EXPERIMENTAL CHARACTERISATION OF CABLE STAYED PAVILION ROOFS

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ABSTRACT
This paper deals with the experimental study carried out on scaled down models (scale 1:100) of cable stayed pavilion roofs (*proposed for a university complex in Trinidad, West Indies*), under simulated boundary flow conditions, at the National Wind Tunnel Facility (NWTF), IIT Kanpur. The proposed cable stayed pavilion roofs are flexible structures, hence sensitive to wind loads. The tests on cable stayed pavilion roof models have been carried out for stand-alone as well as the interfering situations. The pressure coefficients *(mean, maxima, and rms)* have been obtained at various locations and different wind incidence angles (*varying between 0º to 360º @ 10º interval)* by testing the model at design wind speed of 45 m/s (162 kmph), as specified by the user. The test results have been presented in the form of Cp-contours, X-Y plots, and tables.

Keywords: Wind Tunnel, Cable Stayed Pavilion Roofs, Pressure Coefficients

1. INTRODUCTION

The cable stayed pavilion roofs are flexible structure; hence wind sensitive and prone to large wind-induced vibrations. Further, wind forces on a structure are usually estimated considering it, as an isolated structure; however, the practical situation is far different, since, the structure is invariably surrounded by one or more structure(s) in its vicinity. Thus, the flow fields around the neighboring structures would interfere with each other and create a wind field, which may be much different from that for an isolated structure. Aerodynamic interference between two or more structures has been found to modify the response of each of the structure significantly due to change in flow pattern.

As a part of this project, an experimental study on model (1:100 scale) of cable stayed pavilion roofs (*proposed for a university complex in Trinidad, West Indies*), has been carried out at the National Wind Tunnel Facility (NWTF), IIT Kanpur; a state-of-the-art facility having test section cross-section of 3.00m x 2.25m and length 8.75m.

2. TEST SETUP

2.1. Models used

The rigid models of cable stayed pavilion roof, and surrounding buildings and structures (interfering buildings) lying within close vicinity about 120m radius, have been modeled and fabricated at a geometric length scale of 1:100. The roof models have been fabricated in steel through CNC machining, whereas the surrounding buildings/structures have been fabricated out of timber.

2.2. Model instrumentation

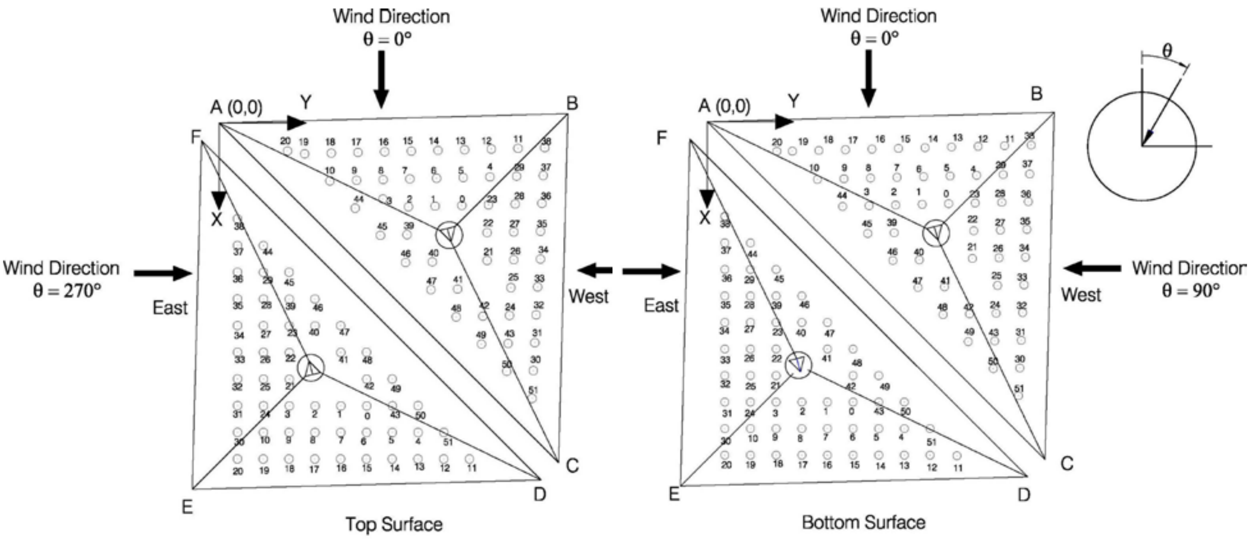

Figure 1: Pressure port locations on top and bottom surfaces of the roof models

The rigid model of the cable stayed pavilion roofs (both the spans) have been instrumented with eight ESP scanners *(PSI make, steady pressure sensors).* Total 208 pressure ports [104 ports on one roof spans (top and bottom surfaces, i.e. 52 on each surface) x two roof spans] have been provided to obtain pressure distribution/ pressure mapping on both the roof surfaces, as shown in figure 1 above.

3. EXPERIMENTAL STUDY

The objective of this part of the study was to determine wind loads on cable stayed pavilion roofs (*both the spans*) by measuring fluctuating pressure patterns (time series) on the scaled down rigid models, as per details mentioned below.

The surface pressure measurement was carried out using high-frequency scanners and high speed data acquisition system. Total eight ESP 32-ports electronic pressure scanners have been used, each having a pressure measuring capacity in the range of ± 5000 Pascal. The accuracy of pressure measurement system used for the study is within ± 2.5 Pascal. The raw data is acquired through a high-speed 16-bit Data Acquisition (DAQ) board (*commercially known as PCI 6032E board from National Instruments*). The application software is developed in LabVIEW, the graphical programming language.

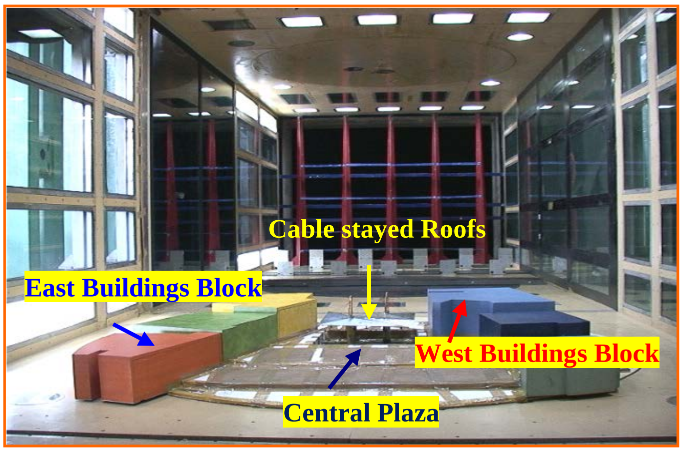

Figure 2: Roof models being tested under interfering situation

3.1. High-frequency pressure integration study

The cable stayed pavilion roof models were instrumented to obtain pressure coefficients as mentioned above. The wind tunnel tests were performed on the models under stand-alone as well as interfering conditions in a simulated boundary layer flow. Figure 2 shows the photograph of cable stayed pavilion roof being tested under interfering configurations, along with some close-ups of roof model.

The time series of raw data was acquired to obtain the mean, maxima, and rms values of pressure coefficients at various port locations, and different wind incidence angles. The raw data was acquired for 20 seconds at a sampling frequency of 10 kHz. Total eight electronic pressure scanners were used, each having 32 pressure ports.

The pressure coefficients (*mean, maximum, and rms*) at various locations and for different wind incidence angles (*varying between 0º to 360º @ 10º interval*) have been obtained by testing the roof models at design wind speed of 45 m/s.

The mean, maximum, and rms values of pressure coefficients have been obtained and plotted (*contour and X-Y plots*) for various locations on the roof surface. Results are also given in the tabular form.

4. RESULTS AND DISCUSSION

The pressure coefficients (*mean, maxima, and rms*) have been obtained for different wind incidence angles for various port locations, under stand-alone and interfering situation.

Some typical results of the present study are given in figure 3. Figure 3 shows contour plots of Cp (*mean pressure coefficients*) for various ports on both the roof surfaces *(top and bottom)* at wind incidence angles θ=0° and 90°, *under interfering condition*. However, it is needless to mention that, to make the study comprehensive, tests have been carried out for wind incidence angles varying between 0° & 360° @ 10° interval. Further, in order to make a comparison of test results, the pressure ports on top and bottom surfaces of the roofs have been located symmetrically on top and bottom surfaces (*along the same vertical line*, *Ref. Fig.1*).

The test results have been verified through analytical methods (basic calculations), for certain wind incidence angles, to establish authenticity. The tests for repeatability have also been performed by repeating the test under same test conditions at different point of time. It has been observed that there exists a good repeatability of the test data. Significant changes in the response (for some cases) are observed due to the presence of interfering building blocks.

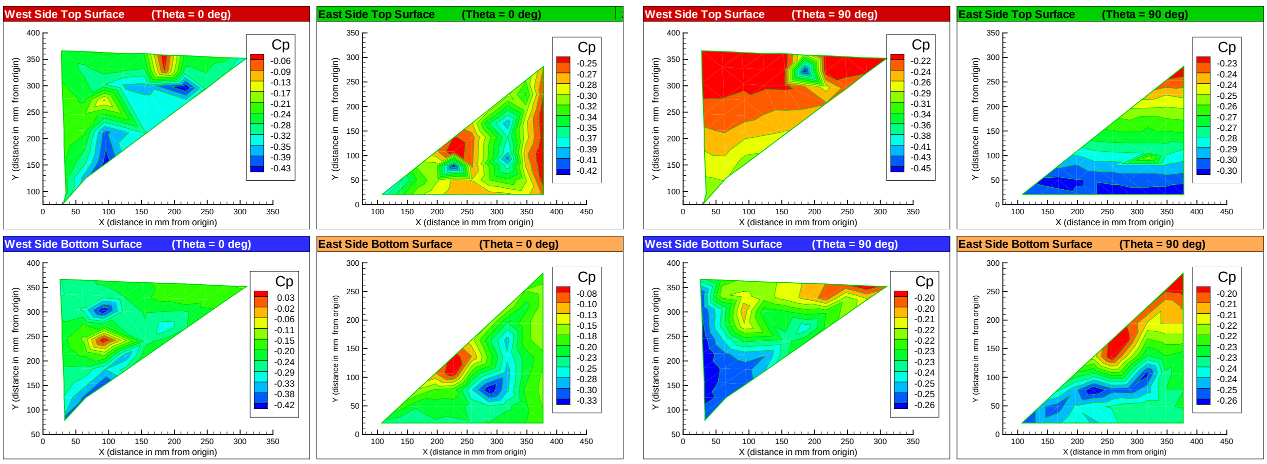

Figure 3: Contour Plots for Cp-mean Distribution on roof surfaces at θ=0^{O} & 90^{O} under Interfering situation

This is mainly due to modifications in the flow field and approach flow characteristics.

For the purpose of explanation, the roof surfaces have been denoted as follows:

WT = **W**est Roof **T**op Surface **WB** = **W**est Roof **B**ottom Surface

ET = **E**ast Roof **T**op Surface **EB** = **E**ast Roof **B**ottom Surface

5. CONCLUSIONS

Following conclusions can be drawn from the experimental study:

i. Suction is observed on the roof surfaces for almost all wind incidence angles; therefore cables need to be designed in such a way that suction is taken care.

ii. Significant changes (*shielding and magnification*) in Cp distribution on roof surfaces have been observed due to nearby interfering buildings. This is mainly due to modification in the flow field and approach flow characteristics.

iii. Magnification in suction is observed for some cases due to interfering structures.

iv. However, due to *shielding* for some locations on WT/WB, Cp reduces by 70% at theta 90°, and no substantial changes are observed for ET and EB. This is because ET/EB are in the wake of WT/WB at theta 90°. As expected, at theta 270°, the above pattern is now reversed.

v. Similarity in Cp variation is observed for 0°&180°and 90°&270° wind incidence angles, as expected. Only the roofs are interchanged, i.e. the pattern observed for WT/WB at 0°, is now observed for EB/ET at 180°, and vice versa. Similarly at theta 90°&270°.

vi. Near the edges suction is higher due to separation of flow, as is generally expected.

vii. The data/test results are in line as with what is expected form the basic flow phenomenon, however, some interesting results have been obtained as mentioned above.

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