BBAA VI International Colloquium on:
Bluff Bodies Aerodynamics & Applications
Milano, Italy, July, 20-24 2008

EXPERIMENTAL STUDY OF WIND PRESSURES ON IRREGULAR-PLAN SHAPE BUILDINGS

J. A. Amin[*] and A. K. Ahuja[†]

[*] Research Scholar, Depatrment of Civil Engineering
Indian Institute of Technology Roorkee, Roorkee, India
e-mail: jamindce@iitr.ernet.in,

[†] Professor,Depatrment of Civil Engineering
Indian Institute of Technology Roorkee, Roorkee, India
e-mails: ahuja_ak@rediffmail.com

Keywords: Wind Pressure Coefficients, L-shape Building, T-shape Building, Bluff Body, Boundary Layer Flow, and Flow Separation.

Abstract

This paper presents the experimental results of wind tunnel model tests to evaluate wind pressure distributions on different faces of typical-plan shape buildings. Models, having the same plan area and height but varying plan shape ("L" and "T") are tested in a closed circuit wind tunnel under boundary layer flow. The models are made from Perspex sheets at a geometrical scale of 1:500. The effectiveness of the model shape in changing the surface pressure distribution is assessed over an extended range of wind directions from 0^0 to 180^0 at an interval of 15^0. Fluctuating values of wind pressure are measured at pressure points on all surfaces and mean, maximum, minimum and r.m.s. values of pressure coefficients are evaluated. The experimental data for "L" and "T" plan shaped building models showed different wall pressure distributions from those expected for rectangular/square models. It is also observed that there is a large variation in pressure along the height as well as along the width of different faces of the models. The location and magnitude of the measured peak pressure co-efficient vary considerably with wind direction. It is also observed that changing the plan dimensions considerably affects the wind pressure distributions on different faces of the building models.

1 INTRODUCTION

Resent advances in the development of high strength materials coupled with more advanced computational methods and design procedures have lead to a new generation of tall buildings which are slender and light. These buildings are very sensitive to the two common dynamic loads-wind and earthquakes. It is necessary to address the serviceability issue, such as human comfort and integrity of structural components during the strong winds. While designing high-rise buildings and its cladding for wind load, the designers refer to relevant codes/standards to pick the wind pressure coefficients and wind force coefficients [1-3]. The Indian code IS: 875 (part-3)-1987 [3] gives the design pressure coefficients and force coefficients for square and rectangular buildings having different side ratios and height, but this code remains silent about the pressure coefficients on typical plan shape tall buildings such as ‘L’ and ‘T’.

Further wind loads evaluated from codes have the following limitations. Wind load/pressure information in codes/standards (i) does not account for the aerodynamic effect of the actual shape of the structure since they are based on box like buildings and (ii) does not allow for any detailed directional effects and assume that the design wind speed will always occur from the aerodynamically severe wind direction. On the other hand, wind tunnel model studies, which are often used to assist in the prediction of the design wind loads for the cladding and structural frame specifically on tall buildings, (i) do physically simulate and predicts the aerodynamics effect of the actual shape of the structure by modeling building in detail, (ii) consider the directionality of the wind climate for the area where the study building is located, and (iii) overall, provide indispensable wind-effect data for the design of the cladding and structural frame work. Therefore, it is proposed to carry out wind tunnel studies on models of “L” and “T” plan shape tall buildings in order to obtain appropriate values of wind pressure coefficients as well as wind pressure distribution on different faces of models.

2 EXPERIMENTAL PROGRAMME

2.1 Details of Models

The models used for the experiments are made of transparent perspect sheets (6 mm thickness) at a geometrical model scale of 1:500. Plan area (10,000 mm^2) and height (300 mm) of both the models having “L” and “T” plan shape are kept same for comparison purpose. The plan and isometric view of the building models are shown in Fig. 1. Both the models are instrumented with more than 150 numbers of pressure taps at six different height levels 25, 75,125,175, 225 and 275 mm from bottom to obtain a good distribution of pressures on all the faces of building models. These pressure taps are placed as near as possible to the edges of the faces to attempt to capture the high pressure variation at the edges of the faces.

2.2 Wind Flow Characteristics

The experiments are carried out in closed circuit wind tunnel at Indian Institute of Technology Roorkee (India) under boundary layer flow. The wind tunnel has a test section of 8.2 m length with a cross sectional dimensions of 1.3 m (width) x 0.85 m (height). Models are placed at a distance of 6.1 m from the upstream edge of the test section. A reference pitot tube is located at a distance of 3.5 m from the grid and 500 mm above the floor of wind tunnel to measure the free stream velocity during experiments. The variation of mean wind velocity with height at the test section is shown in Fig. 2. The velocity profile inside the tunnel has a power-law index (α) of 0.133.

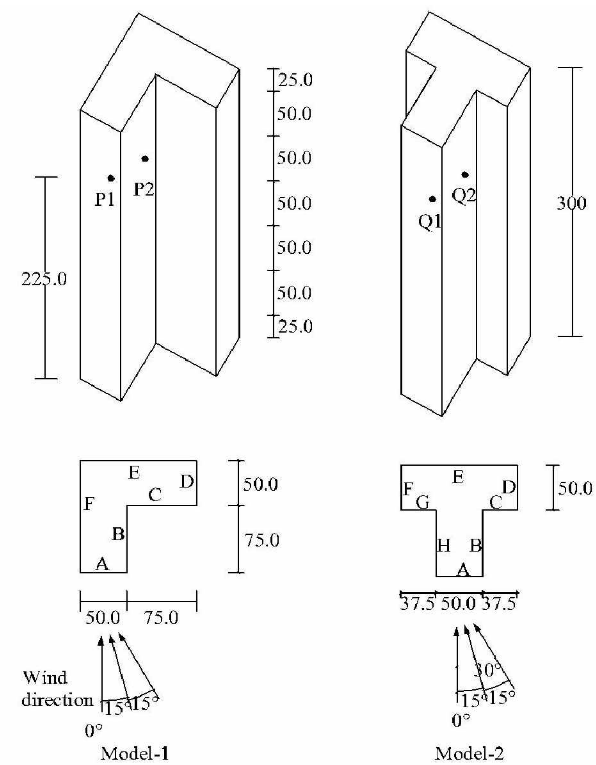

Fig. 1 Plan and isometric view of building models

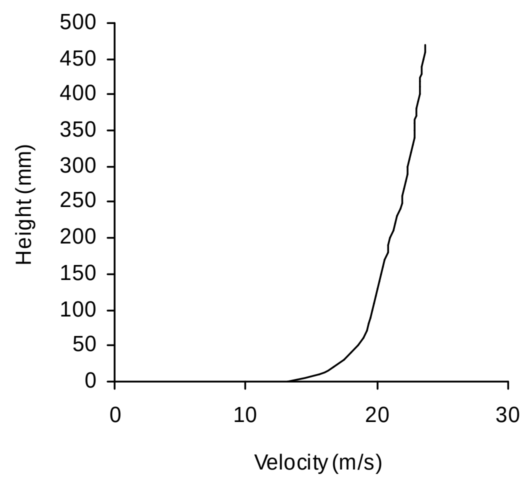

Fig. 2b Velocity profile at the test suction

3 RESULTS AND DISCUSSIONS

Mean, r.m.s., maximum and minimum pressure coefficients on all the surfaces of L-and T-shape building models are evaluated from the fluctuating wind pressure records at all pressure points over an extended range of wind incidence angle namely 0^0 to 180^0 at an interval of 15^0. This information is much useful while designing claddings and structural systems of this type of high-rise building for lateral load.

3.1 L-shape Building Model

The general characteristics and observed pressure distribution on different faces of L-shape building model are summarized as follows:

For wind incidence angle of 0^0, it is observed that the frontal face-A is subjected to positive pressure. However, wind pressure coefficients distribution does not remain symmetrical about the vertical centerline as in the case of rectangular/square bluff body. It increases from left edge to right edge (towards the re-entrant corner) of face-A. It is also observed that the positive mean pressure coefficient increases along the height on face-A of the building model due to increase in wind velocity with height and it varies from 0.35 to 1.00. Inner faces B and C are also subjected to pressure of almost uniform intensity. Although face-B is parallel to face-F, which is a side face, it is subjected to pressure and not suction due to blockage of flow by face-C, which causes stagnation of flow in that re-entrant corner. It is the peculiar characteristics of L-shape building. Side faces D and F are subjected to negative pressure, which increases slightly from windward to leeward edge due to separation of flow. The leeward face-E is subjected to suction but the variation of suction along the height as well as along the width is almost negligible.

As the angle of incident wind increases, a positive pressure on the frontal wall (face-A) reduces. However, higher positive pressure still exists on the re-entrant corner. At the skew wind incidence angles between 30^0 and 60^0 the portion of inner faces B and C towards the re-entrant corners attracts more wind pressures.

3.2 T-shape Building Model

The general characteristics and observed pressure distribution on different faces of T-shape building model are summarized as follows:
Since the flow is symmetrical about the central axis when the wind incidence angle is 0^0 (wind direction perpendicular to the face-A), the stagnation point is in the middle of the front face-A. It is observed that the frontal face-A is subjected to a positive pressure and value of mean pressure coefficients is observed to be increasing with height in the range of 0.6 to 1.1. It is also noticed that face-B and face-H of the T-shape model are subjected to negative pressures where as face-B of the L-shape model is subjected to positive pressures. The exterior edge of face-C is subjected to a positive wind pressures due to direct incidence of flow on that small area where as the portion towards the re-entrant corner of the face-c is still subjected to a suction. The pressure variation and magnitude of pressure coefficients on face-B is, thus largely affected by the length of face-C. The side face-D, face-F and leeward face-E are subjected to negative pressures, whereas the negative pressure coefficients on side face-D increases from windward to leeward edge. The leeward face-E is subjected to suction and the variation of suction along the height as well as along the width is almost negligible. It is also observed that the suction on the leeward and side faces of the building models are significantly affected by the ratio of the width of face-B and face-C.
For wind incidence angle of 105^0 and 120^0, the positive pressure still exists on face-B and face-C. This can be attributed to the direct incidence of flow on the face-B, after skipping over the opposing wing, with a consequent increase of the values.

4 CONCLUSIONS

The following conclusions are drawn from the study reported in this paper.

(i) The wind pressure distribution on the frontal face-A of the L-shape building is not symmetrical about centre line of face as in case of T-shape building.

(ii) As the angle of incidence wind increases beyond 120^0, the pressure field in the inner faces of the L-shape building turns out to be negative and almost uniformly distributed.

(iii) The wind pressure coefficients distribution on inner faces-B and C of both buildings largely depend on the plan-shape and dimension of the inner faces of the buildings.

(iv) Change in the plan-shape of buildings considerably affects the suction on side faces and leeward faces.

REFERENCES

[1] AS/NZS: 1170.2 (2002), *Structural Design Actions, Part-2: Wind Actions*, Australia/ New Zealand Standard, Sydney, Wellington.

[2] ASCE: 7-02 (2002) *Minimum Design Loads for Buildings and other Structures*, Structural Engineering Institute of the American Society of Civil Engineers, Reston.

[3] IS: 875 (part-3) (1987), *Code of Practice for the Design Loads (other than Earthquake) for Buildings and Structures*, B.I.S., New Delhi, India.