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EXPERIMENTAL INVESTIGATION OF INTERFERENCE EFFECTS ON AEROELASTIC MODEL OF NDCT

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Abstract

This paper deals with the experimental study carried out on aero-elastic model of a Natural Draft Cooling Tower (NDCT), in the state-of-the-art boundary layer wind tunnel (BLWT), located at IIT Kanpur, India. The main objective of the study was to determine forces (*both meridional and hoop stress resultants*), moments (*vertical and horizontal bending moments*) and wind pressure distribution on the NDCT model, due to interference, caused by surrounding structures, at different wind incidence angles. A NDCT model at 1:250 scale was tested under simulated flow conditions, for standalone and interference situations. The strain data has been obtained for five different heights, all around the periphery of the model, at 15^o intervals. The mean pressure data has been obtained for nine different heights, all around the periphery of the model, at 15^o intervals. For the interference case, the corresponding mean stress values have been found to be about 848kN/m and 86kN/m respectively, whereas the peak values were 997kN/m and 135kN/m, respectively. The highest net pressure coefficient was obtained as 1.485, for wind incidence 150^o angle. The minimum value of Cp obtained was about -0.92 (occurring at about 75^o angle azimuth), for wind incidence angle of 180^o. From the experimental study, an Interference Factor (IF) of 1.16 has been estimated, for meridional and hoop stress resultants, to account for wind interference effects. The large IF (IF=1.16) shows considerable amount of interference effect on NDCT. However, a maximum increase of about 10% in Cp has been observed, due to surrounding interference structures, and it varies with the location.

Keywords: *BLWT, Wind Tunnel, Natural draft cooling tower, Aero-elastic model, Meridional stress, Hoop stress, Standalone, Interference*

Introduction

The wind loading on a cooling tower (NDCT) is not only affected by its geometry and the oncoming wind, but also by the surrounding structures, lying in the close vicinity of the tower. The interference effect caused by the surrounding structures on the tower, under various wind conditions, cannot be accurately modelled analytically or numerically. Thus, an experimental study on NDCT model in a suitable wind tunnel is required to evaluate these interference effects. The theoretical methods used by the designers, generally assume wind pressure distribution on the outer-side of the shell to be symmetrical about the center-line, in the direction of the wind. The wind pressure coefficient distribution around the shell is obtained from the Indian Standard Code (IS:11504-1985), "Criteria for structural design of reinforced concrete natural draught cooling tower". In the absence of wind tunnel test data, the circumferential wind pressure coefficient (*obtained from the IS code*) is multiplied by 1.43 to account for the load intensification, due to adjacent tower and other surrounding structures. However, this needs to be confirmed from the wind tunnel tests. In addition, the meridional and hoop stress resultants, play an important role in the design of NDCT. These stresses could be significant, particularly in the presence of other major surrounding structures. Although in principle, they can be estimated from the measurement of pressure using a rigid model and corresponding correlations over the NDCT shell surface. The effort required for such calculation is significant. In order to overcome this difficulty, an aero-elastic model is generally used and stress resultants are accurately derived from strain gage measurements. In the present study, an aero-elastic model is used to get meridional and hoop stress resultants, along with pressure loading on the NDCT.

Experimental Setup

The experiments were conducted in a closed-circuit suction-type atmospheric wind tunnel with a test section size of 3m x 2.25m x 8.75m. The maximum achievable wind speed in the test section is 80m/s (290 kmph). For strain measurements, the aero-elastic model was instrumented with strain gages (rosettes) at five different levels along the height, on its inner and outer surfaces. For pressure measurements, pressure ports were made (*on its inner and outer surfaces*) at nine different heights,

Figure 1: Aeroelastic Model of NDCT in WT

at one azimuth angle of the tower model; and instrumented with ESP scanners. The strain information obtained from the model test is used to evaluate the meridional and hoop stress resultants, however, the pressure information obtained from the wind tunnel test, is the wind load distribution on the tower model which is directly used for the design load calculations.

The NDCT model, instrumented with strain rosettes and electronic pressure scanners connected to the pressure ports was mounted on the tunnel floor turn-table. The diameter of the turntable is 2.4m. The surrounding structures in the vicinity of the cooling tower within a diameter of 2.4m (*600m in full scale*) were accommodated on this turntable. In addition, structures (*chimney and associated structures*) those were critical but situated outside the turn-table, were also considered. The test configuration and the experimental setup are shown in Figure 1. The structures on the turn-table can be oriented with any wind incidence angle by rotating the turn-table. However, structures outside turn-table were repositioned manually for each wind incidence angle.

The simulation of appropriate velocity profile (*Atmospheric Boundary Layer Profile*) in the wind tunnel, as per the relevant Indian Standards Code of Practice, corresponding to the terrain category in which the NDCT is proposed to be located, is very important for testing civil structures. In the present case, the ABL profile with a power law index of 0.14 were simulated corresponding to the terrain category No II, class C structures, as specified in the Indian Standard Code IS: 4998 (Pt-I)-1992. The ABL profile and turbulence intensity profile were simulated in the wind tunnel using appropriate roughening devices.

Results

The wind tunnel pressure coefficient distribution results for an interfering case are shown in figure 2 (a&b). As seen (*from the figures 2a &2b*), the maximum positive value of net pressure coefficient is about 1.485 at the height H8 (*near the throat*) for wind incidence of about 150^o. At this wind incidence angle, the NDCT are at staggered angle of 60^o (*wind respect to wind direction*). This arrangement causes significant flow acceleration near the top of NDCT, thus, increases internal flow significantly. Due to the flow acceleration, the internal pressure is reduced which in turn increases the value of

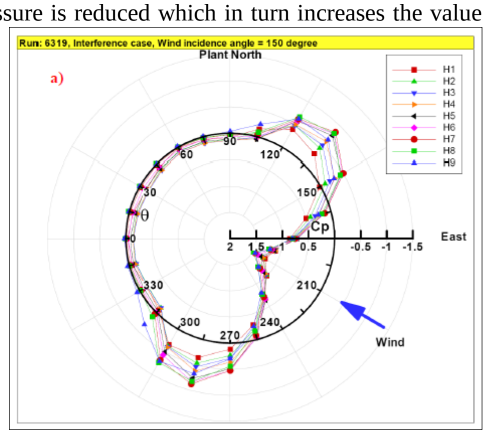

Figure 2a: Net Cp distribution on NDCT under Interference Situation (θ = 150°)

net Cp (=C_{pext} – C_{pint}). The minimum value of Cp is about -0.879 at height H7 (near the throat) when the wind incidence angle is around 150^o and occurring at about 75^o azimuth angle.

In this case, the chimney and the associated structures are just behind the NDCT, causing significant flow acceleration near the top and creating more suction or low pressure zone on the outer face of the NDCT.

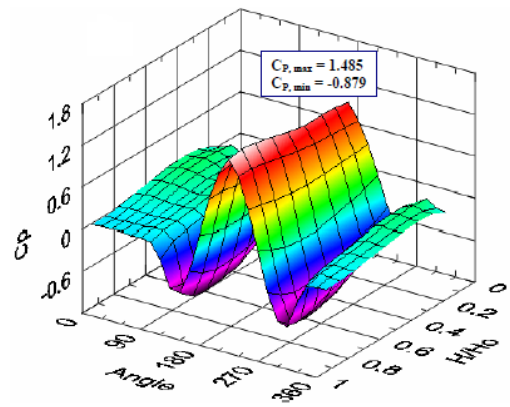

Figure 2b: 3D Net Cp distribution on NDCT under Interference Situation (θ = 150°)

The experimentally measured strain values in the case of interference case have also been analyzed to obtain the forces and moments on the prototype NDCT using the similarity laws. In figure 3, mean stress and moments are shown. The maximum value of the mean meridional stress resultant for the interference case has been found to be 848kN/m corresponding to level, H/Ho = 0.35, and at 300^o wind incidence angle. The maximum mean hoop stress resultant is seen to occur near at the base and its value is 86kN/m. The values of interference factor (IF) for both (*mean meridional stress resultant*) and (*mean hoop stress resultant*) have been evaluated at various heights.

Conclusion

For interference case, the highest net pressure coefficient is obtained as 1.485 at the front stagnation point, when the wind incidence angle is about 150^o. The minimum value of Cp is found to be about - 0.92, when the wind incidence angle is about 180^o (*occurring at 75^o azimuth angle, with respect to wind direction*). Overall, there is about 6% increase in C_{pmax} and about 10% increase in C_{pmin}, due to interference caused by surrounding structures. This load enhancement factor of 10% due to interfering surrounding structures is over and above the load enhancement factor due turbulence in the incoming wind. The nearby structures such as chimney, ESP, boiler, and thermal power station structures, marginally affect the value of C_{pmax}. However, these surrounding structures have significant effect on the C_{pmin}, when the wind incidence angle is around 180^o. The peak values of meridional and hoop stress resultants for the interference case, are 997kN/m and 135kN/m, respectively.

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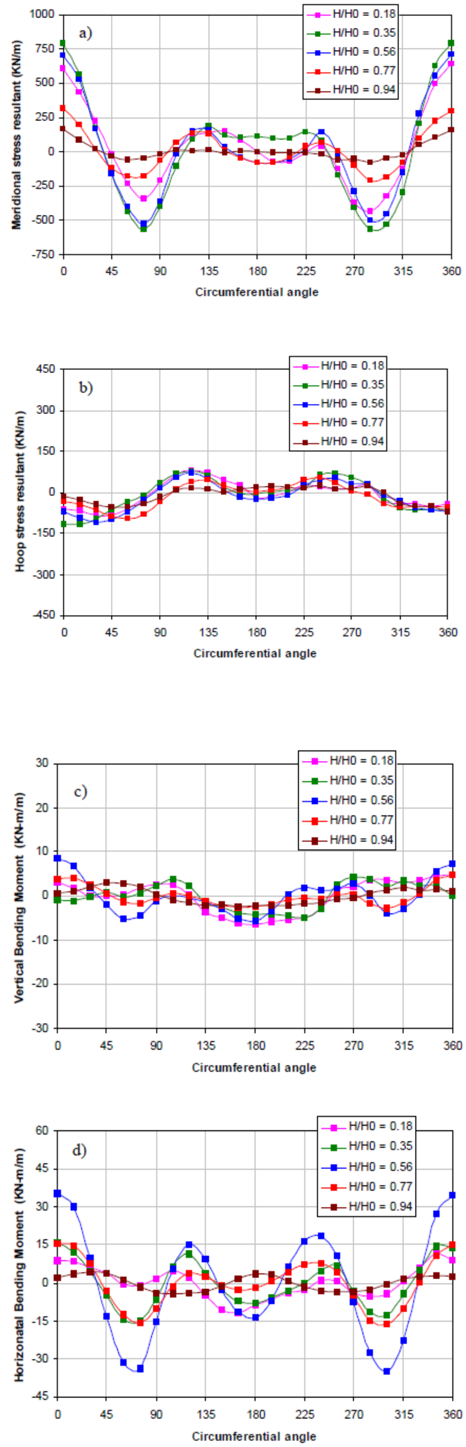

Figure 3: Mean forces and moments on prototype NDCT for Interference Situation (θ = 60°)