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A Study of Shape Effect of Natural Draught Cooling Tower by using Ansys.16.5

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Abstract: ***In thermal power stations cooling Cooling Tower plays vital role. Along with stresses due to wind load, Seismic load, thermal stresses are predominant in tower. Using ANSYS we can check its thermal response which will be function of time. Natural Draught hyperbolic cooling towers are characterizing land marks of power stations. They comprise of a thin concrete shell of revolution are common place in civil engineering infrastructure. The wind load is always the dominant load in the design of the cooling tower due to its large size, complex geometry and thin wall. This paper deals with the study of thermal analysis of two existing cooling towers of 143.50m and 172m high above ground level with varying thickness in accordance with IS 11504. These cooling towers have been analyzed for thermal loads using ANSYS software by assuming fixity at the shell base. The analysis of two existing cooling towers has been carried out using 8 noded SHELL 181 element with uniform SHELL thicknesses.***

Keywords: NDCT, Wind Analysis, IS 11504, Finite Element Modelling, ANSYS

I. INTRODUCTION

1.1 General

A cooling tower is a heat rejection device which rejects waste heat to the atmosphere through the cooling of a water stream to a lower temperature. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or, in the case of closed circuit dry cooling towers, rely solely on air to cool the working fluid to near the dry-bulb air temperature. Common applications include cooling the circulating water used in oil refineries, petrochemical and other chemical plants, thermal power stations and HVAC systems for cooling buildings. The classification is based on the type of air induction into the tower. The main types of cooling towers are natural draft and induced draft cooling towers. Cooling towers vary in size from small roof-top units to very large hyperboloid structures (as in the adjacent image) that can be up to 200 meters (660 ft) tall and 100 meters (330 ft) in diameter, or rectangular structures that can be over 40 meters (130 ft) tall and 80 meters (260 ft) long. The hyperboloid cooling towers are often associated with nuclear power plants, [1] although they are also used to some extent in some large chemical and other industrial plants.

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Although these large towers are very prominent, the vast majority of cooling towers are much smaller, including many units installed on or near buildings to discharge heat from air conditioning.

Fig.1.1

1.2 Code Provision Is 11504 (ClauseNo.6.1pg.no.7)

- The base diameter, air intake, opening height, tower height and throat diameter arc basically determined by thermal design considerations. As the range of possible hyperbolic shell shapes is infinite it is recommended that the designs be confined to the following major proportions which have been extensively adopted in cooling tower constructions. Other proportions shall be carefully studied before adoption:

$$H/D = 1{\cdot}20 \text{ to } 1{\cdot}55$$
$$H_b/H = 0{\cdot}75 \text{ to } 0{\cdot}85$$

- The minimum thickness of the shell shall not be less than 140 mm for towers of height 75 m and above; for towers less than 75 m height the minimum thickness shall not be less than 100 mm.

II. OBJECTIVE OF STUDY

- To Study the linear static analysis of existing cooling towers and intermediate cooling towers or maximum principal stress with varying the height and thickness.
- To Study the comparison between two existing cooling towers (143.5m & 175.5m Height) of Bellary Power plant for modal analysis and static structural
- To find optimum (best suited) cooling tower among these two existing cooling towers For different loads, stresses

III. LOADING ON NDCT IN ACCORDANCE WITH IS 11054

The following loads shall be considered:
a) Dead loads;
b) Wind loads;
c) Earthquake forces;
d) Thermal restraint loads;
e) Construction loads; and

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f) Any other loads such as SNOW loads. Foundation settlement etc**.**

3.1.1Dead Load

Dead load shall be assessed carefully in accordance with IS: 1911-1967. It is desirable to minimize the loading upon the shell due to permanent fixtures. Secondary stresses if any due to permanent fixtures on the shell shall be investigated.

3.1.2 Wind Pressure

The basic wind pressure shall, in general. Conform to IS: 875-2007 excepting in places where local conditions warrant special investigations

The wind pressure coefficient distribution on the shell should preferably be derived from wind tunnel tests of a model of the proposed tower shell shape. As this is not normally practicable, the wind pressure distribution suggested in Appendix A may be used for cooling towers more than 12m in height and not more than 100 m in base diameter. It is recommended that for towers of greater height or built at closer spacing's, wind pressure distribution shall be determined by model tests in a wind tunnel offering appropriate aerodynamic similitude. Such models shall include all adjacent topographical features, buildings and other structures which are likely to influence the wind load pattern on the tower significantly,

Earthquake Forces

Earthquake forces shall conform to IS: 1893-2002. It is recommended that for towers with more than 120 m height or more than 100 m base diameter analysis and design of tower shell, shell supporting structure and its foundation shall be carried out on the basis of model analysis.

3.2. Analysis of Shell

Except for moderately sized towers where membrane analysis gives sufficiently satisfactory results, bending analysis should be carried out as per the elastic theory for thin shells either by classical methods or by numerical methods like finite differences or finite elements. It should include the following information at 10° plan angle and not more than 0'05 of the shell height:

a) Meridional and circumferential direct stress resultants and tangential shear stress resultants,

b) Meridional and circumferential bending moments, and

c) Displacements normal to shell mid surface

The structural action on cooling tower is shown in fig.3.1

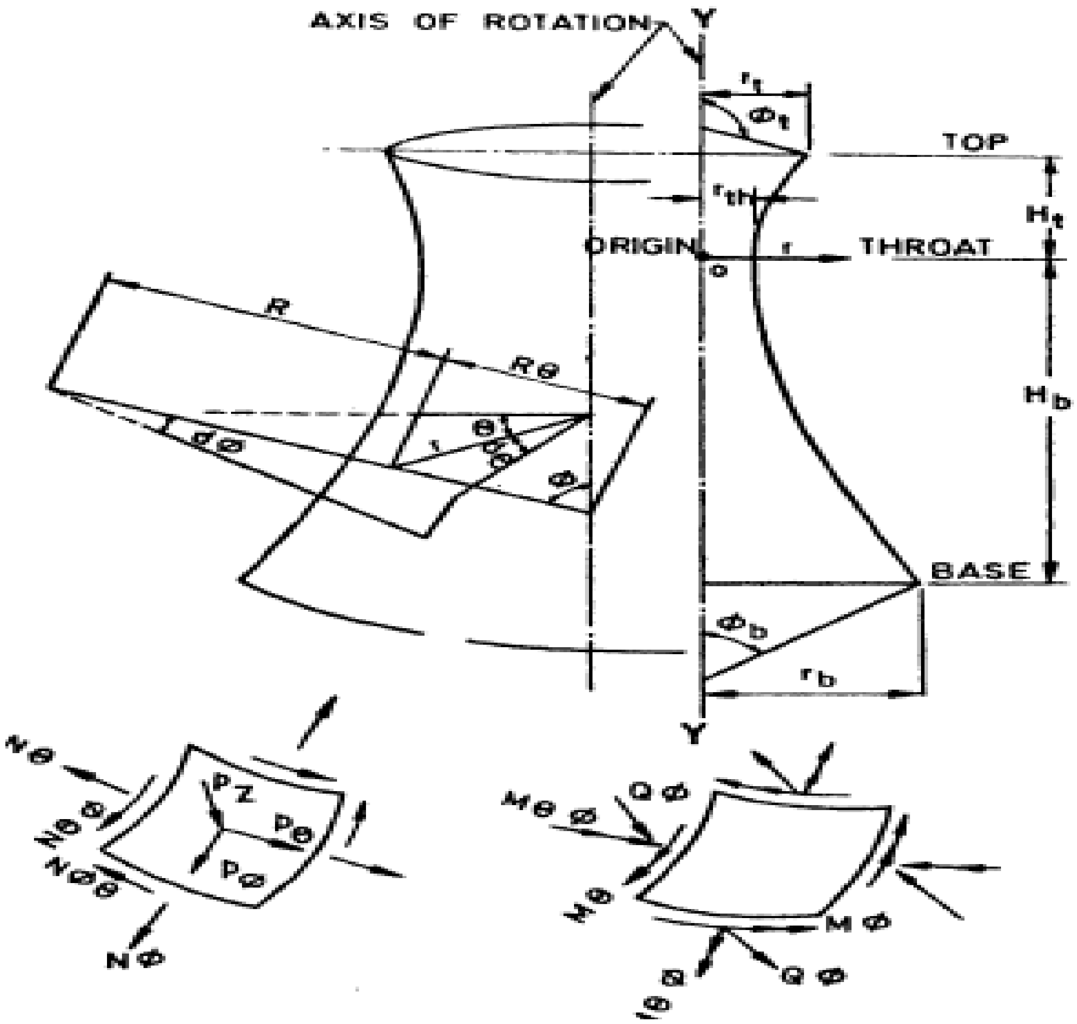

Fig.3.1 Structural action on NDCT

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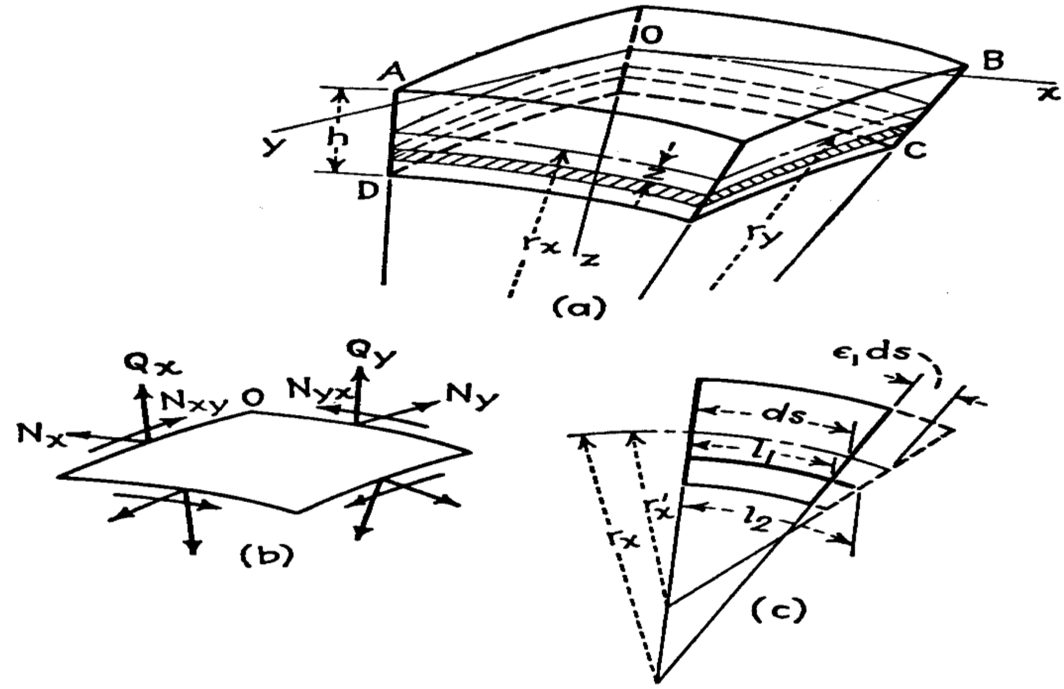

Fig.3.4 Stresses on shell element

IV. NUMERICAL MODELLING IN ANSYS

For modeling of hyperbolic cooling tower surface elements are preferred in that particularly SHELL181, CONTA 174 and TARGE170 is used description of elements are as follows

4.1 SHELL181 Element Description [1]

SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a four-node element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z-axes. (If the membrane option is used, the element has translational degrees of freedom only). The degenerate triangular option should only be used as filler elements in mesh generation. SHELL181 is well-suited for linear, large rotation, and/or large strain nonlinear applications. Change in shell thickness is accounted for in nonlinear analyses. In the element domain, both full and reduced integration schemes are supported. SHELL181 accounts for follower (load stiffness) effects of distributed pressures. SHELL181 may be used for layered applications for modeling composite shells or sandwich construction. The accuracy in modeling composite shells is governed by the first-order shear-deformation theory (usually referred to as Mindlin Reissner shell theory). The element formulation is based on logarithmic strain and true stress measures. The element kinematics allow for finite membrane strains (stretching). However, the curvature changes within a time increment are assumed to be small.

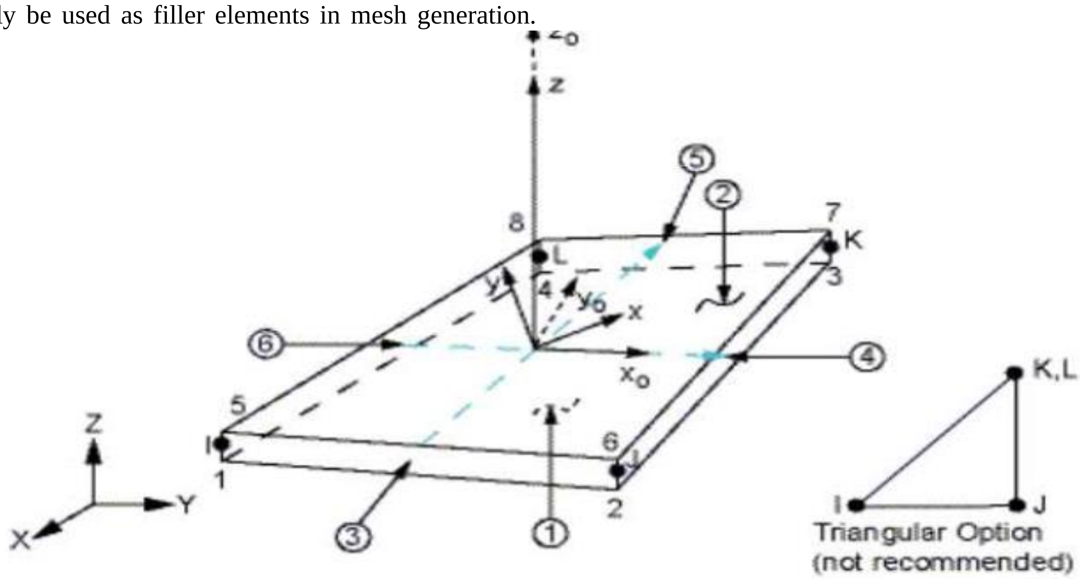

Fig.4.1 SHELL 181

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4.2 CONTA 174 and TARGE170 [1]

The 3-D contact surface elements (CONTA173 and CONTA174) are associated with the 3-D target segment elements (TARGE170) via a shared real constant set. ANSYS looks for contact only between surfaces with the same real constant set. For either rigid-flexible or flexible-flexible contact, one of the deformable surfaces must be represented by a contact surface. If more than one target surface will make contact with the same boundary of solid elements, you must define several contact elements that share the same geometry but relate to separate targets (targets which have different real constant numbers), or you must combine two target surfaces into one (targets that share the same real constant numbers).

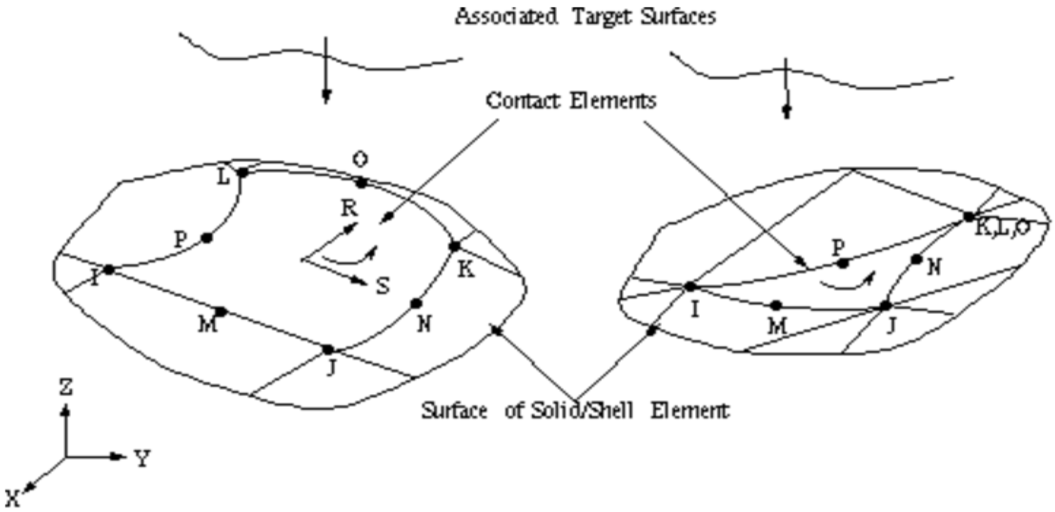
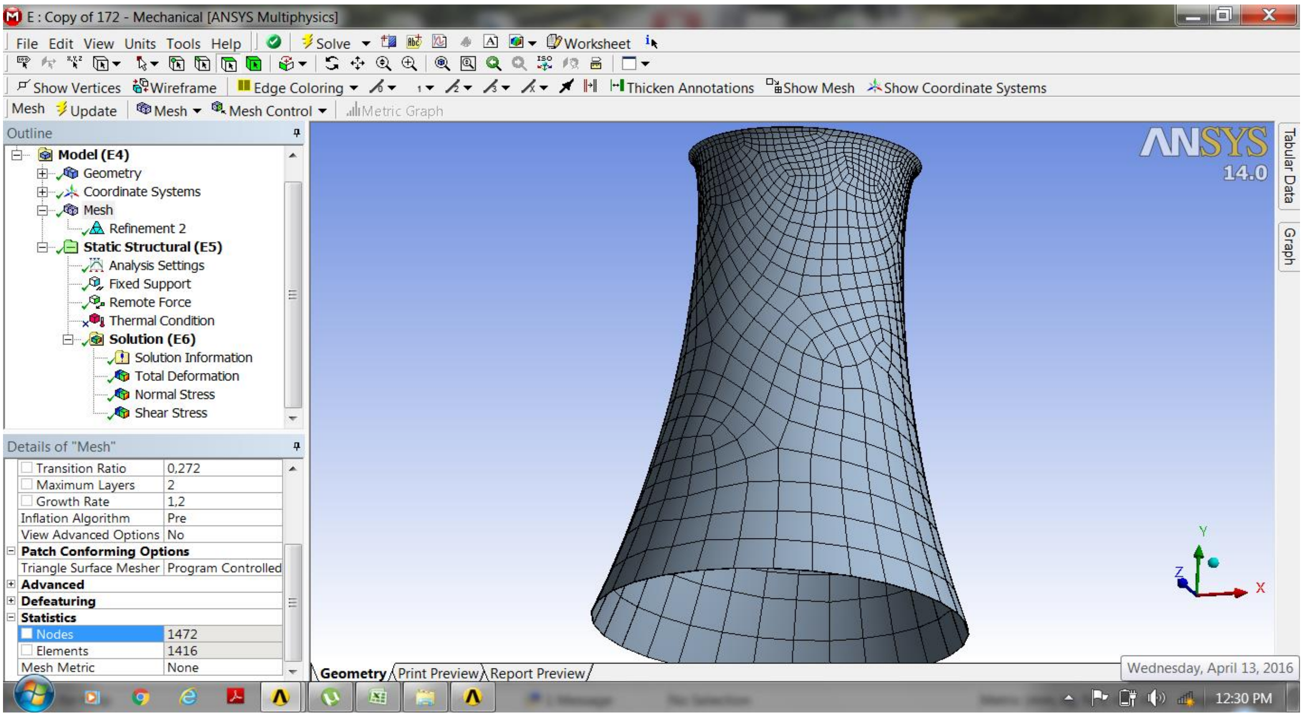


Fig.4.2 CONTA AND TARGET ELEMENT

4.3Finite Element Meshing of Hyperbolic Cooling Tower

In this paper CURVED SHELL element is used for discretization purpose. Each node is assumed to have 4 DOF. Total elements are 1416 and total nodes are 1472



V. PROBLEM STATEMENT

The Total height of the tower CT1 is 143.50 m. 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. Thickness of shell is 0.27m

5.1 Material Properties for Analysis of Cooling Tower (CT)

- Young" s modulus: 31Gpa.
- Poisson" s Ratio: 0.15.
- Density of RCC: 25 kN/m3

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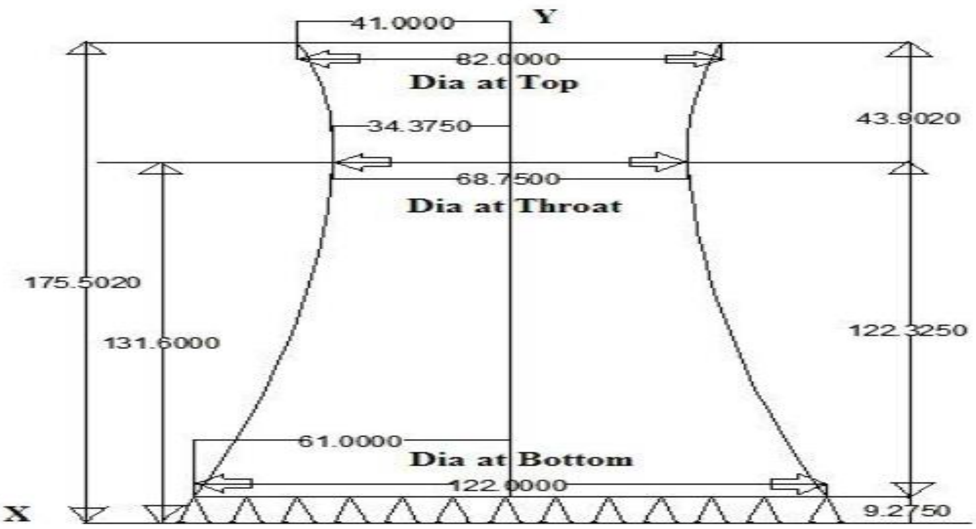

Fig 5.1 Geometry of Existing Cooling Tower (BTPS) (175.50 m)

5.2 Description of Cooling Tower

Table No.5.1

Sl no	Description	Symbols	Cooling tower 1 (CT 1)	Cooling tower 2 (CT 2)
1	Total height	H	143.50m	175.50m
2	Height of throat	Hthr	107.75m	131.60m
3	Diameter at top	Dt	63.6m	82.00m
4	Diameter at bottom	Db	110m	122.00m
5	Diameter at throat level	Dthr	61.0m	68.750m
6	Column Height	Hc	9.20m	9.275m
7	(Hthr/H) ratio		0.750	0.749
8	(Dthr/D) ratio		0.554	0.563

VI. RESULT AND DISCUSSION

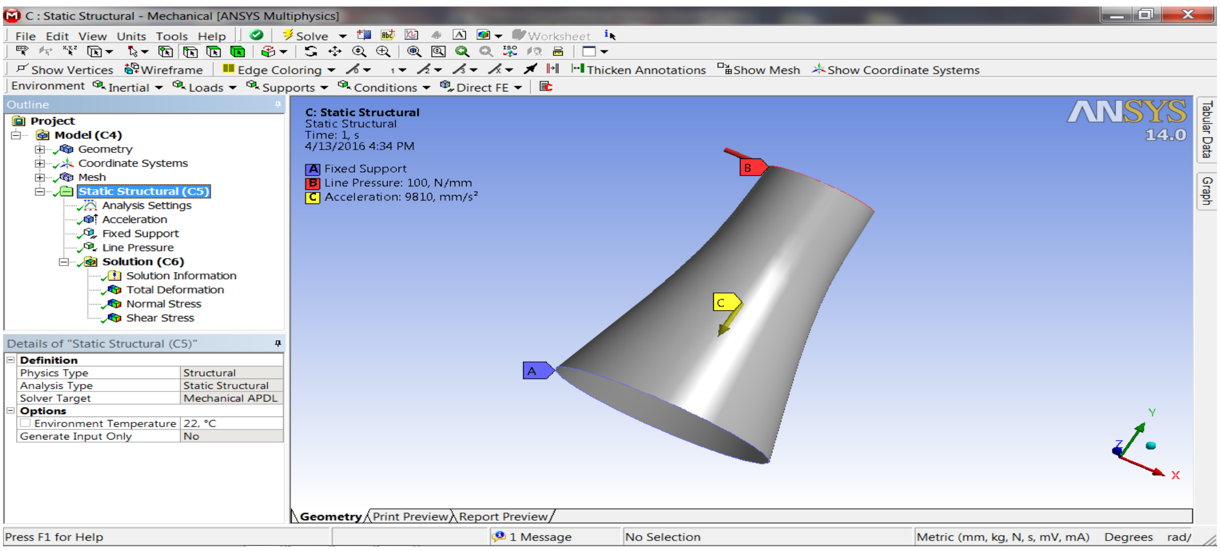

Fig 6.1 Boundary conadition and loading condition

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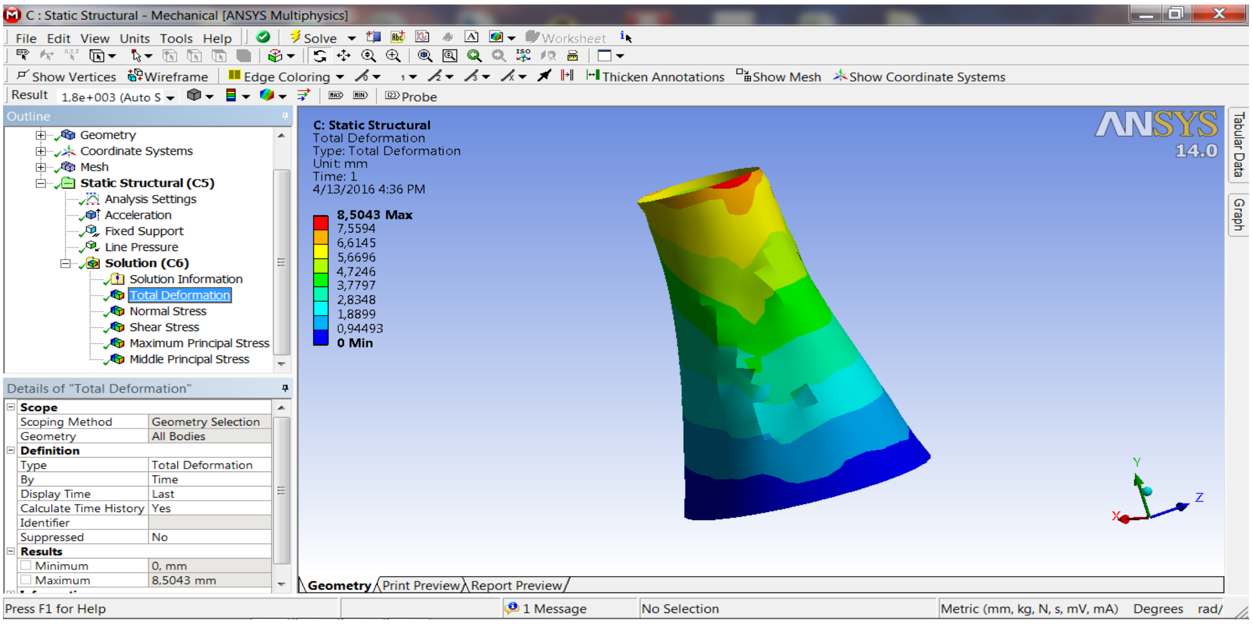

Fig 6.2Maximum Deformation

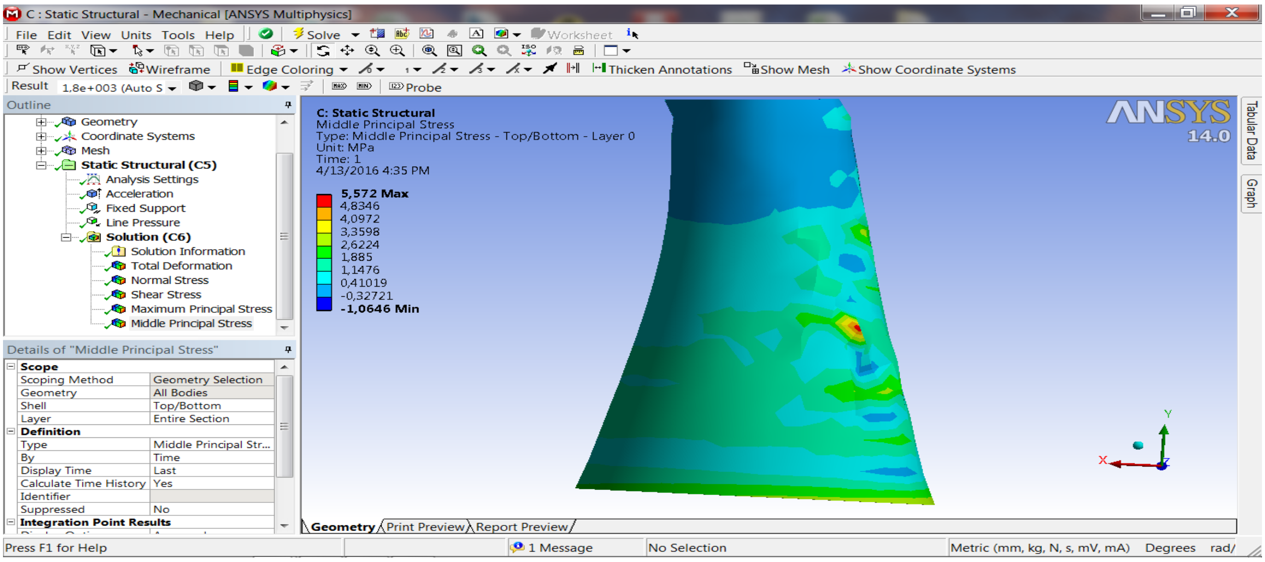

Fig 6.3 Middle Principal Stress

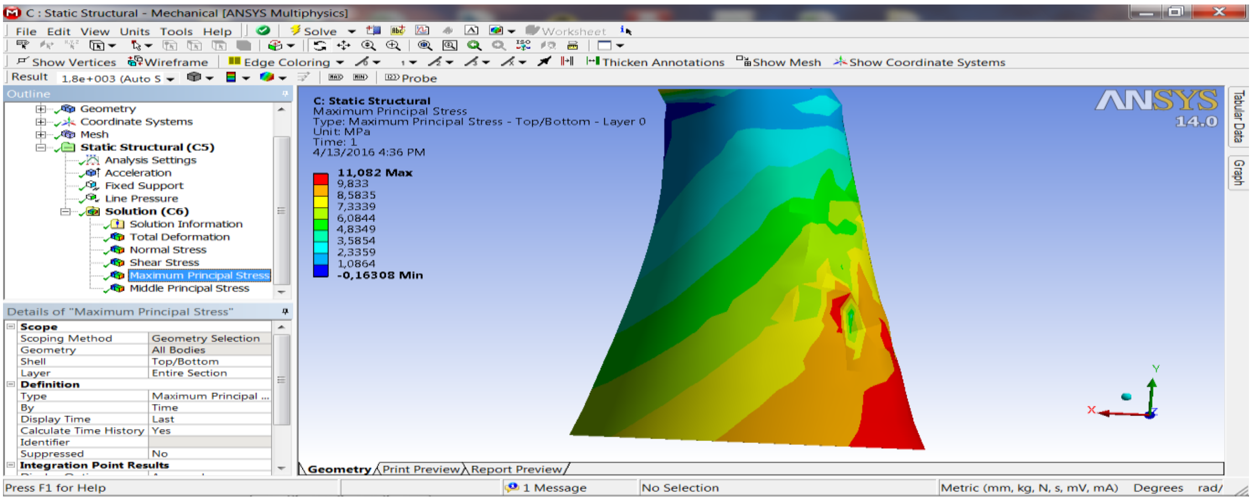

Fig 6.4 Maximum Principal Stress

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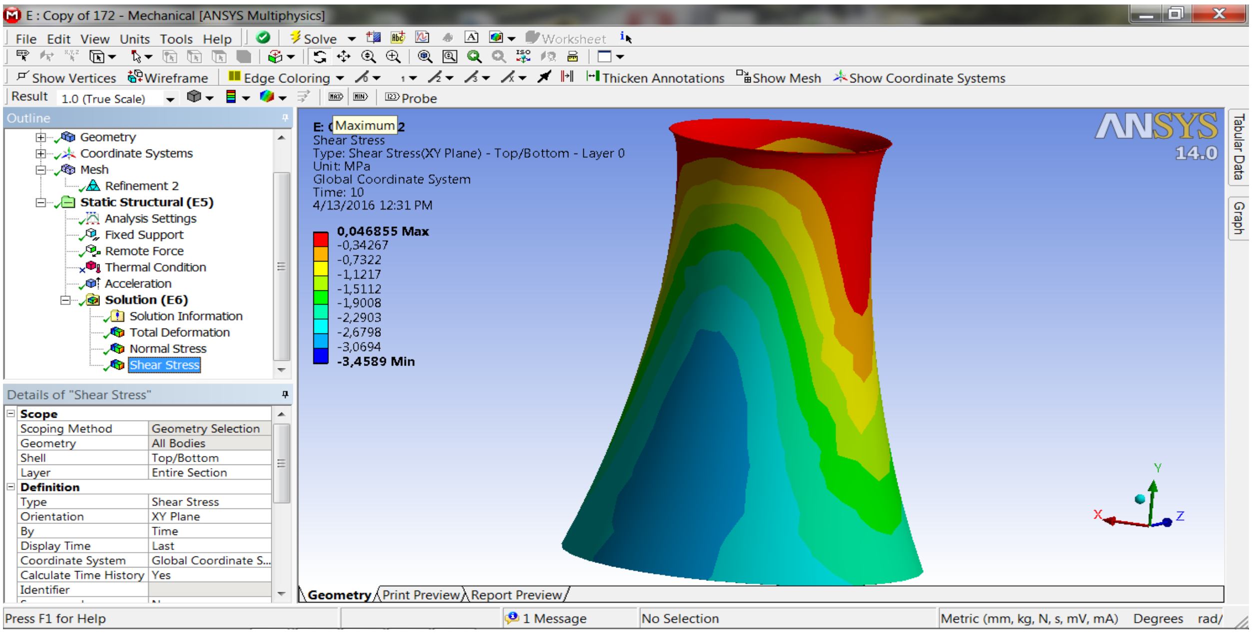

Fig 6.5Shear stress

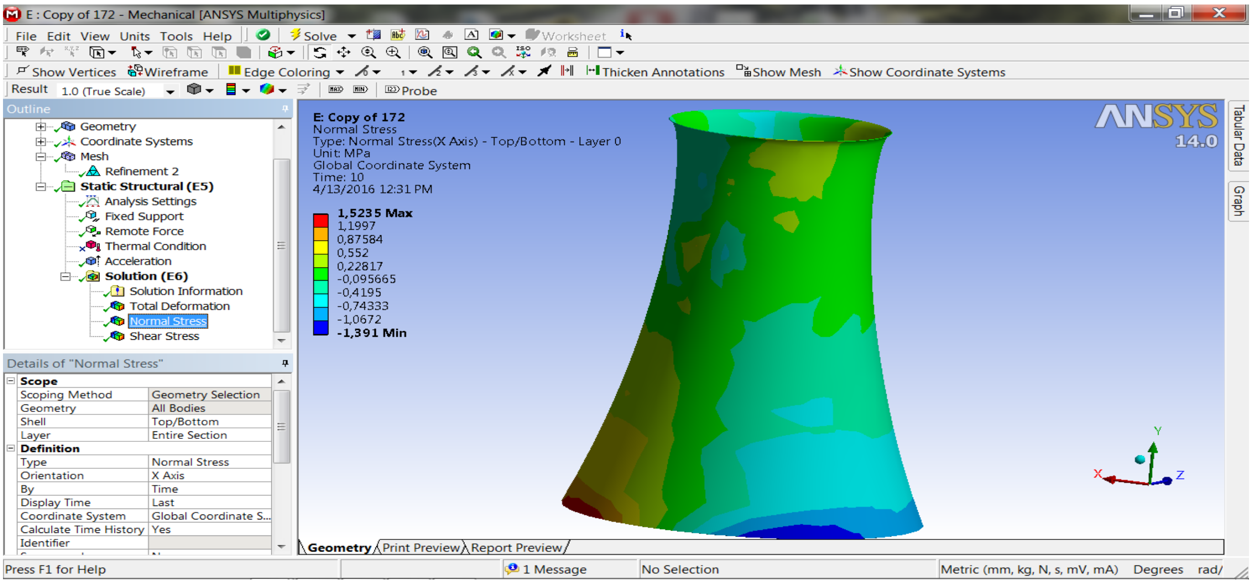

Fig 6.6 Normal Stress

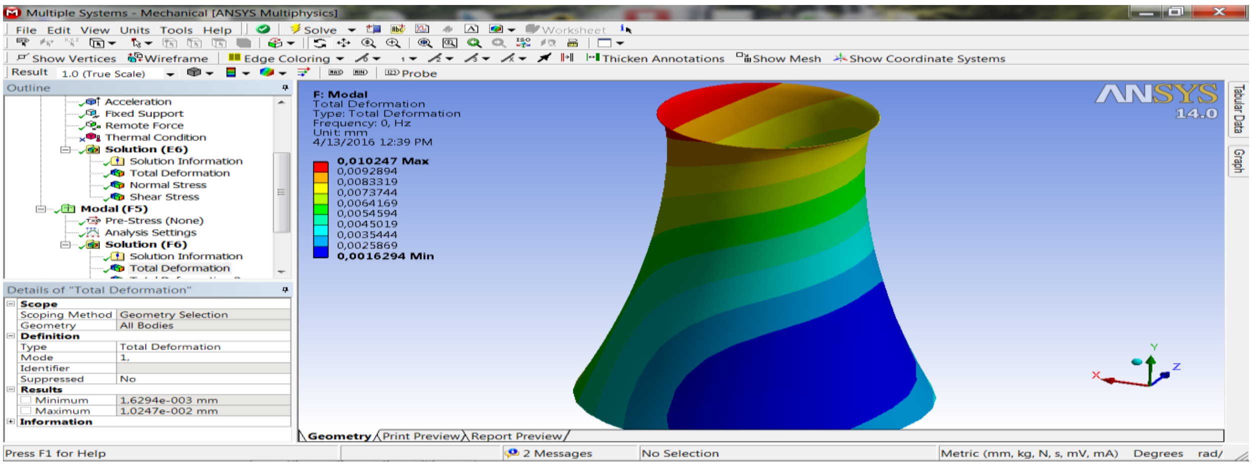

Fig 6.6 Natural Frequency for mode shape 1

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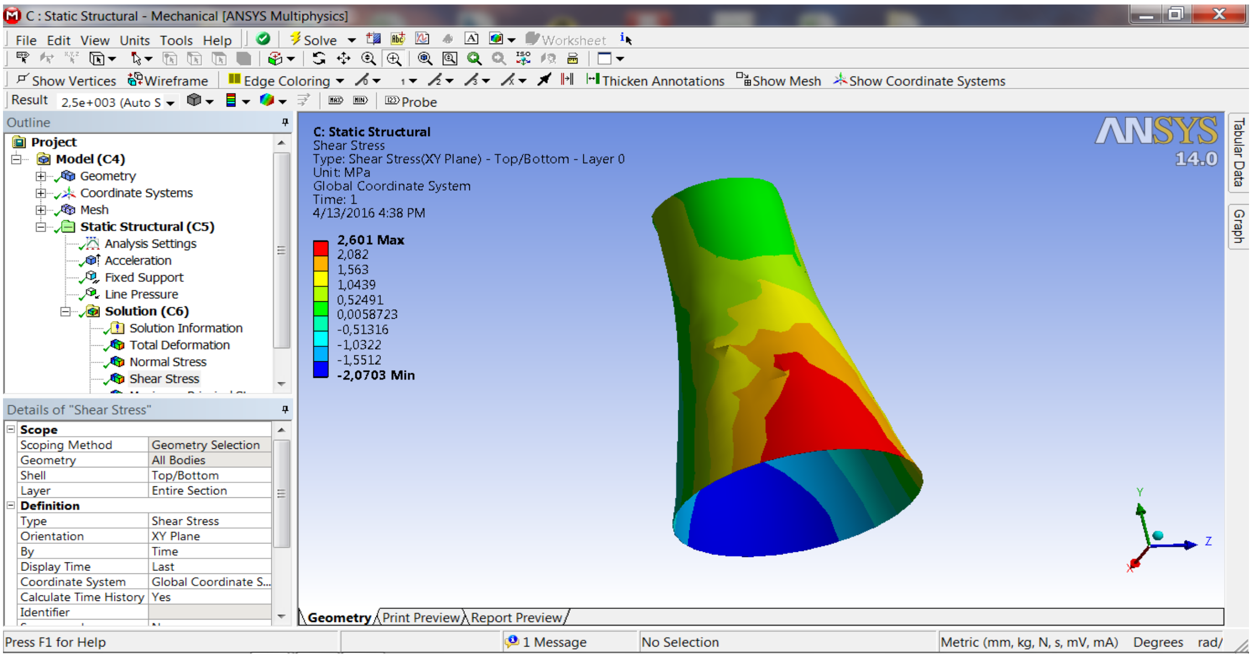

Fig 6.7 Shear Stress

COOLING TOWER TYPE	HEIGHT (m)	THICKNESS (mm)	MAX. DEFORMATION (mm)	MAX. PRINCIPAL STRESS (MPa)	MAX. SHEAR STRESS (MPa)
CT1	175.5	270	8.6	13.49	1.74
CT2	145.5	270	9.7	14.64	2.06

Table No.6.1

COOLING TOWER TYPE	HEIGHT (m)	THICKNESS (mm)	NATURAL FREQUENCY (Hz)	MAX. DEFORMATION (mm)	MAX. PRINCIPAL STRESS (MPa)	MAX. SHEAR STRESS (MPa)
CT1	175.5	270	2.855	8.6	13.49	1.09
		240	4.691	9.44	16.54	1.34
		180	5.57	11.4	18.94	1.59
		140	6.91	13.5	22.92	1.74

Table No.6.2

COOLING TOWER TYPE	HEIGHT (m)	THICKNESS (mm)	NATURAL FREQUENCY (Hz)	MAX. DEFORMATION (mm)	MAX. PRINCIPAL STRESS (MPa)	MAX. SHEAR STRESS (MPa)
CT2	145.5	270	2.93	9.7	14.64	1.84
		240	3.43	10.83	18.70	1.63
		180	5.83	14.68	21.84	1.47
		140	6.12	16.95	25.74	1.32

Table No.6.3

VII. CONCLUSION

In the first stage of study all IS 11841 code provision for design of NDCT is studied and finite element model in ANSYS is proposed against self-weight and lateral load against various dimensions. Following conclusions can be made after analysis

- The increase in thickness shows relatively decrease in deformation but up to maximum value 240 mm for both CT 1 and CT 2.
- The verification of IS 11504 norms is done regarding minimum thickness criteria is done

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- In linear buckling analysis maximum deformation occurs at mode 6 just above base diameter, circular rings need to be provided at that distance
- In modal analysis natural frequencies are increases by increasing thickness of shell.
- Shear stress increased in decreasing thickness of shell

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