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Modal Analysis of a Thermal Power Plant Cooling Tower

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Abstract: Regular Draft Hyperbolic Cooling towers are the describing land signs of power station. They contribute both to a productive vitality yield and to a cautious equalization with our surroundings. These structures are most productive measures for cooling of warm power plants by minimizing the need of water and staying away from warm contamination of water bodies. The Present Paper manages the investigation of static and element examination of hyperbolic cooling towers (i.e. self weight, seismic burden, wind load). Two existing cooling towers are looked over Bellary warm Power station (BTPS) as contextual analysis. The limit conditions considered are Top end free and Bottom end is settled. The Material properties of the cooling towers are youthful modulus 31GPa, Poisson Ratio 0.15 and thickness of RCC 25 kN/m3. Static investigation has been done utilizing 8 node SHELL 93 component and 4 nodes SHELL 63.The behavioral changes because of anxiety convergence of cooling tower is broke down utilizing ANSYS 10 (SHELL 93) component with shifting its tallness and thickness. The goal is to get the ideal stature, with low stretch focus. Seismic and wind examination has been completed for two existing cooling tower utilizing (FEA), SHELL 93 component. The Seismic burdens are completed for 0.5g, 0.6g, 0.7g, ground increasing speed as per IS 1893(part I)- 2002 and IS 1893(part IV)-2005 by modular and Response Spectrum strategy. Wind loads on these cooling towers have been figured as weight by utilizing outline wind weight co productive given in IS 11504-1985 code and outline wind weight at distinctive levels according to IS 875 (Part 3)- 1987 code. Eigen clasping investigation has been done for both existing cooling towers. Greatest Deflection, Maximum Principal Stress and strain, Maximum Von Mises stress, strains are acquired. The variety in max primary anxiety v/s thickness, greatest avoidance v/s thickness is plotted graphically.

Keywords: Cooling Tower, FEA, SHELL Element, Seismic and Wind Load, Stress, Mises.

I. INTRODUCTION

Hyperbolic cooling towers are large, thin shell reinforced concrete structures which Contribute to power generation efficiency, reliability and to environmental protection. Natural draft cooling tower is one of the most widely used cooling towers. It works on the principle of temperature difference between the air inside the tower and outside the tower. Hyperbolic shape of cooling tower is usually preferred due to its strength and stability and larger available area at the base. Hyperbolic reinforced concrete cooling towers are effectively used for cooling large quantities of water in thermal power stations, refineries, atomic power plants, steel plants, air conditioning and other industrial plants. Natural draughts cooling towers (NDCT) is the characterizing landmarks of power stations and are used as heat exchangers in nuclear power plants. They contribute both to an efficient energy output and to a careful balance with our environment. These shell structures are subjected to environmental loads such as Seismic and thermal gradients that is stochastic in nature. A series of a hyperbolic cooling tower is as shown in Fig.1.

Fig.1. Group of Natural Draught Cooling Towers

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. Reinforced concrete (RC) cooling towers, which comprise of a thin concrete shell of revolution, are common place in civil engineering infrastructure that is concerned with the generation of electric power. Large reinforced concrete, natural draught cooling tower structures can be as tall as or even taller than many chimneys, however due to their design and function, they have a very much larger surface area, with a much lower mass to surface area ratio. The present day hyperbolic cooling tower is exceptional structures in view of their sheer size and complexities. The towers involve considerable amount of design work on structural aspect. The analysis of these towers is an interesting and challenging to any structural engineer in view of their size and shape.

II. REVIEW OF RELATED LITERATURE

Hyperbolic Reinforced concrete cooling towers are effectively used for cooling large quantities of water in thermal power stations, refineries, atomic power plants, steel plants, air conditioning and other industrial plants. 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, Response of cooling tower to wind load. This paper deals with the study of two cooling towers of 122m and 200m high above ground level. They calculated the values like meridional forces and bending moments. A. M. El Ansary, 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. Shailesh S Angalekar, Dr. A. B. Kulkarni, 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. Prashanth N, Sayeed sulaiman. 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.. N.Prabhakar (Technical Manager). The Paper describes briefly salient structural features and current practices adopted in the structural design of hyperbolic cooling towers. Cooling towers are undoubtedly exceptional structures which require special expertise both to design and construct.

III. INTRODUCTION TO DYNAMIC ANALYSIS

Earthquakes are caused by faulting, a sudden lateral or vertical movement of rock along a rupture (break) surface. The surface of the Earth is continuous slow motion. This is plate tectonics--the motion of immense rigid plates at the surface of the Earth in response to flow of rock within the Earth. The plates cover the entire surface of the globe. Since they are all moving they rub against each other in some places, sink beneath each other in others, or spread apart from each other. At such places the motion isn't smooth the plates are stuck together at the edges but the rest of each plate is continuing to move, so the rocks along the edges are distorted (what we call "strain"). As the motion continues, the strain builds up to the point where the rock can’t withstand any more bending. With a lurch, the rock breaks and the two sides move. An earthquake is the shaking that radiates out from the breaking rock. Unfortunately, timing of this natural phenomenon cannot be predicted scientifically. Historical records reveal the tendency of earthquakes to revisit regions after an interval of time. This random time interval is called RETURN PERIOD. This is the basis of the seismic conation. There are four zones in the country and they are denoted as II, III, IV and V. Zone I which existed in the earlier versions of the code, has been upgraded to Zone II or higher. The higher the zone, the more vulnerable is that region to a major earthquake. The size of an earthquake is measured by the strain energy released along the fault. It is expressed as MAGNITUDE. The commonly used scale for expressing the magnitude is the Richter scale. Every unit increase in magnitude implies an increase of about 31 times the energy. Dynamic analysis may be performed either by the Time History Method or by the Response Spectrum Method. For cases where a more refined design analysis is desired, response spectra are used as the means for determining lateral forces. A Response spectrum for a particular earthquake shows in a relatively simple way the dynamic characteristics of a given earthquake.

A. Generation of Response Spectra

For the design of RC structures for seismic loading a design spectrum is obtained as per the recommendations of IS 1893 (Part1): 2002 titled “Criteria for Earthquake Resistant Design of Structures”. The parameters considered are type of soil, type of construction, the dynamic behavior of the prototype structure and the appropriate seismic zone. The earthquake spectrum is an average smoothened plot of maximum acceleration as function of frequency or time period of vibration for a specified damping and for a site-specific condition. According to the code, India is classified into four seismic zones i.e. Zone II, Zone III, Zone IV and Zone V. The code specifies forces for analytical design of structures standing on rocks or soil for above four zones and different value of damping of the structure. For the purpose of design acceleration spectrum has been prepared for zone III assuming damping as 5% and the soft soil condition.

IV. TABULATION & RESULTS

A. Static Analysis

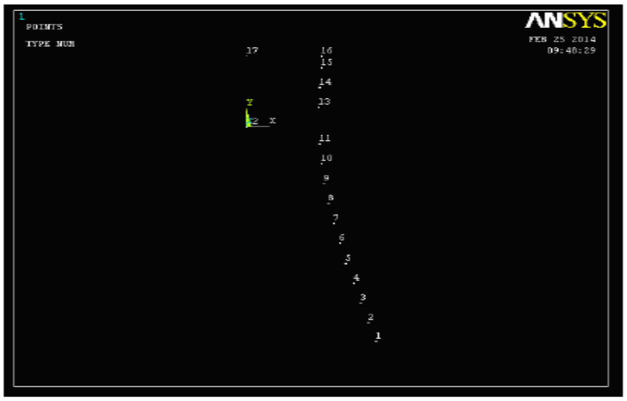


Fig.2. Key points

A) Comparison of cooling towers (CT 1, CT 2, CT 3, CT 4, and CT 5) with varying heights and thicknesses (200mm, 250mm, 300mm, 350mm, 400mm, 450mm, and 50 B) Comparison between two existing cooling towers (CT 1 &

CT 5) for different element types (4 noded SHELL 63 & 8 noded SHELL 93). Models of Deflection, Maximum principal stress, Max principal strain, von Mises stress & strain for cooling tower 1 for static analysis & for 200mm shell thickness 11)

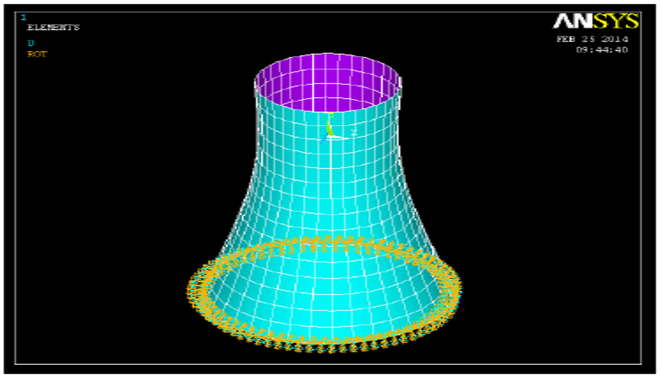


Fig.3. Boundary conditions

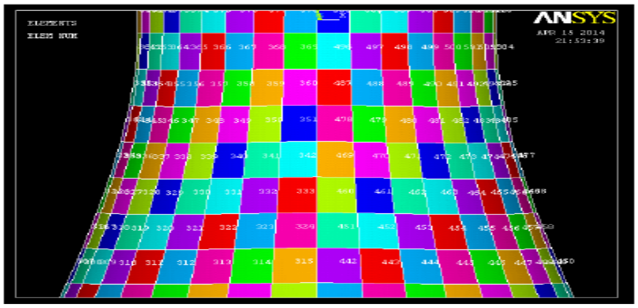


Fig.4. Element numbers in model

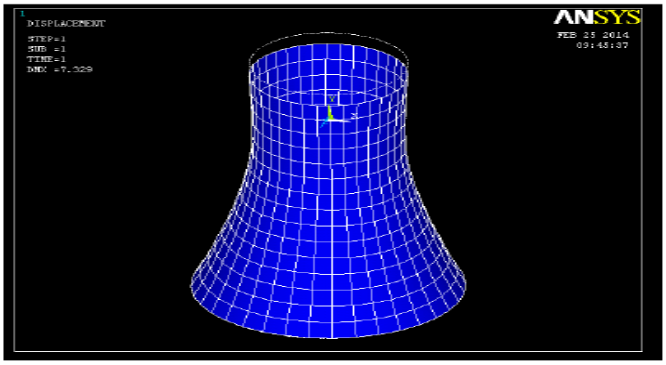


Fig.5. Deflection of CT 1 (200mm thickness)

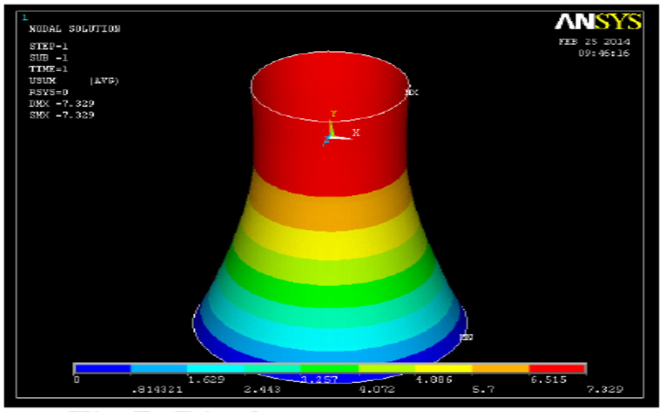


Fig.6. Displacement vector sum

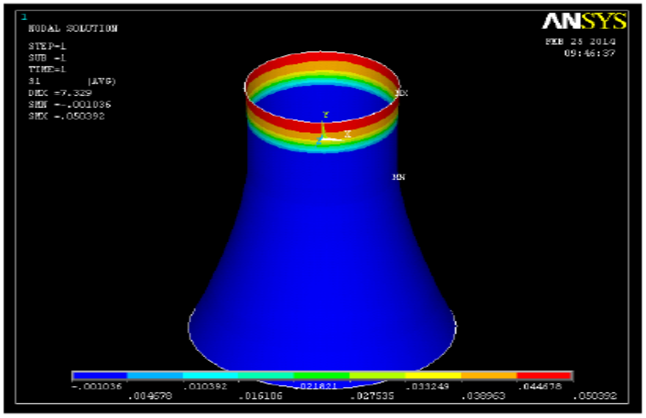


Fig.7. Maximum Principal Stress for CT1

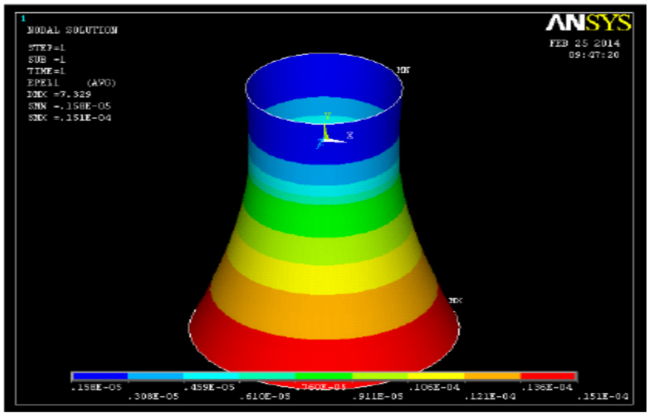


Fig.8. Maximum Principal Strain for CT 1

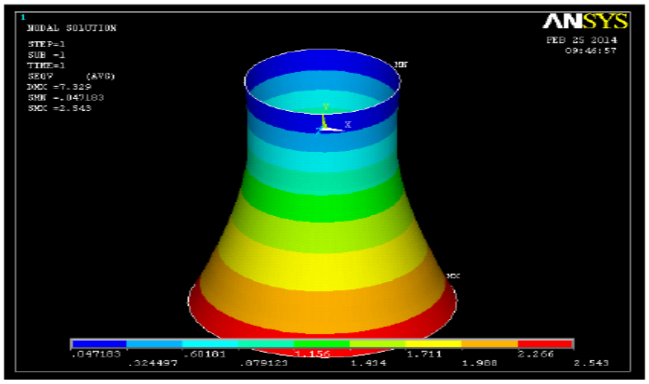


Fig.9. Von Mises Stress for CT 1

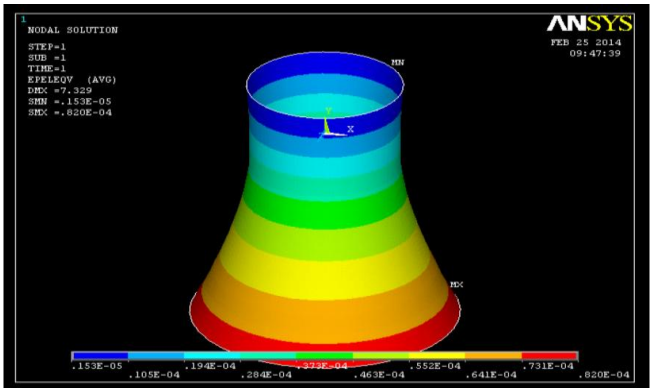
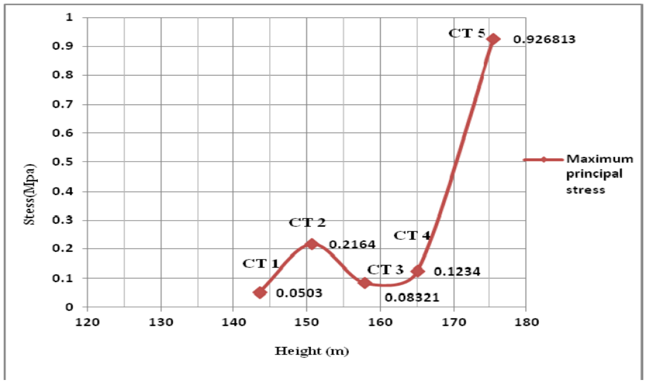
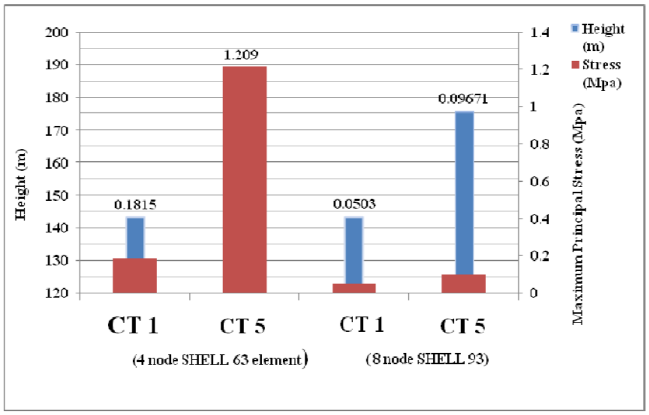


Fig.10. Von Mises Strain for CT 1



Graph 1: Graphical Representation of Stress v/s Height for maximum principal stress for CT1, CT2, CT3, CT4 and CT5 for 200mm SHELL thickness.



Graph 2: Graphical Representation of Height v/s Element type for various stresses for CT 1& CT5 for different element type for 200mm SHELL thickness.

B. Modal analysis

Modal analysis is carried out for two existing cooling towers i.e. CT 1 & CT 5. This method is used to calculate Natural frequency and mode shapes. The Geometry of the model is created in ANSYS by using key points. By assigning the loads and boundary conditions to the model and selecting Modal analysis & giving number of modes to extract as 50 frequencies and solve the problem. The results are compiled in general post processor. Characteristics of cooling tower 1 for 200mm thickness and Mode 1 for model analysis are shown below (Refer Fig no: 11 to 14).

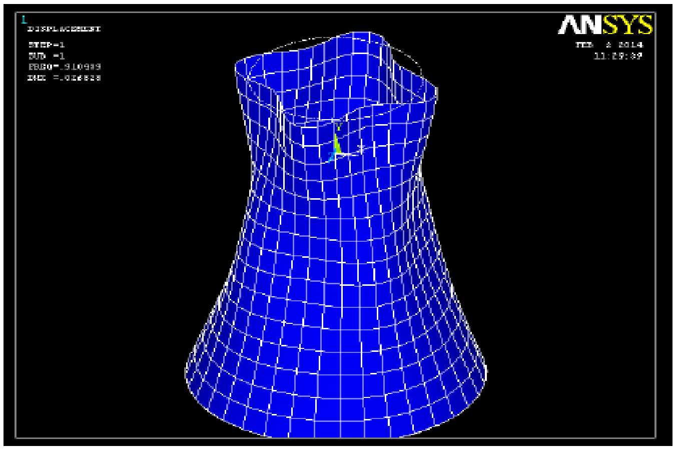


Fig.11. Deflection for CT 1(Mode 1).

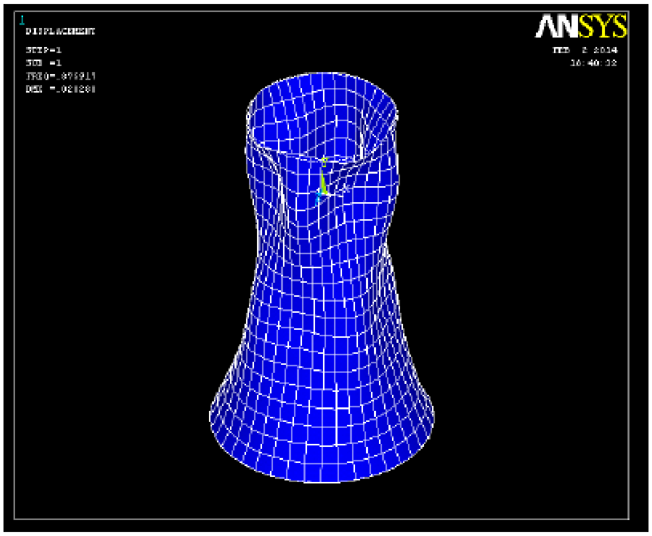


Fig.12. Deflection for CT 5 (Mode 1).

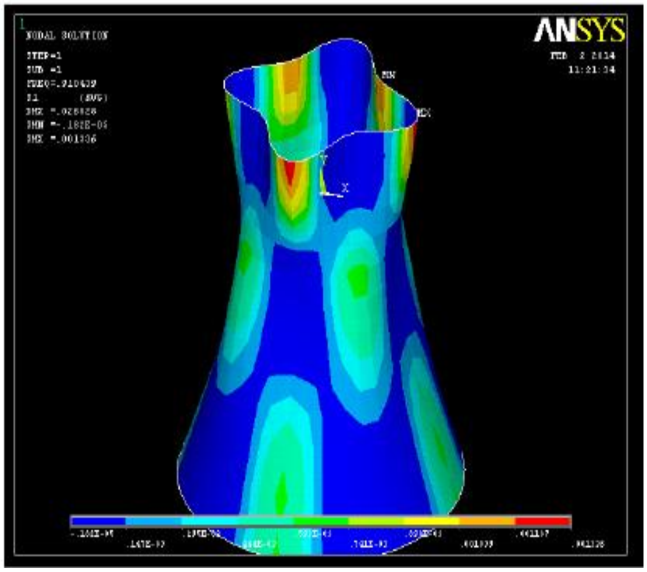


Fig.13. Max Principal Stress for CT 1.

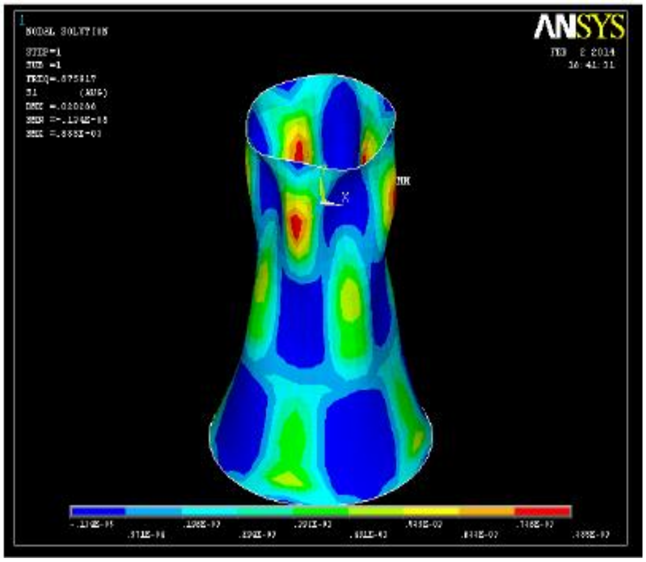


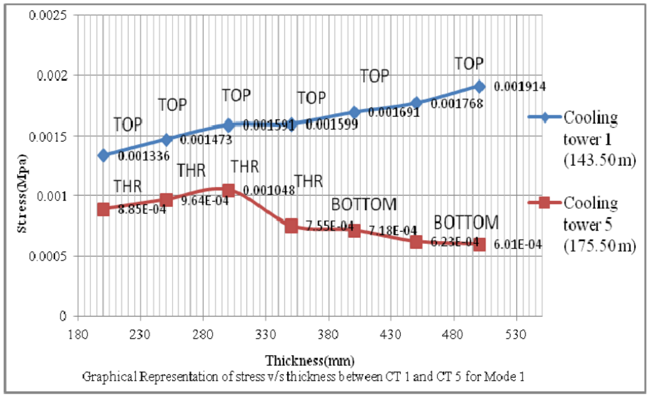
Fig.14. Max Principal Stress for CT5.

TABLE 1. Results of Modal Analysis for CT 1

Thickness (mm)	Modes	Frequency (HZ)	Maximum Principal stress (Mpa)
200	1	0.8759	0.885×10^{-3}
	5	1.005	0.924×10^{-3}
	10	1.087	0.952×10^{-3}
250	1	0.93833	0.964×10^{-3}
	5	1.057	0.00143
	10	1.132	0.865×10^{-3}
300	1	1.009	0.001048
	5	1.085	0.717×10^{-3}
	10	1.205	0.001526
350	1	1.058	0.755×10^{-3}
	5	1.088	0.679×10^{-3}
	10	1.245	0.989×10^{-3}
400	1	1.081	0.718×10^{-3}
	5	1.165	0.001194
	10	1.31	0.001054
450	1	1.095	0.623×10^{-3}
	5	1.249	0.001218
	10	1.382	0.001114
500	1	1.10	0.601×10^{-3}
	5	1.293	0.791×10^{-3}
	10	1.458	0.001167

TABLE II. Results of Modal Analysis for CT 5

Thickness (mm)	Modes	Frequency (HZ)	Maximum Principal stress (Mpa)
200	1	0.8759	0.885×10^{-3}
	5	1.005	0.924×10^{-3}
	10	1.087	0.952×10^{-3}
250	1	0.93833	0.964×10^{-3}
	5	1.057	0.00143
	10	1.132	0.865×10^{-3}
300	1	1.009	0.001048
	5	1.085	0.717×10^{-3}
	10	1.205	0.001526
350	1	1.058	0.755×10^{-3}
	5	1.088	0.679×10^{-3}
	10	1.245	0.989×10^{-3}
400	1	1.081	0.718×10^{-3}
	5	1.165	0.001194
	10	1.31	0.001054
450	1	1.095	0.623×10^{-3}
	5	1.249	0.001218
	10	1.382	0.001114
500	1	1.10	0.601×10^{-3}
	5	1.293	0.791×10^{-3}
	10	1.458	0.001167



Graph3: Graphical Representation of Stress v/s thickness for CT 1& CT5 in (Mode 1)

C. Response Spectra Analysis: 0.5g, 0.6g & 0.7g

Response spectrum analysis is carried out for 0.5g, 0.6g & 0.7g for two existing cooling towers i.e. CT 1 & CT 5. The Geometry of the model is created in ANSYS by using key points & input material models, shell element & make mesh to model in Pre processor. By assigning the loads & boundary conditions to the model and before Spectrum analysis, modal analysis is carried out, after that select spectrum analysis & apply all input data's such as frequencies, seismic co-efficient, square root sum of squares (SRSS) method and solve the problem in solution & read the results in General post processor. Models of cooling tower 1 & 5 for deflection, maximum principal stress are as shown below. (Refer Fig 15 to 18).

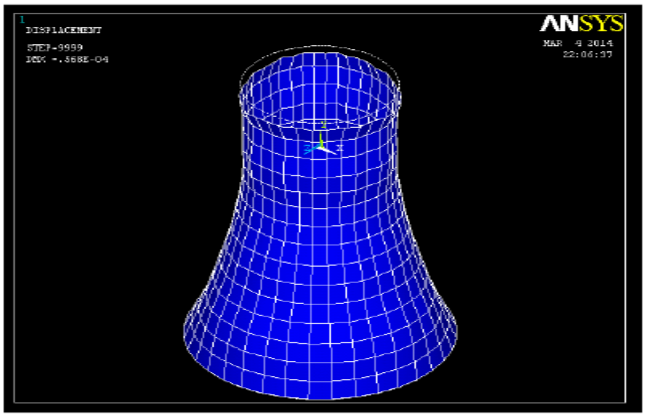


Fig.15. Deflection at 0.5g for CT 1

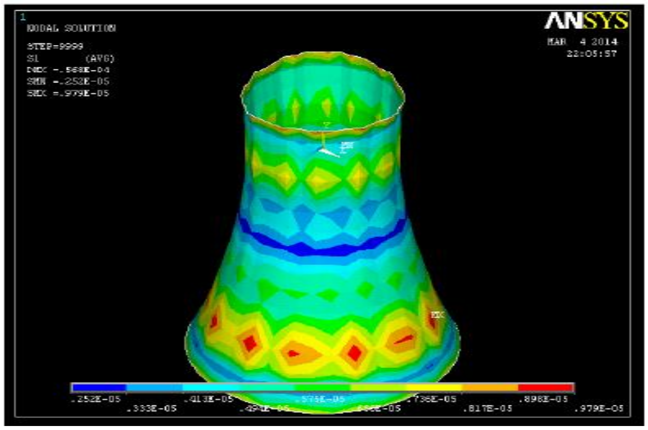


Fig.16. Max Principal Stress for CT 1 (0.5g)

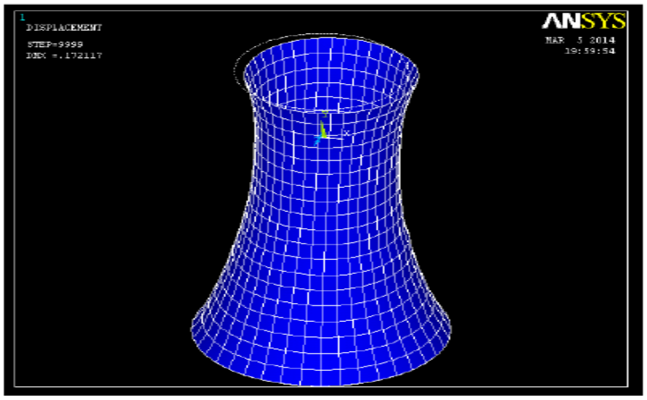


Fig.17. Deflection at 0.5g for CT 5

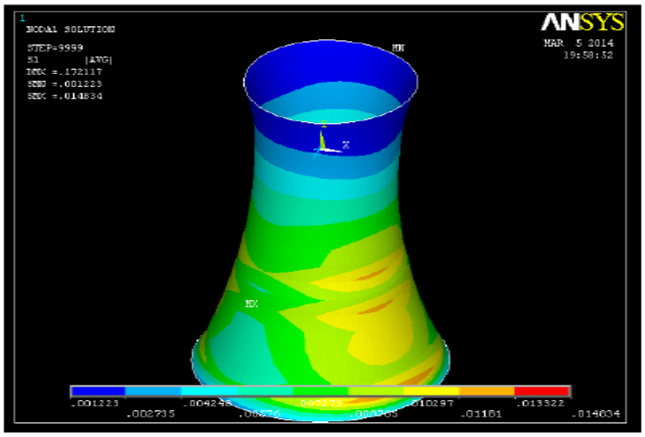
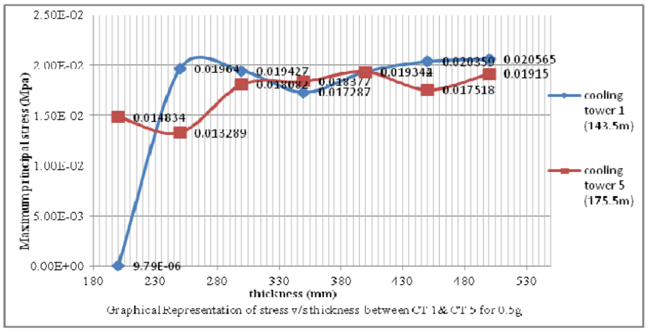
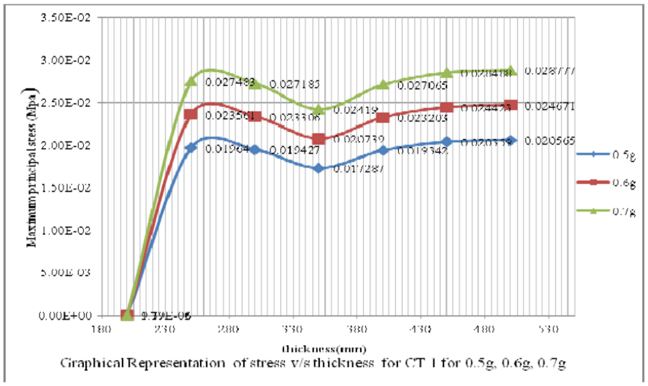


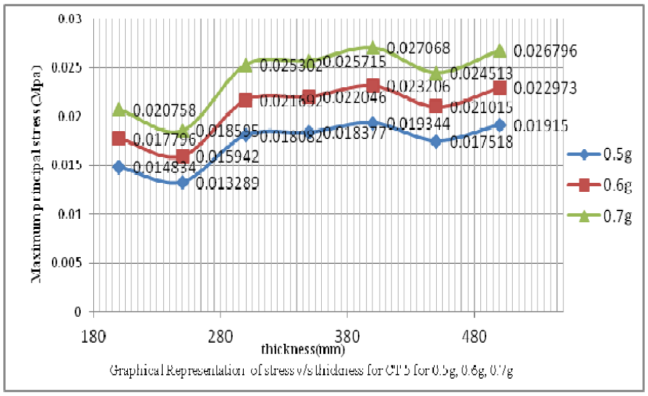
Fig.18. Max Principal Stress for CT 5 (0.5g)



Graph 4: Graphical Representation of Stress v/s thickness between CT 1& CT 5 for 0.5g



Graph 5: Graphical Representation of Stress v/s thickness for CT 1& CT 5 for (0.5g, 0.6g, 0.7g)



Graph 6: Graphical Representation of Stress v/s thickness for CT 1& CT 5 for (0.5g, 0.6g, 0.7g).

D. Wind Analysis

Wind analysis is carried out for two existing cooling towers i.e. CT 1 & CT 5. Geometry of the model is created in ANSYS by using key points & input material models, shell element & make mesh to model in Pre processor. By assigning the loads & boundary conditions and input the Pressures alongside to the model and solve the problem in solution & read the results in General post processor. Models of CT 1 & CT 5 for Deflection, Maximum principal stress are shown below (Refer Fig no 19 to 24).

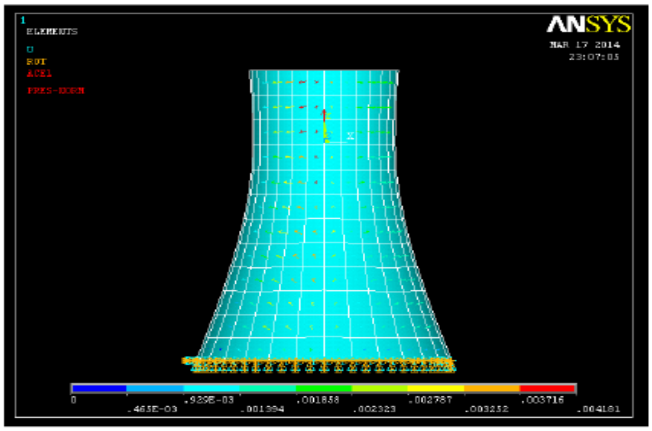


Fig.19. Wind Pressure applied for CT 1.

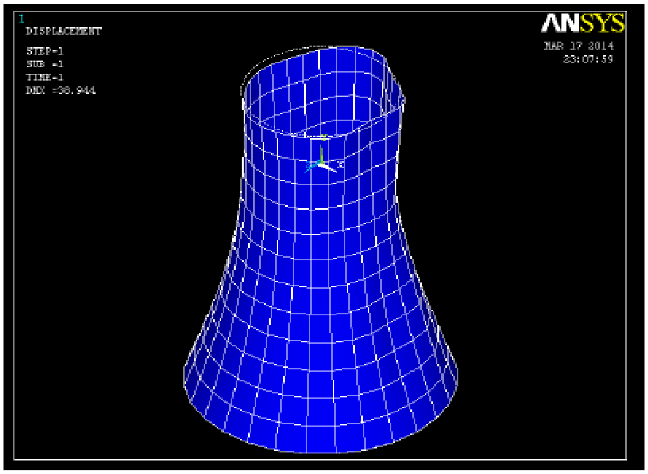


Fig.20. Deflection for CT 1.

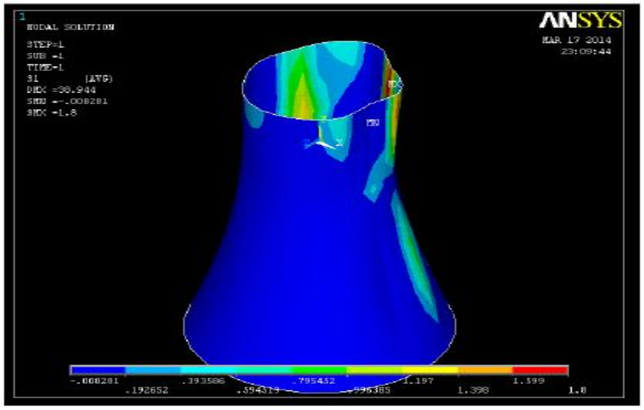


Fig.21. Max Principal Stress for CT 1.

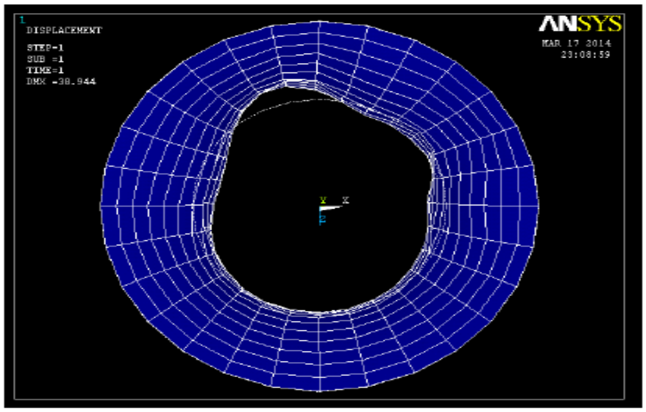


Fig.22. Deflection at Top for CT 1

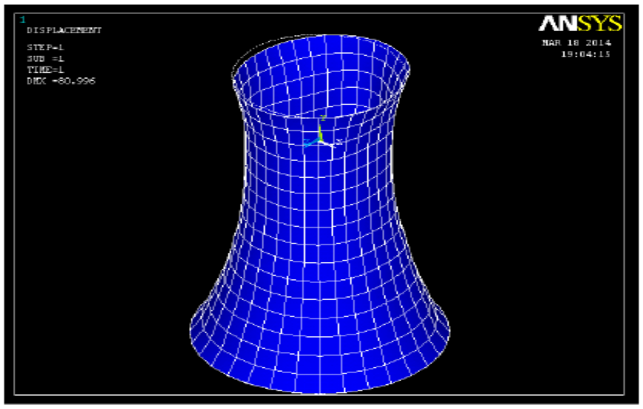


Fig.23. Deflection for CT 5

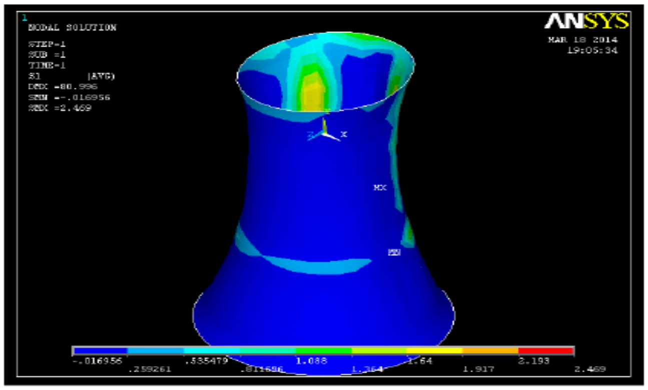
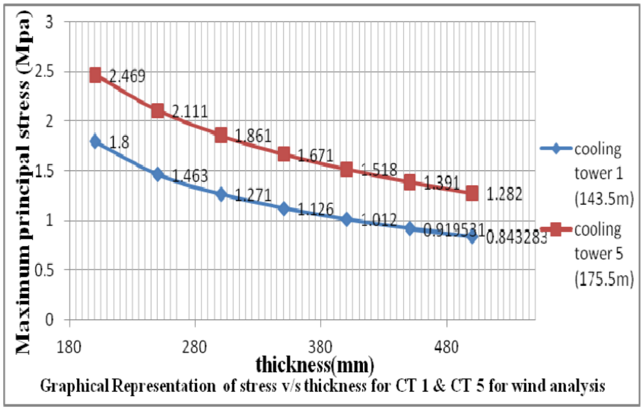


Fig.24. Max Principal Stress for CT 5.



Graph7. Graphical Representation of Stress v/s thickness for CT 1 & CT 5 for wind analysis.

E. Buckling Analysis

Buckling Analysis is carried out for two existing cooling towers (CT 1& CT 5) due to its self weight & varying thicknesses. Eigen buckling analysis is a technique used to determine buckling loads (critical loads at which a structure becomes unstable) and buckled mode shapes (the characteristic shape associated with a structure's buckled response).

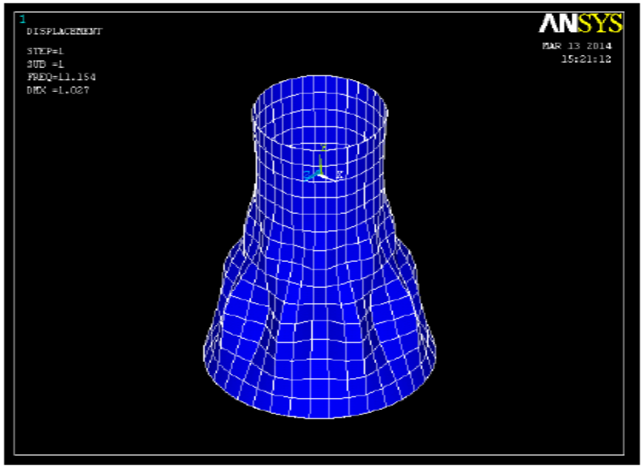


Fig.25. Deflection for CT 1.

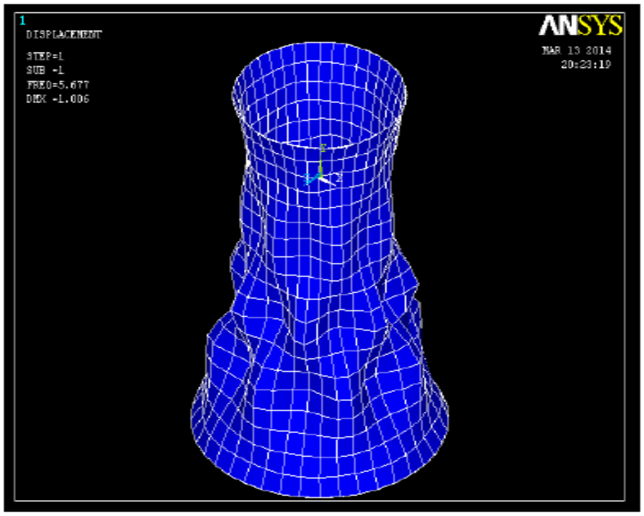


Fig.26. Deflection for CT 5.

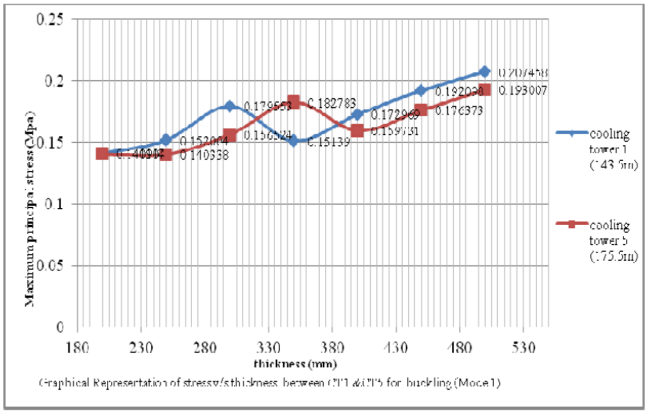
(Buckling mo mode 1) for 200mm SHELL thickness

TABLE III. Results of Buckling Analysis for CT 1

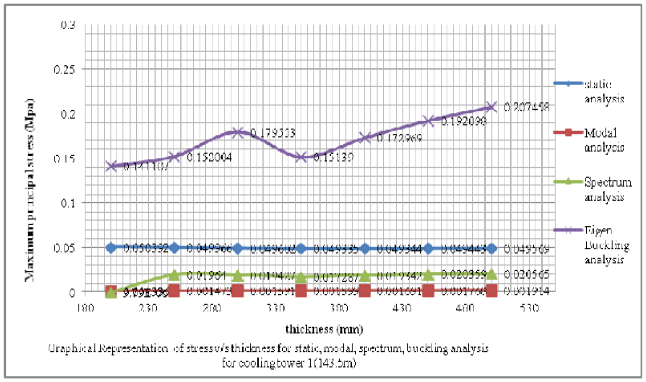
Thickness (mm)	Modes	Frequency (HZ)	Maximum Principal stress (Mpa)
200	1	11.154	0.141107
	3	11.589	0.121869
	5	11.645	0.152701
250	1	15.062	0.152004
	3	15.177	0.176925
	5	15.272	0.111382
300	1	19.013	0.179553
	3	19.046	0.129468
	5	19.806	0.211512
350	1	23.131	0.15139
	3	23.44	0.192193
	5	24.961	0.227134
400	1	27.508	0.172969
	3	28.32	0.212251
	5	29.343	0.12819
450	1	32.172	0.192098
	3	33.495	0.139156
	5	33.616	0.238148
500	1	37.118	0.207458
	3	37.896	0.154163
	5	39.279	0.263028

TABLE IV. Results of Buckling Analysis for CT 5

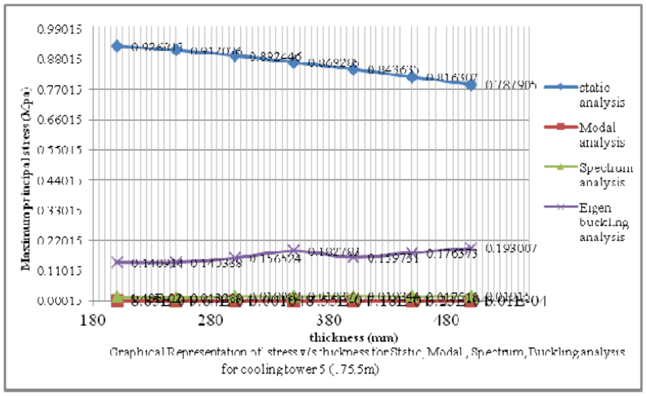
Thickness(mm)	Modes	Frequency (HZ)	Maximum Principal stress (Mpa)
200	1	5.677	0.140914
	3	6.349	0.170463
	5	7.144	0.105226
250	1	7.55	0.140338
	3	8.597	0.166921
	5	8.701	0.110335
300	1	9.645	0.156524
	3	10.406	0.126587
	5	11.152	0.191002
350	1	11.992	0.182783
	3	12.291	0.143113
	5	14.033	0.233165
400	1	14.372	0.159731
	3	14.603	0.209092
	5	17.242	0.256321
450	1	16.654	0.176373
	3	17.484	0.227851
	5	20.773	0.288999
500	1	19.143	0.193007
	3	20.638	0.249987
	5	23.365	0.150298



Graph 8. Graphical Representation of Stress v/s thickness for CT 1& CT 5 for buckling mode 1.



Graph9. Graphical Representation of Stress v/s thickness for CT 1 for static, modal, spectrum, buckling analysis



Graph10. Graphical Representation of Stress v/s thickness for CT 5 for static, modal, spectrum, buckling analysis.

V. CONCLUSION

A. From Graphical Representation of Max Principal Stress v/s thickness for ground acceleration of 0.5g, 0.6g, 0.7g, it is evident that

1. On comparing CT 1 & CT 2 for Maximum Principal stress
   a. The Maximum Principal stress for 200mm thickness is minimum & for 250mm thickness shows maximum stress for CT 1 respectively, whereas CT 2 behave conversely to CT 1 for same thicknesses.
   b. The Maximum Principal Stress for 300mm thickness is maximum & for 350mm thickness shows least maximum stress for CT 1 respectively, whereas CT 2 behave opposite to CT 1 for same thicknesses.
   c. The Maximum Principal Stress for thickness of 450mm & 500mm shows maximum for CT 1 as compared to CT 2.
   d. On comparing CT 1 (143.50m) & CT 2 (175.50m); Initially CT 1 shows less value of stress for 200mm thickness and high value of stress for 500mm thickness respectively, but CT 2 behaves opposite to CT 1 for 200mm & 500mm thickness.
   e. As Ground acceleration increases the stresses developed in shell reaches maximum and the stresses developed in shell portion depends upon the SHELL thickness.

2. The Maximum Principal Stress for CT 1 & CT 2 is same for 400mm SHELL thickness and shows optimality.

B. From Graphical Representation of Deflection v/s thickness for 0.5g, 0.6g, 0.7g, it is evident that

1. The Maximum Deflection for 200mm SHELL thickness is least for CT 1 as compared to CT 2, whereas for thickness of 250mm till 500mm thickness deflection for CT 1 is more as compared to CT 2.
2. The Damping factor used in dynamic loading is 5% of critical damping for maximum considered earthquake, the damping factor as given in IS 1893 Part 4: 2005 code for reinforced concrete is 7%. In Response Spectrum Analysis the 5% & 7% damping gives almost same results in the analysis.

VI. REFERENCES

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