© 2019 IJSRSET | Volume 6 | Issue 4 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology
DOI : https://doi.org/10.32628/IJSRSET196415

Study of Reserved Strength Capacity of Concrete Shell

Shubham Rathi[1], Dr. S. S. Angalekar[2]

[1] PG Scholar, Sinhgad College of Engineering, Vadgaon (BK), Pune, Maharashtra, India

[2] Associate Professor, Department of Civil Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India

ABSTRACT

Hyperbolic cooling towers have become the design standard for all natural-draft cooling towers because of their structural strength and minimum usage of material. The hyperbolic shape is particularly suited to cooling tower construction as the wide base provides a large space for the water and cooling system. As the tower widens out at the top, it supports the turbulent mixing as the heated air makes contact with the atmospheric air. Hyperbolic cooling tower is a tall structure with shells subjected to dead load and wind load. In absence of ground motion, wind becomes the major factor. In this study, 2 major models are studied with I and V column support. Each model is further divided into 2 models, i.e. one with SHELL element and another with SOLID element. All models were modelled and analyzed in ANSYS. The wind loads on these cooling tower have been calculated in the form of pressure by using the circumferentially distributed 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 analysis has been carried out using 8 noded shell element (SHELL281), 8 noded solid element (SOLID185) and 20 noded solid element (SOLID 186).

Keywords : Hyperbolic Cooling Tower, Static and Dynamic Analysis, Finite Element Modelling, ANSYS 18, 8 noded element, 4 noded element, Spread of Plasticity.

I. INTRODUCTION

A cooling tower is an enclosed device, designed for the evaporative cooling of water where hot water gets cooled by direct contact with air. Cooling towers operate on the principle of removing heat from water be evaporating a small portion of water that is recirculated through the unit. The mixing of warm water and cooler air releases latent heat of vaporization, causing a cooling effect to the water. Towers are divided into two main types, the first being named natural draught cooling towers and the second mechanical draught cooling towers. Natural-draught cooling towers are used in nuclear power plants as heat exchangers. These shell structures are subjected to environmental loads such as seismic load, wind load and thermal load. Hyperboloid structures are often designed as tall towers, where the strength of the hyperboloid's geometry is used to support an object high off the ground. They have superior stability and resistance to external forces than ordinary structures. Hyperboloid cooling towers have become the design standard for all natural-draft cooling towers because of their structural strength and minimum usage of material. The hyperboloid shape is particularly suited to cooling tower construction as the wide base provides a large space for the water and cooling system.

II. LITERATURE REVIEW

Sachin Kulkarni, et al., [3] have studied about the hyperbolic cooling tower subjected to dead load, wind load and earthquake load. Analysis was carried out on 5 cooling towers out of which 2 (CT1 and CT5) were existing cooling towers from Bellary Thermal Power Station and 3 (CT2, CT3, CT4) towers were derived by increasing each parameter of CT1 by 5%, 10%, 15% respectively. Analysis was carried out on ANSYS using 8 noded and 4 noded shell element. For wind analysis, deflection was maximum in case of CT5 which increased with increase in height. Also, wind loads dominated earthquake load in zone III.

S .Vijaya Bhaskar Reddy, et al., [7] studied about the effect of varying throat location in wind load response of natural draught hyperboloid cooling tower. Eight typical models of natural draught cooling tower were derived by varying throat location from 70% to 87.5% of total height. Wind analysis was carried out on each of these model and it was observed that throat location plays a vital part in economic design of the structure.

Yogita Vhanungare, et al., [10] studied finite element analysis of hyperbolic cooling tower by the concept of equivalent plate. 175m high cooling tower was considered for the wind analysis. Analysis was carried out in ANSYS software assuming the fixity at shell base. For the analysis, tower with alternative ‘I’ and ‘V’ support was taken. Analysis was carried out using 4 noded shell element. It was observed that ‘V’ support tower showed more displacement as compared to ‘I’ support tower.

Priya Kulkarni, et al., [12] studied wind effect on hyperbolic cooling tower. A total of 3 model were prepared for analysis from which two towers (CT1 and CT3) were existing towers from Bellary Thermal Power Station and one tower (CT2) was derived by increasing all parameters of CT1 by 10%. It was observed that due to wind loading, as the thickness and height increases displacement goes on decreasing. Also, displacement was minimum at bottom part of shell and maximum at top part.

Takashi HARA, [13] studied dynamic response of r/c cooling tower shell considering supporting systems. Analysis was carried out on ‘I’ and ‘V’ supporting systems. Cooling tower subjected to earthquake loading was analyzed using FEM. ‘I’ support systems showed maximum deformation at junction between lintel and column whereas ‘V’ support system showed max deformation in shell region and local deformation was less.

Based on current research conducted, reserved strength capacity of concrete shell has been checked by the aspect of its typical geometrical profile. Hence the objectives are:

- To analyze concrete shell for set of combinations considering effect of self-weight and wind load.
- To check appropriate compatible shell element for the response of shell self-weight and wind load out of set of various 2D and 3D elements.
- From the first yielding point by the consideration of extreme deformity and continuing it for the check of spread of plasticity.

III. MODELLING

The geometric configuration of cooling tower is defined by,

$$r = \Delta r + a \,.\, \sqrt{1 + \frac{(z-125)^2}{b^2}} \qquad \text{eq. (1)}$$

where, r is the radius of the shell at height z (m). Parameters a, b and Δr are shown in Table 1. Also, the radius and the thickness of cooling tower shell are presented in Table 2.

Using these equation and the constants given in table below, geometry of the cooling tower was generated. Mainly two models were prepared, one with I support and other with V support. Further, each column support was analyzed with different elements viz., 8 noded solid element, 20 noded solid element, and 8 noded shell element.

Table 1 Configuration parameters

Height (z)	9.17m-125m	125m-176m
a	51.9644	0.2578
b	113.9896	8.0293
Δr	-15.3644	36.3422

Table 2 Radius and thickness of the shell

	Lintel	Node	Top
Height(z)	9.17m	125m	176m
Radius	58.72m	36.6m	38.0m
Thickness	1.05m	0.24m	0.2m

Geometric profile of the cooling tower is shown in Fig. 1.

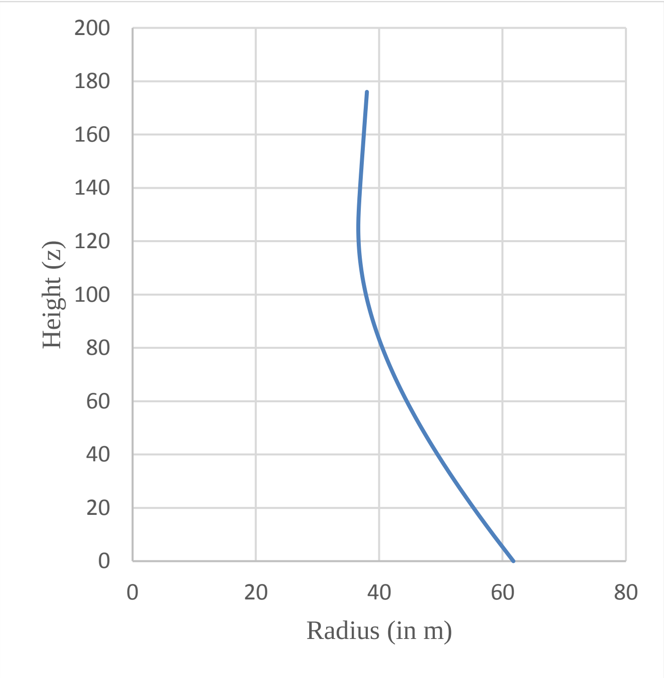

Figure 1. Tower Height vs Radius

Material properties of concrete are shown in Table 3.

Table 3 Material properties of Concrete

Concrete	
Elastic Modulus (E)	34Gpa
Poisson's Ratio (μ)	0.167
Density (ρ)	0.0023kg/cm³
Compressive Strength	36MPa
Tensile Strength	2.7MPa

Using this geometry profile, modelling of cooling tower with 'I' and 'V' support have been done. Fig. 2 and Fig. 3 shows modelled geometry of 'I' and 'V' supports respectively. Modelling has been done in ANSYS.

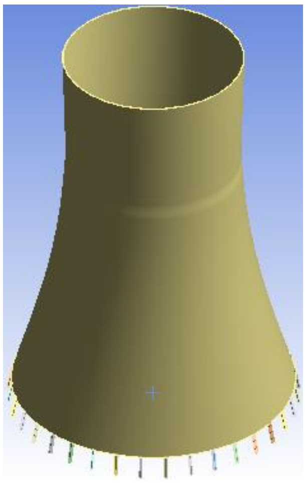

Figure 2. Cooling Tower with I support

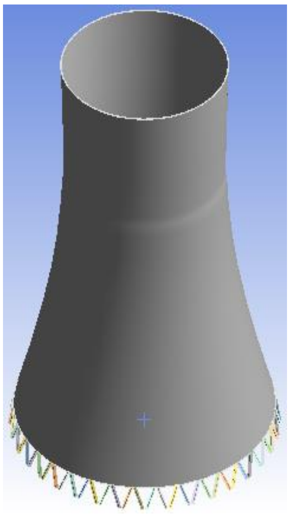

Figure 3. Cooling Tower with V support

IV. VALIDATION

The book, "The Finite Element Method" by O. C. Zienkiewicz and R. L. Taylor have given standard exact results for a cylindrical shell with following geometry and properties:

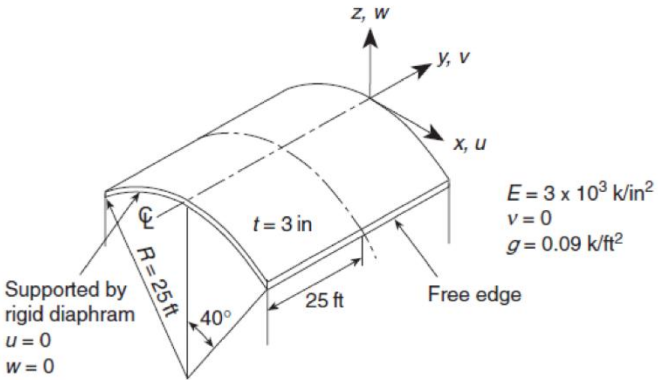

Figure 4. Geometry and Properties of Cylindrical Shell

The same geometry was created in ANSYS for validation purpose. ANSYS results of vertical displacement of center section and longitudinal displacement of support was checked with the standard results of O. C. Zienkiewicz and R. L. Taylor. It was found that the ANSYS results gave a close match with the standard results.

V. ANALYSIS

5.1 Load calculation:

5.1.1 Dead load:

Self-weight of structure is considered in this type of loading. The dead load multiplier for the structure is taken as 1.

5.1.2 Wind load:

The basic wind speed (V_b), from IS: 875 (Part 3) – 1987, is 47m/sec at Tiruchchirappalli. Design life period of cooling tower has been assumed to be 50 years. Open terrain with well scattered obstructions having heights generally between 1.5 to 10 m is taken i.e. Category 2 with class A.

IS 11504 – 1985 gives the coefficient for circumferential variation of wind pressure in hyperbolic cooling towers. As per code, the wind pressure distribution on the outside of the shell is assumed to be symmetrical about the center line in the direction of wind. Circumferential net wind pressure distribution of cooling tower has been shown in Fig. 5.

The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$P_z = 0.6\, V_z^2$$

where,

P_z = design wind velocity in N/m² at height z

V_z = design wind velocity in m/s at height z

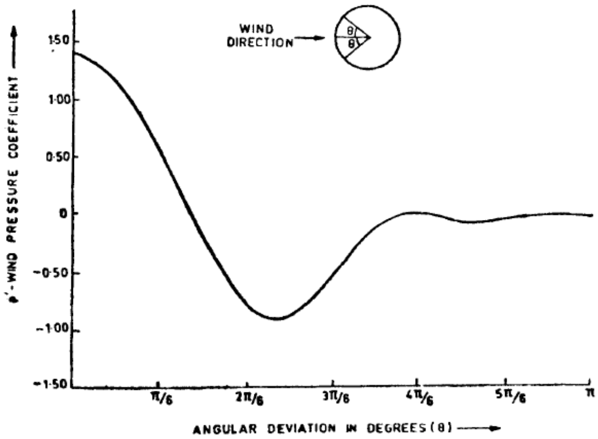

Figure 5. Circumferential net wind pressure distribution

Table 4 Fourier Series F_n

N	F_n
0	-0.00071
1	+0.24611
2	+ 0.62296
3	+0.48833
4	+0.10756
5	- 0.09579
6	- 0.01142
7	+ 0.04551

VI. RESULTS AND DISCUSSION

After analyzing for self-weight and wind load, following results were obtained:

1. 8 noded solid element:

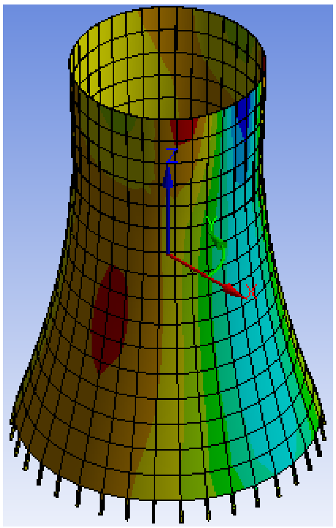

Figure 6. Deflection Contour with I support

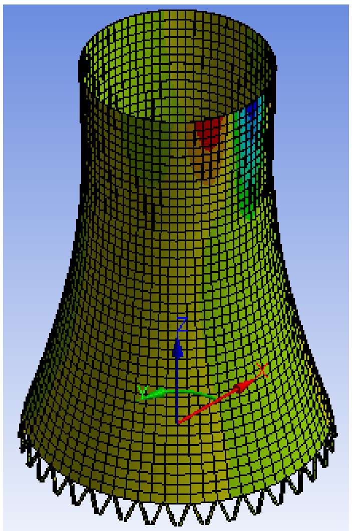

Figure 7. Deflection Contour with V support

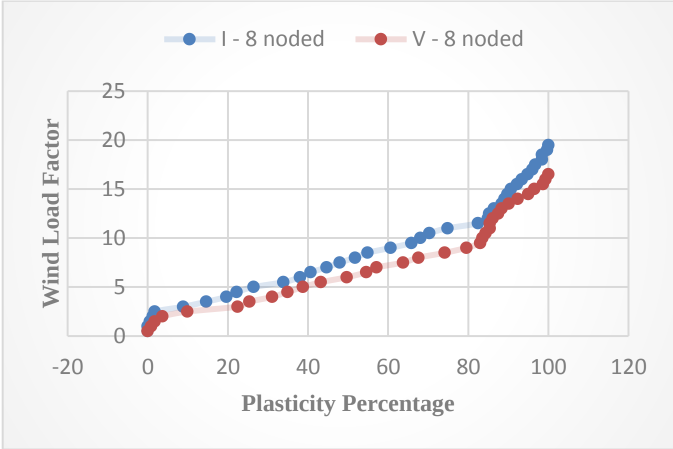

Figure 8. Plasticity Percentage vs Wind Load Factor

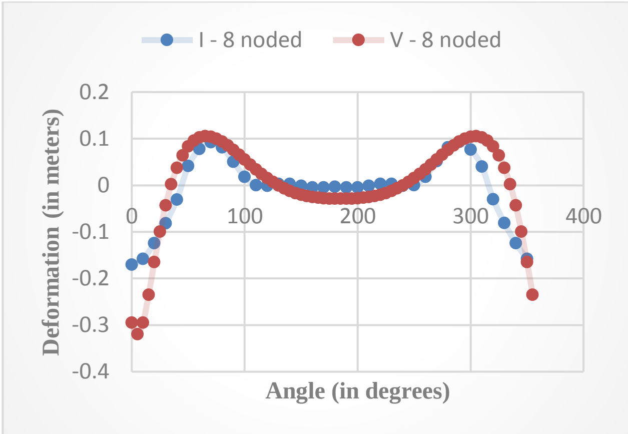

Figure 9. Deformation vs Angle

2. 20 noded solid element:

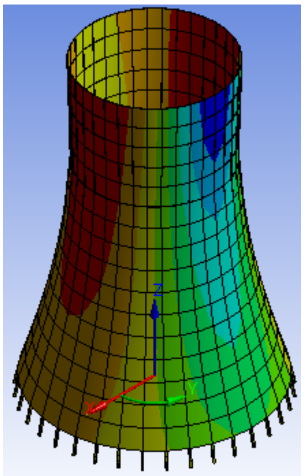

Figure 10. Deflection Contour with I support

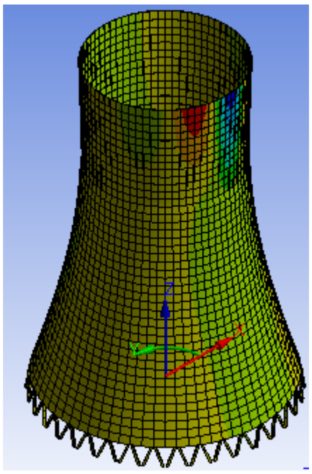

Figure 11. Deflection Contour with V support

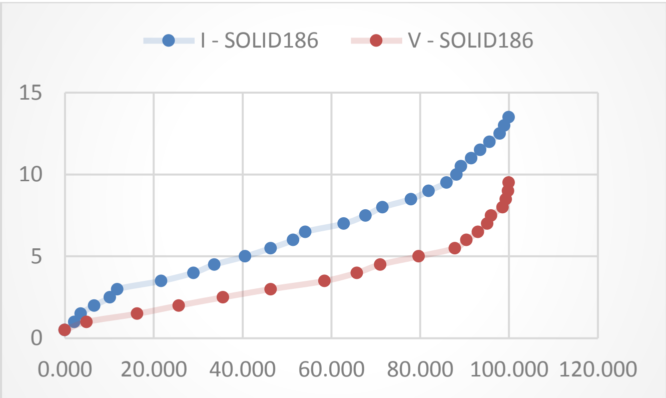

Figure 12. Plasticity Percentage vs Wind Load Factor

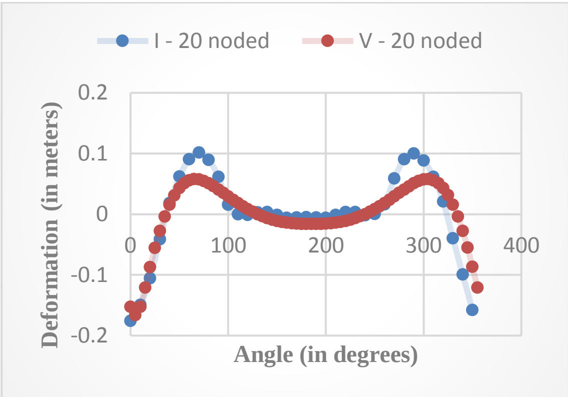

Figure 13. Deformation vs Angle

3. 8 noded shell element:

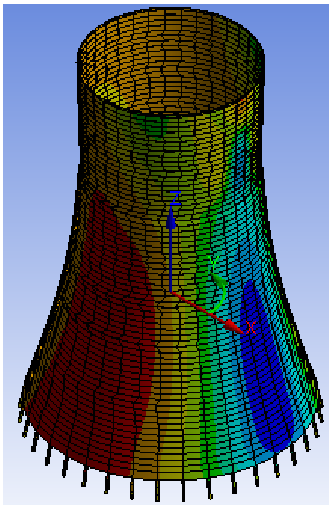

Figure 14. Deflection Contour with I support

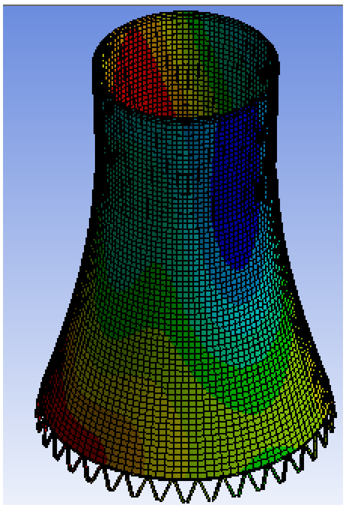

Figure 15. Deflection Contour with V support

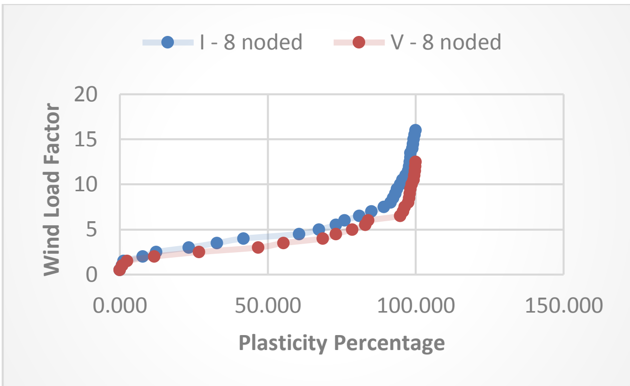

Figure 16. Plasticity Percentage vs Wind Load Factor

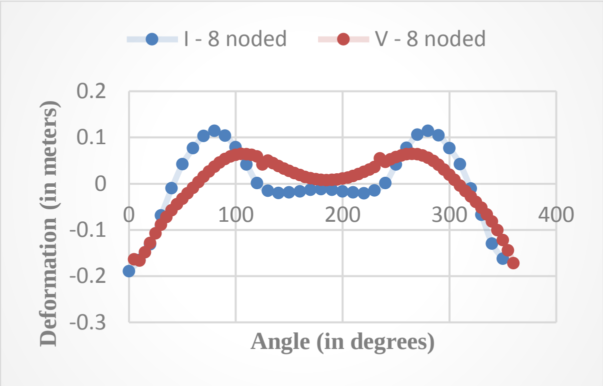

Figure 17. Deformation vs Angle

VII. CONCLUSION

1. From the results, it can be seen that, 'V' support is more flexible than 'I' support cooling tower.
2. Amongst all the element types studied i.e. 8 noded solid element, 20 noded solid element, 8 noded shell element, 20 noded element appeared as most flexible.
3. 8 noded soild element appeared to be most rigid element.

VIII. FUTURE SCOPE

1. Further research is possible by providing reinforcement and checking it for strength regainment.
2. Prestressing edge beam can be added to the tower to check its strength.

IX. REFERENCES

[1]. Wind induced interference effects on natural draught cooling tower, Chiranjit Mishra, et al., International Journal of Progresses in Civil Engineering (2015).

[2]. Drag force coefficient for various shapes of cooling tower subjected to wind load, S. Krishna Kumar, S.Pravin Kumar, International Journal of Computer Sciences and Engineering (2018).

[3]. Static and Dynamic Analysis of Hyperbolic Cooling Tower, Sachin Kulkarni, Prof A. V. Kulkarni, International Journal Of Civil Engineering And Technology (2014).

[4]. Response Study Of Support Systems Of Hyperbolic Cooling Towers, Torna Patil, et al., International Journal of Scientific Research in Science, Engineering and Technology (2017).

[5]. Modal Analysis of Cooling Tower, Mr. M. Ravindra, Md. Faiz Akram, International Journal of Advanced Research Trends in Engineering and Technology (2017).

[6]. Analysis of Natural Draught Hyperbolic Cooling Towers by Finite Element Method Using Equivalent Plate Concept, Shailesh S. Angalekar, Dr. A. B. Kulkarni, International Journal of Engineering Research and Applications (IJERA).

[7]. Effect of Varying Throat Location in Wind Load Response of Natural Draught Hyperboloid Cooling Tower, S. Vijaya Bhaskar Reddy, Borla.Rajagopal, International Journal of Applied Engineering Research (2018).

[8]. Case Study on Effect of Static and Dynamic Loads on Hyperboloid Shell Structure, Sithara T, Ance Mathew, International Journal of Engineering Trends and Technology (2016).

[9]. Study the Effect of Wind Load and Dead Load on RC Hyperbolic Cooling Tower by the Provision of Stiffeners, Mariya Jacob, Aswathi Mohanan, International Journal of Innovative Science, Engineering & Technology (2017).

[10]. Finite element analysis of hyperbolic cooling tower by the concept of equivalent plate, Yogita Vhanungare, Dr. S. S. Angalekar, International Research Journal of Engineering and Technology (2016).

[11]. Response of Cooling Towers to Wind Loads, G. Murali et al., ARPN Journal of Engineering and Applied Sciences (2012).

[12]. Wind effect on Hyperbolic RCC Cooling Tower, Priya Kulkarni and S. K. Kulkarni, International Journal of Current Engineering and Technology (2015).

[13]. Dynamic Response of R/C Cooling Tower Shell Considering Supporting Systems, Takashi Hara

[14]. Effect of Wind Loading on Analysis of Natural Draught Hyperbolic Cooling Tower, Tejas G.

Gaikwad et al., International Journal of Engineering and Advanced Technology (2014).
[15]. IS 875 – 1987 (part 3)
[16]. IS 11504 – 1985
[17]. Finite Element Analysis, S. S. Bhavikatti
[18]. The Finite Element Method (Fifth Edition), Volume 2, Prof. O. C. Zienkiewicz, Prof. R. L. Taylor
[19]. Introduction to Finite Element Analysis, NPTEL
[20]. NPTEL Lecture Notes

Cite this article as :

Shubham Rathi, Dr. S. S. Angalekar, "Study of Reserved Strength Capacity of Concrete Shell", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 6 Issue 4, pp. 230-237, July-August 2019. Available at doi : https://doi.org/10.32628/IJSRSET196415
Journal URL : http://ijsrset.com/IJSRSET196415