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Analysis and Design of a Cooling Tower Considering Wind Pressure and Thermal Effect Using Staad.Pro A Review

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ABSTRACT

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 paper we are presenting review of literatures related to analysis of water tanks.

Keywords : Nonlinear Static Analysis, Deflection Cooling Tower, Analysis, Thermal, Displacement, Forces, Moment.

I. INTRODUCTION

Cooling towers are the essential components of many thermal and nuclear power stations. The towers vary in size that can be up to 200 meters tall and 100 meters in diameter having a complex hyperbolic geometry with thin walls. They may be subjected to a variety of loading conditions such as dead, wind, earthquake, temperature and construction loads. However, the wind load is considered to be the most critical load in the absence of earthquake.

Heat is discharged in power generation, refrigeration, petrochemical, steel, processing and many other industrial plants. In many cases, this heat is discharged into the atmosphere with the aid of a cooling tower. Figure 1.1 shows an example of the application of a cooling tower in a simple steam power plant. Heat is discharged into the atmosphere by the cooling tower via a secondary cycle with water as the process fluid.

The cooling tower (CT) is the most important piece of industrial equipment whose primary purpose is to remove the heat while minimizing water usage. They are often used in power generation plants to cool the condenser feed-water. 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. As a result of this some water is evaporated and is taken away from the bulk of water, which is thus cooled. Thus evaporative cooling technique is used in the case of cooling towers.

II. Literature Survey

We are presenting literature survey of publications, journals, and books related to analysis and design of cooling tower considering safety criterias, lateral load resisting systems, thermal effect and analysis tool.

Kumar and Mathews (2018) [17] the research paper presented that by increasing the mass flow rate of air the performance of cooling tower can be improved. All the performance parameters such as cooling water range, effectiveness, tower characteristic ratio has increased. The increase in the effectiveness of cooling tower was about 20%. When the (L/G) ratio was reduced from 3.25 to 2.60. The outlet temperature of cooled water is reduced to 2k. The effect of inlet water temperature on the performance of cooling tower was studied keeping other parameters such as mass flow rate, injection height, and fill area constant it was found that effectiveness is reduced by 8%. The effect of water mass flow rate was also studied and it was found that by optimizing the mass flow rate of both water and air the effectiveness can be increased. But reducing the mass flow rate of water reduces the output of the cooling tower and inlet water temperature depends on the plant operations.

Mondrety et. al. (2018) [7] the study of static structural, dynamic (model) and seismic behavior of hyperbolic cooling towers i.e. self weight, static loads and ground acceleration for seismic load condition. The boundary conditions considered are Top end free and Bottom end fixed. The material used for cooling tower is concrete. Three different cooling towers will modeled by using SOLIDWORKS 2016 software. Static structural analysis is performed by applying self weight of the cooling tower i.e.: due to gravity, stress, strain and deformation due to load is obtained for each cooling tower. MODAL analysis is performed on cooling tower by fixing it with ground, 6 different deformation modes shapes with respective frequencies are obtained as the result for each cooling tower. Response spectrum analysis is performed to study the seismic effect on cooling tower, for acceleration case 0.5g, 0.6g, and 0.7g.From the modal analysis table, it was conclude that as the height of the cooling tower increase the natural frequency will decrease.

Angalekar and Kulkarni (2018)[13] the research paper exhibited that the support of column to the tower could be supplanted by identical shell components with the goal that the product created could without much of a stretch be used. For such a show, a solitary instance of the pinnacle with elective 'I' and 'V' bolsters was considered displaying the conduct in regard of comparable plates which were indistinguishable from the conduct where the real segment underpins were considered. For this, the wind load over the structure was applied. The outcomes expressed that the proportionate shells gave indistinguishable diverted profiles to the use of the breeze loads, similar to those because of real backings. It was seen that the 'V' underpins give 73.6% more influence than 'I' bolsters on account of segment bolsters just as proportionate plate framework because of the utilization of wind load. The collapse load if there should arise an occurrence of 'I' supportive network was having a 40% higher incentive than on account of 'V' type supportive networks. The structure with the arrangement of reinforcement for example steel plate could support just about 35 to half more crumple load than that of plain concrete.

Chitale et. al. (2018) [10] the research paper presented 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 was modelled in Solid works 2012 and checked for its performance through CFD software. The Model was meshed and analyzed in ANSYS 16.1 Software. The Air Inlet Angles was 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 was estimated and compared. The results stated that the design of Cooling Tower was closely related to Cooling Tower characteristics which was unique for a particular tower and Loading Factor which depends on hot water temperature. The rate of heat loss by water never equals to rate of heat gain by air due to different types of heat losses. It was almost possible to use CFD to carry about performance analysis of Cooling Tower in terms of effectiveness. Results demonstrated that with increase in air inlet angle in any direction, outlet water temperature increases and thus cooling effectiveness gets reduced.

kalpana et. al. (2018) [6] here the author designed draft circular cooling tower Incited draft towers which were commonly mounted with a fan at the highest point of the cooling tower, which permits warm air out and pulls air all through. The high leaving airspeeds lessen the opportunity of re-dissemination. Structure and examination of instigated draft cooling tower were done in thought different loads, for example, wind load, temperature load, self-weight, seismic loads. Planning and examination of the model were finished utilizing logical application Staad Pro. The results concluded that there was distinction between the hypothetical and pragmatic applications as planned model actuated draft cooling tower by considering various kinds of loads, for example, temperature load, seismic load, plate load and so forth., with utilizing Staad pro and IS 875-1987, IS 875 (PART 2) – 1987, IS 1893 (section 1), IS 875 (PART-3) – 1987, IS 456-2000 and IS 8188 codebooks. The codebooks were utilized for the identification of loads condition for the cooling tower in application staad.Pro. The counts have been accomplished for slabs and circular footing.

Patil et. al. (2017) [16] the research paper presented the study of hyperbolic cooling towers having a total height of 175 m supported on „I‟, „V‟ and „H‟ Geometrical Column systems. The modelling of the column was carried out in STAAD-Pro software for wind load, seismic load, self-weight, dynamic loading and harmonic loading. The tower was divided into 4-noded shell elements. Finite element analysis was used for carrying out the analysis of the cooling towers. The study of the different support systems for various aspects like reinforcement, linear elastic response, and elasto-plastic analysis was carried out to make a comparative conclusion for the optimum design of the cooling towers. The results concluded that as „I‟ support is more flexible than „V‟ and „H‟ supports, it is more preferable in earthquake prone areas and where wind intensity is high. As the height of column increases intermediate bracings are required for additional stability, hence the „H‟ columns was considered. The „V‟ type support is preferred from structural point of view.

Athira et. al. (2016)[2] in this project, software modeling, analysis, design and estimation of a cooling tower was done for a site in gas fired power plant for M/S Torrent Energy at Dahej, Gujarat. Study of effect of variations in the tower height and shell thickness on the structural behavior, study of comparison between different seismic analysis methods such as Equivalent static, Response spectrum and Time history, and its result evaluation and interpretation were also performed. Structures were modeled using STAAD Pro V8i and analysed using SAP 2000.Results 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 incorporate P-Δ effect and material and geometric nonlinearity which is true in real structure. Conclusion shell height and shell thickness, height is seen to have the greatest influence on the free vibration response, with increase height significantly increasing displacements. In case of shell thickness variation, it does not affect the top node displacement significantly. So we can infer that shell thickness does not have much effect in overall displacement of shell but, have effect in the local stiffness of the shell.

Das et. al. (2016) [3] the research paper exhibited an analytical examination of basic structural conduct of a Natural Draught Cooling Tower (NDCT) when exposed to dynamic loading. The structural model of the NDCT was created according to the rules and plan criteria in IS 11504-1985. Dynamic loading as both breeze and seismic investigation for example both modular and spectrum examination was done as per the rules given in IS 875(part3)- 1987 and IS: 1083-2002. At last, the outcomes were plotted as far as contour plotting to demonstrate the relocation of structure with time, the part of stresses, and the von-mises pressure that has a place with the subdomain of basic mechanics. From the test results, the deflected state of the shell structure because of dynamic loading was introduced. The time arrangement examination of stresses for example chief pressure, the segment of stresses, Von-Mises pressure was exhibited for range examination as to form plotting. Along these lines, the research paper provided an overview of pressure advancement on the shell structure of a Hyperbolic R/C NDCT.

Venkataiah and Prakash (2016)[8] the research paper determined the max height the cooling towers which could be constructed by making it stable affected by the wind load along with the seismic load. The distinctive radius for the throat, tallness for the cooling towers and thickness for the plates were utilized and the various models were analyzed to obtain the ideal estimations. The basic plate of the ideal model was structured manually. STAAD Pro v8i programming was utilized with the end goal of examination. The results expressed that the nodal removal of the structure expanded by 30% as the stature of the Cooling tower was expanded while the nodal dislodging could be diminished by around 20-25 % by expanding the thickness of the plate utilized for displaying the cooling tower. Mass investment of over 75% was acquired for all the predominant modes. The variety in plate pressure was seen as least (5%) with the expansion in stature of the model and thickness of the plate. The CQC shear of the expanded by around 35% as the tallness of the Cooling tower and thickness of the plate was expanded. Results prompted the end while considering cost-adequacy, the ideal stature for a cooling tower could be considered as 250m, ideal plate thickness as 300mm and ideal throat distance across as 60m.

Angalekar et. al. (2016) [18] the study of hyperbolic cooling tower of 175m high above ground level. This cooling tower has been analyzed for wind load using ANSYS software by assuming fixity at the shell base. For this analysis a single case of the tower with alternative 'I' and 'V' supports is taken up. The wind load on this cooling towers has 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 & 4-noded shell element (SHELL181). The vertical distribution of membrane forces along and the circumferential distributions at base, throat and top levels have been studied for the cooling tower. The results stated that For all loading conditions the displacement is more in 'V' support models than the 'I' support models. The 'V' support cooling tower structure is more flexible structure compared to the 'I' supports cooling tower. The Distortion is minimum at bottom part of shell due to fixed base & maximum at top part of shell. The deflected profile patterns changes as the loading conditions and element changes. The 'V' supports gives 90.89% more sway than 'I' supports at top level of the cooling tower in the case of column supports. The 'V' supports gives 91.76% more sway than 'I' supports at throat level of the cooling tower in the case of column supports. Equivalent plate thickness for 'I' support shell is 0.080m & for 'V' support is 0.075m. The equivalent shells provide identical deflected profiles for the application of the wind loads, as those due to column supports, so the equivalent shell

is proposed as an alternative structural system for the cooling towers having column supports.

Sithara and Mathew (2016)[12] this paper dealt with the static and dynamic investigation of the existing cooling tower of 143.50m high over the ground level. The current cooling tower was browsed Bellary thermal power station. These cooling towers were examined for self-weight, wind loads and seismic loads utilizing ANSYS programming. Two examination techniques done and analyzed were Time history and Response range.

From the examination led on the cooling tower utilizing the two techniques, results expressed that Transient investigation represents post-disappointment condition while accordingly range was not practical. In the transient dynamic investigation, one can catch the seismic failures for a seismic occasion. The conclusion expressed that transient dynamic examination was far superior to the response reaction investigation to precisely foresee the seismic occasion.

Karakas and Daloglu (2015) [1] the exploration work concentrated on a comparative report for the reactions of a cooling tower exposed to wind loadings depicted as per Turkish Standard (TS 498) and Eurocode utilizing symphonious strong ring finite components. Non-axisymmetric wind loadings around the circuit make the cooling tower issue three dimensional. Utilizing consonant components decrease the issue to a two-dimensional issue by communicating the loading as a Fourier arrangement. Subsequently, a finite element program was coded in Matlab joining consonant limited component strategies. The wind examinations of the cooling tower were led utilizing 9-noded consonant strong ring limited component demonstrating. The vertical and circumferential disseminations of the wind loading impact on the cooling tower as indicated by the two gauges were thought about. The circumferential conveyances were communicated utilizing Fourier cosine arrangement and the coefficients demonstrate that while the breeze stacking basically causes undulating disfigurements as indicated by Eurocode and shaft like distortions as per Turkish Standard (TS 498). Additionally, it was understood that the circumferential appropriation of wind pressure affected the extent of relocations and stresses fundamentally just as the district under strain along the periphery of the cooling tower.

Kulkarni et. al. (2015)[14] the research paper presented the research on cooling tower for increasing efficiency and power savings to make it more economical and efficient.

The conclusion stated that a suitable water distribution across the plane area of the cooling tower can increase efficiency of natural draft cooling towers. The deterioration of filling material is one of the concerns. Proper shutdown strategy can save the manpower. It was observed that vertical orientation of packing increases performance, inlet conditions of flow rate of water, air and inlet water temperature are important factors for cooling tower operations. It was further concluded that proper packing, shut down strategy and water distribution was important for optimization of cooling towers. It is important to identify such factors and optimize these for efficient working of cooling towers.

Sachin and Kulkarni (2014)[11] the research paper displayed the investigation of seismic examination of hyperbolic cooling towers. Two existing cooling towers were considered from Bellary warm force station (BTPS) as a contextual analysis. FEA based ANSYS Software was utilized for the examination. The limit conditions considered were Top-end free and Bottom end fixed. The material properties of the cooling tower were youthful's modulus 31GPa, Poisson's Ratio 0.15 and thickness of RCC 25 kN/m3. The investigation was completed utilizing 8 noded SHELL 93 component. Greatest redirection, Maximum Principal Stress and Strain, Maximum Von Mises Stress, Strains were gotten. The variety in max chief pressure v/s thickness, most extreme diversion v/s thickness was plotted graphically. The outcomes prompted the conclusion that acceleration of Ground builds the loads created in shell arrives at the most extreme and the anxieties created in the shell partition relies on the SHELL thickness. The Damping factor utilized in dynamic loading was 5% of basic damping for most extreme thought about a seismic tremor, the damping factor as given in IS 1893 Part 4: 2005 code for strengthened cement is 7%. In Response Spectrum Analysis the 5% and 7% damping gives nearly similar outcomes in the investigation.

Gaikwad et. al. (2014)[15] the research paper presented analysis and designing of a V shaped arrangement of Raker column. Finite Element demonstrating of cooling tower shell was done which partition the shell into the number of plates for the utilization of wind loads on each plate. Gust technique and Peak wind Methods were used to apply wind load. The models were analysed utilizing Staad Pro V8i to plan relative analysis of investigation, structure and constructability. The results expressed that cooling tower reaction was represented by both vertical and circumferential wind conveyance. Designing the cooling towers by utilizing bar type finite element having three or four internal nodes offered an effective vibration investigation which accentuated straightforwardness and adequate exactness for the handy designing needs. A definitive load-bearing limit of the cooling tower shell viable was acquired as 1.925 occasions that of the structure wind pressure that relates to the breeze speed of 40.2 m/s (90 mph). Because of natural factors, the real viable estimations of cement tractable attributes, for example, successful pressure hardening (in the cracks) may differ altogether during the lifespan of a tower. The pressure state in the cooling tower provided the full range from the strain to the pressure area.

Patel and Asthana (2014)[4] the research paper presented observation of the effect of process variable on temperature of water namely Inlet water flow, Inlet air velocity and fill porosity. The results stated that the optimum condition which gives the maximum effectiveness in counter flow FRP cooling tower was obtained with inlet water flow rate kept at level (2 kg/s), air flow rate kept at (2.6 m/s) and fill porosity at level (40%). Improvement in Effectiveness of counter flow FRP cooling tower is 0.22 after taking inlet water flow rate 2.0 kg/s, inlet air rate 2.6 m/s and fill porosity 40%.

Pushpa et. al. (2014) [9] the research paper presented Study of Sensitivity Analysis which showcased the dependency of parameters like air temperature, water temperature, relative humidity and rate of heat loss. By minimizing the size of water droplet, the performance of Natural Draft Cooling Tower can be enhanced.

The conclusion stated that the cooling tower efficiency of Unit 7 is very good. The rate of heat loss is affected by the atmospheric parameters such as air temperature, water temperature, relative humidity and rate of heat loss. The supply of fresh air, the size of droplets and the temperature of warm water will be governing the efficiency of the natural draft cooling tower.

Esmaeil et. al. (2012)[5] the research paper presented finite element analysis for structural response of RCC cooling tower shell comparing two different support systems namely I type column support and V type column support and both were placed at the base. The comparison has been made of the self-weight loading, static wind loading and pseudo static seismic activities the loads are calculated as per the recommendation of relevant IS codes.

The results stated that the I type of supports create higher flexibility at the base of the tower as compared to the V type of supports. In fact the V type of the supports behaves in a manner similar to fixed support at the base. In respect of deflection suffered. At the base the I type of support displays almost five time that of the V type support. At the throat the difference is negligible whereas at the top V type of the support indicates almost ten times the deflection of the I type of the support. However the sign of the deflections are opposite. An important observation is in respect of deflection suffered. At the base the I type of support displays almost four time that of the V type support. At the throat the difference is negligible whereas at the top V type of the support indicates almost 1.5 times the deflection of the I type of the support.

Makovicka et. al. (2006)[4] the research paper presented the behavior of the RC structure of a cooling tower unit under seismic loads and under strong wind loads. The calculated values of the envelopes of the displacements and the internal forces due to seismic loading states were compared with the envelopes of the loading states due to the dead, operational and live loads, wind and temperature actions. The seismic effect takes into account the seismic area of ground motion 0.3 g and the ductility properties of a relatively rigid structure. The ductility was assessed as the reduction in seismic load. In this case the actions of wind pressure was higher than the seismicity effect under ductility correction. The seismic effects, taking into account the ductility properties of the structure, was lower than the actions of the wind pressure. The other static loads, especially temperature action due to the environment and surface insulation was very important for the design of the structure. The comparison revealed that the dominant effect on the structure with reference to its safety (maximum displacements, extreme stress state in selected cross sections, etc.) was exercised by the temperature effect together with the design wind load. The effects of natural seismicity (without reducing of this load by ductility factor R) was comparable with the dynamic wind load within the interval of the design wind velocities. However, technical seismicity may become dominant for the reliability of the structure when there is vibration of selected parts, such as joints, measuring probes installed in the structure for technological purposes, etc.

III. Conclusion

The researchers have tried to find the variation in forces which occurs due to thermal effect following are the outcomes of literature review:

1 Determine that tall structures need to consider lateral load analysis
2 That structure considering thermal effect shows variation at different height.
3 Wind pressure in tall structure shows higher displacement.

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