COMPARATIVE STUDY OF EFFECT SEISMIC AND WIND LOAD ON COOLING TOWER WITH A-FRAME COLUMN AND H-FRAME COLUMN SUPPORT

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ABSTRACT:

Cooling tower is a heat rejection device, which extracts waste heat to the atmosphere though the cooling of a water stream to a lower temperature. R/C cooling towers are used for many kinds of industrial and power plants. These are huge structures and also show thin shell structures. R/C cooling towers are subjected to its self-weight and the dynamic load such as an earthquake motion and a wind effects. This paper deals with the study of cooling towers of 124.8m high above ground level. The cooling towers have been analyzed 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 0.1g, 0.2g & 0.3g in accordance with IS: 1893 by modal analysis. For the purpose of comparison an existing tower of Raichur thermal power plant (RTPS, Karnataka) is considered. For other model of cooling tower, H frame column support varied respect to the reference tower of of RTPS. The results of the analysis include the stress and strain contours. And also the stress and strain contours are plotted and modes of deflection are mapped.

KEYWORDS: *Cooling tower, FEA, Seismic and wind loads.*

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1. INTRODUCTION

Cooling tower is a heat rejection device, which extracts waste heat to the atmosphere though the cooling of a water stream to a lower temperature. Common applications for cooling towers are providing cooled water for air-conditioning, manufacturing and electrical power generation. R/C cooling towers are subjected to its self-weight and the dynamic load such as an earthquake motion and a wind effects. Especially, dynamic analyses of these structures are important factor to design R/C cooling tower structures. Especially, dynamic analyses of these structures are important factor to design R/C cooling tower structures. The structures have huge surfaces of concrete with increasing its constructional height and also, R/C shell structure is usually placed on the supporting columns to take a cold air into it. R/C cooling tower represents the combinations of R/C shell and R/C column structures. the progressive nature of the corrosion-induced deterioration, understanding the root cause, the consequences and associated costs was essential. As such, a condition evaluation was conducted. The total weight of the tower and the static pressure on each column also was determined. Utilizing the collected data, the tower was recreated using a three-dimensional structural engineering computer program. The software included model generation, static, dynamic and linear analyses. Dynamic behavior of R/C cooling tower shell under an earthquake loading is analyzed by use of FEM.

2. FINITE ELEMENT ANALYSIS

The finite element analysis (FEA) is the dominant discretization technique in structural mechanics. The basic concept in the physical interpretation of the FEM is the subdivision of the mathematical model into disjoint (non-overlapping) components of simple geometry called finite elements or elements for short. For many engineering problems analytical solutions are not suitable because of the complexity of the material properties, the boundary conditions and the structure itself. The basis of the finite element method is the representation of a body or a structure by an assemblage of subdivisions called finite elements. ANSYS is a finite element analysis (FEA) code widely used in the computer-aided engineering (CAE) field. ANSYS software allows engineers to construct computer models of structures, machine components or systems; apply operating loads and other design criteria; and study physical responses, such as stress levels, temperature distributions, pressure, etc

3. SHELL GEOMETRY

For the purposes of comparison, a real tower Raichur thermal power station (RTPS) is located in Raichur Dist, and Karnataka State, India, is considered in the current study as the reference design tower. The analysis of Raichur thermal power plant carried by ANSYS software. The cooling tower shell is made up of two hyperbola, one from the throat level to the top of the tower and the from the general equation of the hyperbola used in 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.

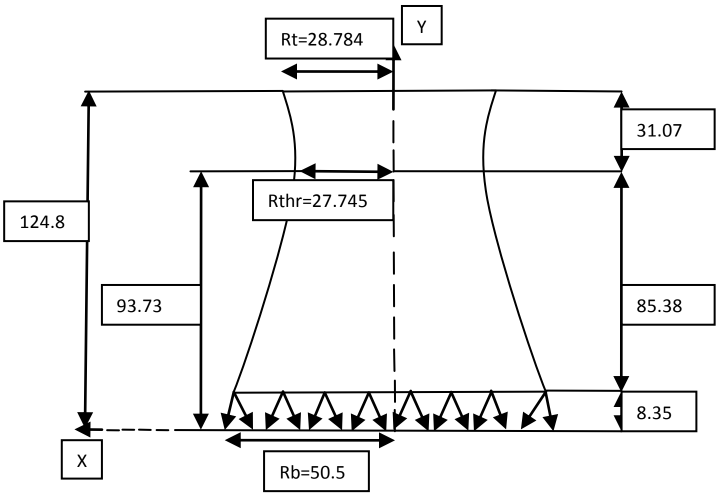

Fig 1: Geometry of RTPS

Table 1: Geometric details of cooling tower (124.8m height)

Sl no	Parameter description	For A and H type of column support
1	Total height H	124.8m
2	Height of throat H_{thr}	93.73m
3	Diameter at top D_t	57.568m
4	Diameter at throat D_{thr}	55.49m
5	Diameter at bottom D_b	101m
6	Diameter of columns D_{col}	750mm
7	Thickness at throat, T_{thr}	175mm

4. FORCES CONSIDERED FOR ANALYSIS

4.1 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 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

4.2 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 k_1 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: $P_z = 0.6\ V_z^2$ N/mm2

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

Grade of concrete fck = M30
Young's modulus of concrete (E)=31Mpa
Poisson's ratio= 0.15
Density of RCC: 25 KN/m3

5.3 Geometric model :

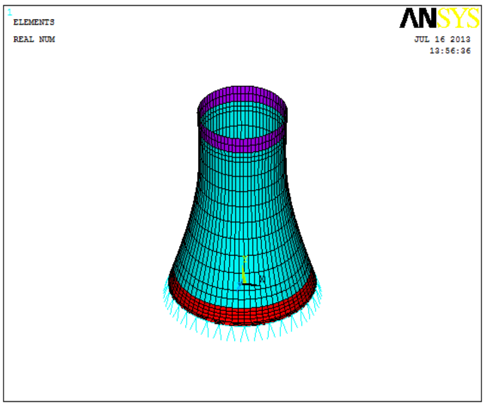

Fig 2: Cooling tower with A-frame column support support

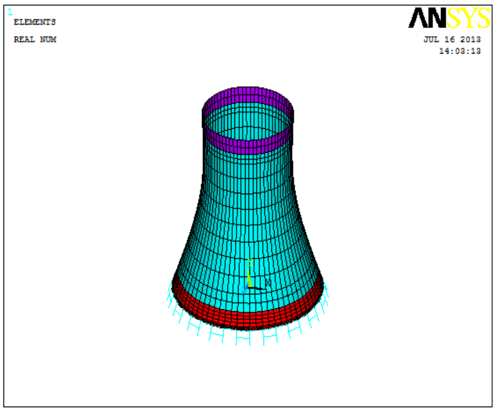

Fig 3: Cooling tower with H- frame column

5.4 Static analysis

The static analysis will be carried for self weight and 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 & boundary conditions to the model and selecting Static analysis and solve the problem in solution & read the results in General post processor.

Figures for A column support

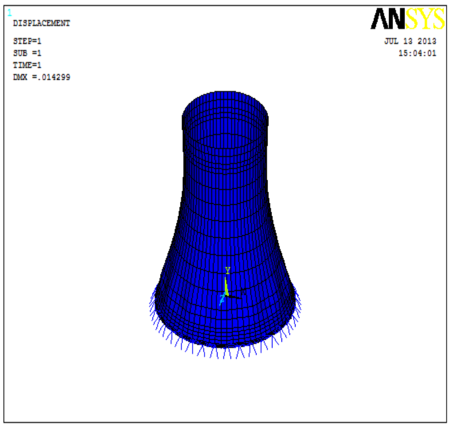

Fig 4 : Deflection for A frame column support

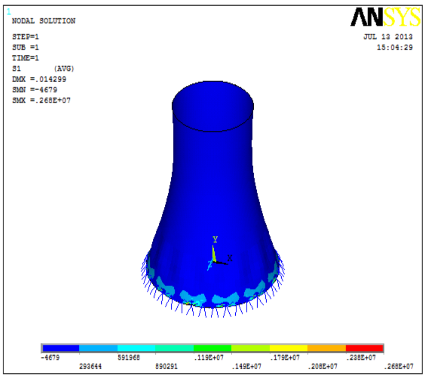

Fig 5: Principal stress for A frame column support

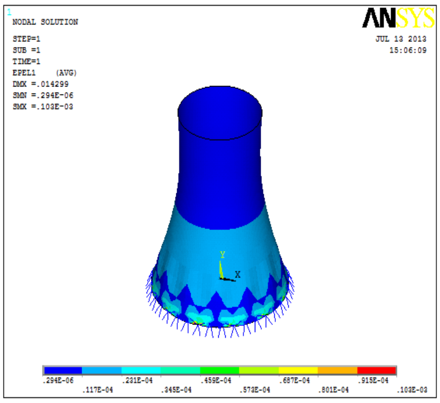
Fig 6: Principal strain for A column support

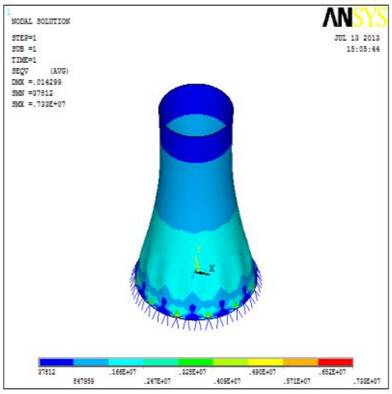
Fig 7: von mises stress for A column support

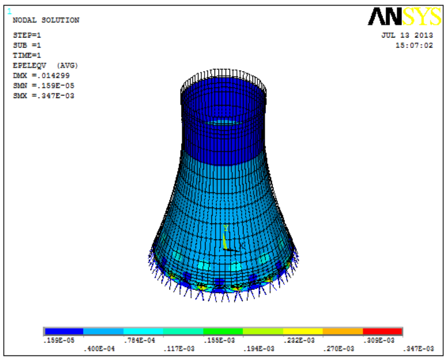

Fig 8: Vonmises strain for A-column support

Figures for H column support

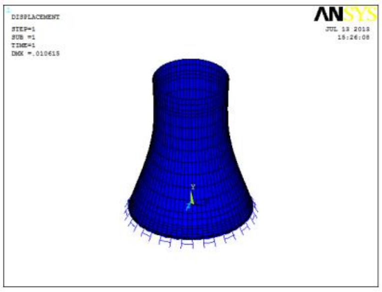
Fig 9: Deflection for H frame column support

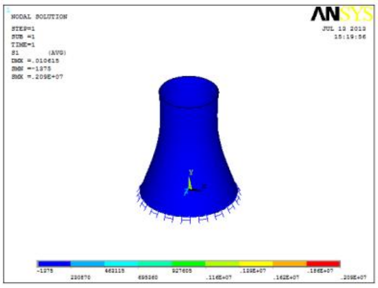
Fig 10: Principal stress for H frame column support support

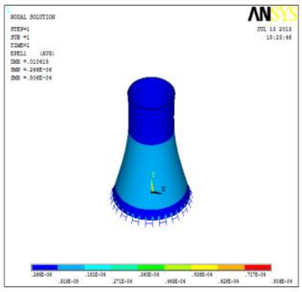
Fig 11: Principal strain for H frame column

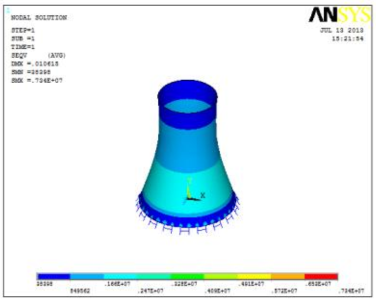
Fig 12: Von mises stress H frame column support

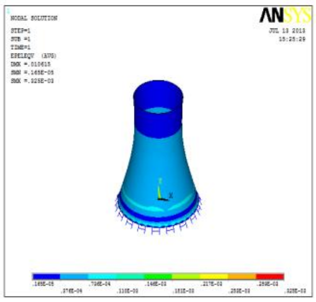
Fig 13: Vonmises strain H frame column support

Table 2: Static analysis results

	A-frame column support	H-frame column support
Max deflection in m	0.0142	0.0106
Max principal stress N/m^2	$0.268x10^7$	$0.209x10^7$
Max principal strain	$0.103x10^{-3}$	$0.806x10\text{-}^4$
Max von mises stress N/m^2	$0.733x10^7$	$0.734x10^7$
Max von mises strain	$0.347x10^{-3}$	$0.325x10^{-3}$

5.5 Modal analysis for free Vibration

The modal analysis will be carried out in accordance with IS-1893(par-1) for the hyperbolic cooling towers.This method used to calculate the natural frequencies (f) and mode (ϕ) shapes of a structure.

For first mode at Frequency 1.023

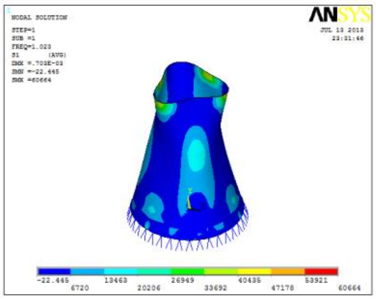

Fig 14: Principal stress for A frame column support

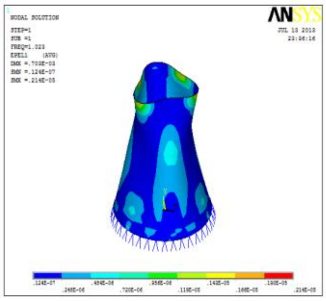

Fig 15: Principal strain for A frame column support

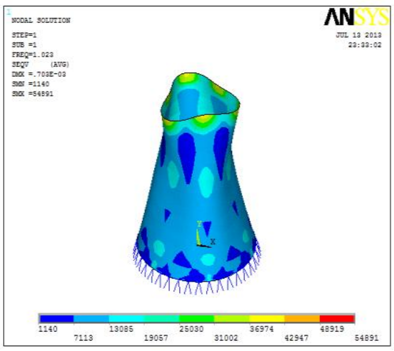

Fig16: Vonmises stress for A frame column support

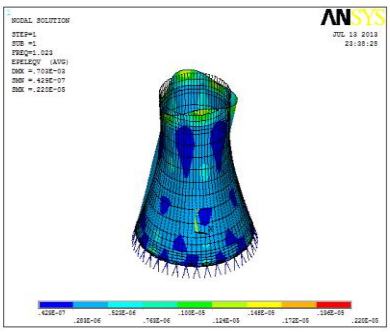

Fig 17 : Vonmises strain for A frame column support

For 1st mode at frequency 0.921

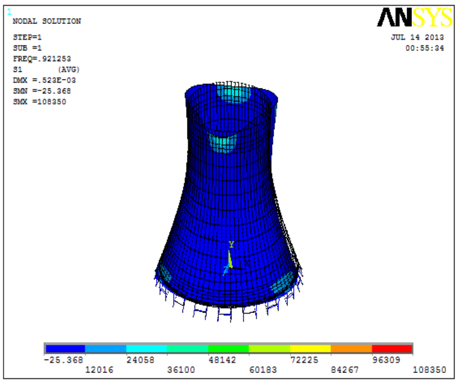

Fig 18: Principal stress for A frame column support

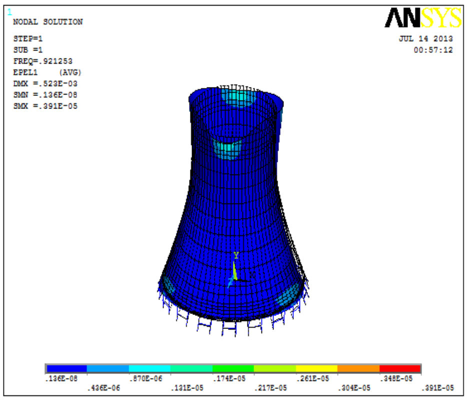

Fig 19: Principal stress for A frame column support

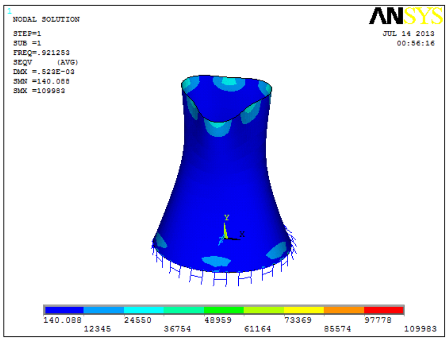

Fig 20: Vonmises stress for H frame column support

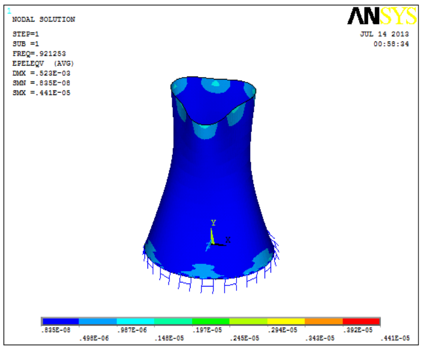

Fig 21 : Vonmises strain for H frame column support

Table 3: Modal analysis results

	A-frame column support	H-frame column support
Max deflection in m	0.703×10^{-3}	0.523×10^{-3}
Max principal stress N/m^2	60664	108350
Max principal strain	0.214×10^{-5}	0.391×10^{-5}
Max von mises stress N/m^2	54891	109983
Max von mises strain	0.220×10^{-5}	0.491×10^{-5}

5.6 Earthquake analysis

The seismic analysis will be carried out in accordance with IS-1893 by modal analysis for the hyperbolic cooling towers. The earthquake analysis of the shell and its support columns including the foundations 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. All the analysis will be carried out as per the theory of elasticity. The design horizontal seismic coefficient Ah for 0.1g, 0.2g & 0.3g of a structure shall be determined.

Response Spectra Analysis for 0.1g

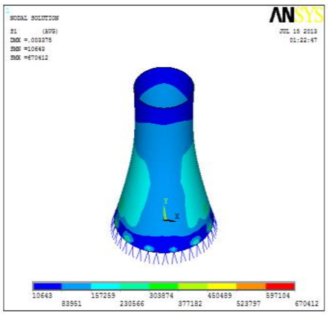

Fig 22: Principal stress for A frame column support

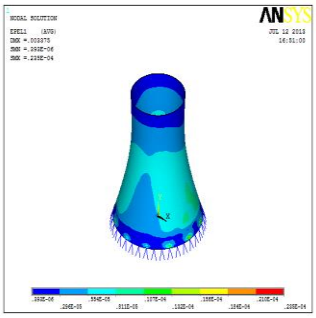

Fig 23: Principal strain for A frame column support

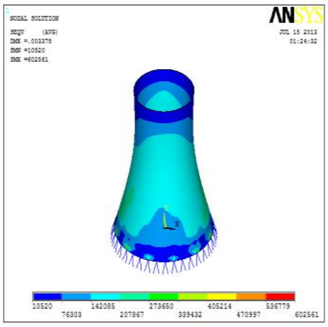

Fig 24: Vonmises stress for A frame column support

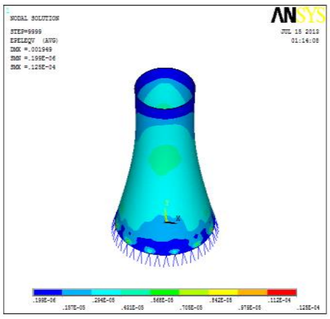

Fig 25: Vonmises stress for A frame column support

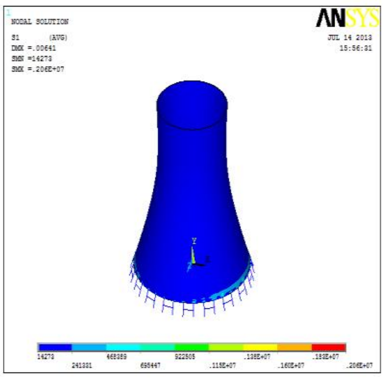

Fig 26: Principal stress for H frame column support

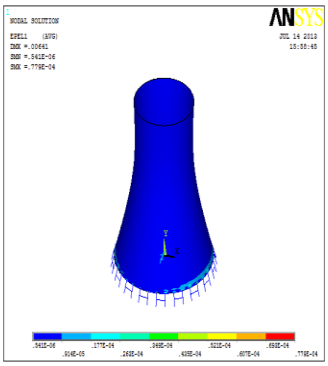

Fig 27: Principal Strain for H frame column support

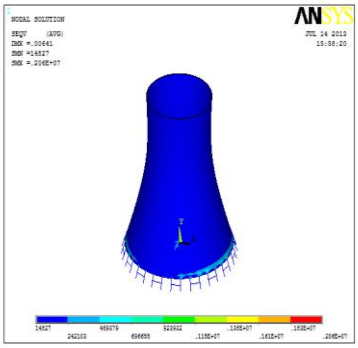

Fig 28: Vonmises stress for H frame column support

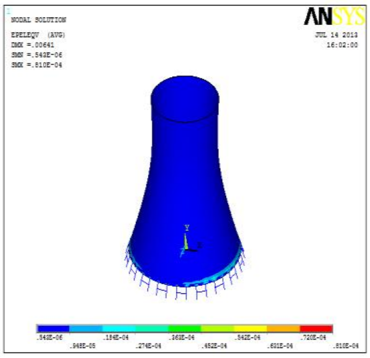

Fig 29: Vonmises strain for H frame column support

Table 4: For response spectra: 0.1g

Series	Deflection in m	Principal stress N/m^2	Principal strain	Von mises stress in N/m^2	Von mises strain
A-frame column support	0.0034	6702412	0.235×10^{-4}	602561	0.125×10^{-4}
H-frame column support	0.00641	0.206×10^{7}	0.779×10^{-4}	0.20×10^{7}	0.810×10^{-4}

Table 5: For response spectra 0.2g

Series	Deflection in m	Principal stress N/m^2	Principal strain	Von mises stress in N/m^2	Von mises strain
A-frame column support	0.0067	0.118×10^{7}	0.41×10^{-4}	0.106×10^{7}	0.393×10^{-4}
H-frame column support	0.0129	0.414×10^{7}	0.157×10^{-3}	0.415×10^{7}	0.163×10^{-3}

Table 6: For response spectra 0.3g

Series	Deflection in m	Principal stress N/m^2	Principal strain	Von mises stress in N/m^2	Von mises strain
A-frame column support	0.01	0.201×10^{7}	0.706×10^{-4}	0.181×10^{7}	0.671×10^{-4}
H-frame column support	0.056	15713	0.579×10^{-6}	16320	0.613×10^{-6}

6. WIND ANALYSIS

Wind pressure on the towers will be assessed on theoretical basis as given in IS-875(part-3)-1987. The complete cooling tower will be designed for all possible wind directions and on the basis of worst load conditions as obtained from theoretical methods.

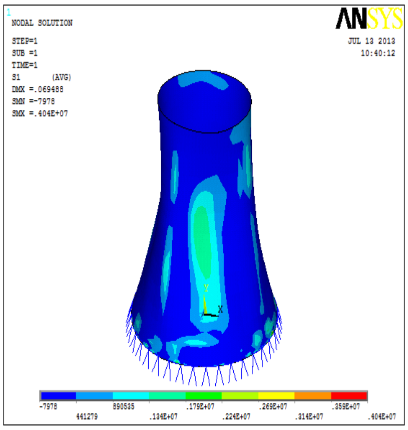

Fig 30: Principal stress for A frame column support.

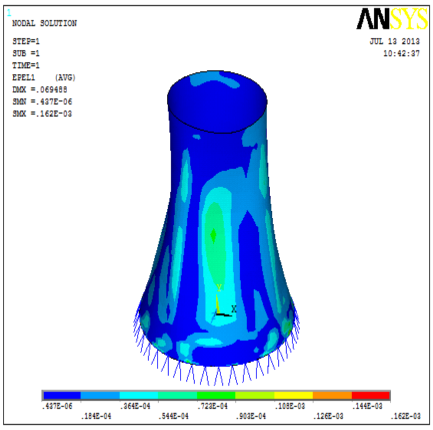

Fig 31: Principal strain for A frame column support

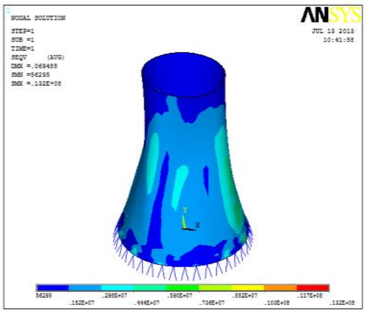

Fig 32 :Vonmises stress for A frame column support

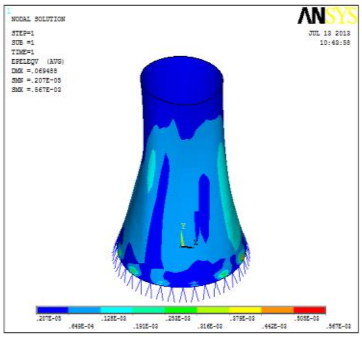

Fig 33: Vonmises strain for A frame column support

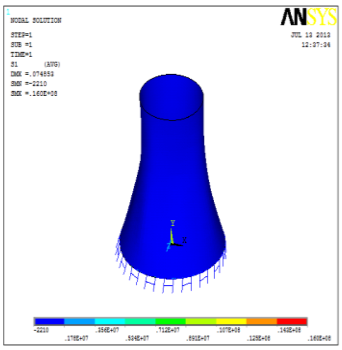

Fig 34: Principal stress for H frame column support

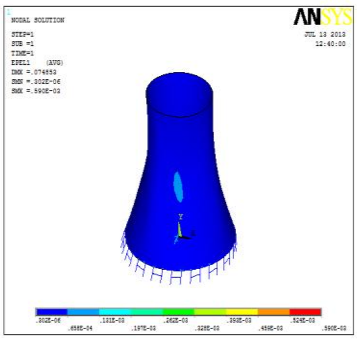

Fig 35: Principal strain for H frame column support

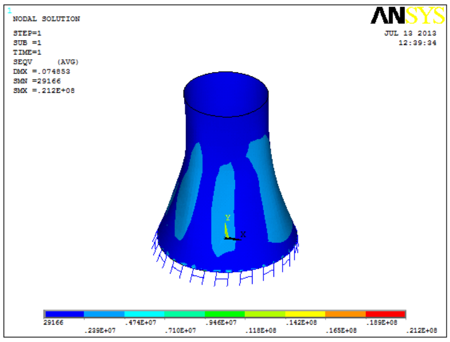

Fig 36: Vonmises stress for H frame column support

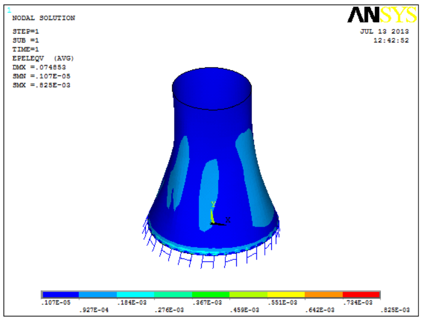

Fig 37: Vonmises strain for H frame column support.

Table 5: Wind analysis results

	A-frame column support	H-frame column support
Max deflection in m	0.0694	0.0748
Max principal stress N/m^2	$0.4041x0^7$	$0.16x10^8$
Max principal strain	$0.162x10^{-3}$	$0.59x10^{-3}$
Max von mises stress N/m^2	0.132x108	$0.212x10^8$
Max von mises strain	$0.567x10^{-3}$	$0.825x10^{-3}$

5. CONCLUSION

This paper presented the numerical analysis of R/C cooling tower with column support under dynamic loading. In numerical analyses, two types of the supporting column systems are adopted and the dynamic response of R/C cooling tower is examined.

1. The principal stresses due to static load (self weight) are greater for A frame support compare to H frame column support.

2.The maximum deflection due to static load (only for self weight) is greater for A frame column support than H frame column support.

3.In the free vibration analysis it has been observed that the principal stress for the first mode is greater for H frame column support than A frame column support.

4.The principal stresses due to wind load analysis for H column support are greater than A column support.

5. The maximum deflection due to wind load is greater for H frame support column compare to A frame column support.
6. The maximum principal stress due to seismic load is greater for A frame column support compare to H frame column support.

7. The maximum deflection due to seismic load is greater for H frame column support compare to A frame column support.

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