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Comparative Study Of The Effect Of Seismic And Wind Loads On Cooling Tower With A-Frame And H-Frame Column Supports

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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 a thermal power plant is considered. For other models of cooling tower, H frame column support varied with respect to the reference tower. 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.

Key words*: Cooling Tower, FEA, Seismic and wind loads, A and H-frame Support.*

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, an existing cooling tower from one of the power station is considered in the current study as the reference design tower. The analysis of reference tower is carried out by ANSYS software. The cooling tower shell is made up of two hyperbolas, one from the throat level to the top of the tower and the other 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.

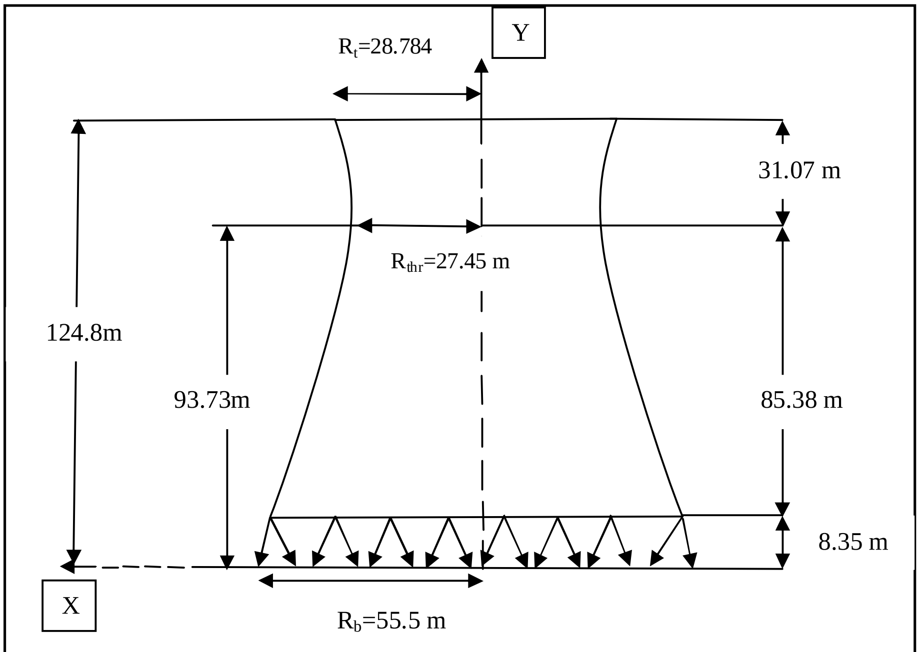


Fig.1: Geometry of the Reference Tower

Figure 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	124.800m
2	Height of throat H_{thr}	93.730m
3	Diameter at top D_t	57.568m
4	Diameter at throat D_{thr}	55.490m
5	Diameter at bottom D_b	101.000m
6	Diameter of columns D_{col}	750 mm
7	Thickness at throat, T_{thr}	175 mm

Table 1

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/mm^2

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:

- The basic wind speed “V_z” at 10 meters above the mean ground level: 39.0 m/sec
- Category of Terrain: Category-2 Class-c
- The risk coefficient factor :1.06

5.2.Material Property

Grade of concrete f_{ck} = M30
Young’s modulus of concrete (E) =31Mpa
Poisson’s ratio= 0.15
Density of RCC: 25 KN/m^3

5.3.Geometric Model

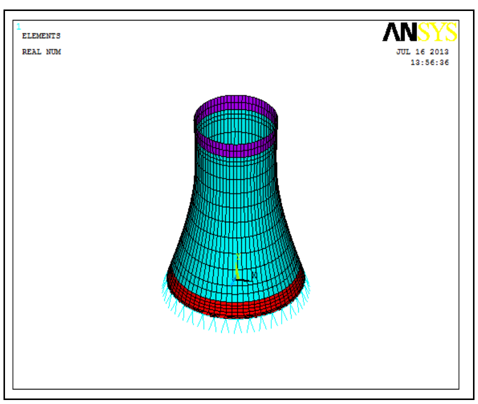


Figure 2: Cooling Tower With A-Frame Column Support

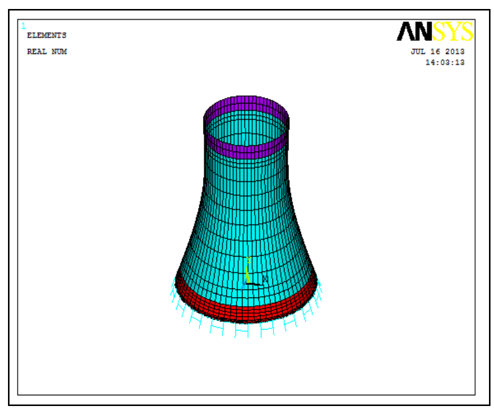


Figure 3: Cooling Tower With H- Frame Column Support

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.

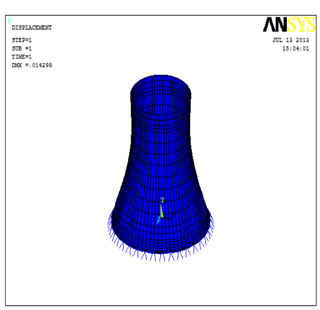


Figure 4 : Deflection For A Frame Column Support

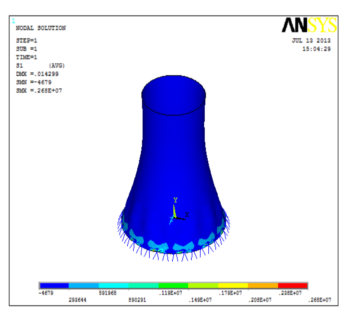
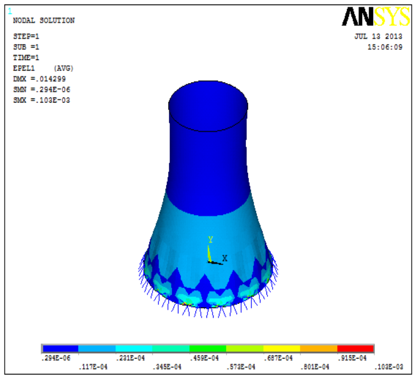


Figure 5: Principal Stress For A Frame Column Support



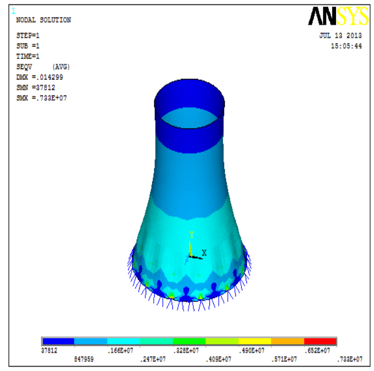


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Figure 6: Principal Strain For A Column Support

Figure 7: Von Mises Stress For A Column Support

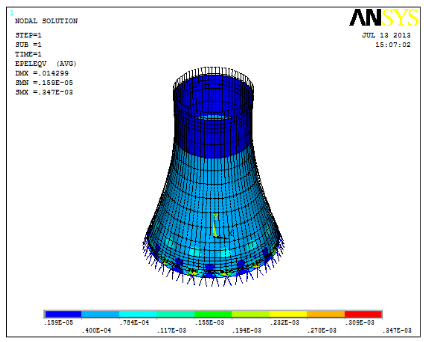
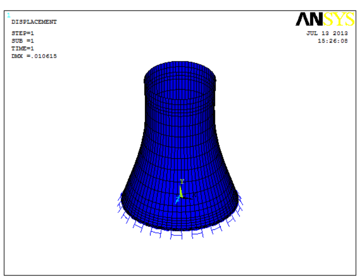
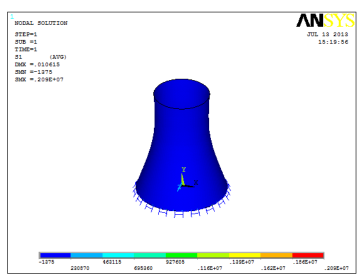


Figure 8: Von Mises Strain For A-Column Support





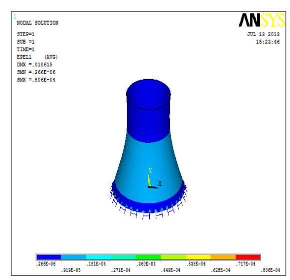
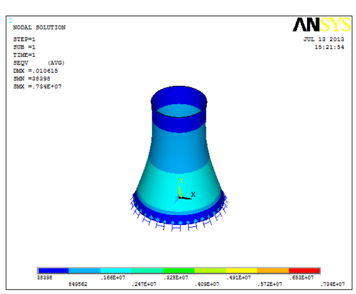


Figure 9: Deflection For H Frame Column Support

Figure 10: Principal Stress For For H Frame Column Support

Figure 11: Principal Strain H Frame Column



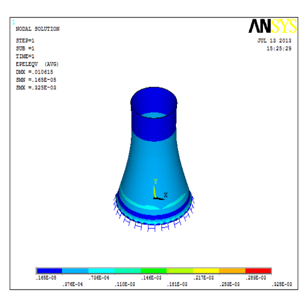


Figure 12: Von Mises Stress H Frame Column Support

Figure 13: Von Mises Strain H Frame Column Support

	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-^{4}
Max Von Mises stress N/m^2	0.733x10^7	0.734x10^7
Max Von Mises strain	0.347x10^{-3}	0.325x10^{-3}

Table 2: Static Analysis Results

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

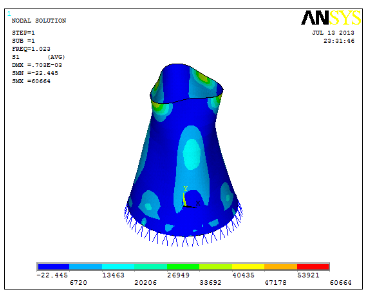


Figure 14: Principal Stress For A Frame Column Support

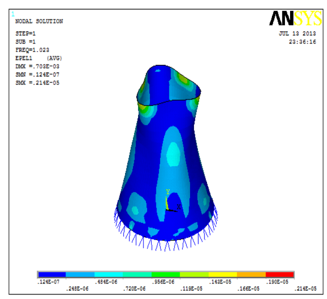


Figure 15: Principal Strain For A Frame Column Support

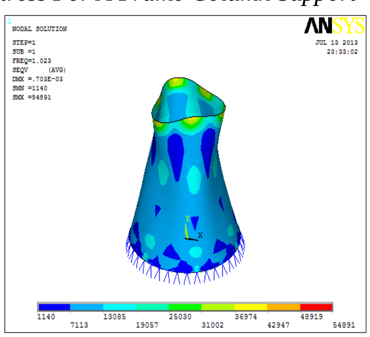


Figure16: Von Mises Stress For A Frame Column Support

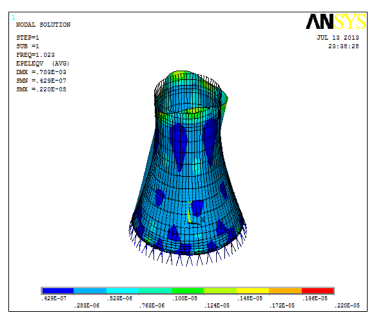
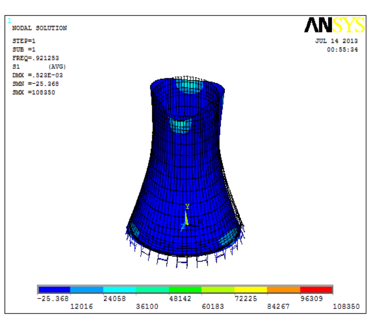


Figure 17 : Von Mises Strain For A Frame Column Support

For 1st mode at frequency 0.921



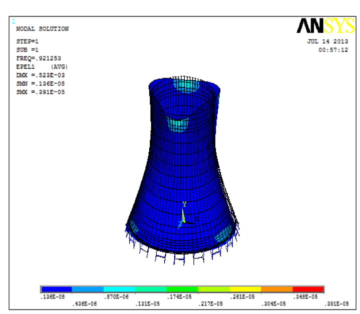
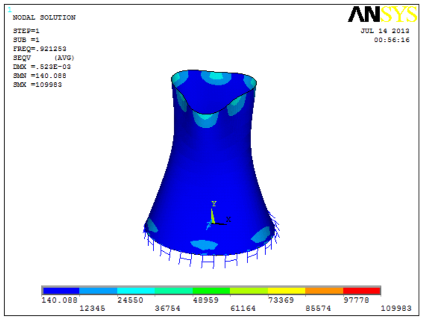


Figure 18: Principal Stress For A Frame Column Support

Figure 19: Principal Stress For A Frame Column Support



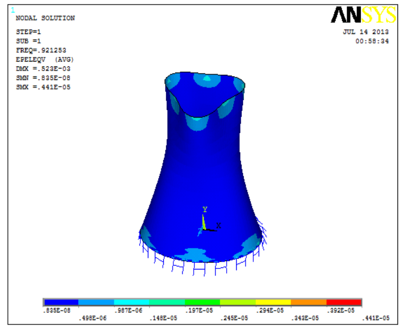


Figure 20: Von Mises Stress For H Frame Column Support

Figure 21 : Von Mises Strain For H Frame Column Support

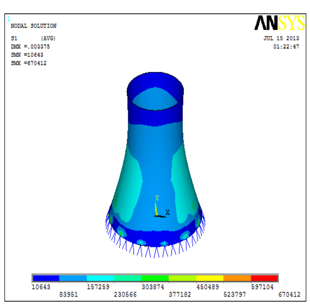
	A-frame column support	H-frame column support
Max deflection in m	0.703×10^{-3}	0.523×10^{-3}
Max principal stress N/m^2	60664	108350
Max principal strain	0.214×10^{-5}	0.391×10^{-5}
Max Von Mises stress N/m^2	54891	109983
Max Von Mises strain	0.220×10^{-5}	0.491×10^{-5}

Table 3: Modal Analysis Results

5.6.Earthquake Analysis

The seismic analysis is 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 is carried out by response spectrum method. Earthquake analysis for the fill supporting structures (RCC frames) is carried out by response spectrum method. All the analysis is carried out as per the theory of elasticity. The design horizontal seismic coefficient A_h for 0.1g, 0.2g & 0.3g of a structure is determined.

Response Spectra Analysis for 0.1g



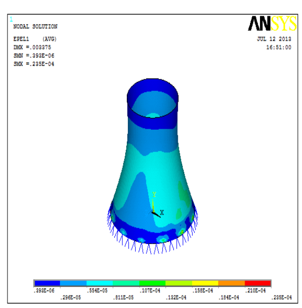


Figure 22: Principal Stress For A Frame Column Support

Figure 23: Principal Strain For A Frame Column Support

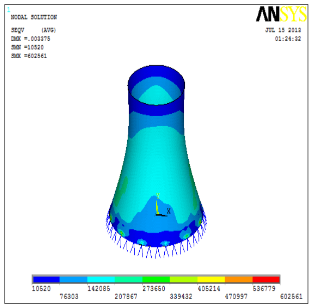


Figure 24: Von Mises Stress For A Frame Column Support

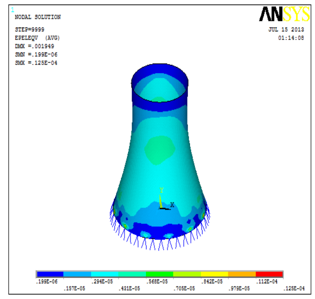


Figure 25: Von Mises Stress For A Frame Column Support

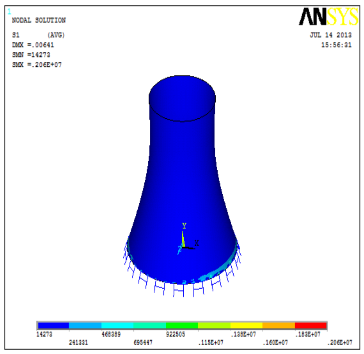


Figure 26: Principal Stress For H Frame Column Support

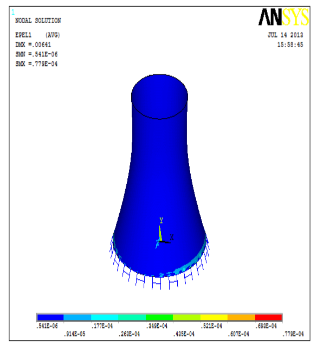


Figure 27: Principal Strain For H Frame Column Support

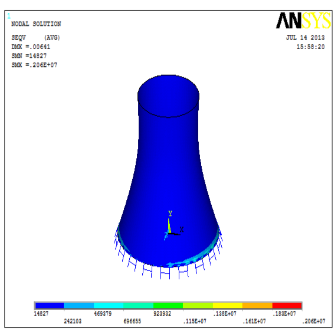


Figure 28: Von Mises Stress For H Frame Column Support

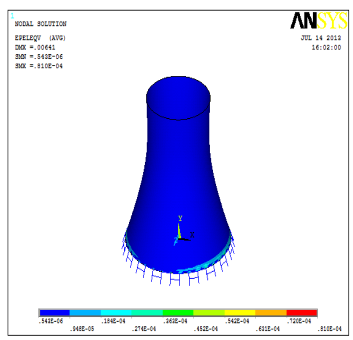


Figure 29: Von Mises Strain For H Frame Column Support

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	0.235x10^{-4}	602561	0.125x10^{-4}
H-frame column support	0.00641	0.206x10^{7}	0.779x10^{-4}	0.20x10^{7}	0.810x10^{-4}

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	0.0067	0.118x10^7	0.41x10^{-4}	0.106x10^7	0.393x10^{-4}
H-frame column support	0.0129	0.414x10^7	0.157x10^{-3}	0.415x10^7	0.163x10^{-3}

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	0.01	0.201x10^7	0.706x10^{-4}	0.181x10^7	0.671x10^{-4}
H-frame column support	0.056	15713	0.579x10^{-6}	16320	0.613x10^{-6}

Table 6: For Response Spectra 0.3g

6.Wind Analysis

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

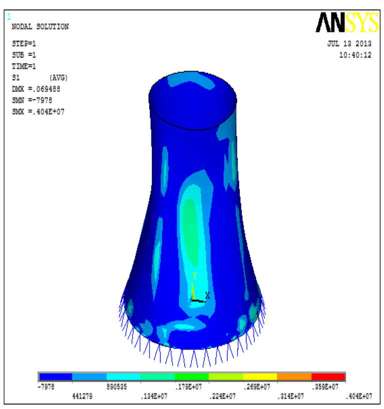


Figure 30: Principal Stress For A Frame Column Support.

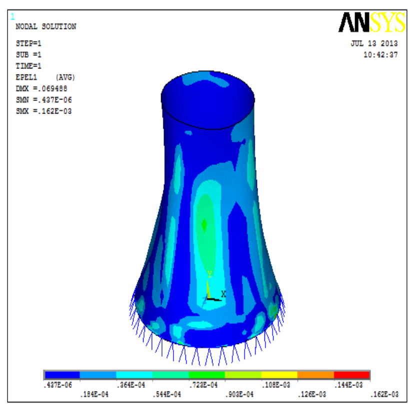


Figure31: Principal Strain For A Frame Column Support

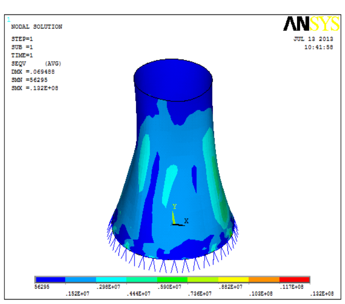


Figure 32 :Von Mises Stress For A Frame Column Support

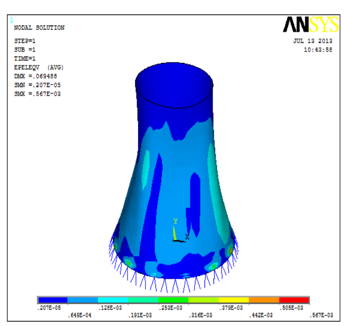


Figure 33: Von Mises Strain For A Frame Column Support

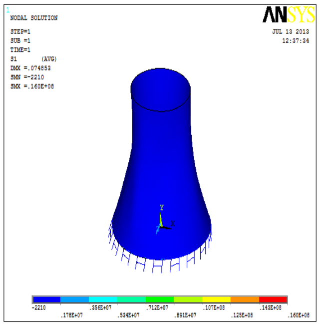


Figure 34: Principal Stress For H Frame Column Support

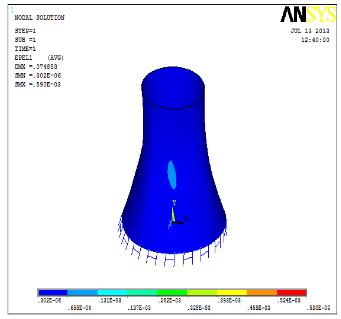


Figure 35: Principal Strain For H Frame Column Support

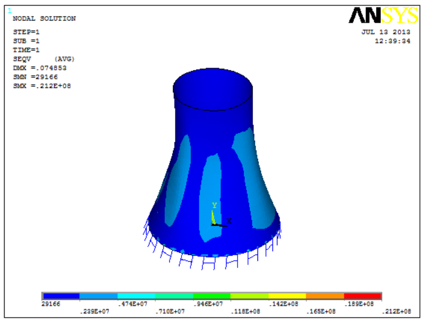


Figure 36: Von Mises Stress For H Frame Column Support

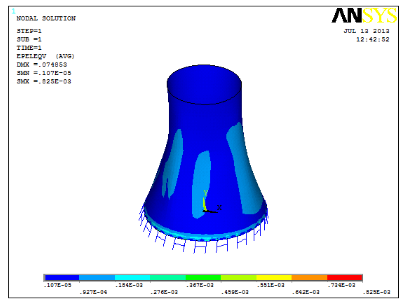


Figure 37: Von Mises Strain For H Frame Column Support

	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}

Table 5: Wind Analysis Results

7.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.

- The principal stresses due to static load (self weight) are greater for A-frame support compared to H-frame column support.
- The maximum deflection due to static load (only for self weight) is greater for A-frame column support than H-frame column support.
- 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.
- The principal stresses due to wind load analysis for H- frame column support are greater than A-frame column support.
- The maximum deflection due to wind load is greater for H-frame support column compared to A-frame column support.
- The maximum principal stress due to seismic load is greater for A-frame column support compared to H-frame column support.
- The maximum deflection due to seismic load is greater for H-frame column support compare to A-frame column support.

8.References

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