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A CASE STUDY OF HYBERBOLIC COOLING TOWER UNDER SEISMIC LOADS

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ABSTRACT

Hyperbolic cooling towers are large, thin shell reinforced concrete structures which contribute to environmental protection and to power generation efficiency and reliability. The safety of hyperbolic cooling towers is important to the continuous operation of a power plant. It is observed from the analysis that maximum displacement, support reactions, support moments, stresses and bending moments in plates due to seismic loading on a hyperbolic cooling tower is continuous function of geometry (top diameter, throat diameter and height). earthquake zone plays the important role in analysis. So from the above work it can be observed that 300 thickness, throat diameter 64m and height 150 m is much efficient among all but if height is mandatory to extent than height should not be more than 159m (height taken from actual work). and 170 m height is critical.

KEYWORDS: Hyperbolic cooling tower, seismic forces, node displacement, shear force etc.

INTRODUCTION

Hyperbolic cooling towers are large, thin shell reinforced concrete structures which contribute to environmental protection and to power generation efficiency and reliability. The cooling tower shell is supported by a truss or framework of columns bridging the air inlet to the tower foundation.The two loading types affect different parts of the structure. While the earthquake activates the entire 360° cross section, the wind load tends to concentrate its influence over only about 180°. This has a marked effect upon the amplification of the loading forces into the meridional shell forces. Following prominent literature reviews-

Gupta (1996) reviewed that the safety of hyperbolic cooling towers is important to the continuous operation of a power plant. Depending upon the site, earthquake may govern the design of the tower. Methods of seismic analysis have been presented. It is concluded that the response spectrum method of analysis is of maximum practical use. A method to construct the design response spectra for various earthquake zones is presented. An earthquake motion consists of three components; however, it is shown that designing for one horizontal component only is adequate.

T Aksu(1998)showed that the Column supported hyperboloid cooling towers are analyzed with a finite element formulation including the effects of thickness shear deformations and the term *z/R*. Both shell and columns are modeled by using the same curved trapezoidal finite element with 40 degrees of freedom. The stress concentration at the shell column junctions is studied by taking into account the effect of the column support width.

Dieter Busch*et.al* (2005) reviewed that In the years 1999 to 2001 a new natural draft cooling tower has been built at the RWE power station at Niederaussem, with 200 m elevation the highest cooling tower world-wide. For many reasons, such structures cannot be designed merely as enlargement of smaller ones, on the contrary, it is full of innovative new design elements. The present paper starts with an overview over the tower and a description of its geometry, followed by an elucidation of the conceptual shape optimization. The structural consequences of the flue gas inlets through the shell at a height of 49 m are explained as well as the needs for an advanced high performance concrete for the wall and the fill construction. Further, the design and structural analysis of the tower is described with respect to the German codified safety concept for these structures. Finally, the necessity of extended durability of this tower is commented.

Zingoni*et.al*(2005) worked on Damage, deterioration and the long-term structural performance of cooling-tower shells from the issues of response to short-term loading and immediate causes of collapse in the early part of this period, to the issues of deterioration phenomena, durability and long-term performance in more recent times.

Norton *et. al.*(2006) studied the effect of asymmetric imperfection of the earthquake response of hyperbolic cooling tower. A linear computer program was used to evaluate several towers. The result showed that the bending stresses produced by the imperfection can be substantial fraction of the conventional membrane stresses.

Table 1: Cases in earthquake zone IV

Case Number	**Height (m)**	**Top diameter (m)**	**Thickness (mm)**
Case 1	159	64	300
Case 2	159	64	400
Case 3	159	70	300
Case 4	159	70	400

Table 2:Cases in earthquake zone V

Case Number	**Height (m)**	**Top diameter (m)**	**Thickness (mm)**
Case 5	159	64	300
Case 6	159	64	400
Case 7	159	70	300
Case 8	159	70	400

RESULT AND DISCUSSION

The results & Conclusion in this paper are of the existing cooling tower of height 159m

2.1 Displacement

2.1.1 Displacements in Earthquake zone IV

Table 3:Comparison of nodal displacement of cooling tower diameter 300mm (Max^{m}Rst)

Height of Cooling Tower	Node Displacement for 64m & 70 m throat diameter cooling tower	
	64m Throat diameter	70m Throat diameter
159	33.620	31.947

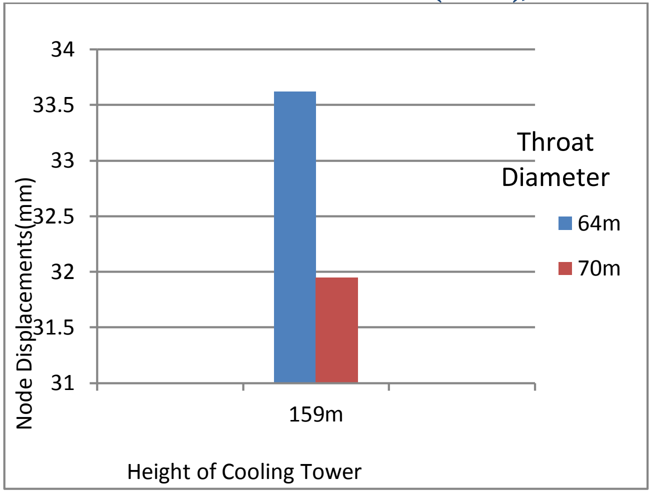
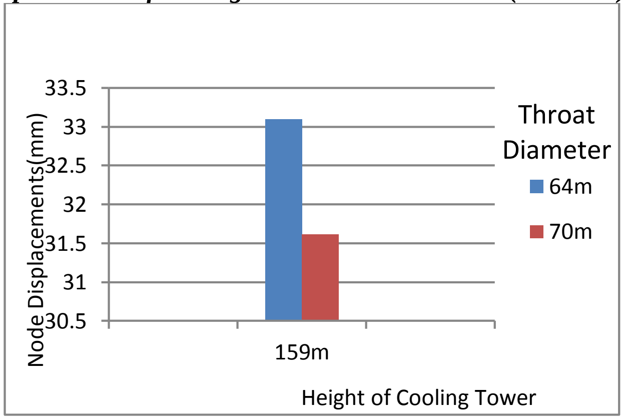


Fig. 1: Graph of nodal displacement of cooling tower diameter 300mm (Max^{m}Rst)under earthquake zone IV

Table 4:Comparison of nodal displacement of cooling tower diameter 400mm (Max^{m}Rst)

Height of Cooling Tower	Node Displacement for 64m & 70 m throat diameter cooling tower	
	64m Throat diameter	70m Throat diameter
159	33.093	31.619

Fig 2: Graph of of nodal displacement of cooling tower diameter 400mm (Max^{m}Rst) under earthquake zone IV



2.1.2 Displacements in Earthquake zone V

Table 5: Comparison of nodal displacement of cooling tower diameter 300mm (Max^{m}Rst)

Height of Cooling Tower	Node Displacement for 64m & 70 m throat diameter cooling tower	
	64m Throat diameter	70m Throat diameter
159	41.639	41.078

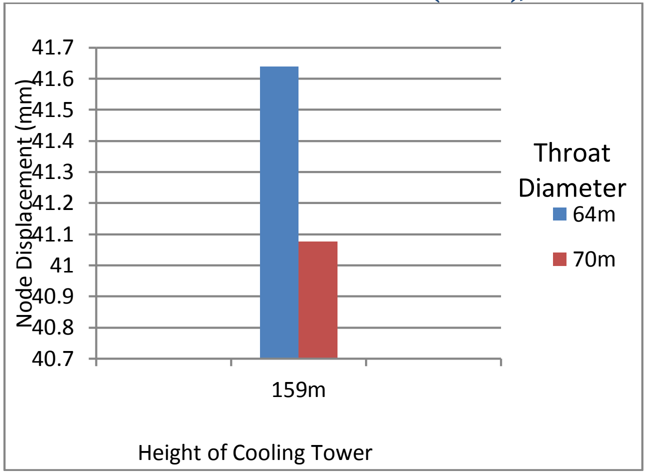


Fig. 3: Graph of nodal displacement of cooling tower diameter 300mm (Max^{m}Rst)under earthquake zone V

Table 6: Comparison of nodal displacement of cooling tower diameter 400mm (Max^{m}Rst)

Height of Cooling Tower	Node Displacement for 64m & 70 m throat diameter cooling tower	
	64m Throat diameter	70m Throat diameter
159	40.943	40.635

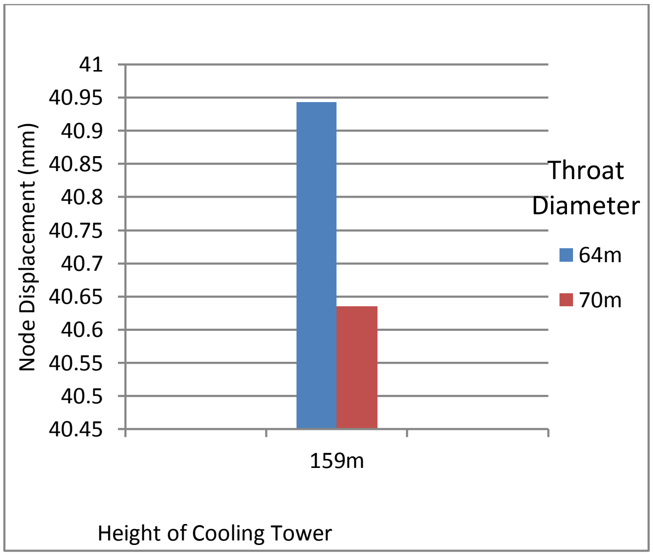


Fig. 4: Graph of nodal displacement of cooling tower diameter 400mm (Max^{m}Rst)under earthquake zone V

2.2 Support Reaction

Table 7 Comparison of support reactions for throat diameter 64 m under seismic zone IV

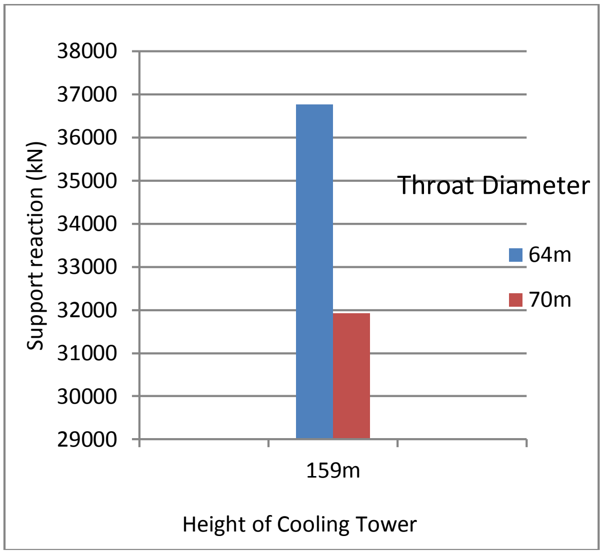


Fig. 5 Graphofsupport reaction of cooling tower diameter 300mm under earthquake zone IV

Table 8 Comparison of support reactions for throat diameter 70 m under seismic zone IV

Height Of Cooling Tower	Support Reactions (KN)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	31917.471	42557.148

Height Of Cooling Tower	Support Reactions (KN)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	36762.703	49015.842

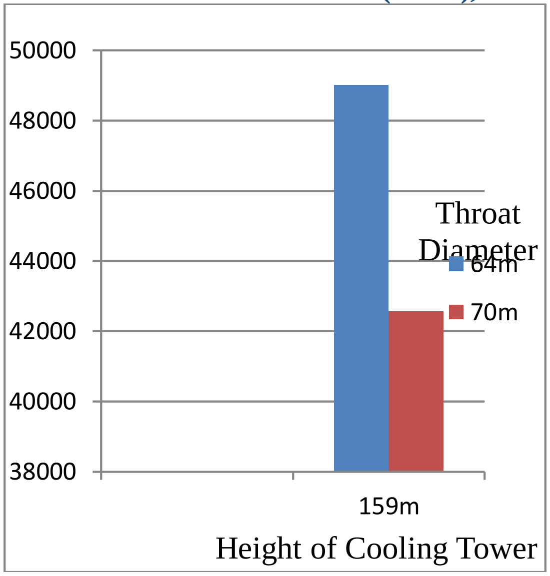


Fig. 6 Graph of support reactionof cooling tower diameter 400mm under earthquake zone IV

Table 9 Comparison of support reactions for throat diameter 64 m under seismic zone V

Height Of Cooling Tower	Support Reactions (KN)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	40148.738	53530.219

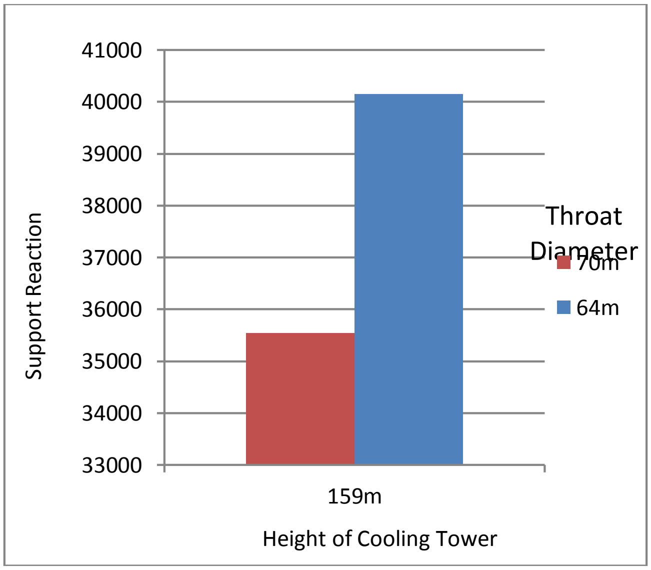


Fig. 7 Graph of support reactionof cooling tower diameter 300mm under earthquake zone V

Table 10Comparison of support reactions for throat diameter 70 m under seismic zone V

Height Of Cooling Tower	Support Reactions (KN)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness

159	35535.828	47381.875

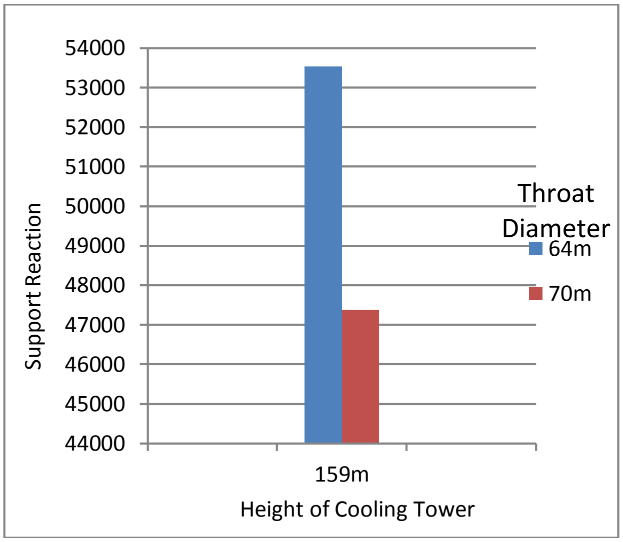


Fig. 8 Graph of support reactionof cooling tower diameter 400mm under earthquake zone V

2.3 Support Moments

Table 11 Comparison of support moments for throat diameter 64m under seismic zone IV

Height Of Cooling Tower	Support Moment (KN-m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	17110.275	22862.023

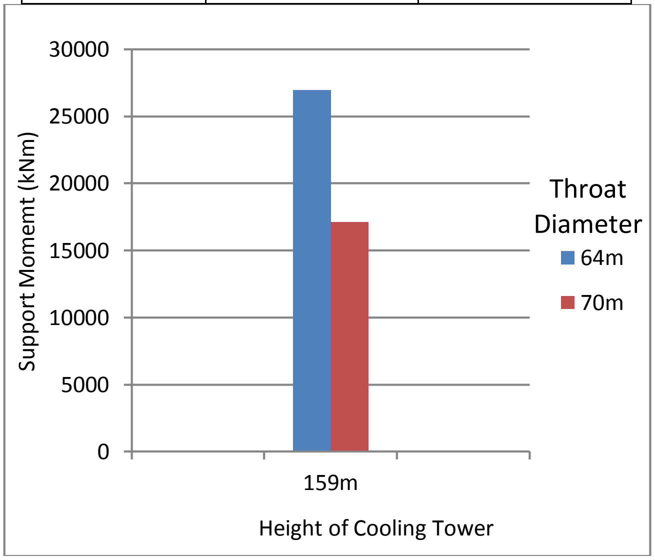
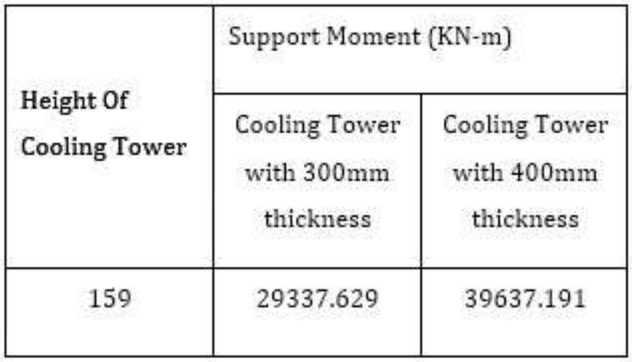


Fig.9 Graph of support momentof cooling tower diameter 300mm under earthquake zone

Table 12 Comparison of support moments for throat diameter 70m under seismic zone IV



Height Of Cooling Tower	Support Moment (KN-m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	29337.629	39637.191

Table 13Comparison of support moments for throat diameter 64 m under seismic zone

Height Of Cooling Tower	Support Moment (KN-m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	26932.635	36173.148

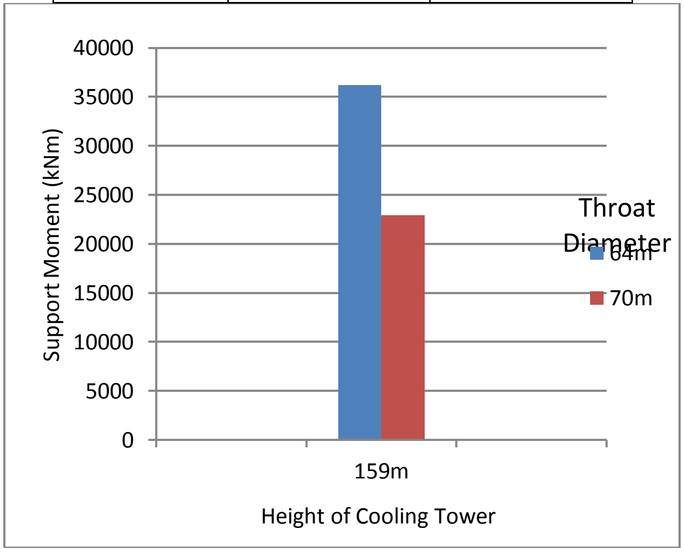


Fig. 10 Graph of support moment of cooling tower diameter 400mm under earthquake zone IV

Table 14Comparison of support moments for throat diameter 64 m under seismic zone V

Height Of Cooling Tower	Support Moment (KN-m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	29337.629	39637.191

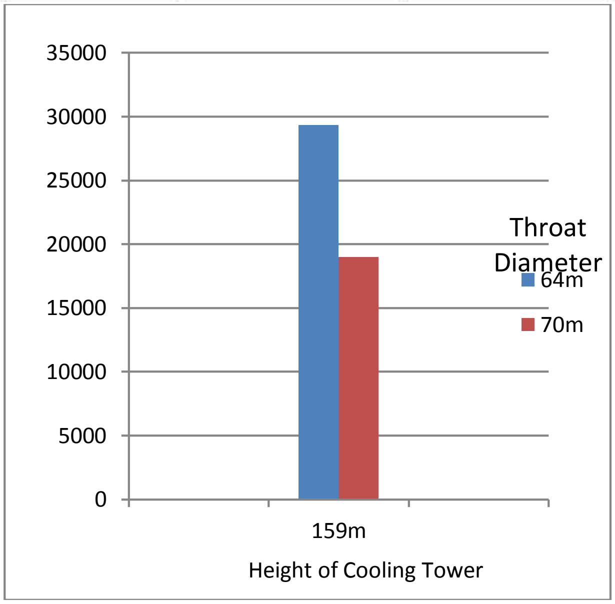


Fig. 11 Graph of support moment of cooling tower diameter 300mm under earthquake zone V

Table 15 Comparison of support moments for throat diameter 64 m under seismic zone V

Height Of Cooling Tower	Support Moment (KN-m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	19019.438	25934.945

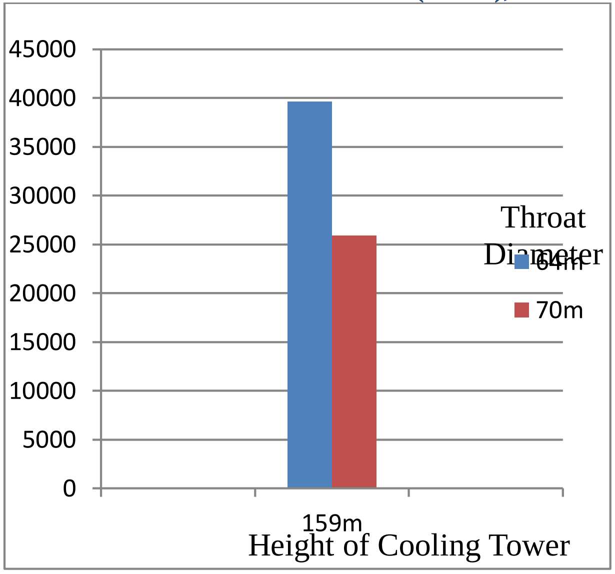


Fig. 12 Graph of support moment of cooling tower diameter 400mm under earthquake zone V

2.4 Membrane Stresses

Table 16Comparison of membrane stresses for throat diameter 64 m under seismic zone IV

Height Of Cooling Tower	Membrane Stress (N/mm^2)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	5.001	4.873

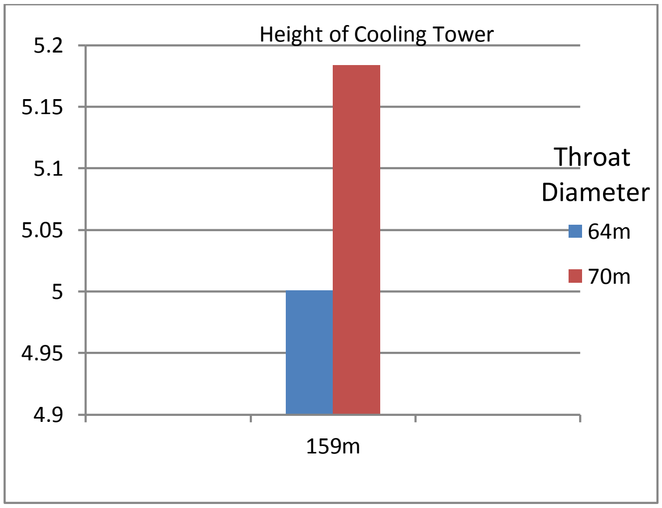


Fig. 13 Graph of membrane stressesof cooling tower diameter 300mm under earthquake zone IV

Table 17Comparison of membrane stresses for throat diameter 70 m under seismic zone IV

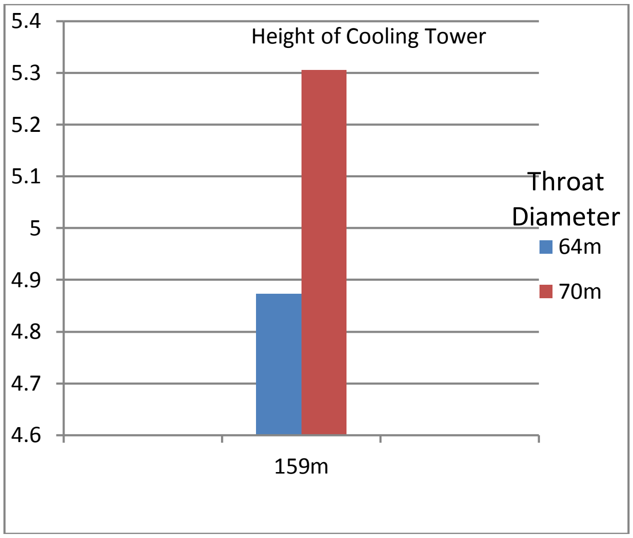
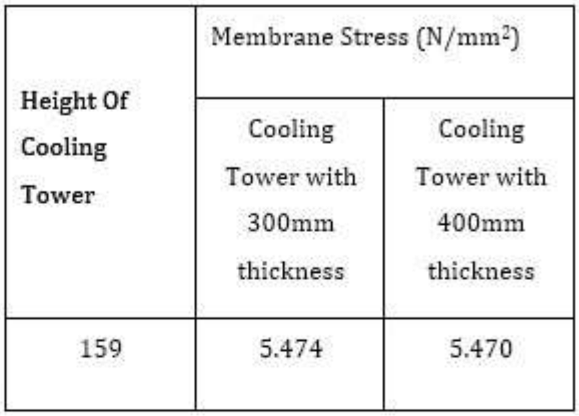


Fig. 14 Graph of membrane stresses of cooling tower diameter 400mm under earthquake zone IV

Table 18 Comparison of membrane stresses in plates for throat diameter 64 m under seismic zone V



Height Of Cooling Tower	Membrane Stress (N/mm^2)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	5.474	5.470

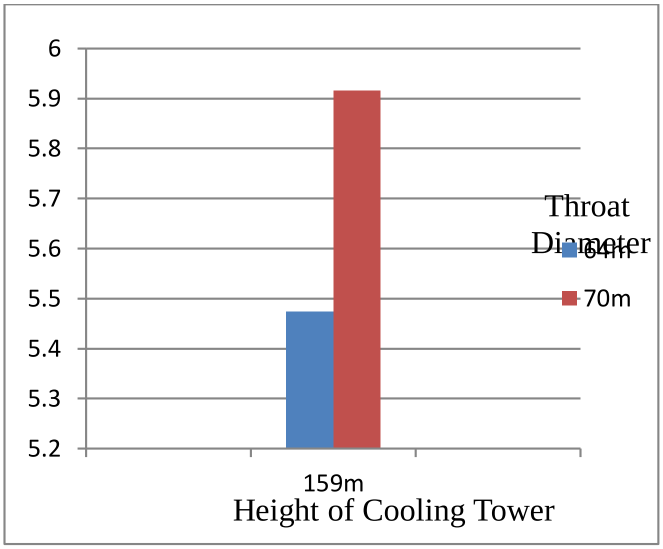
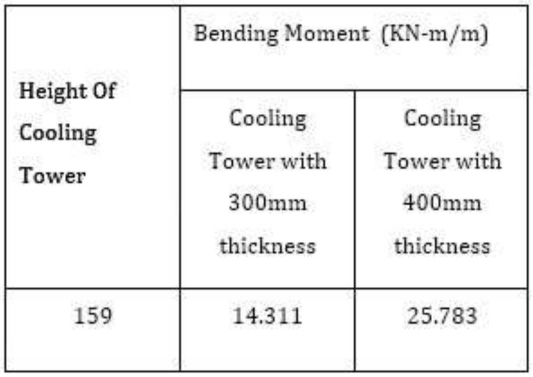


Fig. 15 Graph of membrane stressesof cooling tower diameter 300mm under earthquake zone V

Table 19 Comparison of membrane stresses in plates for throat diameter 64 m under seismic zone V



Height Of Cooling Tower	Bending Moment (KN-m/m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	14.311	25.783

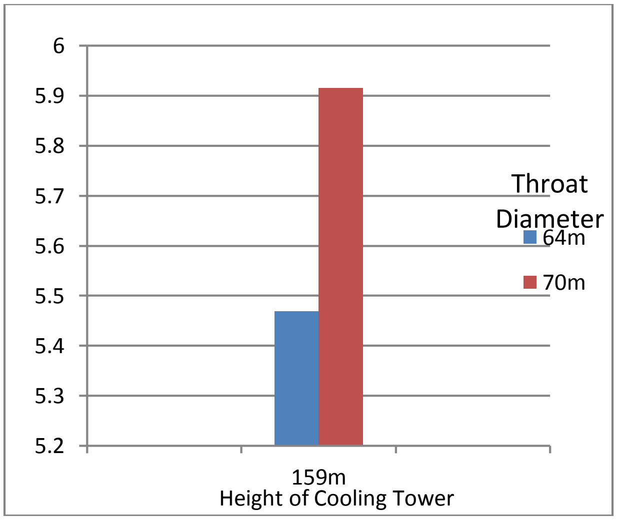


Fig. 16 Graph of membrane stressesof cooling tower diameter 300mm under earthquake zone V

2.5 Bending Moment in plates

Table 20 Comparison of bending moments in plates for throat diameter 64m under seismic zone IV

Height Of Cooling Tower	Bending Moment (KN-m/m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	11.645	20.981

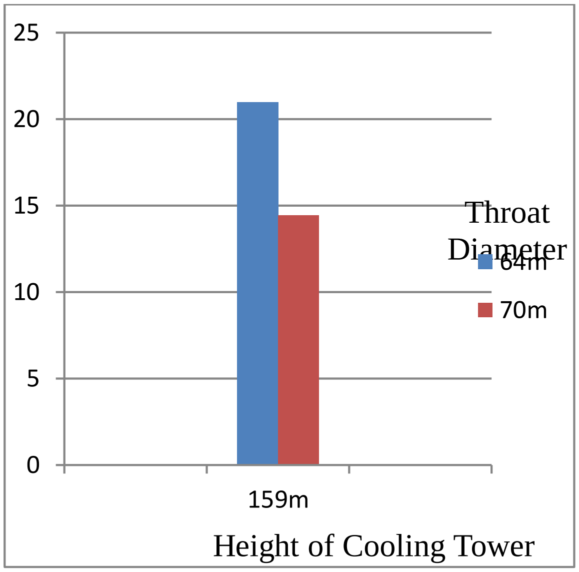


Fig. 17 Graph of bending momentin plates of cooling tower diameter 400mm under earthquake zone IV

Table 21Comparison of bending moments in plates for throat diameter 64m under seismic zone IV

Height Of Cooling Tower	Bending Moment (KN-m/m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	8.087	14.448

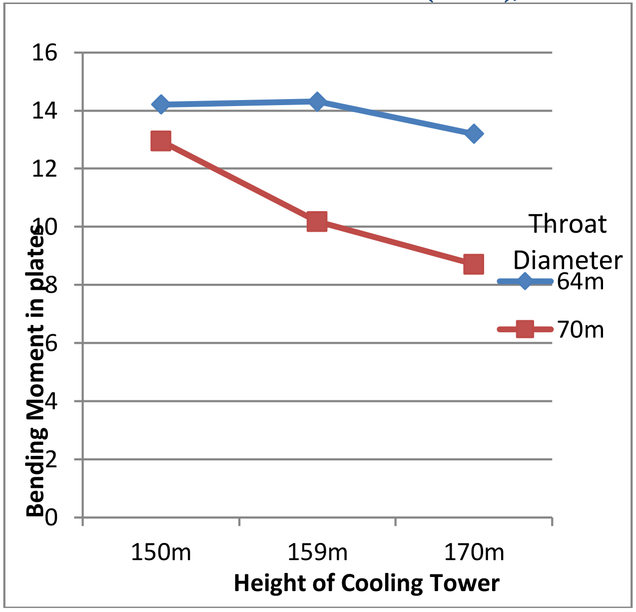
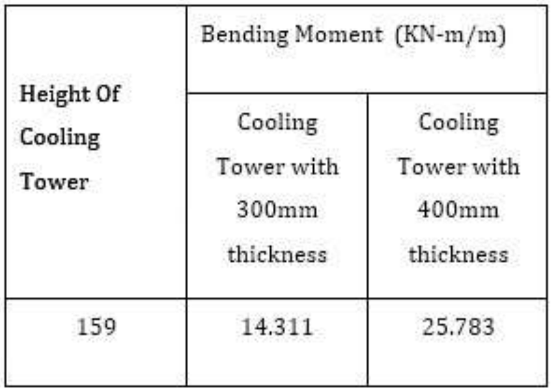


Fig. 18 Graph of bending momentin plates of cooling tower diameter 400mm under earthquake zone IV

Table 22Comparison of bending moments in plates for throat diameter 64 m under seismic zone V



Height Of Cooling Tower	Bending Moment (KN-m/m)	
	Cooling Tower with 300mm thickness	Cooling Tower with 400mm thickness
159	14.311	25.783

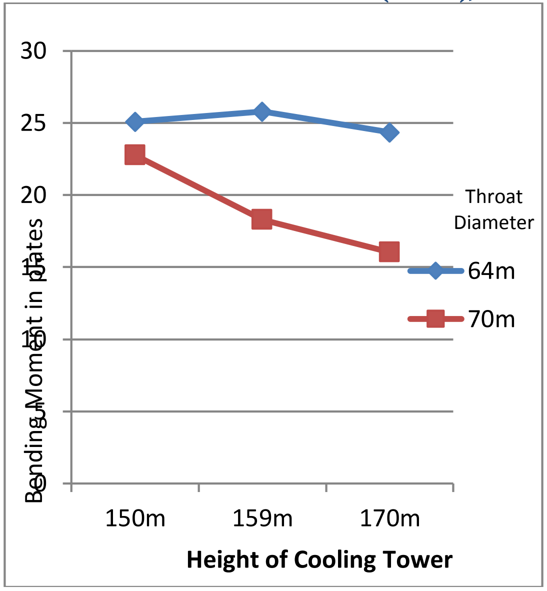


Fig. 19 Graph of bending momentof cooling tower diameter 400mm under earthquake zone V

CONCLUSION

- In the present study, the particular case of 159m high chimney is based on the live case and the results analysed for different parameters are most adorable as compared to 150m & 170m high chimneys
- Maximum nodal displacement

a) , for constant thickness & throat diameter, on increasing height of the structure, the resultant of nodal displacement increases.
b) for constant thickness, the resultant of nodal displacement decreases as height & throat diameter of the structure increases.
c) The cooling tower of all the three considered heights with 64m throat diameter having higher displacements as compared to the cooling towers with 70m throat diameter for 300mm & 400mm thicknesses respectively.
d) Higher values of nodal displacements are found in seismic zone V as compared to the values in seismic zone IV.

- **Maximum support reaction;**

a) for constant thickness & throat diameter, on increasing height of the structure, the support reaction increases.
b) The cooling tower of all the three considered heights with 64m throat diameter having lower support reactions as compared to the cooling towers with 70m throat diameter for 300mm & 400mm thicknesses respectively.
c) the combination of 150m cooling tower, 64m throat diameter with 400mm thickness are giving the higher values of support reactions.
d) Higher values of support reactions are found in seismic zone V as compared to the values in seismic zone IV.
e) The cooling tower having 159m height with all other parametric combinations having least values of support reactions.

- **Maximum support moment**

a) for constant thickness & throat diameter, on increasing height of the structure, the support moments decreases.
b) The cooling tower of all the three considered heights with 64m throat diameter having lower support moments as compared to the cooling towers with 70m throat diameter for 300mm & 400mm thicknesses respectively.
c) the combination of 159m cooling tower, 64m throat diameter with 400mm thickness are giving the lower values of support moments.
d) Higher values of support moments are found in seismic zone V as compared to the values in seismic zone IV.

- **Maximum shear stress in plates;**

a) shear stresses in plates of the hyperbolic cooling towers are found to approximately equal.

- **Maximum membrane stress in plates;**

a) for constant thickness & throat diameter, on increasing height of the structure, the membrane stresses in plates found increasing.
b) for constant thickness, membrane stresses in plates increases as height & throat diameter of the structure increases.
c) Higher values of membrane stresses in plates are found in seismic zone V as compared to the values in seismic zone IV.
d) The percentage change in the values of membrane stresses in plates is negligible.

- **Maximum bending moment in plates;**

a) for constant thickness & throat diameter, on increasing height of the structure, the bending moment in plates increases.
b) The cooling tower of all the three considered heights with 64m throat diameter having lower bending moment in plates as compared to the cooling towers with 70m throat diameter for 300mm & 400mm thicknesses respectively.
c) Higher values of bending moment in plates are found in seismic zone V as compared to the values in seismic zone IV.

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