TO STUDY THE EFFECT OF SEISMIC LOADS AND WIND LOAD ON HYPERBOLIC COOLING TOWER OF VARYING DIMENSIONS AND RCC SHELL THICKNESS.

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ABSTRACT:

Natural draught cooling towers are very common in modern day thermal and nuclear power stations. These towers with very small shell thickness are exceptional structures by their shear size and sensitivity to horizontal loads. This paper deals with study of hyperbolic cooling tower of varying dimensions and rcc shell thickness, for the purpose of comparison a existing tower is consider, for other models of cooling tower the dimensions and thickness of rcc shell is varied with respect to reference cooling tower. The boundary conditions should be consider as been top end free and bottom end is fixed. The material properties of the cooling tower have young modulus 31GPa, poission Ratio 0.15 and density of rcc 25 Kg/m3.These cooling towers have been analyzed for seismic loads & wind load using Finite Element Analysis. The seismic load will be carried out for 0.5g, 0.6g& 0.7g in accordance with IS: 1893 (part 1)-2002 and by modal analysis and wind loads on these cooling towers have been calculated in the form of pressures by using the design wind pressure coefficients as given in IS: 11504-1985 code along with the design wind pressures at different levels as per IS: 875 (Part 3) - 1987 code. The analysis has been carried out using 8-noded 93 Shell Element. The outcome of the analysis is max deflection, max principal stress & strain, max von mises stress & strain.

Keywords: Cooling tower, FEA, Seismic analysis & wind analysis.

1. INTRODUCTION:

The natural draught cooling tower is a very important and essential component in the thermal and nuclear power stations. These are huge structures and also show thin shell structures. Cooling towers are subjected to its self-weight and the dynamic load such as an earthquake motion and a wind effects. In the absence of earthquake loading, wind constitutes the main loading for the design of natural draught cooling towers. A lot of research work was reported in the literature on the seismic &wind load on cooling tower [1 to 5].

G. Murali *et al*., [1] Response of cooling tower to wind load. He studied the two cooling towers of 122m and 200m high above ground level. They calculated the values like meridional forces and bending moments. D.Makovička, Acta Polytechnica [2], Studied Response Analysis of an RC Cooling Tower under Seismic and Windstorm Effects. The calculated values of the envelopes of the displacements and the internal forces due to seismic loading states are compared with the envelopes of the loading states due to the dead, operational and live loads, wind and temperature actions. Finite element model is established; then mechanical characters of the tower under gravity, temperature load and wind loads are analyzed. A. M. El Ansary [3], Optimum shape and design of cooling tower, study is to develop a numerical tool that is capable of achieving an optimum shape And design of hyperbolic cooling towers based on coupling a non-linear finite element model developed in-house and a genetic algorithm optimization technique. R.L.Norton [4], studied the effect of asymmetric imperfection on the earth quake response of hyperbolic cooling tower. Shailesh S[5], software package utilized towards a practical application by considering problem of natural draught hyperbolic cooling towers. The main interest is to demonstrate that the column supports to the tower could be replaced by equivalent shell elements so that the software developed could easily be utilized.

2. Description of the Geometry of the Tower:

For the purposes of comparison, an existing tower Bellary thermal power station (BTPS) is located in Kudatini Village, Bellary Dist, and Karnataka State, India, is considered in the current study as the “reference design” tower. The total height of the tower is 143.5 m. As shown in Fig. 1, the tower has a base, throat and top radii of 55 m, 30.5 m and 31.85 m, respectively, with the throat located 107.75 m above the base.

The geometry of the Hyperboloid revolution:

$$\frac{R_o^2}{a_o^2} - \frac{Y^2}{b^2} = 1$$

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

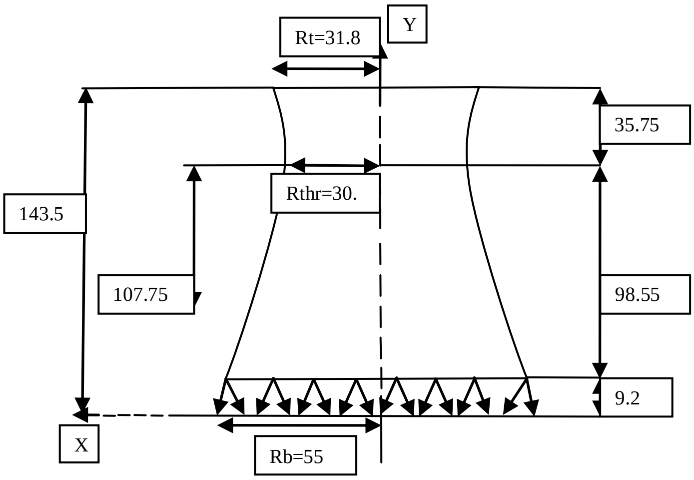

Figure 1: Geometry of BTPS

Table 1: Geometric details of cooling tower

SI no	Description Parameters	Parametric value		
		CT1 (Reference)	**CT2 (Decreased)**	**CT3 (Increased)**
1	Total height, H	143.5 m	136.2 m	150.67 m
2	Height of throat, H_{thr}	107.75 m	102.36 m	113.13 m

3	Diameter at top, D_t	63.6 m	60.5 m	66.8 m
4	Diameter at bottom, D_b	110 m	104.5 m	115.5 m
5	Diameter at throat, D_{thr}	61 m	57.94 m	64 m
6	Thickness at thoart, T_{thr}	200 mm	250 mm	150 mm
7	Column Height	9.2 m	8.74 m	9.66 m

3. Earthquake Forces:

The seismic analysis will be carried out in accordance with IS: 1893 by modal analysis of the hyperbolic cooling towers, the earthquake analysis of the shell will be carried out by response spectrum method. Earthquake analysis for the fill supporting structures (RCC frames) will be carried out by response spectrum method. For the Calculation of the Design Spectrum, the following Factors were considered as per IS 1893 (part I) 2002.
Zone factor: For Zone III = 0.16
Importance factor (I) = 1.00
Response reduction factor (R) = 3.00
Average response acceleration coefficient Sa/g =Soft soil site condition.
The design horizontal seismic coefficient Ah for 0.5g, 0.6g & 0.7g of a structure shall be determined by the following expression: Maximum considered Earthquake (MCE) of 2% probability.

4. Wind loads:

The wind pressure at a given height [P_z] will be 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=1.06 will be considered. For coefficient K_2 terrain category 2 as per table 2 of IS: 875 (part-3)-1987 will be considered. The wind direction for design purpose will be the one which world induces worst load condition. Coefficient K3 will be 1 for the tower under consideration. The wind pressure at a given height wills b e computed theoretically in accordance to the IS codal provision given as under:

$$P_z = 0.6\ Vz2\ N/m2$$

$$\text{Where } V_z = Vb \times K1 \times K2 \times k3$$

Computation of wind pressure (P_z) along the wind direction by Gust factor method

5. FINITE ELEMENT MODELING:

Due to the complexity of the material properties, the boundary conditions and the tower structure, finite element analysis is adopted. The finite element analysis of the cooling towers has been carried out using ANSYS V.10. The analysis has been carried out using 8-noded shell element (SHELL 93). In the present study, only shell portion of the cooling towers has been modelled and fixity has been assumed at the base.

5.1 ANSYSV.10:

ANSYS is a commercial FEM package having capabilities ranging from a simple, linear, static analysis to a complex, non linear, transient dynamic analysis. It is available in modules; each module is applicable to specific problem. Typical ANSYS program includes 3 stages Pre processor, Solution & General Post processor.

6. Material Properties for Analysis of CT:

- Young modulus: 31Gpa.
- Poisson Ratio: 0.15.
- Density of Rcc: 25 KN/m3.

7. Tabulation & Results:

CT 1: BTPS as reference of cooling tower.

CT 2: Decrease the dimensions & Increase the thickness of cooling tower.

CT 3: Increase the dimension & decrease the thickness of cooling tower.

7.1 Static analysis:

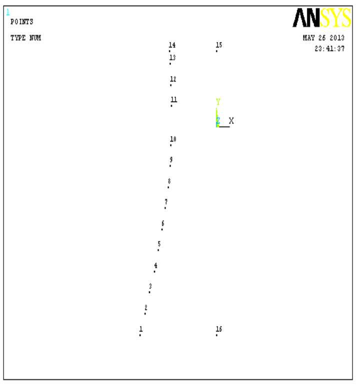

Fig5: Key points

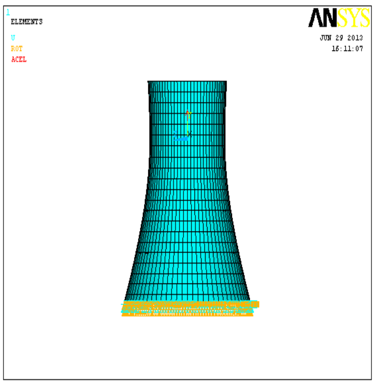

Fig6: Geometric model with BC

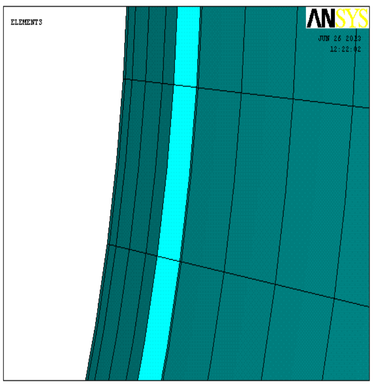

Fig7: Thickness of RCC shell

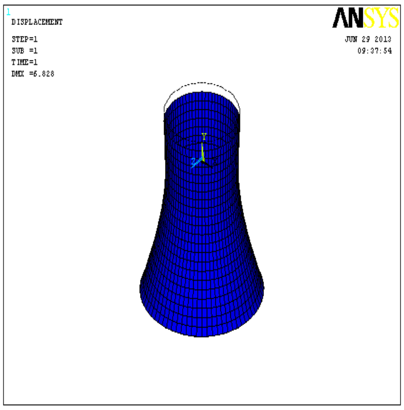

Fig8: Deflection in CT1

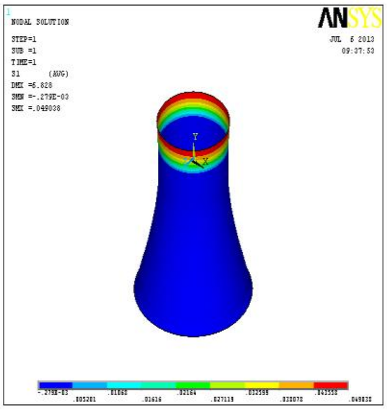

Fig9: Principal Stress in CT1

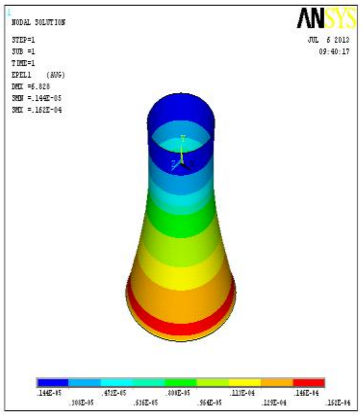

Fig10: Principal Strain in CT1

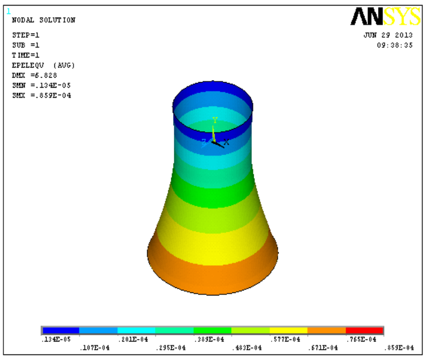

Fig11: Von mises Stress in CT1

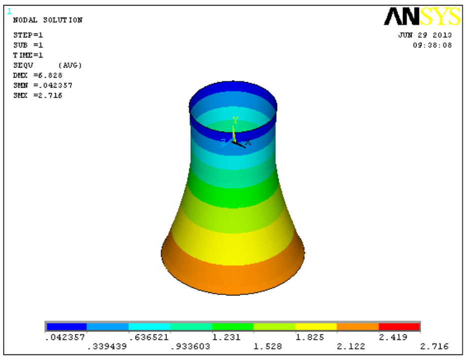

Fig 12: Von mises Strain in CT1

Table 2: Results of Static analysis

Series	Max Deflection (mm)	Max Principle		Max Von mises	
		Stress (mpa)	Strain	Stress (mpa)	Strain
CT 1	6.828	0.049038	0.162 $\times10^{-4}$	2.716	0.859$\times10^{-4}$
CT 2	6.079	0.054505	0.146 $\times10^{-4}$	2.521	0.796$\times10^{-4}$
CT 3	7.032	0.063277	0.157$\times10^{-4}$	2.651	0.838 $\times10^{-4}$

7.2 MODAL ANALYSIS:

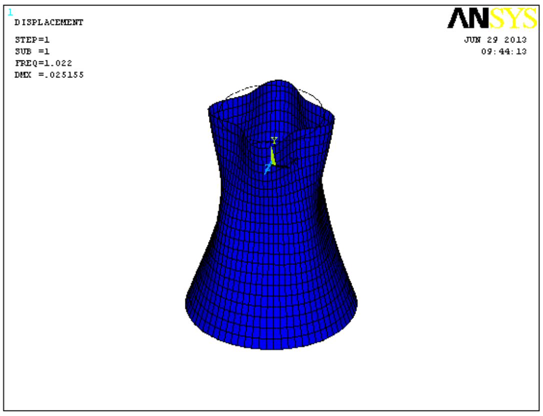

Fig 13: Deflection at 1st mode @ freq 1.022 In CT1

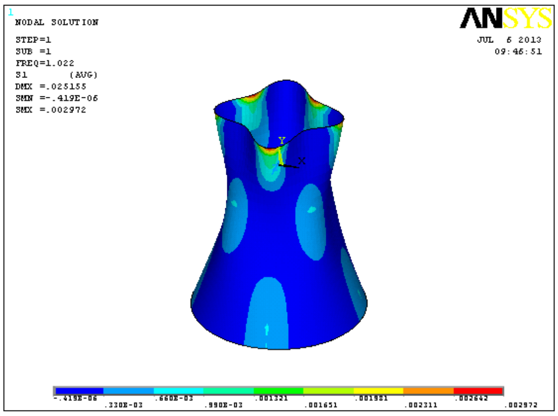

Fig 14: Principal Stress at 1st mode @ freq 1.022 in CT1

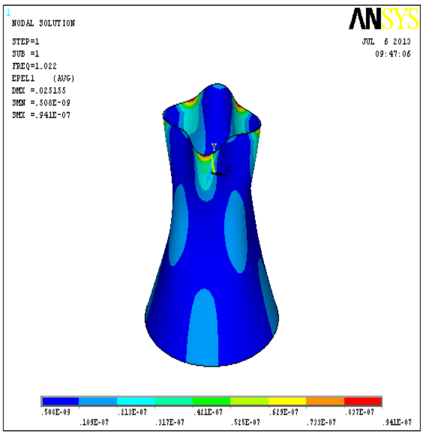

Fig15: Principal Strain at 1st mode 1.022 in CT 1

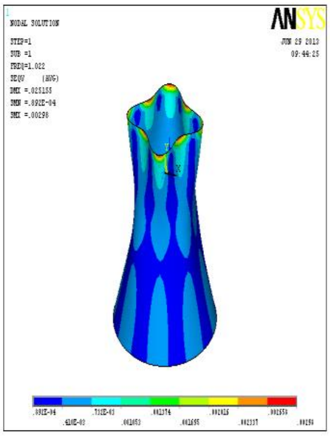

Fig 16: Von mises Stress 1st mode @ freq 1.022 in CT 1

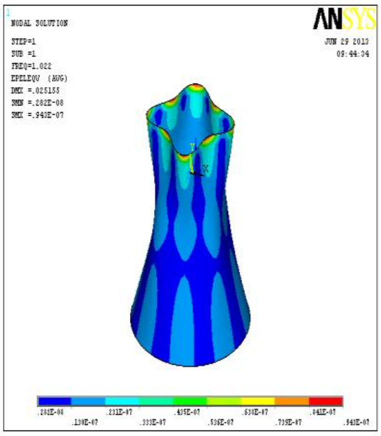

Fig 17: Von mises at 1st @ freq 1st mode @ freq 1.022 in CT1

Table 3: Results of Modal analysis

Series	Modes	Freq (HZ)	Max Deflection (mm)	Max Principal		Max Von Mises	
				Stress	Strain (mpa)	Stress (mpa)	Strain
CT1	1	1.022	0.02515	0.002972	0.941 $x10^{-7}$	0.00298	0.943 $x10^{-7}$
	5	1.305	0.024832	0.001647	0.521 $x10^{-7}$	0.001652	0.523 $x10^{-7}$
	10	1.512	0.01977	0.001328	0.415 $x10^{-7}$	0.001303	0.412 $x10^{-7}$
	1	1.137	0.026128	0.001849	0.582 $x10^{-7}$	0.001824	0.577 $x10^{-7}$

CT2	5	1.49	0.020358	0.001381	0.434 x10^{-7}	0.001355	0.429 x10^{-7}
	10	1.67	0.021157	0.002332	0.732 x10^{-7}	0.002277	0.194 x10^{-8}
CT3	1	0.8076	0.026254	0.00146	0.446 x10^{-7}	0.001394	0.441 x10^{-7}
	5	0.9904	0.025641	0.002206	0.665 x10^{-7}	0.002014	0.637 x10^{-7}
	10	1.189	0.020245	0.002329	0.705 x10^{-7}	0.00212	0.671 x10^{-7}

7.3 Response Spectra Analysis: 0.5g, 0.6g & 0.7g

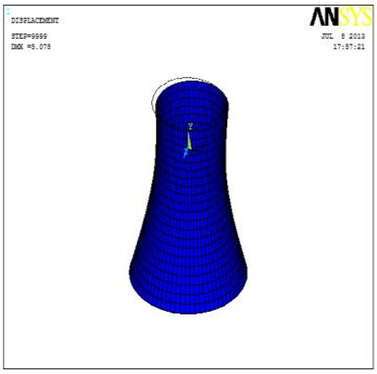

Fig18: Deflection at 0.5g, CT1

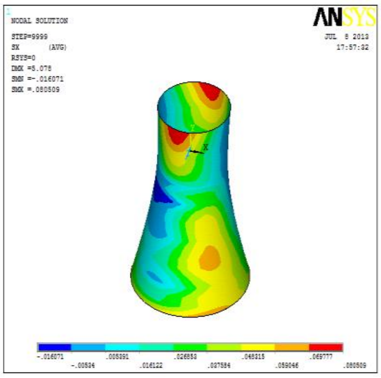

Fig19: Von mises Stress at 0.5g, CT1

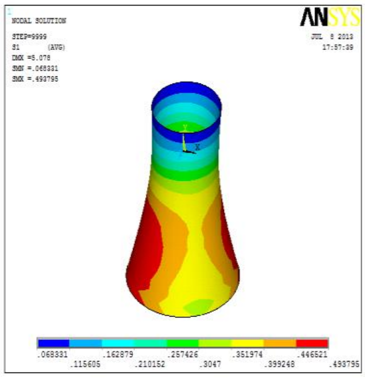

Fig20: Von mises Strain at 0.5g, CT1

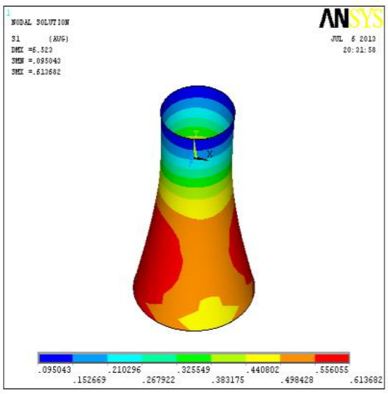

Fig21: Principal Stress at 0.5g, CT1

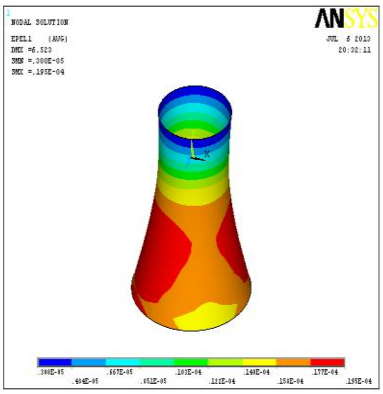

Fig22: Principal Strain at 0.5g, CT1

Table 4: Results of Response Spectrum Analysis: 0.5g

Series	Max Deflection (mm)	Max Principle		Max Von mises	
		Stress (mpa)	Strain	Stress (mpa)	Strain
CT 1	6.523	0.613682	0.195 $x10^{-4}$	0.609945	0.193 $x10^{-4}$
CT 2	5.902	0.578328	0.183 $x10^{-4}$	0.589108	0.186 $x10^{-4}$
CT 3	0.119 $x10^{-8}$	0.231 $x10^{-9}$	0.705 $x10^{-14}$	0.220 $x10^{-9}$	0.695 $x10^{-14}$

Table 5: Results of Response Spectrum Analysis: 0.6g

Series	Max Deflection (mm)	Max Principle		Max Von mises	
		Stress (mpa)	Strain	Stress (mpa)	Strain
CT 1	8.547	0.756147	0.244 $x10^{-4}$	0.773432	0.245 $x10^{-4}$
CT 2	7.083	0.693995	0.220 $x10^{-4}$	0.706931	0.224 $x10^{-4}$
CT 3	0.143 $x10^{-8}$	0.277 $x10^{-9}$	0.845 $x10^{-14}$	0.254 $x10^{-9}$	0.834 $x10^{-14}$

Table 6: Results of Response Spectrum Analysis: 0.7g

Series	Max Deflection (mm)	Max Principle		Max Von mises	
		Stress (mpa)	Strain	Stress (mpa)	Strain
CT 1	9.971	0.882172	0.284 $x10^{-4}$	0.902337	0.285 $x10^{-4}$
CT 2	8.263	0.809658	0.256 $x10^{-4}$	0.824752	0.261 $x10^{-4}$
CT 3	0.167 $x10^{-8}$	0.323 $x10^{-9}$	0986 $x10^{-14}$	0.307 $x10^{-9}$	0.973 $x10^{-14}$

7.4 Wind Analysis:

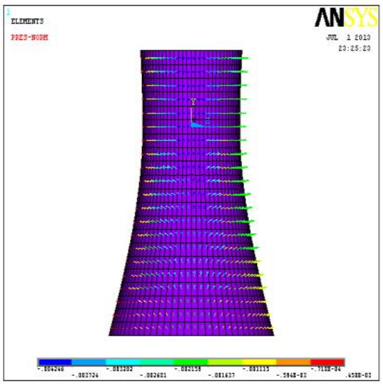

Fig23: Wind pressure applied

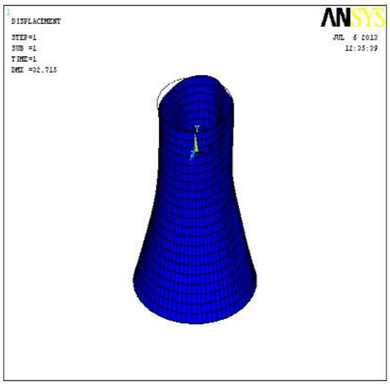

Fig 24: Deflection

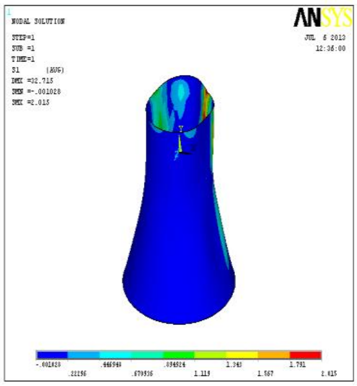

Fig25: Principal Stress

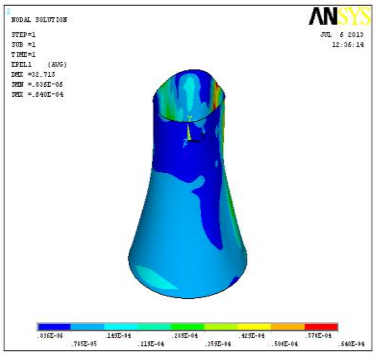

Fig26: Principal Strain

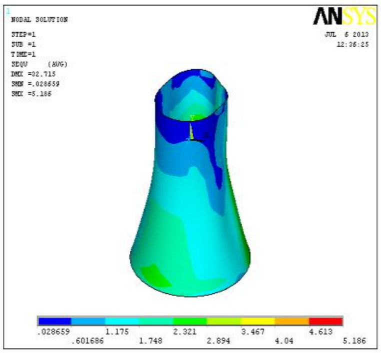

Fig27: Von mises Stress

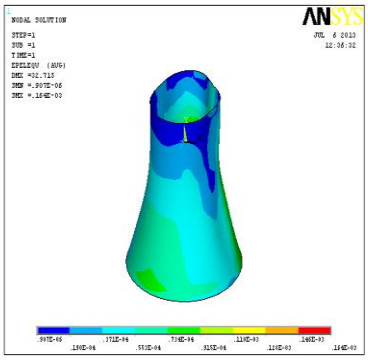

Fig28: Von mises Strain

Table 7: Results of Wind analysis

Series	Max Deflection (mm)	Max Principle		Max Von mises	
		Stress (mpa)	Strain	Stress (mpa)	Strain
CT 1	32.715	2.015	0.640x10-4	5.186	0.164 x10-3
CT 2	23.922	1.295	0.421 x10-4	4.521	0.146 x10-3
CT 3	57.295	2.59	0.804 x10-4	5.32	0.157 x10-3

8. Conclusions:

The main aim of analysis works on CT as follows. In the present study FEA of 3CT viz CT1, CT2, CT3 has been carried out to evaluate principle stress and strain, Von mises stress and strain and deflection.

1) If dimension is less, deflection is also less and if dimension is more, deflection also more.
2) The deflection in static analysis is least for CT2 comparssion to reference tower CT1 and CT3.
3) The principal stresses in static analysis i.e. (self weight) are observed to be less for CT2 then the reference tower CT1.
4) In the free vibration analysis it has been observed that the principal stress for the 1st mode is greater for CT1 than CT2 and CT3.
5) It is evident from the seismic analysis. The principal stress observed to be least for CT2 & CT3 comparssion to reference tower CT1.
6) It is evident from the seismic analysis that the deflection is the least in CT2 & CT3 compare to reference tower CT1.
7) It is evident from the wind load analysis that the deflection is the least in CT2. &principal stress is least in CT2 compare to the reference tower CT1and CT3.

9. Future to scope:

- Thermal stress will not been considered for this project, it will be done in future with the help of mechanical engineers
- Non linear analysis will also be applied to the above studies.

10. References:

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