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Review on Analysis and Design of RCC Cooling Tower Using STAAD-Pro

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Abstract: Cooling tower is a device which converts hot water into cold water due to direct air contact. It works on the temperature difference between the air inside the tower and outside the tower. Natural draft cooling tower is one of most widely used cooling tower. Hyperbolic shape of cooling tower is usually preferred because of its strength and stability and large available area at the base due to shape.

As it is very important structure in nuclear and chemical plants, it should be continuously assessed for its stability under self-weight, and lateral loads like wind load and earthquake load. Therefore, cooling towers have been analyses for wind load 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 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.

These towers with very small shell thickness are exceptional structures by their sheer size and sensitivity to horizontal loads. The present study deals with the analysis of cooling tower maximum displacement, support reactions, support moments, stresses and bending moments in plates due to seismic loading, wind loading and dead load i.e., its self-weight on a hyperbolic cooling tower is continuous function of geometry.

Keywords: Cooling Tower, Wind Load, Stresses and Moments

I. INTRODUCTION

Cooling tower is a tall cylindrical concrete tower used for cooling water or condensing steam from an industrial process. It is a heat rejection device which extracts waste heat to the atmosphere through the cooling of a water stream to a lower temperature. It is generally of 2 shapes, hyperboloid or hyperbolic and rectangular. Hyperboloid cooling towers will be around 130-200m tall and 100 mm in diameter while the rectangular cooling towers will be around 40m tall and 80m long. Cooling tower is generally made of concrete and rebar. The type of foundation required for each cooling tower, e.g., individual foundations, ring foundation or piling, is determined according to the ground conditions.

Applications of cooling tower include Oil refineries, petrochemical and other chemical plants, thermal power stations and HVAC systems for cooling buildings. The safety of hyperbolic cooling towers is important to the continuous operation of a power plant. Depending upon the site, earthquake may govern the design of the tower. 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. The cooling load is determined by the amount of heat that needs to be extracted from a given process or peak comfort cooling demand. The cooling tower must be adequately sized to reject this same amount of heat to the atmosphere. Cooling towers are used to reject heat through the natural process of evaporation. Warm recalculating water is sent to the cooling tower where a portion of the water is evaporated into the air passing through the tower.

Cooling Towers are divided into two main Types, the first being named natural draught cooling towers and the second mechanical draught cooling towers. In natural draught cooling tower (NDCT), the circulation of air is induced by enclosing the heated air in a chimney which then contains a column of air which is lighter than the surrounding atmosphere. This difference in weight produces a continuous flow of air through the cooling tower as long as water at a temperature above the wet bulb temperature is circulated through the cooling tower. NDCT makes use of the stack effect of a chimney above the packing to induce air flow up through the packing in counter -flow to the water.

A. AIM

The aim of the present work is to analyze the RCC cooling tower in STAAD-PRO and design the parts of the cooling tower.

II. OBJECTIVE

1) To analyze the cooling tower for wind load in STAAD-PRO
2) To analyze the cooling tower for seismic load in STAAD-PRO
3) To compare the cooling tower for different parameters
4) To interpret support reactions and moments
5) To interpret membrane stresses in the plate
6) To evaluate the performance of cooling tower by varying the parameters such as thickness and height of tower shell
7) To study the effect of these parameters on structural behaviors of cooling tower

III. LITERATURE SURVEY

Cooling tower is a device which converts hot water into cold water due to direct air contact. It works on the temperature difference between the air inside the tower and outside the tower.

A. *Literature Review*

Athira C R et al, 2016 [3] The safety of hyperbolic cooling towers is important to the continuous operations of a power plant. Depending upon the site, wind and earthquake may govern the design of the tower. During comparison of different analysis methods, the behavior of structure under El-Centro earth quake using nonlinear dynamic time history analysis showed higher nodal drift when compared to other two. Percentage variation b/w ES & RS, RS & TH, ES & TH obtained are 30%, 63%, and 73% respectively. From the above study it can be concluded that time history analysis predicts the structural responses more accurately in comparison with equivalent static method and response spectrum method as it incorporates P-Δ effect and material and geometric nonlinearity which is true in real structure.

Akash Goyal et al, 2017 [2] It is observed from the analysis that maximum displacement, support reactions, support moments, stresses and bending moments in plates due to seismic loading, wind loading and dead load i.e. its self-weight on a hyperbolic cooling tower is continuous function of geometry (top diameter, throat diameter and height). Earthquake zone plays the important role in analysis. So from this work it can be observed that 300 mm thickness, throat diameter 60m and height 250m is much efficient among all but if height is mandatory to extent than height should not be more than 159m (height taken from actual work) and 170 m height is critical.

Iqbal Hafeez Khan et al, 2015 [9] It is observed from the analysis that maximum displacement, support reactions, support moments, stresses and bending moments in plates due to seismic loading on a hyperbolic cooling tower is continuous function of geometry (top diameter, throat diameter and height). Earthquake zone plays the important role in analysis. So, from this work it can be observed that 300 thickness, throat diameter 64 m and height 150 m is much efficient among all but if height is mandatory to extent than height should not be more than 159m (height taken from actual work) and 170 m height is critical. For seismic zone IV & V, for constant thickness, the resultant of nodal displacement decreases as height & throat diameter of the structure increases. The cooling tower of all the three considered heights with 64m throat diameter having higher displacements as compared to the cooling towers with 70m throat diameter for 300mm & 400mm thicknesses respectively.

Parth R. Chhaya et al 2014 [15] Cooling tower response is governed by both vertical and circumferential wind distribution. The ultimate load bearing capacity of the cooling tower shell under consideration is obtained as 1.925 times that of the design wind pressure that corresponds to the wind velocity of 40.2 m/s (90 mph). The nonlinear behavior is commenced by the formation of horizontal tension cracks in the windward meridian at the 43% height of the cooling tower shell. Free vibration analysis technique maybe used in a seismic analysis using the enforced seismic design needs of NDCT. The stress state in the cooling tower takes the full range from the tension to the compression domain. With the increase in height, wind vibration coefficients first increase, then decrease, and reach their maximum at the top section. Priya Kulkarni et al, 2015 [16] The present paper deals with study of thermal analysis on cooling towers. As a case study cooling towers from Bellary Thermal Power Station (BTPS) are selected. These cooling towers are analyses using software Staad. ProV8i by assuming top end free and fixity at base. The material properties of cooling towers are young's modulus 2.1Mpa, Poisson Ratio 0.15 and Density of RCC 25kN/m3. The results of the analysis include displacement in X, Y, Z directions and Maximum Principal Stress is obtained. The variation in Displacement v/s thickness, max principal stress v/s thickness is plotted graphically. The rate of heat loss is affected by the atmospheric parameters such as air temperature, water temperature, relative humidity and rate of heat loss. Due to thermal loading, the displacement at top of cooling tower in X and Z direction goes on increasing with decrease in thickness and height. Due to thermal loading, the displacement in Y direction goes on increasing as thickness and height increases.

Pujaa Venkataiah et al, 2016 [17] From the analysis results, it can be concluded that the nodal displacement of the structure increases by 30% as the height of the Cooling tower is increased while the nodal displacement can be reduced by around 20-25 % by increasing the thickness of the plate used for modeling the cooling tower. Mass participation of more than 75% is obtained for all the dominant modes. The variation in plate stress was found to be minimum (5%) with the increase in height of the model and thickness of the plate. The CQC shear of the increased by around 35% as the height of the tower and thickness of the plate is increased. From the above results taking cost effectiveness into consideration, the optimum height for a cooling tower can be considered as 250m, optimum plate thickness as 300mm and optimum throat diameter as 60m.

Sachin Kulkarni et al, 2014 [20] The study deals with the modal analysis of hyperbolic cooling towers. Two existing cooling towers are chosen from Bellary thermal power station (BTPS) as case study. FEA based ANSYS Software is used for the analysis. The boundary conditions consider red are Top end free and Bottom end fixed. The material properties of the cooling tower are young's modulus 31GPa, Poisson's Ratio 0.15 and density of RCC 25 kN/m3. The analysis is carried out using 8 noded SHELL 93 element. Natural frequencies, Maximum de flection, Maximum principal stress & strain, Maximum Von Mises stress, strains are obtained. The variation in max principal stress v/s thickness, maximum deflection v/s thickness is plotted graphically.

Saeid Sabouri- Ghomi et al 2006 [21] had Done Thermal Design of Industrial Cooling Tower and Determined the Complete Performance Parameters with Given Inlet and Outlet Conditions and Considering Several Possible Losses. They Investigated That Cooling Tower Performance Increases with Increasing Air Flow Rate and Cooling Tower Characteristic Decreases with Increase in Water to Air Mass Ratio.

Scawthorn [22] have Evaluated Performance of Cooling Tower in Thermal Power Plant by Varying Water Inlet Temperature, Air Inlet Temperature and Mass Flow Rate of Water. They Found That Efficiency of Cooling Tower Increases by Increasing Water Inlet Temp, Air Inlet Temperature and Decreases by Increasing Mass Flow Rate.

Shailesh S. Angalekar et al 2010 [24] In Their Research Have Analyzed A Forced Draft Cooling Tower by Varying Air Inlet Parameters and By Varying Air Inlet Angles in Horizontal And Vertical Direction And Both. The Cooling Tower Model Has Been Prepared in Solid Works 2013 And It Has Been Meshed Using ICEM CFD 14.5 Software and Meshed Models Have Been Analyzed Using FLUENT Software. On the Basis of Temperature Contours Obtained, They Found That Outlet Temperature of Water Increases as The Air Inlet Angle Increases Which Will Lead to Decrease In Effectiveness.

Shailesh S. Angalekar 2015 [25] In Their Research Carried Out the CFD Analysis on A Counter Flow Cooling Tower Reference Model. The Model Has Been Prepared in Creo And Meshed and Analyzed Through ANSYS 12.1. The Analysis Is Carried Out by Simultaneous Varying of Three Parameter Inlet Water Flow Rate, Inlet Air Rate and Fills Porosity and Applied Taguchi Method to Carry Out the Optimization. They investigated That Cooling Tower Gives Best Performance at Lower Mass Flow Rate of Water, High Mass Flow Rate of Air and Fill Porosity Of 50%.

V.S.N. Raju [29] The Detailed Methodology of Design of Counter Flow Cooling Tower Based on The Input Process Parameters by Considering Different Types of Possible Losses. The Designed Cooling Tower Is Then Modelled in Solid works 2012 And Checked for Its Performance Through CFD Software. The Model Has Been Meshed and Analyzed in ANSYS 16.1 Software. The Air Inlet Angles Have Been Varied Along Horizontal and Vertical Direction and Temperature Contours Have Been Obtained. Based on Outlet Cold Water Temperature for Different Air Inlet Angles, The Effectiveness of Cooling Tower Has Been Estimated and Compared. Xin Jia 2013 [30] The Rate of Heat Loss by Water Never Equals to Rate of Heat Gain by Air Due to Different Types of Heat Losses. It Is an Almost Possible to Use CFD To Carry About Performance Analysis of Cooling Tower in Terms of Effectiveness. Results Clearly Demonstrates That with Increase in Air Inlet Angle in Any Direction, Outlet Water Temperature Increases and Thus Cooling Effectiveness Gets Reduce

B. Summary Of Literature

1) From the above study it can be concluded that time history analysis predicts the structural responses more accurately in comparison with equivalent static method and response spectrum method as it incorporates P-Δ effect and material and geometric nonlinearity which is true in real structure.
2) Cooling tower response is governed by both vertical and circumferential wind distribution
3) The Detailed Methodology of Design of Counter Flow Cooling Tower Based on The Input Process Parameters by Considering Different Types of Possible Losses.
4) The Rate of Heat Loss by Water Never Equals to Rate of Heat Gain by Air Due to Different Types of Heat Losses
5) The study deals with the modal analysis of hyperbolic cooling towers.
6) Two existing cooling towers are chosen from Bellary thermal power station (BTPS) as case study.

7) FEA based ANSYS Software is used for the analysis.
8) The boundary conditions considered are Top end free and Bottom end fixed.
9) The material properties of the cooling tower are young's modulus 31GPa, Poisson's Ratio 0.15 and density of RCC 25 KN/m3.
10) The analysis is carried out using 8 nodded SHELL 93 element. Natural frequencies, Maximum de flection, Maximum principal stress & strain, Maximum Von Mises stress, strains are obtained.

IV. METHODOLOGY

Modeling a building involves the modeling and assemblage of its various load carrying elements. The model must ideally represent the mass distribution, strength, stiffness and deformability. The first part of this chapter gives a summary of various parameters such as material properties, basic geometry required to define the model. Accurate modeling of the nonlinear properties of various structural elements is very important in nonlinear analysis. In this study, STAAD Pro v8i is used for the modeling and analysis of the structure.

A. *Material Properties*

This section provides the properties of the material used for the modeling of the cooling tower. Reinforced concrete with a unit weight of 25 KN/m3, Poisson's ratio of 0.2, damping ratio of 5% and elastic modulus of 39 GPa are to be considered.

1) *Loading:* Dead load, wind load and seismic load are to be applied on the structure. Dead load shall be calculated on the basis of the unit weights taken in accordance with IS: 875 (part 1)-1987. Wind loads shall be taken as specified in IS: 875 (part 3)-1987. Seismic load shall be taken in accordance with IS: 1893 (part 1)-2002. The instances where concentrated loads occur, special consideration should be given in analysis and design. From this methodology the cooling tower shall be analyzed for the different load cases and the comparison shall be carried out for the different parameters of the cooling tower. Maximum nodal displacement, support reactions and stress for each case are to be determined and compared to study the impact of the different load conditions for varying height and thickness of plate in a simulated model.
2) *Implications:* The safety of hyperbolic cooling towers is important to the continuous operation of a power plant. Therefore, the analysis is required to know maximum displacement, support reactions, support moments, stresses and bending moments in plates due to seismic loading, wind loading and dead load i.e., its self-weight on a hyperbolic cooling tower is continuous function of geometry

V. DISCUSSION

1) The ultimate load bearing capacity of the cooling tower shell under consideration is obtained as 1.925 times that of the design wind pressure that corresponds to the wind velocity of 40.2 m/s (90 mph).
2) The nonlinear behavior is commenced by the formation of horizontal tension cracks in the windward meridian at the 43% height of the cooling tower shell.
3) Free vibration analysis technique maybe used in a seismic analysis using the enforced seismic design needs of NDCT.
4) The stress state in the cooling tower takes the full range from the tension to the compression domain.
5) With the increase in height, wind vibration coefficients first increase, then decrease, and reach their maximum at the top section (Parth R. Chhaya et al 2014).
6) The present paper deals with study of thermal analysis on cooling towers. As a case study cooling towers from Bellary Thermal Power Station (BTPS) are selected.
7) These cooling towers are analyzed using software Staad. ProV8i by assuming top end free and fixity at base.
8) The material properties of cooling towers are young's modulus 2.1Mpa, Poisson Ratio 0.15 and Density of RCC 25kN/m^3.
9) The results of the analysis include displacement in X, Y, Z directions and Maximum Principal Stress is obtained.
10) Due to thermal loading, the displacement in Y direction goes on increasing as thickness and height increases (Priya Kulkarni et al, 2015).

VI. CONCLUSION

1) Principal stresses, Von Mis stresses are maximum in cooling tower considering with earthquake analysis
2) Top combined stress and bottom combined stresses are found to be more in case of cooling tower without EL.
3) Displacement is maximum as the height goes on increasing.
4) Reactions found to be more in case of more height of cooling tower.

REFERENCES

[1] Parth.R.Chhaya, Nizam.M.Mistry and Anuj K. Chandiwala, "A Review On Effect Of Wind Loading On Natural Draught Hyperbolic Cooling Tower", International Journal of Advance Engineering and Research Development, Volume 1, Issue 12, December -2014.

[2] Priya Kulkarni and S. K. Kulkarni, "Thermal Effect on RCC Hyperbolic Cooling Tower", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 9, September 2015.

[3] Sachin Kulkarni and Prof A.V. Kulkarni, "Modal Analysis Of Reinforced Concrete Cooling Towers", International Journal of Advance Engineering and Research Development, Volume 1, Issue 12, December -2014.

[4] Iqbal Hafeez Khan, Rakesh Patel and AslamHussain, "Parametric Analysis Of Hyperbolic Cooling Tower Under Seismic Loads Through Staad.Pro", International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 09 | Dec-2015.

[5] Pujaa Venkataiahand, P. Prakash, "Seismic Analysis and Design of a Hyperbolic Cooling Tower", International journal of scientific engineering and technology research, Vol.05, Issue.12, May-2016, Pages:2413-2415.

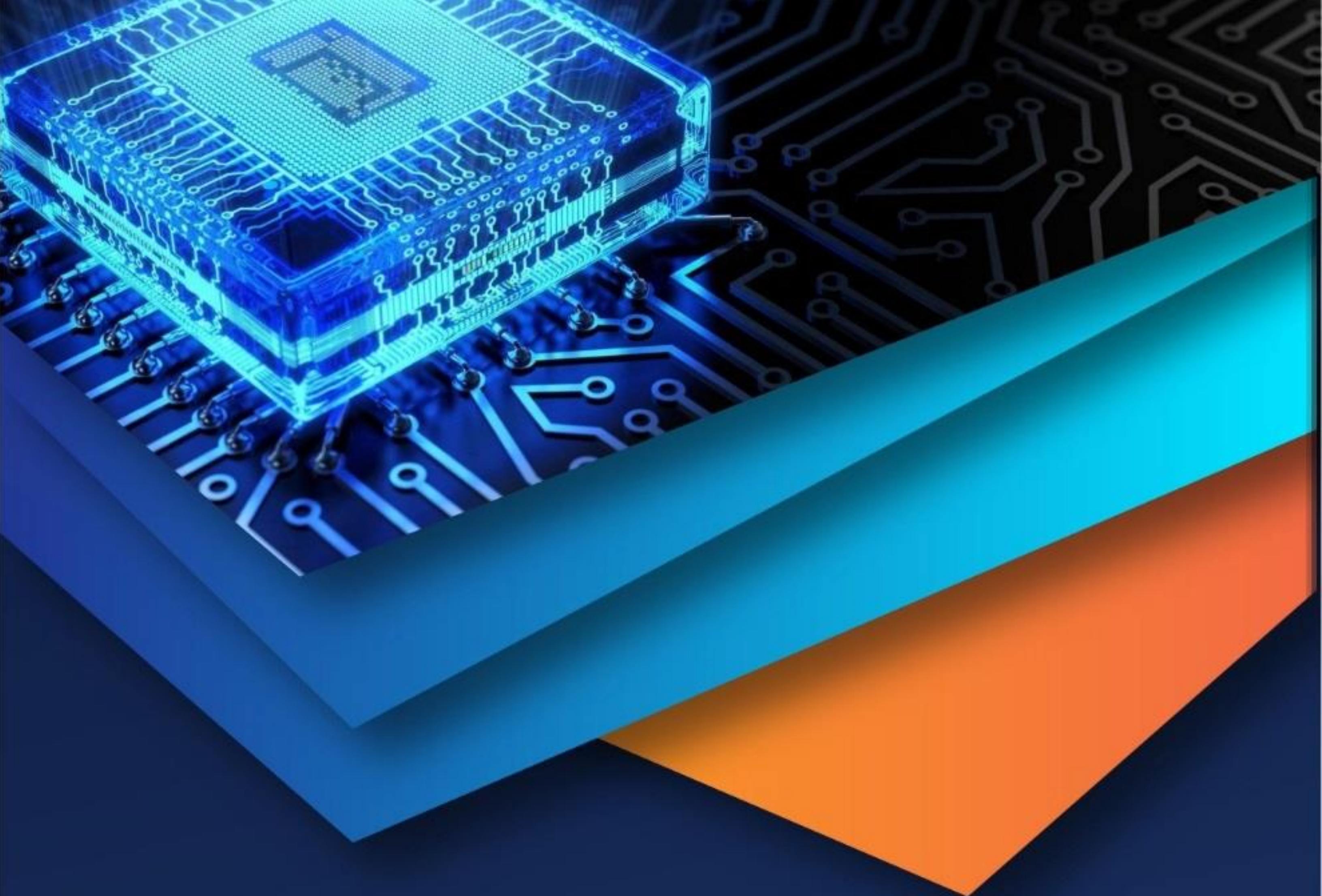
[6] AkashGoyal, A N Shankar and S K Sethy, "Parametric Analysis of Hyperbolic Cooling Tower under Seismic Loads, Wind Loads and Dead Load through Staad. Pro", International Journal of Engineering Research & Science (IJOER), Vol-3, Issue-8, August- 2017

[7] Athira C R, Rahul K R, Reshma R Sivan, Seethuvijayan and Nithin V Sabu, "Linear and Nonlinear Performance Evaluation and Design of Cooling Tower at Dahej", IOSR Journal of Mechanical and Civil Engineering (IOSR -JMCE), International Conference on Emerging Trends in Engineering & Management.

[8] R. Purusothaman, "Planning, Designing And Analyzing Of Cooling Tower", International Journal of Advanced Research in Civil, Structural, Environmental and Infrastructure Engineering and Developing, Volume: 3

[9] Dr. S. N. Tande and Snehal S. Chougule, "Linear and Nonlinear Behaviour of R. C. Cooling Tower under Earthquake Loading", International Journal of Latest Trends in Engineering and Technology, 2(4), 2013, 370-379.

[10] Shailesh S. Angalekar and Dr. A. B. Kulkarni, "Analysis of Natural Draught Hyperbolic Cooling Towers by Finite Element Method Using Equivalent Plate Concept", International Journal of Research and Applications, 1(2), 144-1



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