THE EFFECT OF SEISMICAND WIND LOADS ON COOLING TOWEROF VARYING RCC SHELL THICKNESS AND SIZE OF SHELL OPENING

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ABSTRACT

This paper deals with the study of cooling tower of 124.8m high above ground level.The cooling towers have been analysed for wind loads using Finite Element Analysis by assuming fixity at the shell base. The 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 seismic load will be carried out for 0.3g, 0.4g& 0.5g in accordance with IS:1893 by modal analysis.For the purpose of comparisonanexisting tower of Raichurthermal power plant(RTPS, Karnataka)is considered.Forothermodels of cooling towers thethickness of the shell andopening are varied with respect to the reference tower of RTPS.The analysis has been carried out using 8-noded shell element (SHELL 93).The results of the analysis includethe stress and strain contours. And alsothe stress and strain contoursare plotted and modes of deflection are mapped.

Key Words: Cooling Tower, Finite Element Analysis, seismic and Wind loads

1. INTRODUCTION

A cooling tower is astructure used to reduce the temperature of water stream by extracting heat from water and emitting it to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly. Cooling towers areable to lower the water temperatures unlike the devices that use only air to reject heat, like the radiator in a car, and are therefore more cost-effective and energy efficient. Normally cooling towers are hyperbolic shells. The structural efficiency of a cooling tower depends on the dimensions of the tower shell, the thickness of the shell wall and the opening sizes in the shell wall. Openings should be of smallest dimensions required and shaped such that stress concentration is minimized at the boundary of the opening.Openings will be provided with additional reinforcement at each edge equal to 50% of reinforcement intercepted by the openings in the direction parallel to the edges. In addition, diagonal reinforcement will be provided at each corner as close as possible. The total cross-sectional area in $cm^2$of this reinforcement will be 0.5d, at each corner where‘d’ is the shell thickness in cm. No horizontal thrust due to the inlet piping will be transmitted to the shell.

2. FINITE ELEMENT ANALYSIS

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 towershas been carried out using ANSYS. The shellelement is the most efficient element for the solution ofshells having the arbitrary geometry and it accounts forboth membrane and bending actions. The analysis hasbeen 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.

3. FORCES CONSIDERED FOR ANALYSIS

3.1 Seismic Forces

The seismic analysis is carried out in accordance with IS-1893-2002.The analysis of the shell is carried out by response spectrum method.

For Raichur thermal power plant factors considered as per IS 1893 (part I) 2002 for this analysis:

Zone Factor: Zone III	= 0.16
Importance Factor (I)	= 1.00
Response Reduction Factor (R)	= 3.00

Maximum considered Earthquake (MCE) of 2% probability

3.2 Wind Loads

Wind pressure on the towers is assessed on theoretical basis as given in IS codes. The complete cooling tower is designed for all possible wind directions and on the basis of worst load conditions as obtained from theoretical methods.

The wind pressure acting at a given height $P_z$is computed as per IS:875(part3)-1987. For computing the design wind pressure at a given height the basic wind speed (V_b) is taken as 39m/sec at 10m height above mean GL. For computing design wind speed (V_z) at a height z the risk co-efficient k1 is considered. For k_2 terrain category 2 and class ‘c’ as per table 2 of IS: 875(part3)-1987 considered. Co-efficient k_3 will be 1.0 for the tower under consideration. The wind pressure at a given height is computed theoretically in accordance to the IS code as: $P_z = 0.6Vz^2$ N/mm2

4. SHELL GEOMETRY

The cooling tower shell is made up of two hyperbolas, one from the throat level to the top of the tower and the other from the throat level to the ring beam level. The general equation of the hyperbola used in the present design is:

$$\{(x-d)^2/a^2\} - \{y^2/b^2\} = 1$$

Where,

d= radius of cylinder around which hyperbola is wound
x=radius,
y=vertical distance
a, b= hyperbola constants

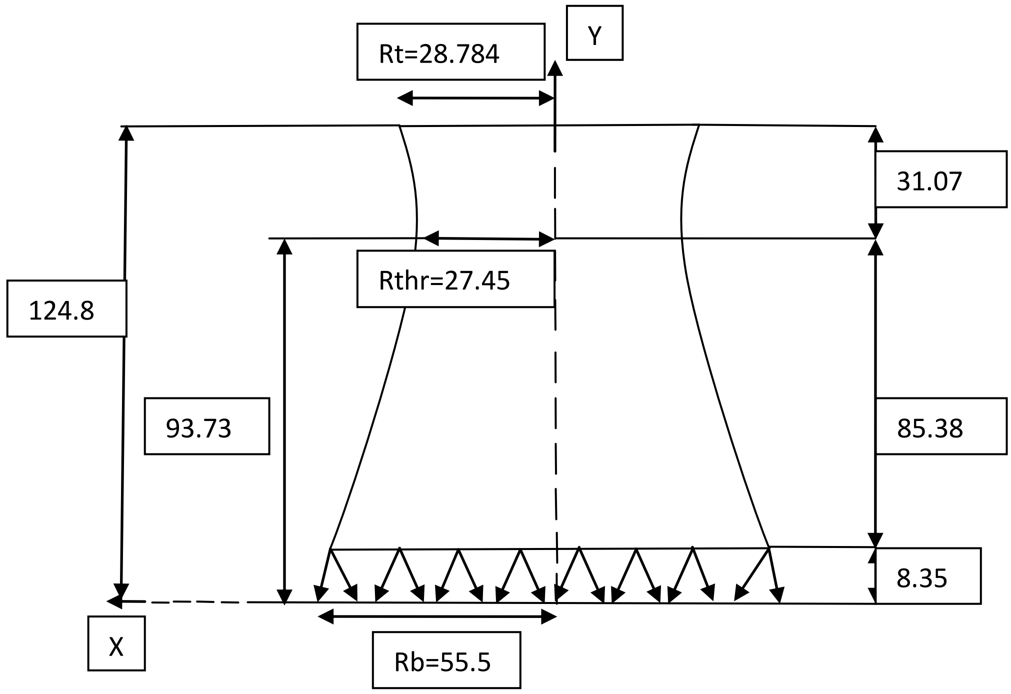


Figure 1: Geometry of RTPS

Table-1 Geometrical details of cooling tower shell (124.8m height)

Sl.No.	Parameter Description	Parametric Values		
		CT 1 (RTPS-Ref. Shell)	CT2 (increased)	CT3 (decreased)
1	Total height, H	124.8m	124.8m	124.8m
2	Height of throat, H_{thr}	31.07m	31.07m	31.07m
3	Diameter at top, D_t	57.568m	57.568m	57.568m
4	Diameter at bottom, D_b	94.8m	94.8m	94.8m
5	Diameter at throat,D_{thr}	55.49m	55.49m	55.49m
6	Thickness at thoart, T_{thr}	175mm	225mm	125mm
7	Size of openings, D_{opn}	1800mm	2000mm	125mm

Note: CT1: Raichur thermal power plant as a reference tower
CT2: Increased thickness and size opening of cooling tower.
CT 3: decreased thickness and size opening of cooling tower.

5. SEISMIC ANALYSIS AND DESIGN

5.1 Design Parameters

The various design parameters for the project site, as defined in IS: 875(part-3) are:

a) The basic wind speed “V_z” at 10 meters above the mean ground level: 39.0 m/sec

b) Category of Terrain: Category-2 Class-c

c) The risk coefficient factor:1.06

5.2 Material Property:

1. Young’sModulus: 31Gpa
2. Poisson Ratio: 0.15
3. Density of RCC: 25 KN/m3

Maximum considered Earthquake (MCE) of 2% probability

5.3 Static Analysis:

Static analysis will be carried out only by considering self-weightand fixity at the shell base.First we creating the Geometry of the model in ANSYS by using key points & we have to input material models, shell element & make mesh to model in Pre processor. By assigning the loads to the model and selecting Static analysis and solve the problem in solution & read the results in General post processor.

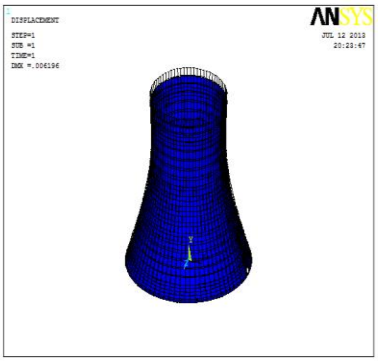
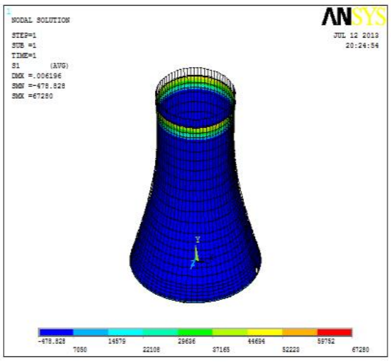
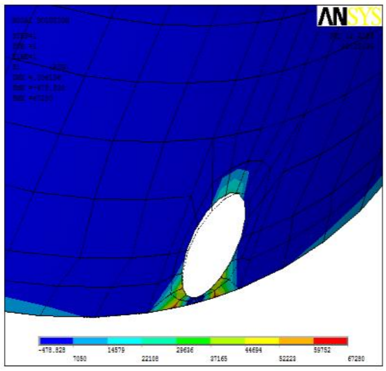




Fig. 2:Deflection for ref.towerFig.3:Principalstressfor ref.tower

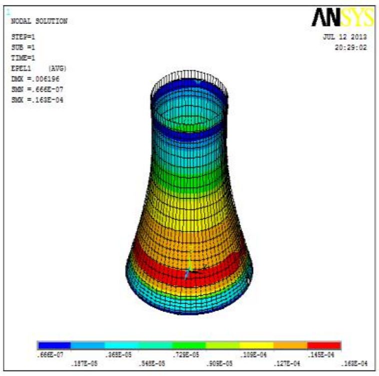
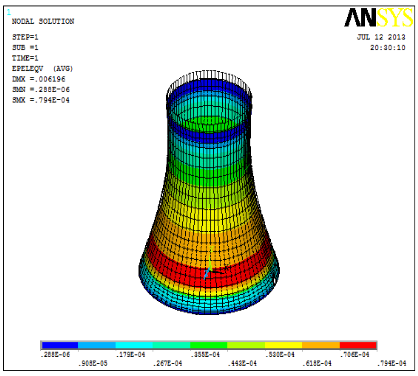



Fig.4: Principal Strainfor ref.towerFig. 5: Von MisesStrain for ref.tower

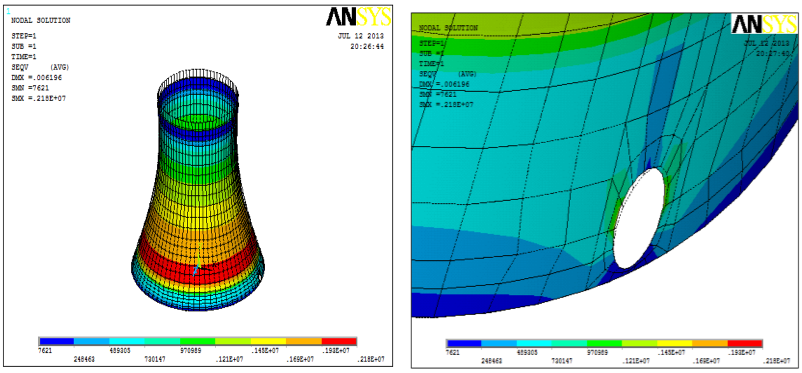


Fig.6: Von Mises Strain for ref.tower

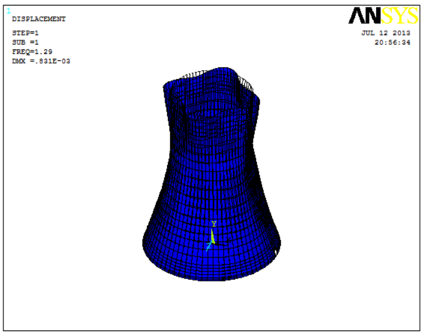
Table 2:Static analysis results

Shell No.	Max. Deflection (m)	Max Principal		Principal stress at shell opening (N/m^2)	Max. Von Mises	
		Stress (N/m^2)	Strain		Stress (N/m^2)	Strain
CT 1	0.006196	67280	0.163×10^{-4}	-478.826to14579	0.218×10^{7}	0.794×10^{-4}
CT 2	0.005959	60357	0.161×10^{-4}	-455.507to26572	0.211×10^{7}	0.771×10^{-4}
CT 3	0.006638	166168	0.165×10^{-4}	-517.95to147647	0.228×10^{7}	0.831×10^{-4}

5.4 Modal Analysis for Free Vibration:

The modal analysis will be carried out in accordance with IS 1893 (part I) 2002.This method used to calculate the Natural frequency (f)and mode shape (ϕ) of a structure.First we creating the Geometry of the model in ANSYS by using key points & we have to input material models, shell element & make mesh to model in Preprocessor. By assigning the loads to the model and selecting Modal analysis, giving number of modes to extract as 50 frequencies and solve the problem in solution & read the results in General post processor.-

For First Mode At Frequency 1.29



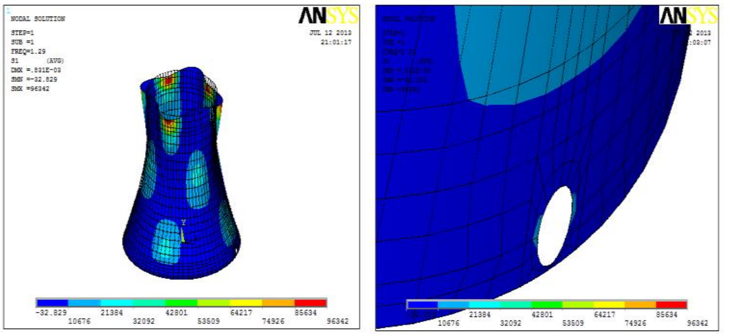
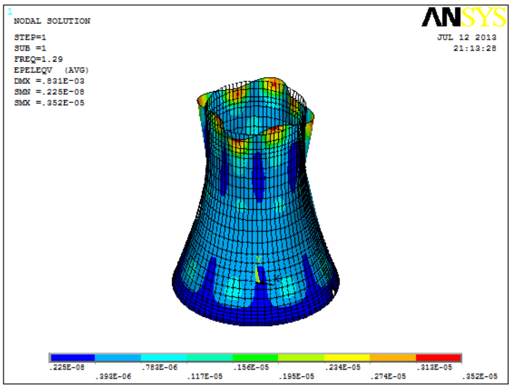


Fig.7:Deflection for ref.tower Fig.8: principal stressfor ref.tower



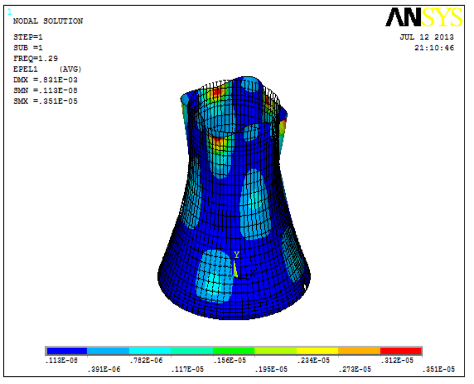


Fig.9:Von Mises strainfor ref.towerFig.10: principal strainfor ref.tower

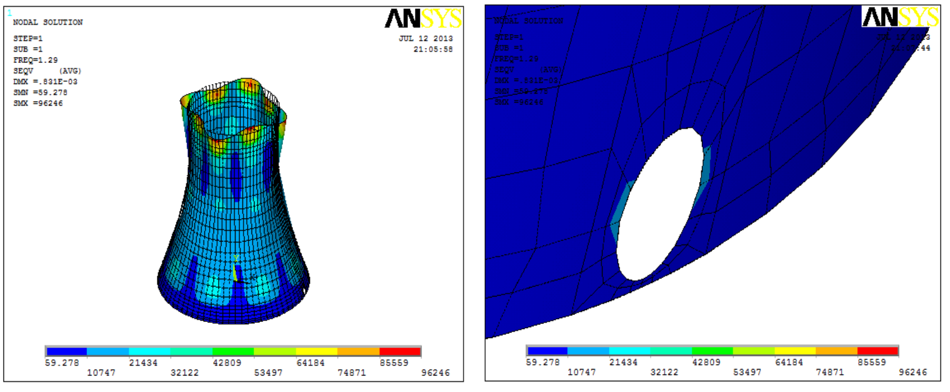


Fig.11:Von Mises stressfor ref.tower

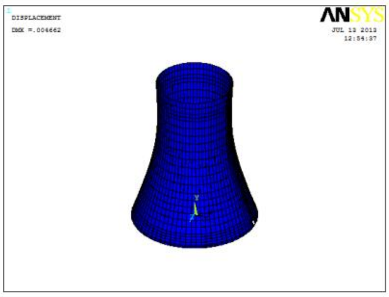
Table 3:Modal analysis results

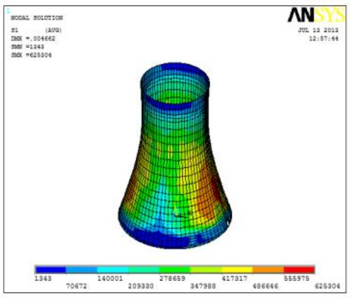
Series	Max. Deflection (m)	Max. Principal		Principal stress at shell opening (N/m^2)	Max. Von Mises	
		Stress (N/m^2)	Strain		Stress (N/m^2)	Strain
CT 1	$0.831 x10^{-3}$	96342	$0.3519 x10^{-5}$	-32.829to10676	96246	$0.352 x10^{-5}$
CT 2	$0.748 x10^{-3}$	55138	$0.201 x10^{-5}$	-16.53to6112	55094	$0.201 x10^{-5}$
CT 3	$0.925 x10^{-3}$	95544	$0.349 x10^{-5}$	-32.82	95267	$0.348 x10^{-5}$

5.5 **Response Spectra Analysis:**

The seismic analysis will be carried out for 0.3g,0.4g,0.5g(g: Gravity acceleration 9.81m/sec^2) in accordance with IS 1893 (part I) 2002,the earthquake analysis of the shell will be carried out by response spectrum method.

Response Spectra Analysis:0.3g





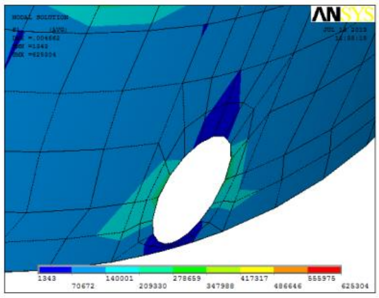


Fig.12:Deflectionfor ref.towerFig.13: Principal stressfor ref.tower

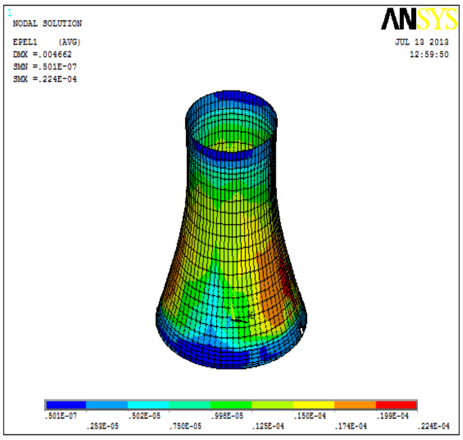
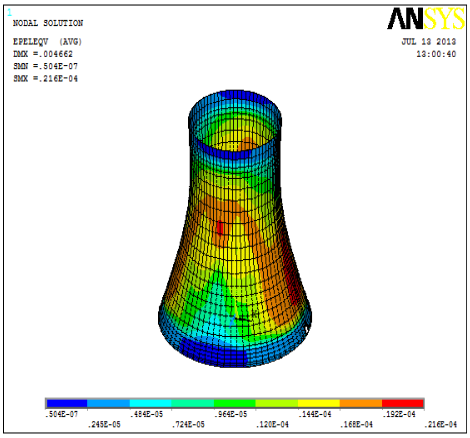



Fig.14:Principal strainfor ref.towerFig.15:Von mises strain for ref.tower

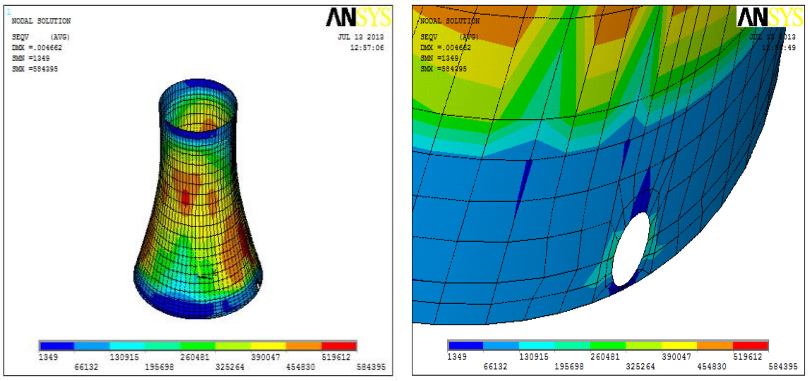


Fig.16: Von mises stressfor ref.tower

Table 4: Seismic analysis result:0.3g

Series	Max Deflection (m)	Max Principal		principal stress at shell opening (N/m^2)	Max Von mises	
		Stress (N/m^2)	Strain		Stress (N/m^2)	Strain
CT 1	0.00463	625304	0.224 $x10^{-4}$	1343to140001	584395	0.216 $x10^{-4}$
CT 2	0.00439	557276	0.197$x10^{-4}$	1577to248554	528617	0.190 $x10^{-4}$
CT 3	0.00516	645916	0.233 $x10^{-4}$	6301to148438	625157	0.229 $x10^{-4}$

Table 5: Seismic analysis result: 0.4g

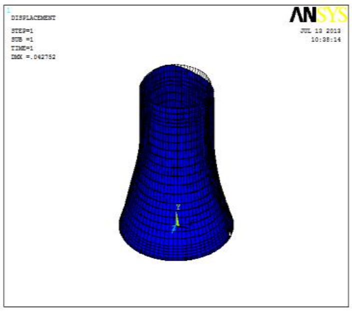
Series	Max Deflection (m)	Max Principal		principal stress at shell opening (N/m^2)	Max Von mises	
		Stress (N/m^2)	Strain		Stress (N/m^2)	Stress ()
CT 1	0.00621	833738	0.299 x10^{-4}	1791to18668	778193	0.288 x10^{-4}
CT 2	0.00595	743035	0.267 x10^{-4}	2102to 33146	704823	0.258 x10^{-4}
CT 3	0.00688	861222	0.311 x10^{-4}	8401to197917	833542	0.305 x10^{-4}

Table 6: Seismic analysis result: 0.5g

Series	Max Deflection (m)	Max Principal		principal stress at shell opening (N/m^2)	Max Von mises	
		Stress (N/m^2)	Strain		Stress (N/m^2)	Stress
CT 1	0.00448	601698	0.216x10^{-4}	1293to134716	562334	0.208 x10^{-4}
CT 2	0.00744	928795	0.333x10^{-4}	2628to414257	881029	0.322 x10^{-4}
CT 3	0.00860	0.108x10^{7}	0.389x10^{-4}	10501to247396	0.104 x10^{7}	0.321x10^{-4}

6.0.WIND ANALYSIS :

The 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.



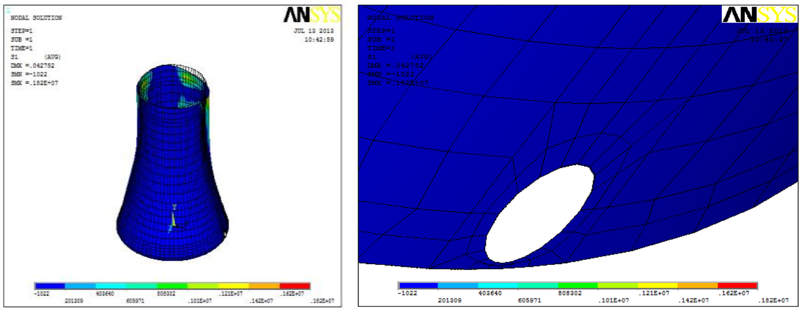
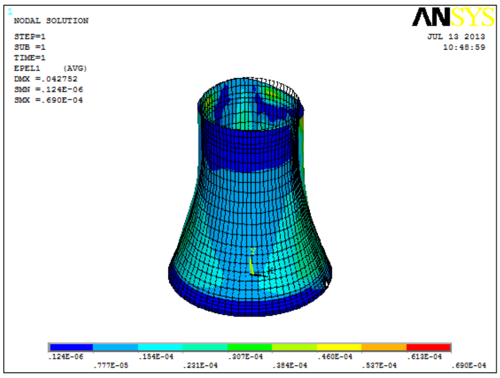


Fig.17:Deflection for ref.towerFig.18: Principal stressfor ref.tower



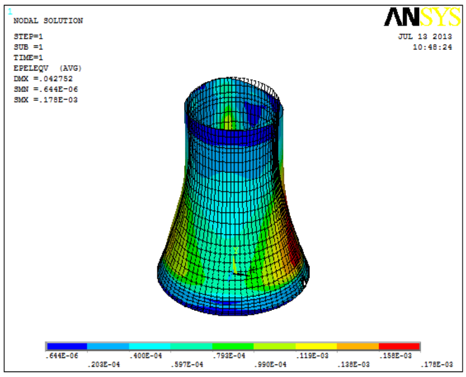


Fig:19:Principal strainfor ref.towerFig.20:Von mises strain for ref.tower

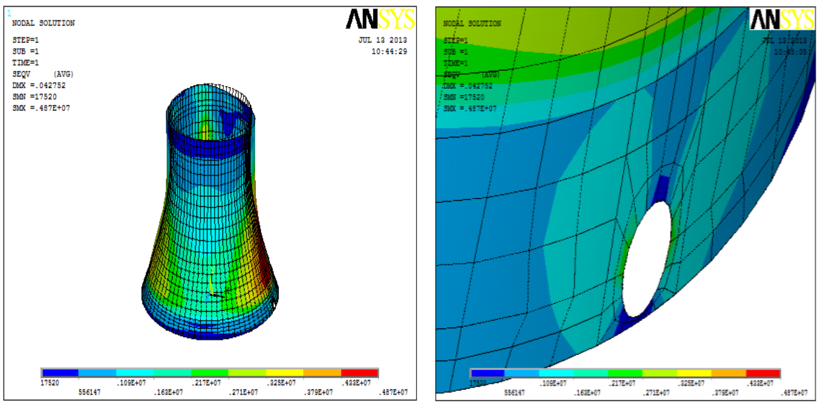


Fig.21: Von mises stress for ref.tower

Table 7: wind analysis results

Series	Max Deflection (m)	Max Principal		principal stress at shell opening (N/m^2)	Max Von mises	
		Stress (N/m^2)	Strain		Stress (N/m^2)	strain
CT 1	0.04275	0.182×10^{7}	0.690×10^{-4}	-1022	0.487×10^{7}	0.1728×10^{-3}
CT 2	0.033	0.132×10^{7}	0.482×10^{-4}	-913.27	0.412×10^{7}	0.150×10^{-3}
CT 3	0.05963	0.311×10^{7}	0.125×10^{-3}	-1554	0.621×10^{7}	0.22×10^{-3}

SUMMARY AND CONCLUSIONS

1. The principal stresses in static analysis i.e. (self-weight) are observed to beless for CT2 (whose thickness and the size of the shell opening is more) then the reference tower CT1 (reference tower).

2. The deflection in static analysis is least for CT2(whose thickness is more and opening size more)comparison to reference tower CT1 and decreased thickness and opening size of tower CT3.

3. In the free vibration analysis it has been observed that the principal stress for the 1st mode is greater for CT1 (reference tower) than CT2 and CT3.

4. It is evident from the seismic analysis.The principal stress observed to be least for tower CT2(whose thickness is more and opening size more) comparison to reference tower CT1 and decreased thickness and openings size of tower CT3.The principal stress is maximum for (CT3 whose thickness is reduced and opening size smaller).

5. It is evident from the wind load analysis that the deflection is the least in CT2 (whose thickness is more and opening size more)comparison to reference tower CT1 and decreased thickness and openings size of tower CT3.The principal stress is maximum for CT3 (whose thickness is reduced and opening size smaller).

6. It is evident from the wind load analysis the principal stress is least in CT2 (whose thickness is more and opening size more) compare to the reference tower CT1and decreased thickness and openings size of tower CT3.

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