VISUALIZATION AND MEASUREMENT OF FLOW ABOUT A LOW RISE BUILDING: SEPARATION AND RECIRCULATION ZONES

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INTRODUCTION

Comparison of pressure data between wind-tunnel and full-scale studies for flow around low buildings has been of special interest in the recent past (Cochran 1992, Tieleman 1994 and others). It was observed that the values of peak and RMS pressure coefficients for the worst-suction taps are consistently lower in the wind-tunnel tests than those seen in full-scale tests. Various theories, including the effects of Reynolds number and small-scale turbulence, have been suggested to explain these differences. The flow in the immediate vicinity of the building is expected to influence the pressures more than the approaching wind. To better understand the flow mechanism in the separated flow regions that produce these worst negative pressures, Colorado State University (CSU) and Texas Tech University (TTU) are conducting experiments in both wind-tunnel model scale (CSU) and full scale (TTU) under the CSU/TTU Cooperative Program in Wind Engineering (CPWE). This is a five-year (1995-1999) research program, completion of which will eventually lead to a better explanation of the peak-load generating mechanism and provide data that will result in improved wind-tunnel simulation and computational methods. Investigation of the wind flow about low buildings is one of the three major emphasis areas in this cooperative research. Mainly two flow cases are being investigated; flow normal to the walls of the TTU building producing separated flow on the roof, and flow at oblique angles with respect to these walls producing corner roof vortices. Visualization and measurement of flow and its correlation with pressure fluctuations and characteristics of the approaching wind are of interest in this study. In this paper, detailed full-scale studies at TTU and its comparison with the wind-tunnel studies at CSU for flow approaching normal to the building walls are discussed. The goal of this paper is to document the flow characteristics of the separation bubble and the reattachment regions and to find its relationship with the upstream wind and its effects on the pressure fluctuations. The results of this study are also compared with those of fundamental studies done in wind tunnels such as Kiya and Sasaki (1983), Castro and Haque (1988), Cherry et al. (1984), and those of full scale such as Wagaman (1993), Hoxey and Richards (1993) and Letchford (1995). The preliminary results of the full-scale visualization and measurement at TTU have been reported in Sarkar and Zhao (1996).

METHOD

Flow Visualization

Three different methods have been successfully employed at TTU for flow visualization in full scale. These methods are the tuft-grid method, the smoke injection technique and the airfoil-grid method. In all the three cases, visualizations were more effective at night when flood lights were used for illumination. An 8-mm videocam was used to record the flow in each method. In the tuft-grid method, a 20 ft x 7 ft metal frame with a 6-in. grid was used. Colored yarn segments tied to the nodes of this grid aided in the visualization process. A high-performance smoke generator (IF-100), along with a number of smoke bombs tied to a metal grid placed along the centerline of the building, was used for visualization in the smoke-injection technique. The airfoil-grid is a relatively new method for full-scale applications. Several light-weight airfoils made out of Balsa wood and 80-lb paper were fixed to a metal grid such that they were free to rotate in the plane of the grid. Reflective tape on the side of the airfoils was used to aid visualization at night.

Flow visualization on a TTU building model at CSU involved a Coherent Innova 70-5 Argon-ion water cooled laser operating in multi-line mode. The laser beam was reflected and spread into a sheet by lenses mounted on the wind-tunnel ceiling. The light sheet was aligned along the centerline of the model. Glycerin smoke was introduced for visualization with the light sheet that was recorded on an SVHS camera.

Flow Measurement

Direct and systematic flow measurements of velocities within the separation bubble were carried out separately as well as simultaneously with flow visualization, approaching flow and pressure measurements. Two ultrasonic anemometers were used to measure the velocities in full scale. The ultrasonic anemometers are capable of detecting flow reversal which is a flow characteristic within the separation bubble. The spatial resolution of the ultrasonic anemometers compares very well with wind-tunnel measurements by hot-film probes on geometrically-scaled models (usually 1:50 or 1:100 scale). Vertical velocity and turbulence profiles were measured along both the axes of the TTU building roof.

RESULTS

The effectiveness of each of the three flow visualization techniques used in full scale is discussed in Sarkar and Zhao (1996). The dimension and form of the separation bubbles along the short axis and along the long axis of the TTU building were established and compared with each other and with those measured in the CSU wind tunnel and those mentioned in the past studies. It was observed that the flow close to the roof was strongly sheared horizontally. As the flow moved downstream, the flow became less sheared. The separation bubble in full scale was observed to be very dynamic. It was observed to be a cyclic process with its formation, growth and breakdown. The mean velocities above the boundary of the separation bubble were consistently higher ($\approx$1.5 times) than that of the roof-level upstream wind. The fluctuating characteristic of the flow within the separation bubble revealed low correlation between point pressure and local flow and a very high turbulence level that varied with height above roof and length along the downstream direction. The highest turbulence region with significant flow reversal occurred close to the roof and to the leading edge and coincided with regions of the lowest pressures. The intermittent nature of the local flow reflected the dynamic process of the separation bubble and it seems to play a decisive role in the peak-pressure generating process rather than the magnitude of the local velocity. More definitive conclusions will be made in the full paper after all the data are analyzed and compared between full scale and wind tunnel.

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