidity of the air. Air with a lower relative humidity has a greater ability to absorb water through evaporation than air with a higher relative humidity, simply because there is less water in the air.

Cooling Towers are divided into two main Types, the first being named natural draught cooling towers and the second mechanical draught cooling towers. In natural draught cooling tower (NDCT), the circulation of air is induced by enclosing the heated air in a chimney which then contains a column of air which is lighter than the surrounding atmosphere. This difference in weight produces a continuous flow of air through the cooling tower as long as water at a temperature above the wet bulb temperature is circulated through the cooling tower. NDCT makes use of the stack effect of a chimney above the packing to induce air flow up through the packing in counter-flow to the water.

**II. THERMAL LOAD**

The temperature difference between the inside and outside faces of cooling towers are usually of the upto of 10°C to 20°C in the extreme circumstances. It is found that these temperature gradients do not cause excessive tensile stress in the shell, but only increase meridional forces in shell by about 10% then those calculated purely for self weight+ wind load case. The effect of sun’s radiation is to produce stresses in shell opposite to those arising from thermal gradients i.e. the internal cold face is subjected to tension. It is found that for the case when one side of tower is exposed to the sun and other in shade, with a temperature differential of 5°C , the stresses in shell are quite small. Thermal analysis temperature difference between inlet & outlet of the cooling tower is taken into consideration = 9.28°C

**III. GEOMETRY OF COOLING TOWERS**

The geometry of the Hyperboloid revolution

$$\frac{R_0^2}{a_0^2} - \frac{y^2}{b^2} = 1 \quad \dots\dots\dots (1)$$

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

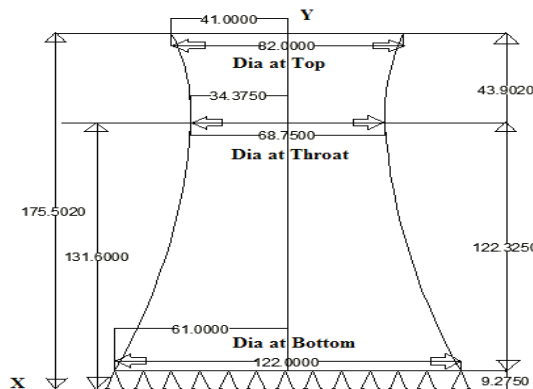


Fig.1. Geometry of existing Cooling Tower (BTPS)

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

SR NO	DESCRIPTION	SYMBOLS	PARAMETRIC VALUES		
			CT1	CT2	CT3
1	Total height	H	143.5m	157.85m	175.50m
2	Height of throat	H <sub>thr</sub>	107.75m	118.525m	131.60m
3	Diameter at top	D <sub>t</sub>	63.6m	69.96m	82.00m
4	Diameter at bottom	D <sub>b</sub>	110m	121.00m	122.00m
5	Diameter at throat level	D <sub>thr</sub>	61.00m	67.10m	68.075m
6	Column height	H <sub>c</sub>	9.20m	10.12m	9.275m
7	(H <sub>c</sub> /H) ratio		0.750	0.750	0.750
8	(D <sub>thr</sub> /D <sub>b</sub> ) 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<sup>3</sup>. 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 thermal loading to the model from front view, isometric view and bottom view.

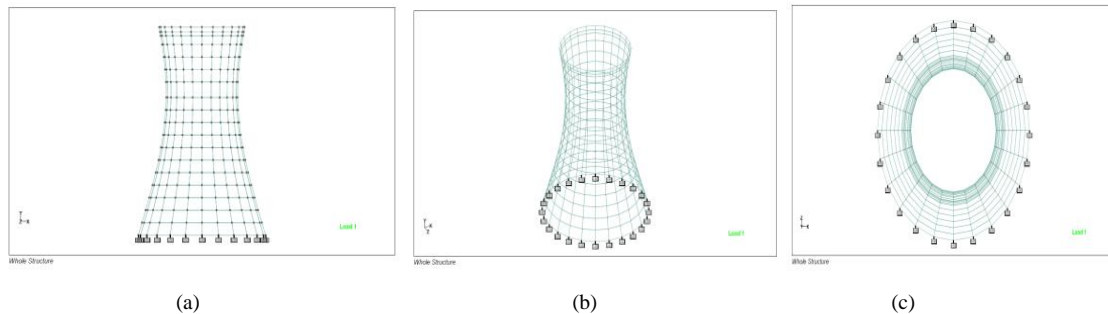


Fig.2 Cooling Tower (a) Front view (b) Isometric view (c) Bottom view



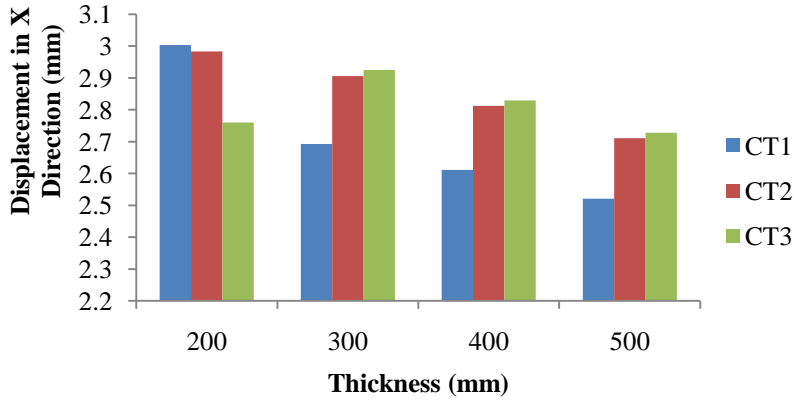
Fig.3 Application of thermal load (a) Front view (b) isometric view

#### IV. TABULATION AND RESULTS

It is found that due to thermal loading variation of displacement in X and Z direction is same and a cooling tower whose thickness and also height is minimum is having maximum displacement. Therefore CT1 is found to undergo more displacement than other two i.e. CT2 and CT3

**Table 2: Displacement due to Thermal Load in X Direction in (mm)**

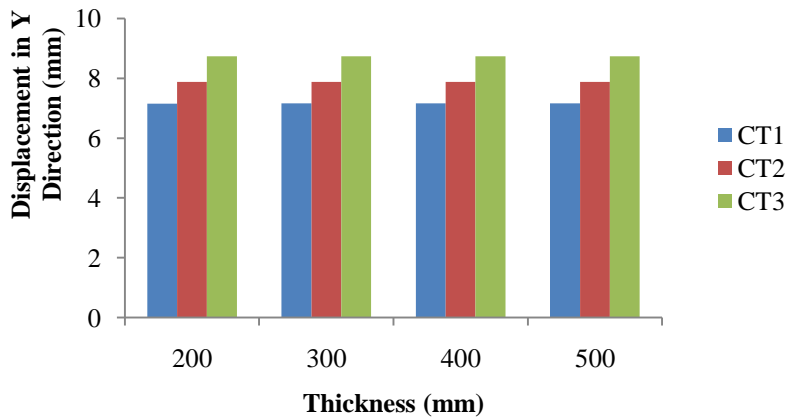
Thickness (mm)	Cooling Tower1	Cooling Tower2	Cooling Tower3
200	3.003	2.983	2.76
300	2.693	2.906	2.925
400	2.611	2.812	2.83
500	2.521	2.711	2.728



Graph 1: Variation of Displacement in X direction for different thickness

Table 3: Displacement due to Thermal Load in Y Direction

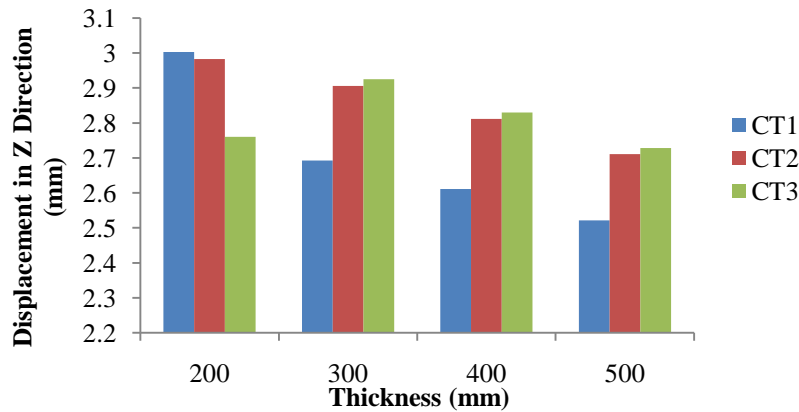
Thickness (mm)	Cooling Tower1	Cooling Tower2	Cooling Tower3
200	7.157	7.875	8.732
300	7.159	7.877	8.734
400	7.161	7.878	8.736
500	7.163	7.88	8.738



Graph 2: Variation of Displacement in Y direction for different thickness

Table 4: Displacement due to Thermal Load in Z Direction

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cooling Tower3
200	3.003	2.983	2.76
300	2.693	2.906	2.925
400	2.611	2.812	2.83
500	2.521	2.711	2.728



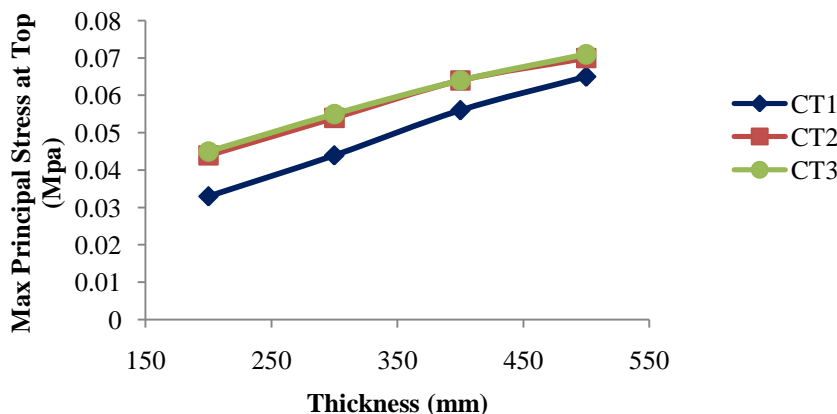
Graph 3: Variation of Displacement in Y direction for different thickness

**A. PRINCIPAL STRESS**

The following tables and graphs shows variation of maximum and minimum principal stress at top and bottom due to thermal loading. It is observed from Graph 4 and Graph 6 that as thickness and height of cooling tower increases maximum principal stress at top increases and also Graph 5 and Graph 7 represents as the thickness and height increases minimum principal stress at bottom increases.

Table 5: Max Principal Stress at Top

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cooling Tower3
200	0.033	0.044	0.045
300	0.044	0.054	0.055
400	0.056	0.064	0.064
500	0.065	0.07	0.071



Graph 4: Variation of Max Principal Stress at Top for different thickness

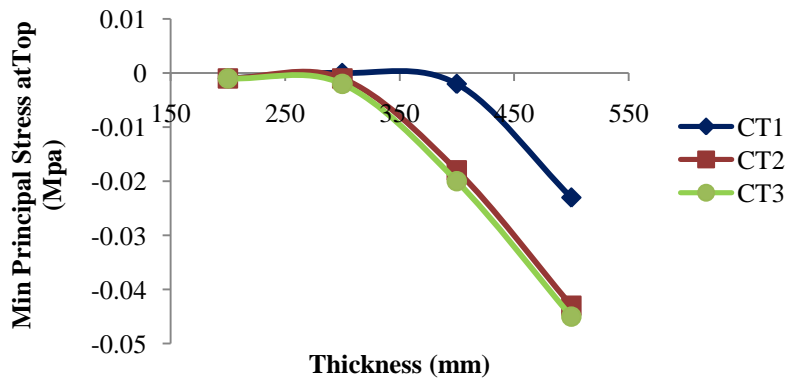
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Vol. 4, Issue 9, September 2015

Table 6: Min Principal Stress at Top

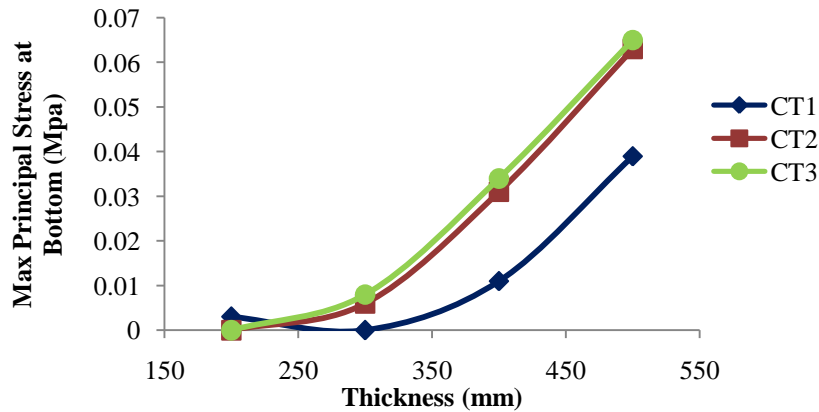
Thickness (mm)	Cooling Tower1	Cooling Tower2	Cooling Tower3
200	-0.001	-0.001	-0.001
300	0	-0.001	-0.002
400	-0.002	-0.018	-0.02
500	-0.023	-0.043	-0.045



Graph 5: Variation of Min Principal Stress at Top for different thickness

Table 7: Max Principal Stress at Bottom

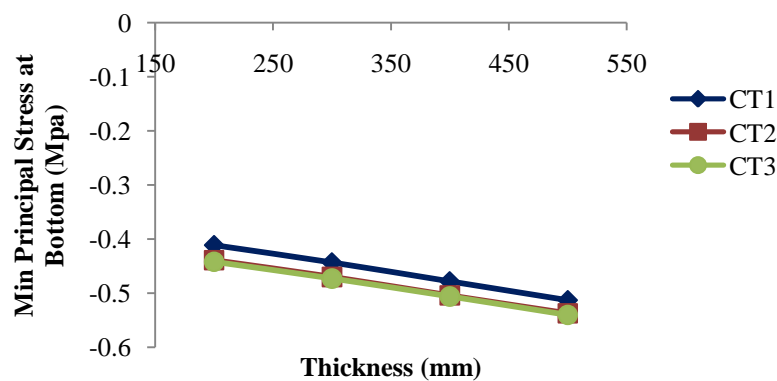
Thickness (mm)	Cooling Tower1	Cooling Tower2	Cooling Tower3
200	0.003	0	0
300	0	0.006	0.008
400	0.011	0.031	0.034
500	0.039	0.063	0.065



Graph 6: Variation of Max Principal Stress at Bottom for different thickness

**Table 7: Min Principal Stress at Bottom**

Thickness (mm)	Cooling Tower1	Cooling Tower2	Cooling Tower3
200	-0.411	-0.439	-0.442
300	-0.443	-0.47	-0.473
400	-0.478	-0.504	-0.506
500	-0.513	-0.537	-0.54



**Graph 7: Variation of Min Principal Stress at Bottom for different thickness**

## V. CONCLUSION

1. The rate of heat loss is affected by the atmospheric parameters such as air temperature, water temperature, relative humidity and rate of heat loss.
2. Due to thermal loading, the displacement at top of cooling tower in X and Z direction goes on increasing with decrease in thickness and height.
3. Due to thermal loading, the displacement in Y direction goes on increasing as thickness and height increases.
4. Principal stress due to thermal loading goes on increasing with increase in its thickness and height.

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ISSN(Online) :2319-8753  
ISSN (Print) : 2347-6710

# International Journal of Innovative Research in Science, Engineering and Technology

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 4, Issue 9, September 2015**

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