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COMPARATIVE STUDY OF HYPERBOLIC COOLING TOWERS

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***Abstract:** Natural Draft Towers, rely on the heat of the water to generate the air movement inside the tower. They are only used for very large capacity systems such as Electricity Generation Plants, where they are called Hyperbolic Towers. As it is very tall structure it is normally assumed that wind analysis is important. But there are some locations where stresses developed due to wind are less than stresses developed by earthquake force. Therefore the predominance of lateral force (either wind or earthquake) depends on location of cooling tower. There are so many work has been done on cooling tower but, yet to verify behavior of cooling tower-shell against wind load with and without stiffening ring beam using ANSYS needs extensive focus. To find out optimal solution of shell dimensions without stiffening ring beam. To find out optimal solution of shell with stiffening ring beam. To study the effect of number of stiffening ring beam, location of stiffening ring beam and size of stiffening ring beam against the lateral load like wind load. The area discussed above yet to study comprehensively. The results of analysis against wind load without stiffening ring beam are within the permissible limit of (deflection, Equivalent Elastic Strain and Equivalent Stress). In additional all results are varying in range of 40% to 80% of the maximum values in radial direction and in meridional direction.*

***Key words:** Finite Element Method, Cooling Tower, Shell Elements, 20-noded Hex (Solid), 15-noded Wed (Solid), 10-noded Tetrahedron (Solid), Total Deformation, Equivalent Von-Mises Strain, Equivalent Von-Mises Stress.*

I. INTRODUCTION

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 drawn into the tower through an air inlet at the bottom. Hyperbolic shape of cooling tower is usually preferred because of its strength and stability and large available area at the base due to shape. Cooling tower is supported on columns of different shapes such that A, V, X, and I. And these columns are rested on annular beam. These supporting columns behave as air inlets. Natural draft cooling tower is a structure which is mostly found at nuclear and chemical plants. Cooling towers are used for evacuation of heat from these plants. It is very tall and slender structure. Shutting down of this structure due to any of reason causes great inconvenience and loss of revenue. Therefore, cooling tower should be analyzed for loads expected to act on it. Cooling tower should be analyzed by self-weight and wind loading. As it is very tall structure it is normally assumed that wind analysis is important. But there are some locations where stresses developed due to wind are less than stresses developed by earthquake force. Therefore the predominance of lateral force (either wind or earthquake) depends on location of cooling tower.
The hyperbolic shape is made because of greater structural strength and stability of the shell is provided by this shape. The concrete tower is supported on a set of reinforced concrete columns and Concrete is used for the tower shell with a height of up to 200 m. These cooling towers are mostly only for large heat duties because large concrete structures are expensive.

II. DESIGN CONSIDERATIONS

(a) Size and Shape: Structural concrete shall be of designed mix complying with the relevant provision of IS: 456-2002". The minimum grades of concrete for structural components shall be as follows: i) M25 - for ranker columns, shell and ring beams, ii) M20 - for all other members. As the range of possible hyperbolic shell shapes is infinite it is recommended that the designs be confined to the following major proportions which have been extensively adopted in cooling tower constructions. Other proportions shall be carefully studied before adoption:

$$H/D = 1.20 \text{ to } 1.55$$
$$H_b/H = 0.72 \text{ to } 0.85$$

The minimum thickness of the shell shall not be less than 140 mm for towers of height 75 m and above; for towers less than 75 m height the minimum thickness shall not be less than 100 mm.
(b) ***Spacing:*** *It* is recommended that the cooling towers in a group be spaced at clear distance of not less than 0.5 times the base diameter of the largest cooling tower in the group.
(c) Minimum reinforcement: It to be provided in each direction shall be as follows: 0.35 percent of gross cross-sectional area when mild steel bars are used, and 0.25 percent when cold-worked steel high strength deformed bars are used. The maximum spacing shall be restricted to twice the thickness of the shell in either direction. It is preferable to

provide reinforcement at both faces of the shell. For shells of thickness 175 mm and above two layers of reinforcement shall invariably be provided.

(d) Cover: Where two layers of reinforcement are provided, the clear cover to reinforcement shall not be less than 25 mm. This cover of min. 25 mm needs rigorous control on steel positioning, concrete quality and concrete compaction.

III. PROBLEM FORMULATION

- **Parameters of cooling tower:**

Top Diameter	= 40 m	
Throat Diameter	= 35 m	
Height of Tower	= 90 m	
Distance of Top from Throat Level	= 23 m	
Base Diameter	= 66.39 m	
Thickness of Shell	= 0.4 m	
H/D	= 1.35	(1.20 < H/D < 1.55)
H_T/H	= 0.74	(0.72 < H_T/H < 0.85)

Sr. No.	Location of ring beam
CT_1	Throat[3] and Top[1]
CT_2	Throat and Bottom[5]
CT_3	Throat and Central (upper)[2]
CT_4	Throat and Central (Bottom)[4]
CT_5	Throat , Top and Bottom
CT_6	Throat , Top and Central (upper)
CT_7	Throat , Top and Central (Bottom)
CT_8	Throat , Bottom and Central (upper)
CT_9	Throat , Bottom and Central (Bottom)
CT_10	Throat , Bottom , Top and Central (upper)
CT_11	Throat , Bottom , Top and Central (Bottom)
CT_12	at all locations

- **Case-1:**

Table 1- Types of Cooling Towers

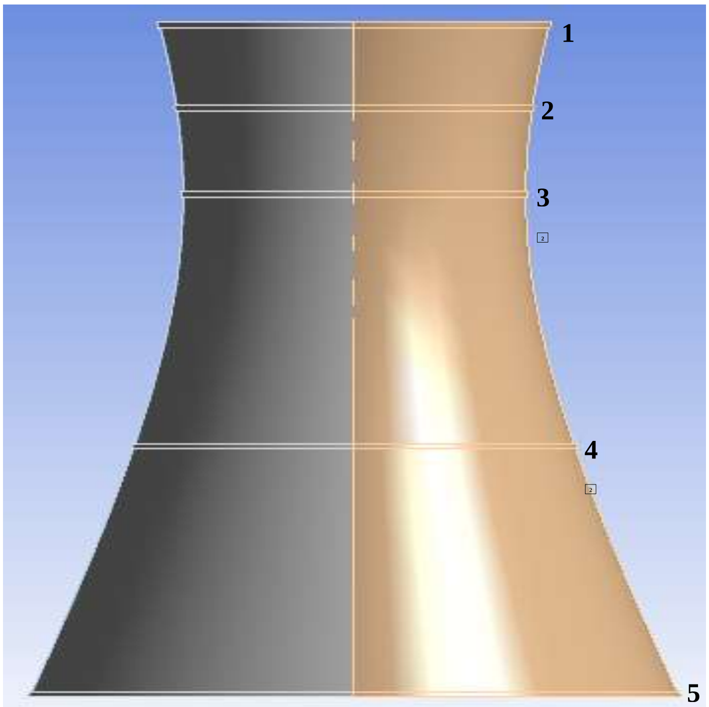

Fig. 1- Ring Beam Location

- **Case-2:**

Table 2- Types of Cooling Towers according to Thickness of shell

Up to Down	Thickness of Shell Curvature(mm)				
Parts	CT_1	CT_2	CT_3	CT_4	CT_5
1	200	200	200	200	200
2	400	300	250	300	250
3	600	400	350	350	300
4		500	450	400	350
5		600	550	450	400
6			600	500	450
7				550	500
8				600	550
9					600
10					650

Table 3- Properties of Cooling Tower Analysis

Material	Concrete
Density	2300 Kg/m^3
Modulus of Elasticity	30000 MPa
Poisson Ratio	0.18
Wind Pressure	1.5 KN/m^2 (-Z Direction)
Fixed Support	At Base
Size of Mesh	1000 mm
Types of Elements	A) 20-noded Hex (Solid) B) 15-noded Wed (Solid) C) 10-noded Tetrahedron (Solid)
Degree of Freedom	Three translational DOF at each node

IV. RESULTS AND DISCUSSION

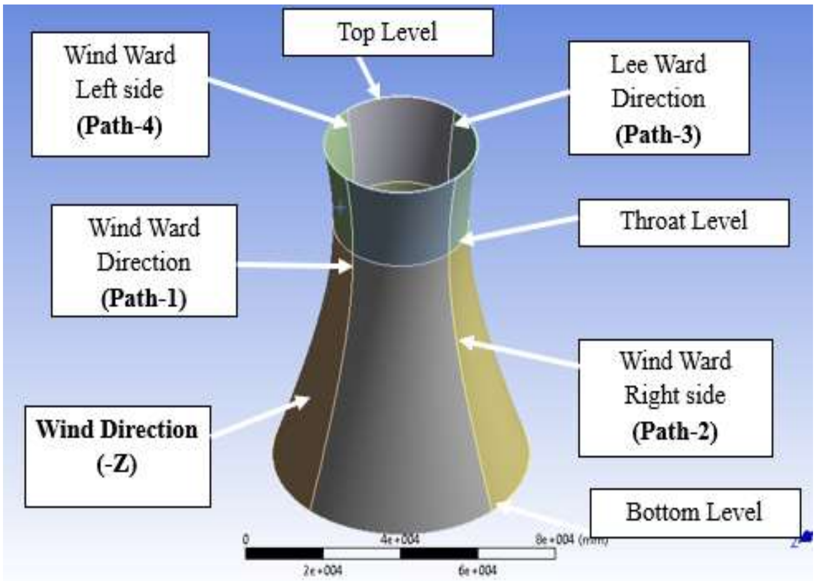

Fig. 2- Cooling tower Path Location

- **Deformation(Case-1):**

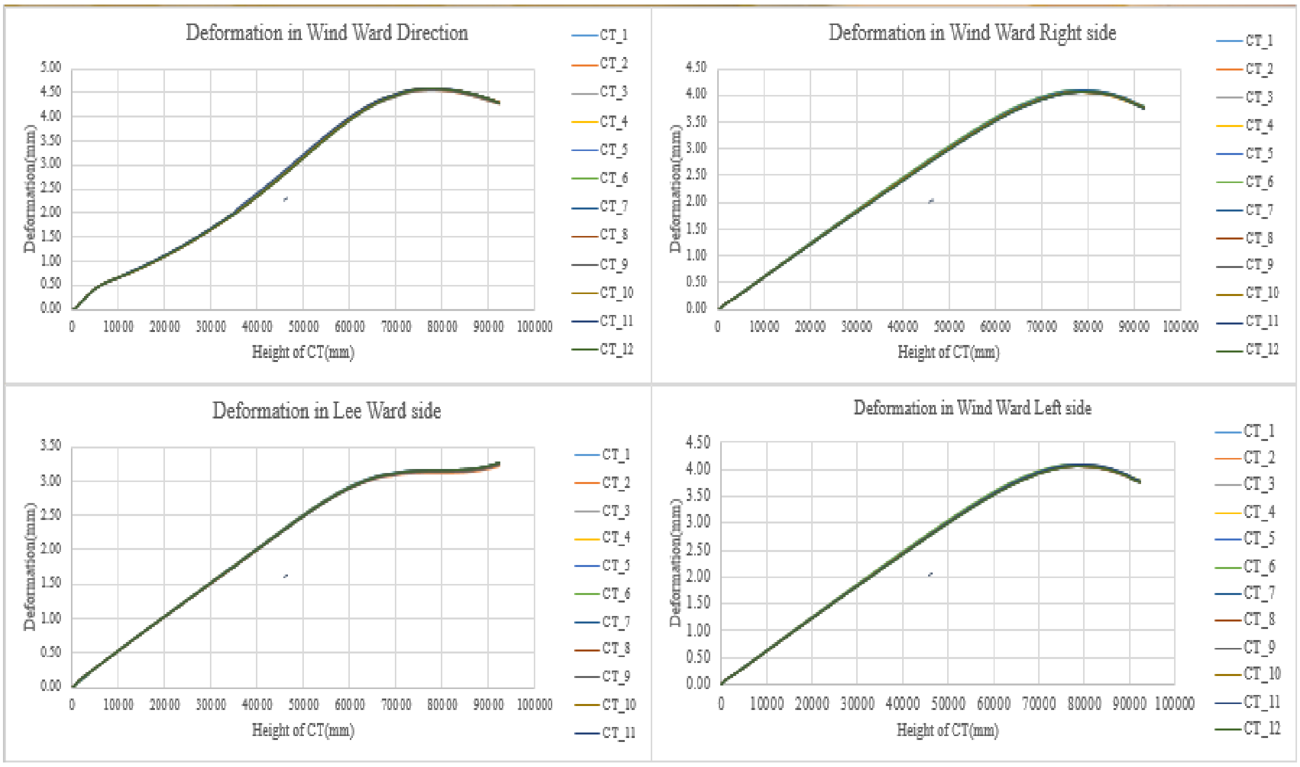

Fig. 3- Meridional Deformation of Case-1

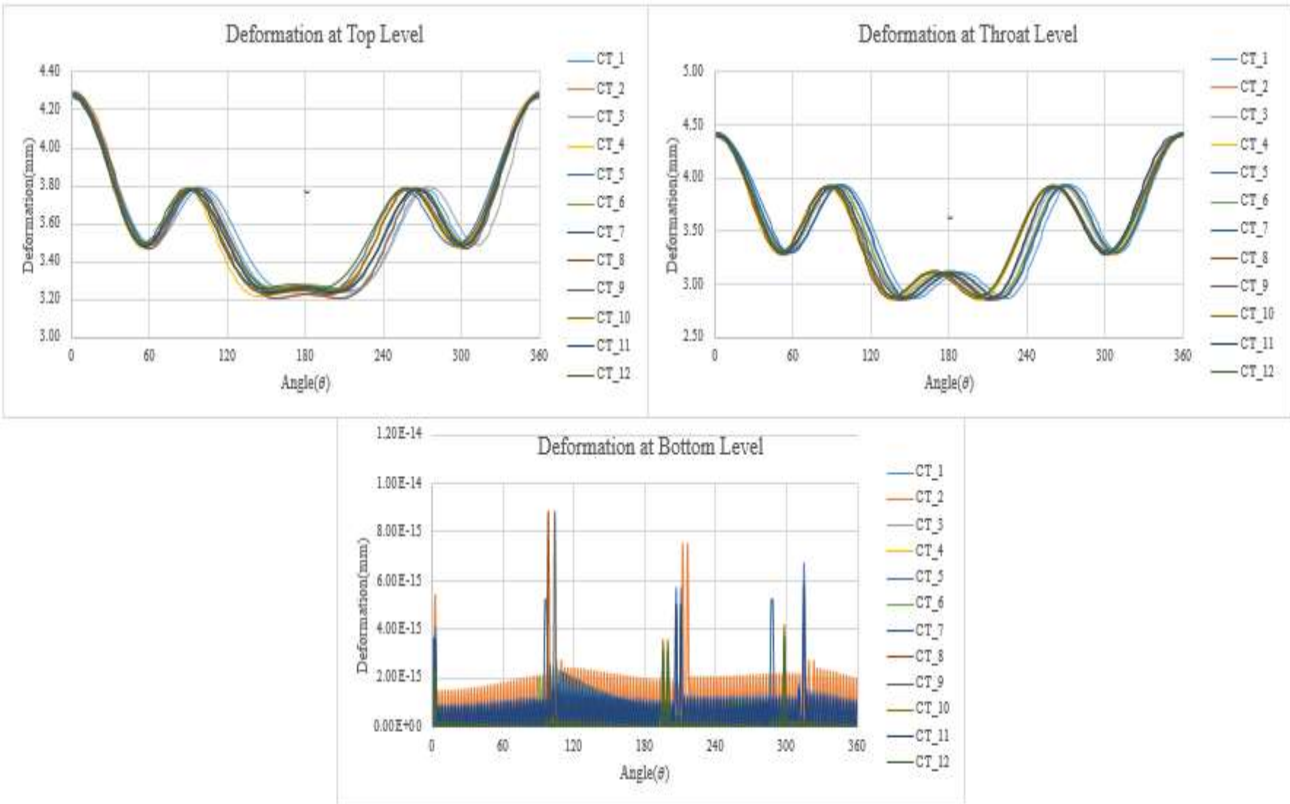

Fig. 4- Radial Deformation of Case-1

- **Equivalent Strain (Von-Mises)(Case-1):**

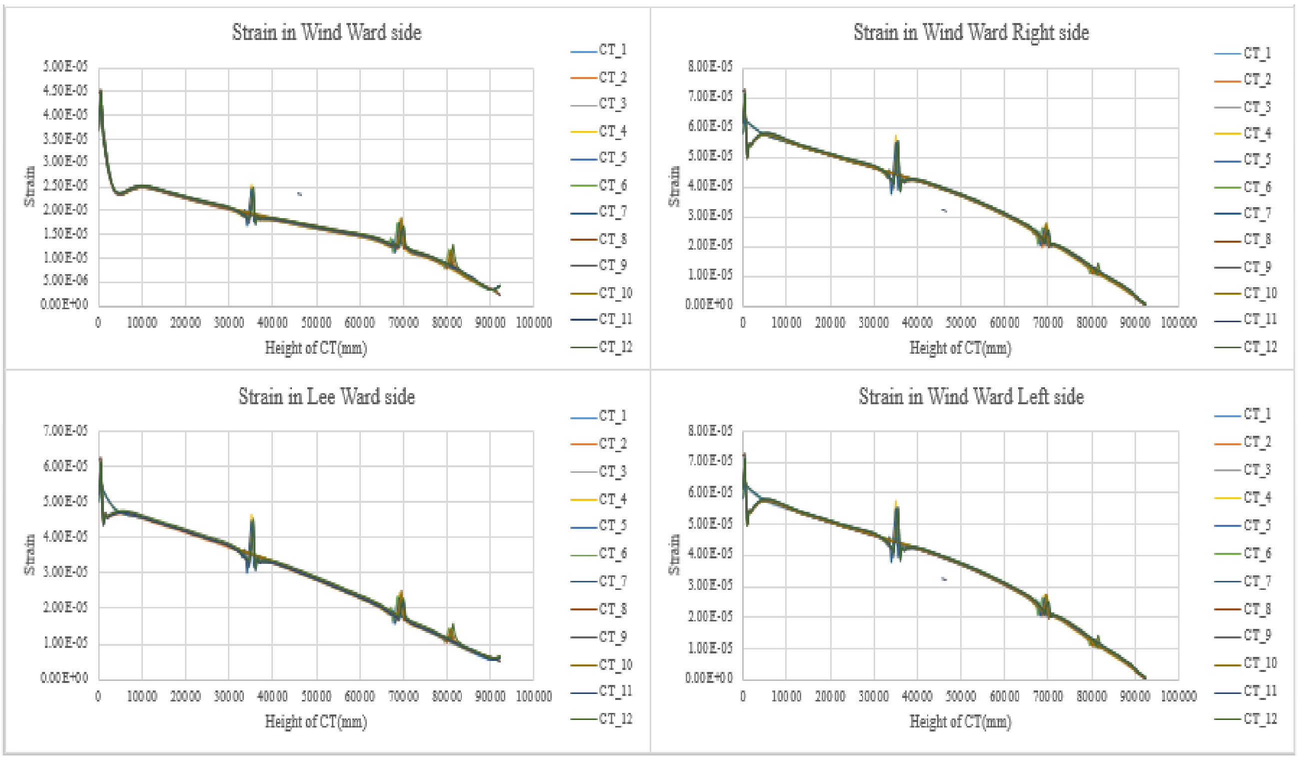

Fig. 5- Meridional Equivalent Strain (Von-Mises) of Case-1

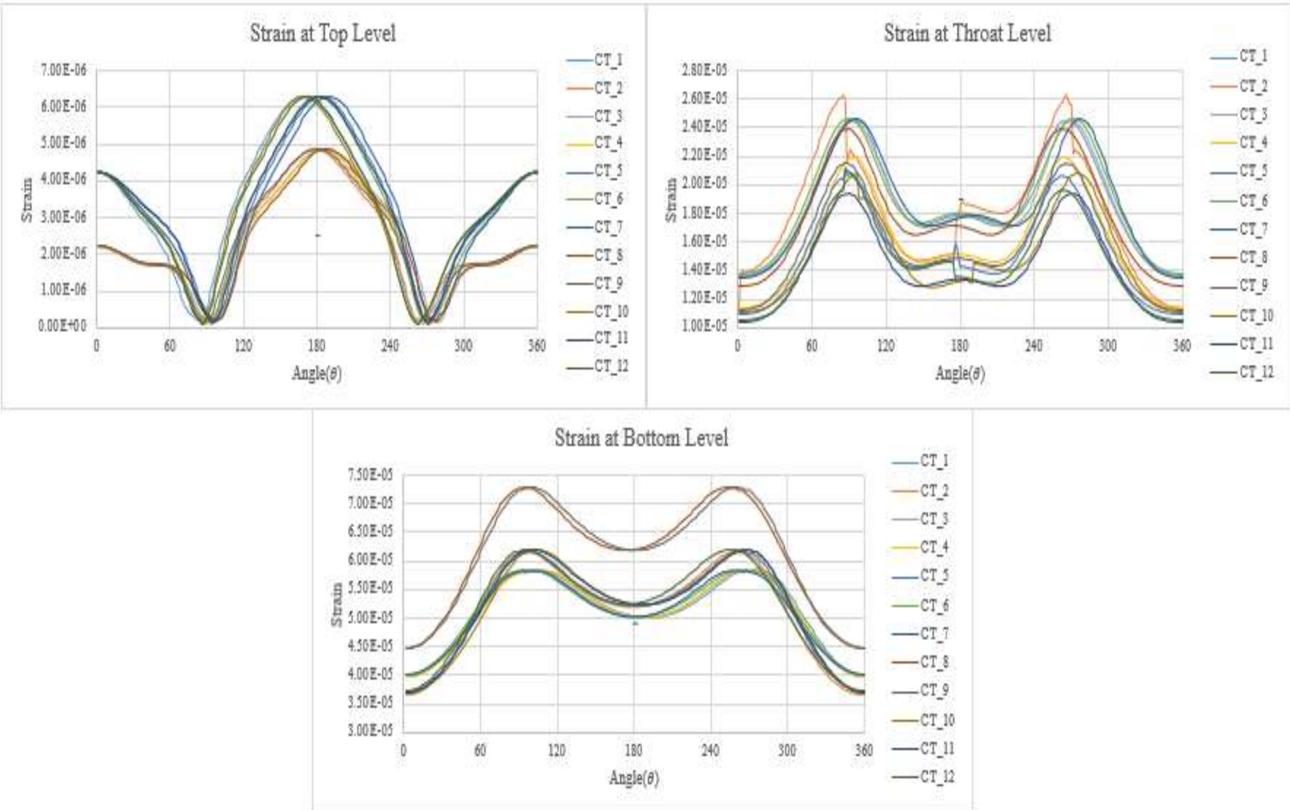

Fig. 6- Radial Equivalent Strain (Von-Mises) of Case-1

- **Equivalent Stress (Von-Mises)(Case-1):**

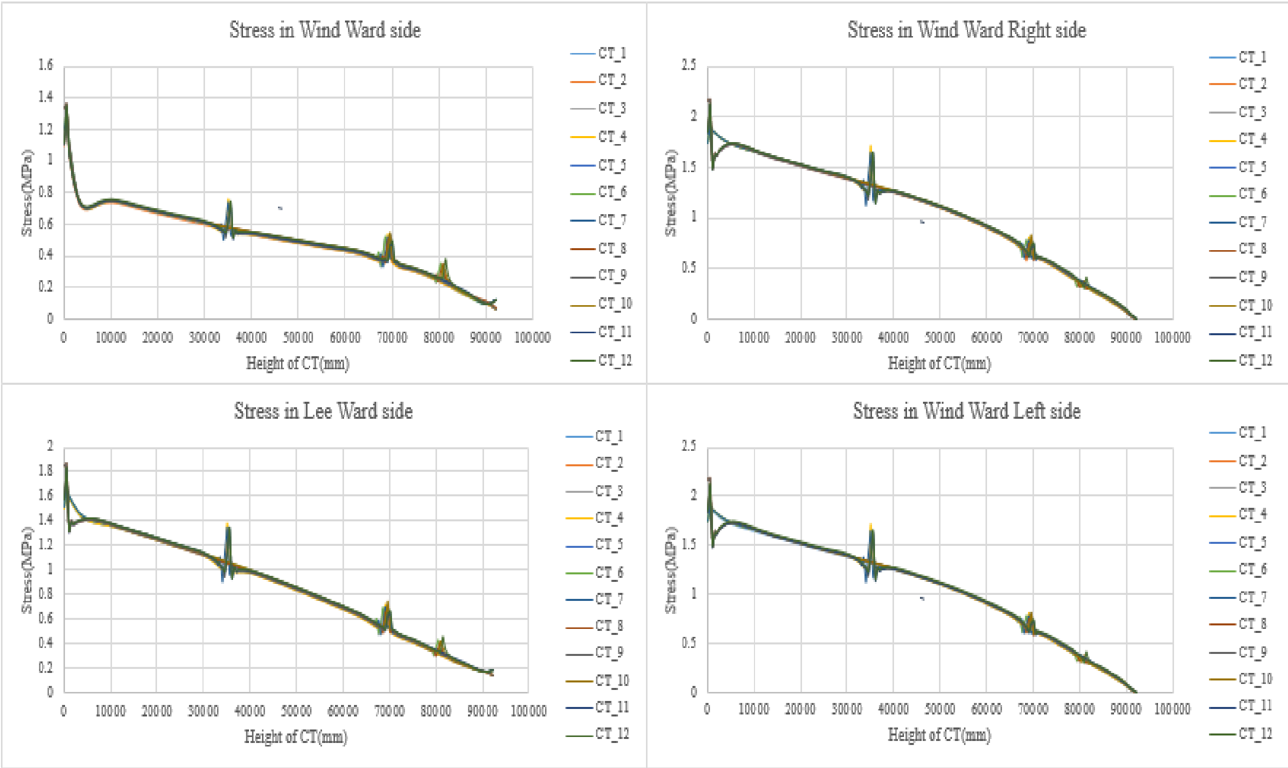

Fig. 7- Meridional Equivalent Stress (Von-Mises) of Case-1

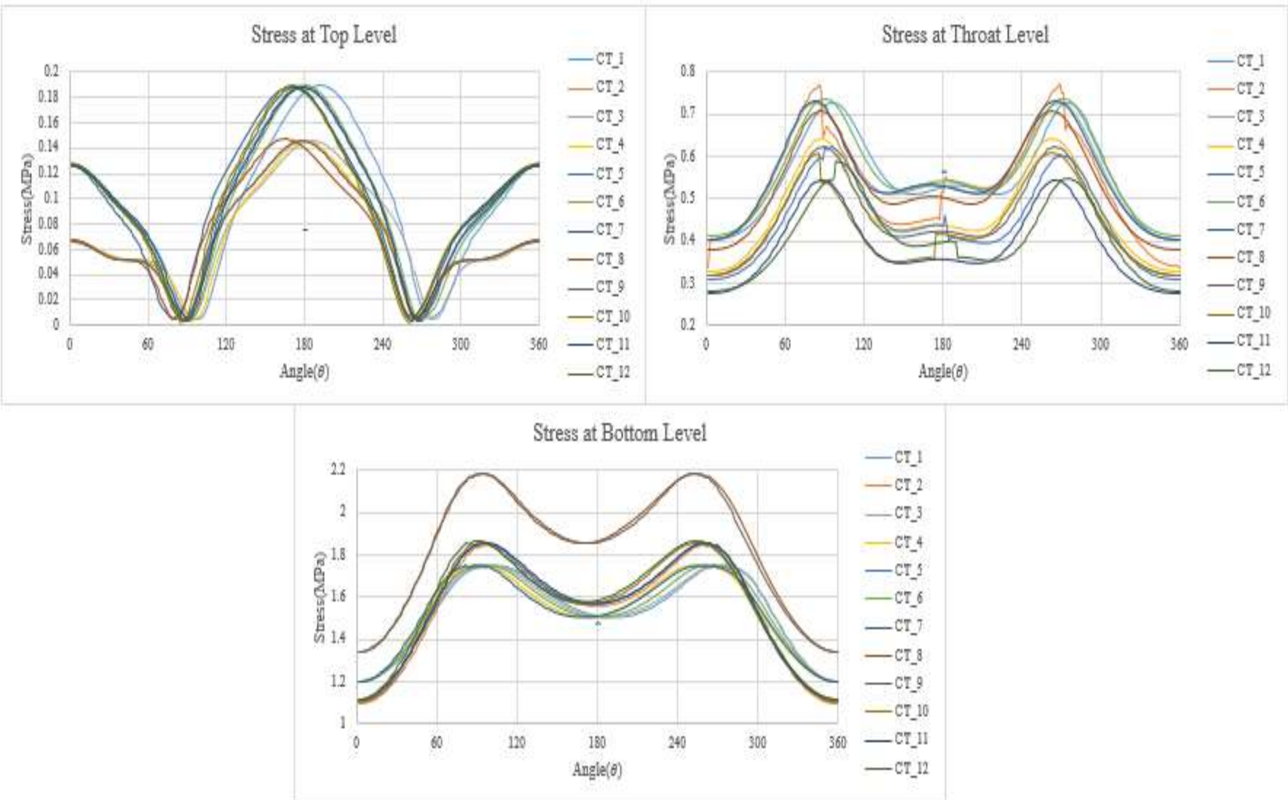

Fig. 8- Radial Equivalent Stress (Von-Mises) of Case-1

- **Deformation(Case-2):**

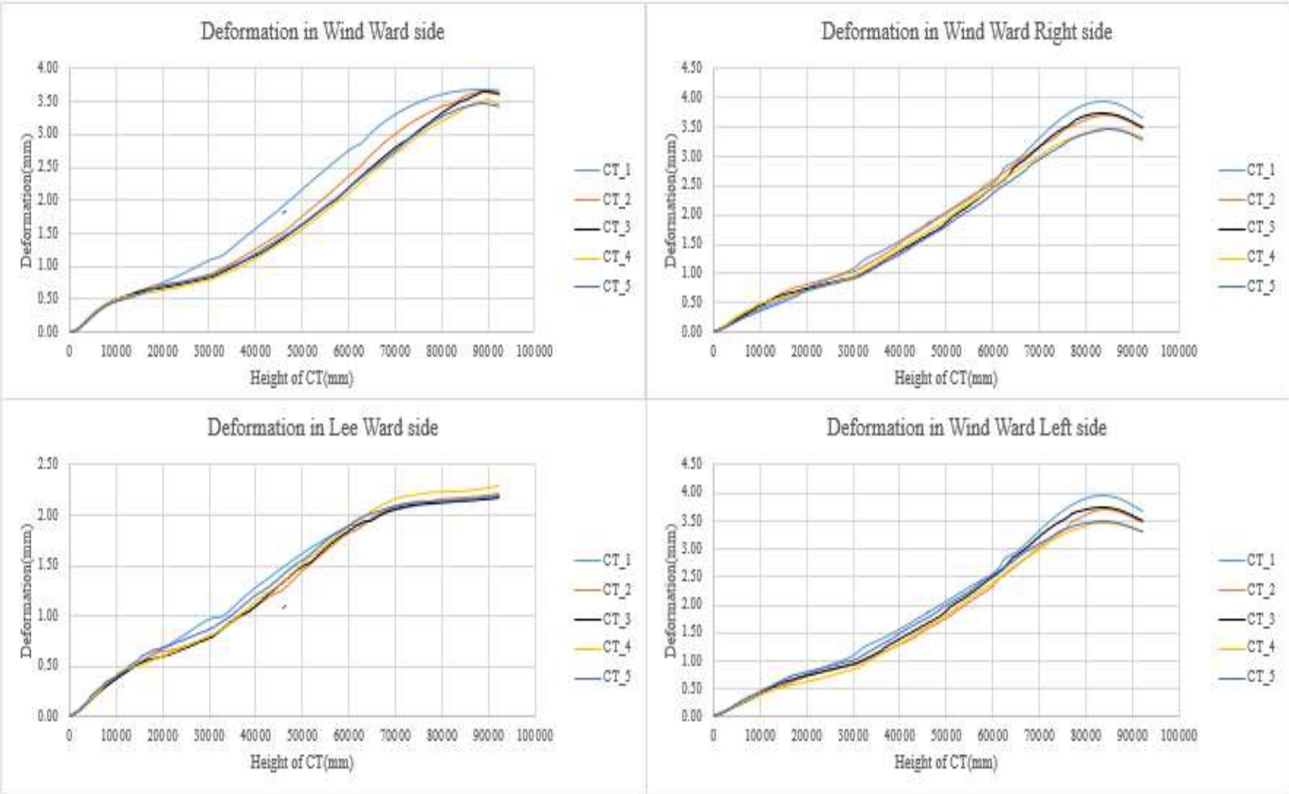

Fig. 9- Meridional Deformation of Case-2

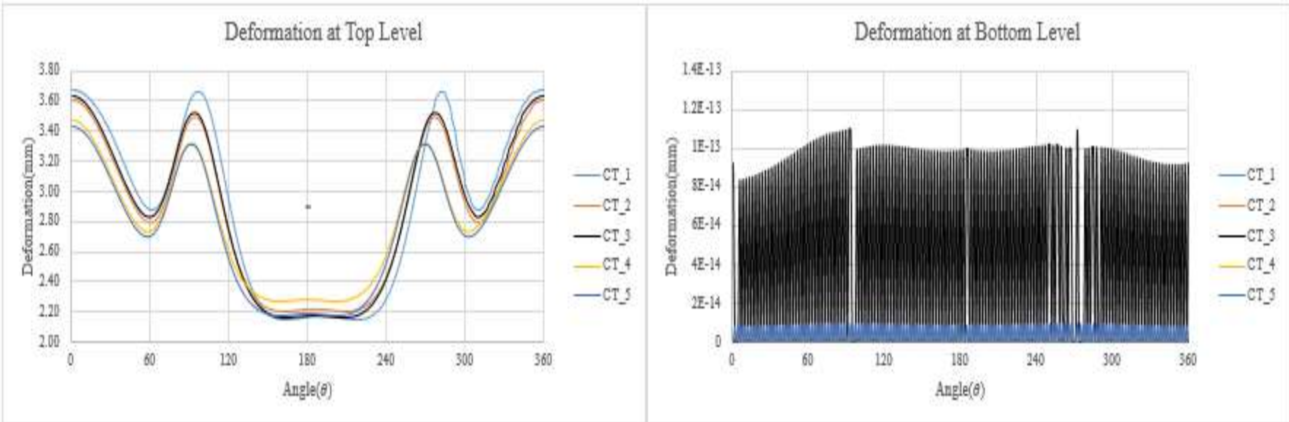

Fig. 10- Radial Deformation of Case-2

- **Equivalent Strain (Von-Mises)(Case-2):**

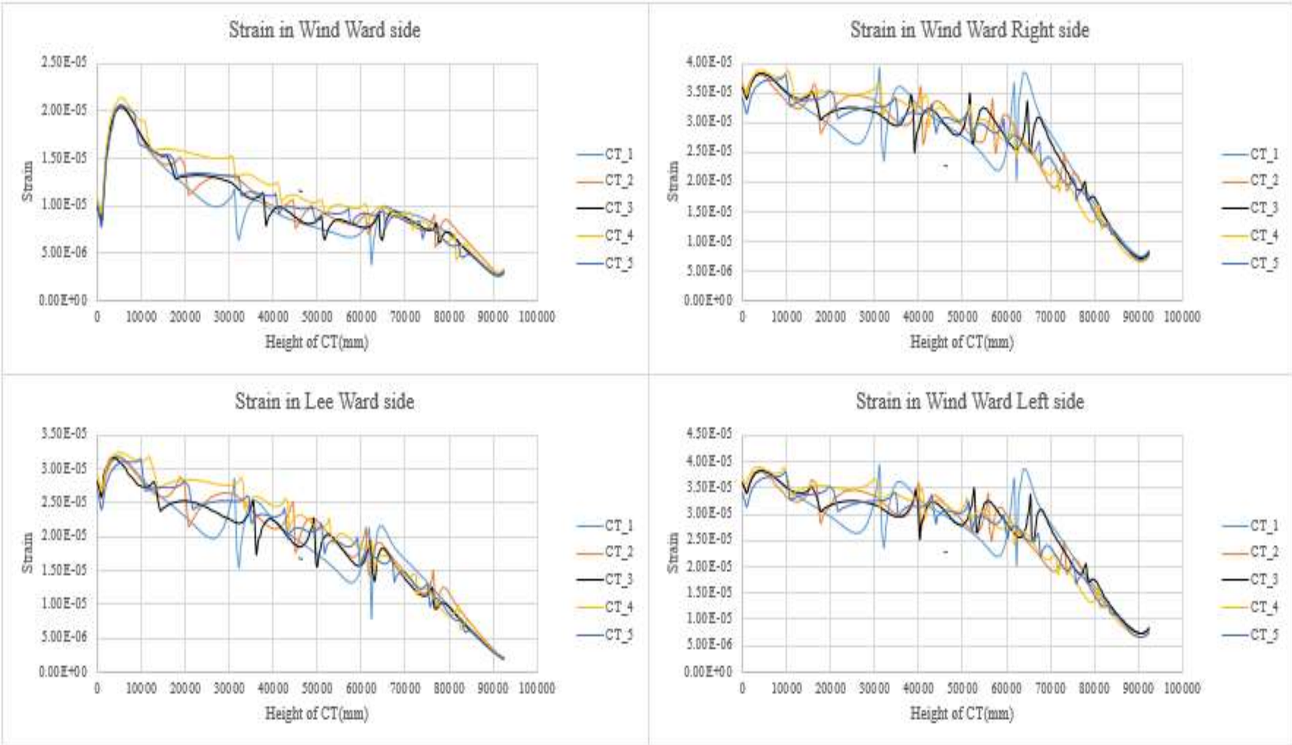

Fig. 11- Meridional Equivalent Strain (Von-Mises) of Case-2

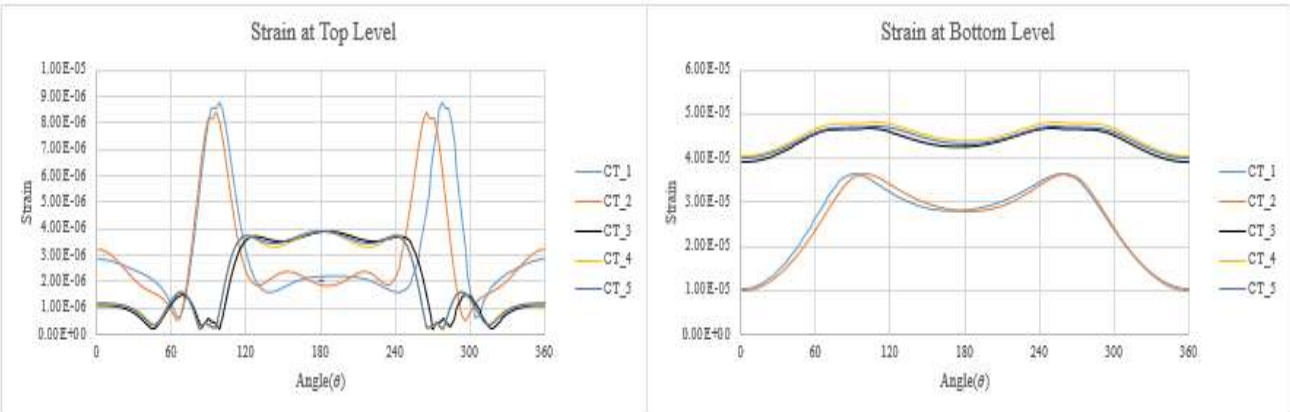

Fig. 12- Radial Equivalent Strain (Von-Mises) of Case-2

- **Equivalent Stress (Von-Mises)(Case-2):**

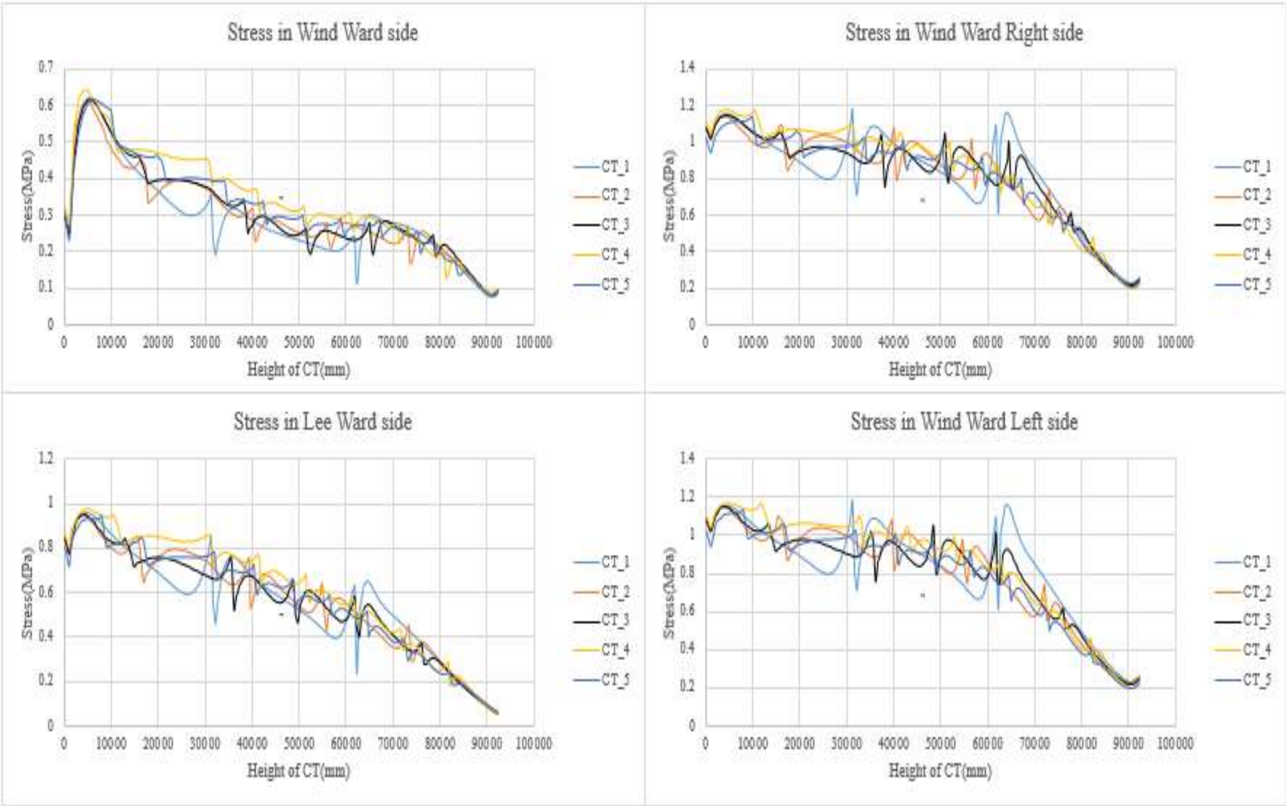

Fig. 13- Meridional Equivalent Stress (Von-Mises) of Case-2

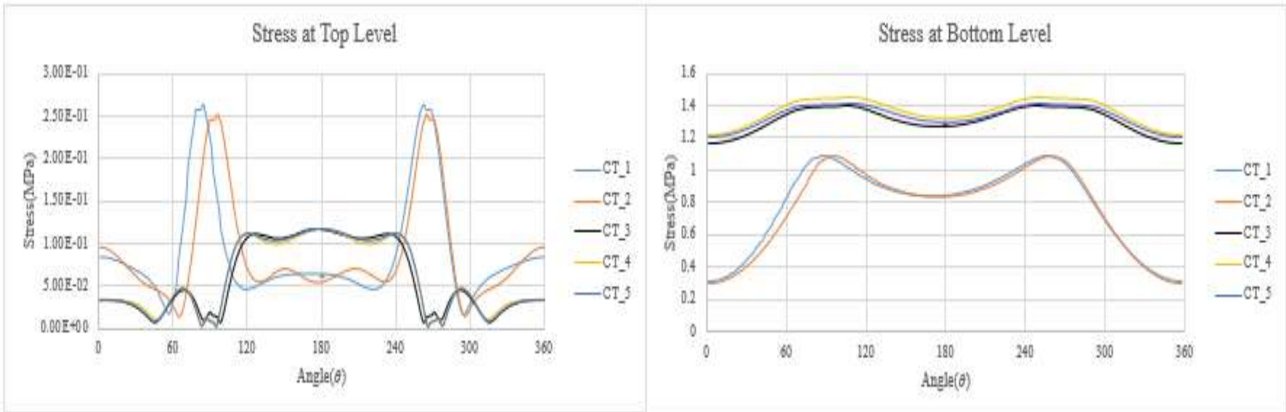

Fig. 14- Radial Equivalent Stress (Von-Mises) of Case-2

V. SUMMARY OF RESULTS

- **CASE-1:**

The results of analysis results shows that the maximum Deflection in CT_6 is 4.58 mm at Throat Level. The value of permissible deflection is 90mm (90000/1000). All Deflection values are within the limit of 40% to 80% of maximum deflection in all cases in throw-out the body.

The results of analysis results shows that the maximum Strain in CT_9 is $7.27*10^{-5}$ at Bottom Level. The value of permissible Strain is $3.5*10^{-3}$. All Strain values are within the limit of 30% to 80% of maximum Strain in all cases in throw-out the body.

The results of analysis results shows that the maximum Stress in CT_12 is 2.16 MPa at Bottom Level. The value of permissible Equivalent Stress 15($0.466*\sqrt{f_{ck}}$) N/mm^2 and 3.5($0.7*\sqrt{f_{ck}}$) N/mm^2 of Compressive Stress and Tensile Stress respectively. All stress values are within the limit of 40% to 85% of maximum deflection in all cases in throw-out the body.

- **CASE-2:**

The results of analysis results shows that the maximum Deflection in CT_1 is 3.93 mm at 84 m from bottom. The value of permissible deflection is 90mm (90000/1000). All Deflection values are within the limit of 30% to 60% of maximum deflection in all cases in throw-out the body.

The results of analysis results shows that the maximum Strain in CT_4 is $4.73*10^{-5}$ at Bottom Level. The value of permissible Strain is $3.5*10^{-3}$. All Strain values are within the limit of 40% to 80% of maximum Strain in all cases in throw-out the body.

The results of analysis results shows that the maximum Stress in CT_4 is 1.42 MPa at Bottom Level. The value of permissible Equivalent Stress $15(0.466*\sqrt{f_{ck}})$ N/mm^2 and $3.5(0.7*\sqrt{f_{ck}})$ N/mm^2 of Compressive Stress and Tensile Stress respectively. All stress values are within the limit of 40% to 85% of maximum deflection in all cases in throw-out the body.

VI. CONCLUSIONS

Concluded from above all results, that when the ring beam is provided at throat, top and upper central i.e. (CT_6) locations, it gives the maximum deformation at throat level. When the ring beam is provided at throat, bottom and down central i.e. (CT_9) locations, it gives the maximum strain at bottom level. When the ring beam is provided at all locations (Top, throat, bottom, upper central and down central) i.e. (CT_12), it gives the maximum stress at bottom level. In case 3, the i.e. CT_1 (parts-3) gives the maximum deformation at 84 m height, which is above throat level. In i.e. CT_4 gives the maximum Strain and Stress at bottom level. In these five cooling towers the maximum deformation, strain and stress are given in i.e. CT_6, CT_9 and CT_12 respectively.

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