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Evaluation of wind pressure on low-rise building projections and surrounding terrain under the influence of tornado like flow

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SUMMARY:
Wind loading on buildings caused by straight line boundary layer winds has been thoroughly investigated in the past. The effects of vortex loading on structural projections will induce crosswind loads and torsional loads on low rise building which has severe dynamic resonant effect not only on the structural projections but also on over all structural elements of a building. These structural projections can be in the form of cantilever balconies, canopies, sunshades, overhangs, aesthetically projected elements. The purpose of each of these projections is different and designed to suit the convenience of habitats. During the tornado, the damage of projections becomes flying debris due to the fatigue effect of fluctuating pressure. In the present study, a model of low-rise buildings is tested under the influence of tornado-induced vortexes. Models were tested for F3 – F4 tornado for the wind speed 60m/s to 90m/s. Tornadoes of vortex core diameter 0.46 m to 1.06 m In a smooth open terrain, simulations were carried out. A prototype of model of building in a scale of 1:400, actual dimensions of building is 20m x 20m x 10 m; the prototype model is prepared using flexi glass. An arrangement is made to study the effect of building on the ground terrain in surrounding region of building. Model was provided with pressure tapping to measure the surface pressure on all the walls and roof.

Keywords: Tornado Simulator, Low rise building, Attached canopy

1. INTRODUCTION

Tornado events have caused insurance losses and as many as lives. Despite the high expense and destruction caused by tornadoes, the body of information about tornadoes has evolved steadily. This is since tornadoes are short-lived, it is difficult to forecast where and where they will strike, and it is difficult to obtain real-time wind speed and pressure data in tornadoes.

Much of the analysis of tornado vortices has been reduced to experimental simulators and numerical models. Tornadoes -like vortices simulated in labs have been attempted to measure tornado characteristics based on experiments, but there have been little attempts at quantifying the load caused by swirling tornado winds in low-control buildings as force and pressure coefficients. The tornadoes' flow structure depends on the relation between the tangential and the radial flows in the vortex. The ratio of angular momentum of the swirling flow to radial inflow into the vortex, which is known as the swirl ratio, is defined at a given radial distance. In the past, the swirl ratio (S) has been the most often used parameter to classify simulated tornadoes flow structure.

The effects of vortex loading on structural projections will induce crosswind loads and torsional loads on low rise building which has severe dynamic resonant effect not only on the structural projections but also on over all structural elements of a building. These structural projections can be in the form of cantilever balconies, canopies, sunshades, overhangs, aesthetically projected elements. The purpose of each of these projections is different and designed to suit the convenience of habitats.

The available information in these wind design codes are very limited and based on researches carried out in wind tunnels without the consideration of tornado attacks. In the situation of tornadoes, the suggested design parameters may not be sufficient for safe design of such projections. Therefore, it is necessary to carry out study on buildings with structural projections under the effect of vortex aerodynamic loading generated using tornado simulator

2. EXPERIMENTAL DETAILS

The building model was tested under the simulated tornado like wind flow of tornado simulator of Tokyo Polytechnic University, Japan. Before the placement of the model on the ground, pressure is measured on the ground for 80 m x 80m area. This study was carried out to understand the behavior of tornado like flow on the bare ground. For this measurement of pressure on bare ground, tornado position was also changed in longitudinal and later direction by 10 m, 20 m and 30 m. laterally, model of building was fixed on the ground and pressure on building as well as ground was measured. The measurement of pressures was also carried out with the different position of tornado flow. Figure -1 shows the different measurement of model and bare ground with different position of tornado flow.

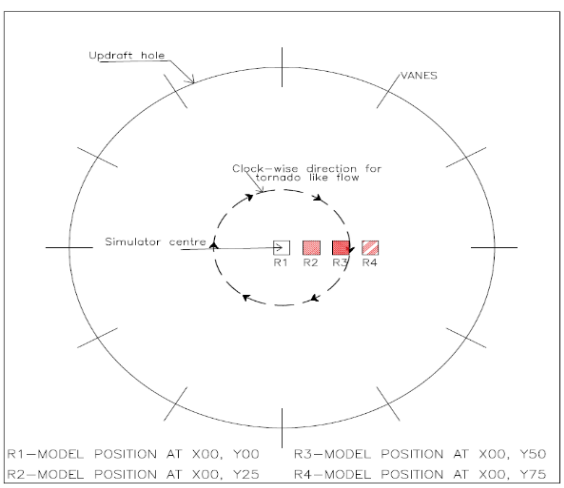

Figure 1. Building Model position on simulator floor

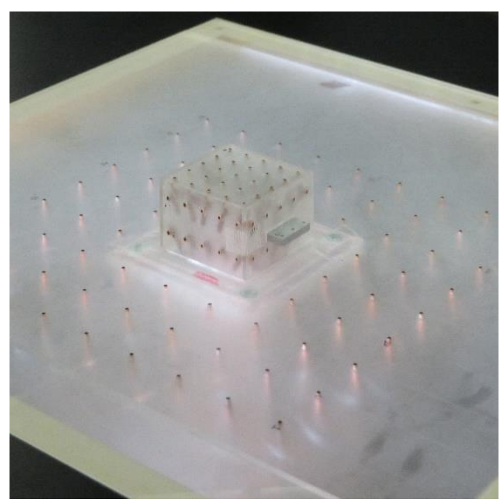

Figure 2. Building prototype and its surroundings

2.1 Model Dimensions

It was proposed to conduct surface pressure measurement on the models of flat roof building under the influence of tornado vortex. The prototype was small industrial building with flat roof having dimensions L = 20 m, B= 20 m and height H= 10 m. To understand the behavior of tornado like flow induced pressure on the ground and the surrounding to the building, a square area of 80 m x 80 m with pressure tapping points is considered Figure 2 depicts this.

2.2 Model Scale

Models were prepared as geometric similar model of prototype on a scale of 1:400 by flexi-glass sheet to conduct the tests. No. of pressure tapping were provided at all the walls and roof surface of model for measuring the pressures. Similarly, surrounding ground model was prepared with the same material and number of pressure tapping was provided. The measured pressures were presented in the form of external pressure coefficients and compared with available data in wind design codes or presented by other researchers.

2.3 Detail of Pressure Points

The pressure on building and surrounding ground was measured with the help of pressure tapping provided on the surfaces. Pressure taping was provided with a copper tube of internal diameter 1 mm and external diameter as 1.4 mm. These copper tubes were further connected to PVC tubing of 1 m length which was further connected to pressure measuring instrument.

Table 1. Number of pressure points provided on different surfaces

Structural Element	Pressure points	Remarks
Flat roof	25	
Sides (4 sides)	40	10 points on each side
Canopy of length 8m (model length 20mm)	6	3 Top and 3 Bottom
Canopy of length 12m (model length 30mm)	8	4 Top and 4 Bottom

3. EXPERIMENTAL SETUP

3.1 Tornado Simulator

A translating tornado-like flow simulator, as shown in Figure 3, was used for the current analysis. It depicts an updraft system fitted with an axial flow fan, which converts surrounding air into the confluence area, where it converges collectively at the vortex's center before ascending. There is a honeycomb structure in the convection zone.

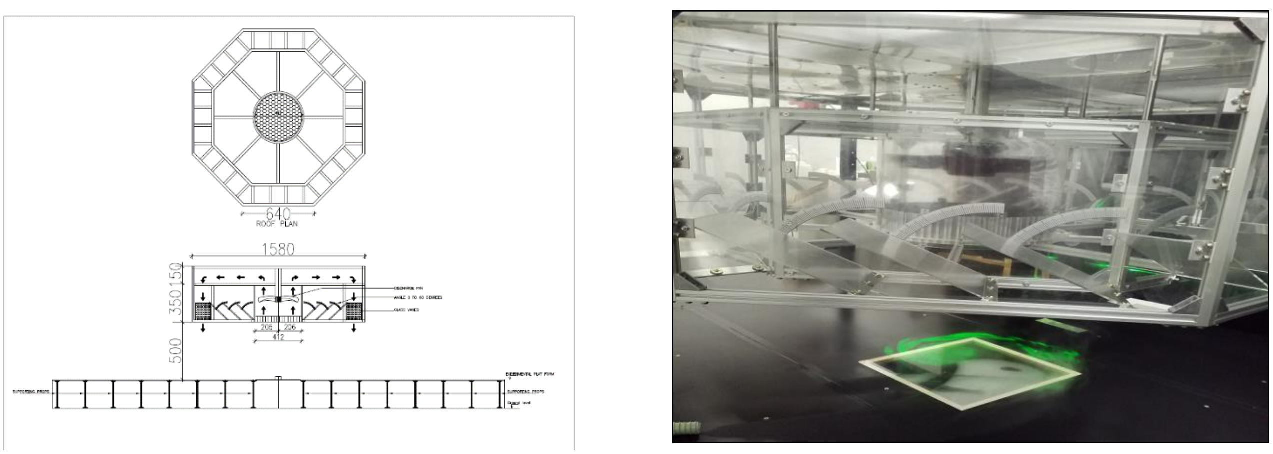

Figure 3. Tornado-like flow simulator at Tokyo Polytechnic University, JapaN

3.2 Velocity Measurement System

In order to quantify the vortex properties such as a tornado generated by the tornado simulator, PIV tests are taken before models are put on the ground level. While instantaneous PIV measurements indicate that, a tornado-like vortex is more turbulent as vortex size increases, a sequence of instantaneous PIV measurements in the cinema show that a tornado-like vortex is more turbulent as vortex size increases. - The study portrays vortex activity, such as general tornadoes, based on time-to-average results of PIV measurements from one system to the next. PIV results of time-averaged data are used to demonstrate the three-dimensional mechanisms of vortex flow, such as tornadoes.

4. CONCLUSION

i. Pressure on simulator terrain floor captured the nature and distribution of pressure coefficient under tornado like flow, with the central core registering higher pressure suction compared to the periphery of terrain.
ii. The tornado pressure on terrain is not affected significantly by the presence of the building
iii. Roof experienced higher pressure coefficient compering with the walls.
iv. Anti-symmetry was observed in pressure distribution on opposite sides.
v. Roof center experience lesser pressure coefficients compared with the roof edges when the tornado is center of model.
vi. The pressure of the roof core increases as the tornado moves out of the building model core.
vii. Maximum pressure coefficient on roof experienced when tornado is 30m away from the center of building.
viii. Maximum negative pressure coefficient is on the upper surface of canopy and maximum negative pressure coefficient is absorbed at 10 degree slope and 20 degree slope.
ix. Maximum positive pressure coefficient is on the upper surface of canopy and increases with the increase of slope

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