Static wind analysis of existing natural draft cooling tower at Surathgarh, Rajasthan, India

Dhanendra Koli[1], Chandrakant Pol[2].
[1]MTech((Structure), [2]Assistant Professor (Applied Mechanics)
[1] Walchand college of Engineering, Sangli, India

Abstract: The Natural draft cooling towers are the hyperbolic shells of revolution in shape and are supported on closely spaced inclined columns. These towers have very small shell thickness which are exceptional structures by their utter size and sensitivity to horizontal loads. Wind loading on NDCT governs critical cases due to its much larger height. This paper deals with effect of wind on Natural draught hyperbolic cooling tower. In this paper, efficient Analysis of cooling tower is presented with V- shape configuration of Raker column. The existing cooling tower is chosen from Suratgarh Super Thermal Power Station in Rajasthan, India as case study. Finite element modelling and analysis of cooling tower shell is done in SAP2000. The loading for wind analysis is done as per IS-800 Part3 (2015).

Index Terms - Natural draft cooling tower, Wind Load analysis, SAP2000.

1. INTRODUCTION

These structures are most commonly found in power generation plants. Hyperbolic cooling towers are large, thin shell reinforced concrete structures which Contribute to power generation efficiency, reliability and to environmental protection. It works on the principle of temperature difference between the air inside the tower and outside the tower. Hyperbolic shape of cooling tower is usually preferred due to its strength and stability and larger available area at the base. As the cooling water absorb the latent heat of steam in the condenser, the temperature of the water increases. The hot water coming out of the condenser cannot be used again in a closed system without pre reaches near to T_s saturation temperature of steam at condenser pressure and the condenser vacuum cannot be maintained. Therefore, it is absolutely necessary to pre cool the water coming out of condenser before using again. Hyperbolic reinforced concrete cooling towers are effectively used for cooling large quantities of water in thermal power stations, refineries, atomic power plants, steel plants, air conditioning and other industrial plants. 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.

1.1 Components of Natural Draft Cooling Tower Components of Natural Draft Cooling Tower

The main components of natural draft wet cooling tower are nozzle, fill, drift eliminator and water basin. The warm water is sprayed through a grid of nozzle over the packing. The packing or fill is a multi-layered lattice with large specific air to water contact surface, which obstructs the free fall of water, thereby extending the heat and mass transfer time. The fill breaks up water flow into droplets, increases the contact area and contact time with air, and therefore improves the heat transfer rate and efficiency of cooling tower.

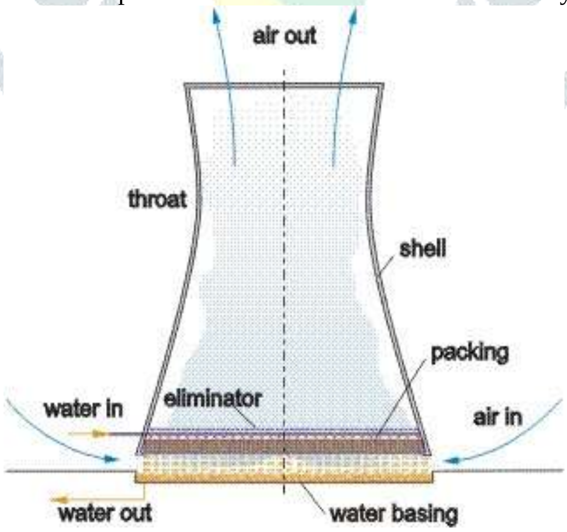

Figure 1: natural draft cooling tower

1.2 Proposed Work

This work is focused on effects of wind forces on natural draft cooling tower. The existing cooling tower at Suratgarh, Rajasthan is selected and analyzed for wind loadings as per Indian standards IS: 11504:1985 and IS 875 Part 3(wind load); 2015.

1. Cooling towers are considered to be fixed at their support. Soil flexibility is not considered in the present study.
2. The hyperbolic shape is given by the considerations mentioned as per IS 11504-1985.
3. The variation of thickness is considered over the full height of the tower.

Only wind load and dead load are taken into consideration for analysis.

2 ANALYSIS OF STEEL CHIMNEY

Analyzed self-supported steel chimney as per Indian Standard IS 6533 (Part 1 & 2):1989 through an example calculation. A typical chimney to be located at Mumbai is taken for the example. The chimney is first analysed for static wind load, seismic loading, and Dynamic wind load for mode (1, 2, and 3), Design lateral wind, and check for possible resonance.

2.1 Assumptions

1. The wind pressure varies with the height. It is zero at the ground and increase as the height increases. For the purpose of design, it is assumed the wind pressure is uniform throughout the height of the structure.
2. The calculation purpose of static wind, It is assumed that the load (projected area multiplied by the wind pressure) is acting at the centre of pressure.
3. The base of the tower is perfectly rigid.

2.2 Details of existing cooling tower.

a. Type of tower: Natural Draft Cooling Tower.
b. Height of tower: 177.25 m
c. Diameter of shell at base of tower: 64.748 m
d. Throat Diameter: 36.501 m
e. Diameter of shell at top of tower: 38.415 m
f. Column Diameter: 1.35 m
g. Bottom ring beam: 1.35x0.5 m
h. Top ring beam: 0.25x0.5 m
i. Thickness of shell above throat: 0.25 m
j. Thickness of shell up to throat section-0.33 m
k. Height of columns above ground level: 10.05 m
l. Height of throat level above ground level: 133.22m
m. Diameter at base of column: 67.91 m
n. Basic wind speed: 47 m/s

The V-shaped orientation of columns used. There are 48 nos. of V-shaped columns constructed along periphery of shell of tower.

2.3 Material properties of cooling tower.

- Shell and beam section
  - Concrete-M35
  - Reinforcement-HYSD fe500
- Column
  - Concrete-M40
  - Reinforcement-HYSD fe500

2.4 Static Wind Load Calculation

The wind force becomes critical on cooling tower due to its larger height. The distribution of wind pressure depends upon the shape and direction of wind incidence. According to IS: 875(Part 3)-2015 Code of Practice for Wind Loads.

Design wind speed (V_z) = V_b x k1 x k2 x k3 x k4
Basic wind speed (V_b)
Probability factor (k1)
Terrain Roughness and height factor (k2)
Topography factor (k3)
Importance factor for the cyclonic region (k4)
Design wind pressure (P_z) =0.6 x $(V_z)^2$

The wind pressure calculation is done for entire height and for each horizontal angle and pressure applied on half part of shell in global Y-direction. The analysis is done in FEA software.

2.5 Result and Discussion

- The displacements due to wind load are mentioned below:
  - Maximum displacement in x-direction- 62.01 mm
  - Maximum displacement in y-direction- 83.58 mm
  - Maximum displacement in z-direction- 2.52 mm
- Allowable displacement - H/500
  - 177250/500=354.5 mm
- Reactions at base of tower:
  - Due to dead load in z-direction- 414514.336 kN
  - Due to wind load in y-direction-37602.595 kN.

3 CONCLUSIONS

The 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 47 m/s. 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.

REFERENCES

[1] IS: 11504:1985, Criteria for structural design of reinforced concrete natural draught cooling tower, New Delhi, India: Bureau of Indian standards.

[2] IS 875 Part 3(wind load); 2015, "Design Loads (Other Than Earthquake) For Buildings and structures — Code of Practice", Bureau of Indian Standards, New Delhi (2005)

[3] Sachin Kulkarni, Prof A. V. Kulkarni, "Static and Dynamic Analysis of Hyperbolic Cooling Tower" Volume 5, Issue 9, pp. 09-26, September (2014).

[4] 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.

[5] Neetesh Singh Raghuvanshi, Dr. Alok Singh, "The influence of air flow inlet region modifications on the local efficiency of natural draft cooling tower operation." Strojniškivestnik Journal of Mechanical Engineering, vol. 57, no. 10, pp. 750-759, DOI:10.5545/svjme.2010.208.

[6] Tao Ning, "Damage, Deterioration and the Long-term Structural performance of Cooling-tower Shells: A Survey of Developments over the past 50 Years." Engineering Structures, 27,1794-1800.

[7] Akihiro KUNISUE, "Disaster Management for Cooling Tower- Case Study", ISSN: 2248-9622, Vol. 6, Issue 5, pp.09-14 (Part - 7), May 2016.

[8] Parth. R. Chhaya, Nizam. M. Mistry, Anuj. K. Chandiwala, "A review on effect of wind loading on natural draft cooling tower", International Journal of Advance Engineering and Research Development, Volume 1, Issue 12, December -2014.

[9] B. RANJITH KUMAR, J. CHANDRAMOULI, C. SREEDHAR, "Modal Analysis of a Thermal Power Plant Cooling Tower", ISSN 2348–237Vol.08, Issue.08, July-2016.

[10] Prashanth N, Sayeed sulaiman, "To study the effect of seismic loads and wind load on hyperbolic cooling tower of varying dimensions and RCC shell thickness" International Journal of Emerging Trends in Engineering and Development Issue 3, Vol.4 (June-July 2013) ISSN 2249-6149.

[11] G. Murali, C. M. Vivek Vardhan and B. V. Prasanth Kumar Reddy, "RESPONSE OF COOLING TOWERS TO WIND LOADS", ARPN Journal of Engineering and Applied Sciences, VOL. 7, NO. 1, JANUARY 2012 ISSN 1819-6608.