ANALYSIS AND DESIGN OF HYPERBOLIC COOLING TOWER USING STAAD.PRO

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Abstract:

Cooling towers are the biggest heat and mass transfer devices that are in wide spread use. It works on the temperature difference between the air inside the tower and outside the tower. In this study cooling tower in analyzed under the effect of earthquake forces using STAAD pro software. 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. Based on these results, salient conclusions are drawn. Hyperbolic cooling towers are large, thin shell reinforced concrete structures which contribute to environmental protection and to power generation efficiency and reliability. Cooling tower is an integral part of every thermal power generation plant. Basically cooling tower are heat rejection devices used to transfer heat from hot water to the atmosphere air. Investigation involves experimental and two-dimensional computational fluid dynamics analysis of an actual industry operated cooling tower. Inlet water temperature and mass flow rate of water and air are having main influence on the performance of counter flow induced draft cooling tower. In cooling tower water is made to trickle down drop by drop, or form a thin layer over flat surface so that it comes into direct contact with air moving upwards in opposite direction. The heat transfer from the water to the air steam raises the air's temperature and its relative humidity to 100% and this air is discharged to the atmosphere. Likewise other parameters such as range, tower characteristic ratio can also be increased considerably, pressure at outer region, temperature variations. In this study we will perform dynamic analysis of a tall tower considering thermal effect over the inner layer of the tower and wind pressure to determine its stability in terms of temperature, cracks, stability, resistivity, forces and displacement. Keywords: – Cooling tower, Modeling, Earthquake, Stresses, Temperature, STAAD pro.

INTRODUCTION

GENERAL

A cooling tower is a semi closed device for evaporative cooling of water by contact with air. The main function of cooling tower is to remove waste heat into the atmosphere from condenser. It is a wooden, steel or concrete structure and corrugated surfaces or baffles or perforated trays are provided inside the tower for uniform distribution and better atomization of water in the tower. 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 tower, 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. As hot air moves upwards through the tower, fresh cool air is drawn into the tower through an air inlet at the bottom. The hyperbolic shape is made because of following reasons. More packing can be fitted in the bigger area at the bottom of the shell, the entering air gets smoothly directed towards the centre because of the shape of the wall, producing a strong upward draft, and greater structural strength and stability of the shell is provided by this shape. The direct rejection of hot water to these reservoirs could lead however to thermal pollution problems. Where location of industrial plant is such that cooling water in large quantities is scarce, then the water must be cooled and recycled. Cooling towers originated in the 19th century through the development of condensers for use with the steam engine Condensers use relatively cool water, via various means, to condense the steam coming out of the cylinders or turbines. This reduces the back pressure, which in turn reduces the steam consumption, and thus the fuel consumption, while at the same time increasing power and recycling boiler-water. However the condensers require an ample supply of cooling water, without which they are 2 impractical. While water usage is not an issue with marine engines, it forms a significant limitation for many land-based systems. By the turn of the 20th century, several evaporative methods of recycling cooling water were in use in areas lacking an established water supply, as well as in urban locations where municipal water mains may not be of sufficient supply; reliable in times of demand; or otherwise adequate to meet cooling needs. In areas with available land, the systems took the form of cooling ponds; in areas with limited land, such as in cities, they took the form of cooling towers. These early towers were positioned either on the rooftops of buildings or as freestanding structures, supplied with air by fans or relying on natural airflow. An American engineering textbook from 1911 described one design as "a circular or rectangular shell of light plate in effect, a chimney stack much shortened vertically (20 to 40 ft. high) and very much enlarged laterally. At the top is a set of distributing troughs, to which the water from the condenser must be pumped; from these it trickles down over "mats" made of wooden slats or woven wire screens, which fill the space within the tower."

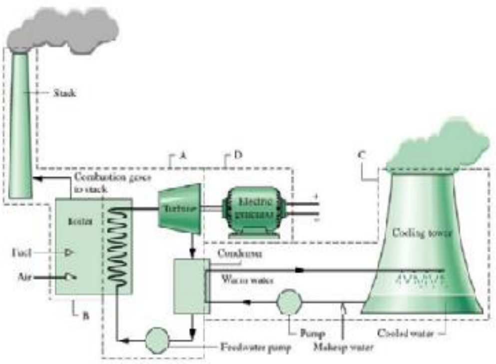

FIG:-1

OBJECTIVES:

The Primary objectives of the study are:

1. To determine thermal effect on structural members of the tower.
2. To Analyze the cooling tower structure considering wind pressure.
3. To Analyze the structure using Analysis tool STAAD.Pro.

MATERIALS AND METHODOLOGY :

Load Case Details

Seismic Loads (Is 1893: 2002)

When a structure is subjected to ground motion, it responds in shaking fashion. The random motion of structure is possible in all possible directions mainly in horizontal (X) and vertical (Y) directions. This motion causes the structure to vibrate in all three directions. This seismic forces must be evaluated from IS: 1893:2002. 3.1.2 DEAD LOAD (IS 875: 2007 Part 1) These are the external loads which acts vertically downward and arises due to the selfweight of the structure. Dead loads are static forces that are relatively constant for an extended time. They can be in tension and compression. The term can refer to laboratory test method or to the normal usage of a material or structure. 3.1.3 LIVE LOAD (IS 875: 2007 Part 1) Live loads are usually unstable or moving loads. These are dynamic loads may involve considerations such as impact, momentum, vibration, slosh dynamics of fluids, etc. 3.1.4 TEMPERATURE LOAD Temperature changes leading to thermal expansion because thermal loads. 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. 25 3.2 DETAILS OF MODELLING The modeling of the structure is done in STAAD Pro. The Total height of the tower is 91.463 m. The tower has a base, throat and top radii of 82.583m, 46.042m and 50 m respectively. 3.3 **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, and elastic modulus of 39 GPa were considered for the finite-element modeling of the cooling tower. 3.4 LOADING Dead load, wind load and seismic load were 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. Dynamic loads of interest include wind loads and seismic actions that are time dependent and asymmetric. The use of equivalent static loads simplifies the analysis, however, it does not account for interaction between the frequencies of the applied load and the characteristic natural frequencies of the structure and limited knowledge on the dynamic behavior of structure. Parameters that are considered for wind loading according to IS875-Part 3 26 3.5

FLOWCHART OF MODELING:

PROCEDURE OF ANALYSIS

Modeling Of Hyperbolic Cooling Tower

1.Go to new project > select space > give file name and location > Give length units as m and force units as KN > Click next > add beam > finish. ¬Now from the main tool select geometry and then run structural wizard > select the model type as surface/plate models > select cooling tower > give the dimensions as height =91.463m, top diameter as = 50m, throat diameter as = 46.042m, and distance of top from throat as 20m. Click on apply and merge model with STAAD.PRO model

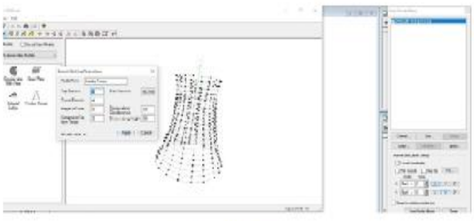

Fig 3.1 Modeling of tower

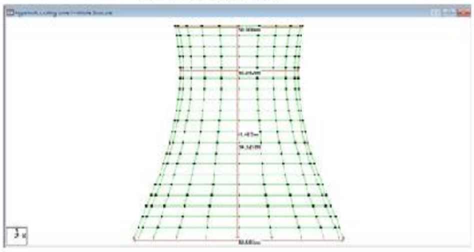

FIG:-2

RESULTS:

The table shows the maximum force value of support reactions developed for the critical load combination which may possible to act on the cooling tower. They are as listed in below table:

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	416	6 TEMPERATU	189E+3	-2.132	1.258	17.998	-6.919	-417E+3
Min FX	406	6 TEMPERATU	-189E+3	-2.132	-1.258	-17.998	-6.919	417E+3
Max FY	406	36:GENERATE	-17.7E+3	48.4E+3	0.021	0.317	-0.083	-19.6E+3
Min FY	416	1 SX-	-1.38E+3	-3.75E+3	-0.000	0.003	0.016	-478.092
Max FZ	411	6 TEMPERATU	-1.258	-2.132	189E+3	417E+3	-6.919	17.998
Min FZ	401	6 TEMPERATU	1.258	-2.132	-189E+3	-417E+3	-6.919	-17.998
Max MX	411	6 TEMPERATU	-1.258	-2.132	189E+3	417E+3	-6.919	17.998
Min MX	401	6 TEMPERATU	1.258	-2.132	-189E+3	-417E+3	-6.919	-17.998
Max MY	401	44:GENERATE	-1.19E+3	25.7E+3	-9.22E+3	10.9E+3	795.269	1.9E+3
Min MY	411	35:GENERATE	1.19E+3	42.8E+3	15.4E+3	18.1E+3	-796.365	1.9E+3
Max MZ	406	6 TEMPERATU	-189E+3	-2.132	-1.258	-17.998	-6.919	417E+3
Min MZ	416	6 TEMPERATU	189E+3	-2.132	1.258	17.998	-6.919	-417E+3

Maximum and Minimum Node displacements: The maximum and minimum value of node Displacements for the critical load combination which may possible to occur in the cooling tower. They are as listed in below table:

	Node	L/C	X (m)	Y (m)	Z (m)	Resultant (m)	rX (rad)	rY (rad)	rZ (rad)
Max X	326	6:TEMPERATU	0.091	0.090	0.000	0.128	-0.00000	0.00000	0.00037
Min X	336	6:TEMPERATU	-0.091	0.090	-0.000	0.128	0.00000	0.00000	-0.00037
Max Y	1	6:TEMPERATU	-0.000	0.267	0.066	0.274	0.00422	0.00000	0.00000
Min Y	6	36:GENERATE	0.003	-0.006	-0.000	0.007	-0.00000	-0.00000	-0.00019
Max Z	321	6:TEMPERATU	-0.000	0.090	0.091	0.128	-0.00037	0.00000	-0.00000
Min Z	331	6:TEMPERATU	0.000	0.090	-0.091	0.128	0.00037	0.00000	0.00000
Max rX	381	6:TEMPERATU	0.000	0.023	0.030	0.038	0.01085	-0.00000	-0.00000
Min rX	391	6:TEMPERATU	-0.000	0.023	-0.030	0.038	-0.01085	-0.00000	0.00000
Max rY	99	32:GENERATE	-0.000	-0.005	-0.000	0.005	0.00001	0.00003	0.00001
Min rY	93	32:GENERATE	0.000	-0.004	0.000	0.004	-0.00001	-0.00003	0.00001
Max rZ	396	6:TEMPERATU	-0.030	0.023	0.000	0.038	0.00000	-0.00000	0.01085
Min rZ	386	6:TEMPERATU	0.030	0.023	-0.000	0.038	-0.00000	-0.00000	-0.01085
Max Rst	4	6:TEMPERATU	0.031	0.267	0.037	0.274	0.00248	0.00000	-0.00341

Maximum and Minimum Beam displacements: The maximum and minimum value of beams Displacements for the critical load combination which may possible to occur in the cooling tower. They are as listed in below table:

	Beam	L/C	d (m)	X (m)	Y (m)	Z (m)	Resultant (m)
Max X	445	6:TEMPERATU	9.758	0.075	0.109	0.000	0.133
Min X	455	6:TEMPERATU	9.758	-0.075	0.109	0.000	0.133
Max Y	401	6:TEMPERATU	3.911	-0.028	0.268	-0.055	0.275
Min Y	407	36:GENERATE	3.911	0.003	-0.007	0.000	0.008
Max Z	450	6:TEMPERATU	9.758	0.000	0.105	0.075	0.133
Min Z	441	6:TEMPERATU	0.000	0.000	0.109	-0.075	0.133
Max Rst	403	6:TEMPERATU	3.911	0.010	0.265	-0.061	0.275

CONCLUSION:

- The analysis and design of cooling tower was done using STAAD pro.
- The dimension of plate thickness is taken between 1200mm to 1800mm.
- The cooling tower was analyzed and designed for dead load, seismic load, different live loads and constant temperature of 250 degree Fahrenheit for axial elongation, 200 degree Fahrenheit f

for top to bottom and150 degree Fahrenheit for side to side.

- Cooling towers are specialized heat exchangers, but instead of the usual conduction - convection heat transfer of shell and tube heat exchangers, it generates cooling by bringing water and air into contact. This cooling is achieved through evaporative cooling and sensible heat transfer.
- In ideal condition, the heat loss by water must be equal to heat gain by air.But in actual practice it is not possible because of some type of losses.
- Cooling tower performance increases with increase in air flow rate and characteristic decreases with increase in water to air mass ratio.
- From the design we obtained the reinforcement required for each plate and the beams .
- The Maximum Principal stress in plate section for top and bottom of the element plate section of the cooling tower is in plate 362 and the value is 37.328 N/mm2
- Maximum positive and maximum negative shear force, membrane and Bending moment developed in the plate section increases from bottom to top.
- the maximum force value of support reactions developed for the critical load combination which may possible to act on the cooling tower is more due to the temperature loads and combinations.
- From the analysis it is observed that the temperature effect is more at the bottom and it decreases in the top of tower so we should increase the plate thickness of the tower is more at the bottom to resist the thermal effect. Maximum thermal effect is 13244.5 Kn/m2 and the minimum is -37327.6 Kn/m2 .
- The maximum principal major stress is 57.03 Kn/m2 foe wind x direction and the minimum is -16.33Kn/m2 .

REFERENCES:

[1]. Z. Zhai, S. FU, Improving cooling efficiency of dry cooling towers under cross wind conditions by using wind break methods, Applied Thermal Engineering 26(2004) 914- 923

[2]. J. Smrekar, I .Kustrin, J. Oman, methodology for evaluation of cooling tower performance –part 1:description of the methodology, Energy Conversion and management 52 (2011) 3257-3264.

[3]. Fisenko, S.P.,Petruchik, A.I. and Solodukhin, A.D .Evaporative cooling of water in a natural draft cooling tower. International Journal of Heat and Mass Transfer, 45:4683- 4683-4694, 2002

[4]. Mohiuddin AKM, Kant K. Knowledge base for the base for the systematic design of wet cooling towers. Part II: fill and

other design parameters. Int J Refrig 1996;19(1):52-60.0

[5]. N Prashanth, Sayeed Sulaiman, M U Aswath," To Study The Effect Of Seismic and Wind Loads on Hyperbolic Cooling Tower of Varying Dimension and RCC Shell Thickness", The International Journal of Science & Technoledge, Vol 1, Issue 3, (2013).

[6]. Sachin Kulkarni, A. V. Kulkarni, "Static and Dynamic Analysis of Hyperbolic Cooling Tower", International Journal of Civil Engineering and Technology, Volume 5, Issue 9, pp. 09-26, (2014).

[7]. S. N. Tande, Snehal S. Chougule, "Linear and Nonlinear Behavior of R. C. Cooling Tower under Earthquake Loading", International Journal of Latest Trends in Engineering and Technology (IJLTET), Vol. 2, Issue 4, (2013).

[8]. Takashi Hara, "Dynamic response property of cooling tower structures", Hara Challenge Journal of Structural Mechanics Vol. 1, Issue 1, pp. 38–41, (2015).

[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), 144-148

[11] Nain S.S., Sihag P., Luthra S., "Performance evaluation of fuzzy-logic and BP-ANN methods for WEDM of aeronautics super alloy", MethodsX, 2018, Vol. 5-Issue.

[12] Venkateshwarlu M., Reddy M.N., Kumar A.K., "A case study on assessment of ground water quality parameters in and around Lambapur Area, Nalgonda District, Telangana State", International Journal of Civil Engineering and Technology, 2017, Vol. 8-Issue 7.

[13] Venkataiah V., Mohanty R., Pahariya J.S., Nagaratna M., "Application of Ant Colony Optimization Techniques to Predict Software Cost Estimation", Lecture Notes in Networks and Systems, 2017, Vol. 5-Issue.

[14] Mahender K., Kumar T.A., Ramesh K.S., "Performance study of OFDM over multipath fading channels for next wireless communications", International Journal of Applied Engineering Research, 2017, Vol. 12-Issue 20.

[15] Kumar D.S., Mukhopadhyay S., Chatterjee A., "Magnetization and susceptibility of a parabolic InAs quantum dot with electronâ€"electron and spinâ€"orbit interactions in the presence of a magnetic field at finite temperature",

Journal of Magnetism and Magnetic Materials, 2016, Vol 418-Issue.