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Benchmark studies on a building model exposed to tornado-like flow in three different simulators

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SUMMARY:
Tornadoes are extreme wind phenomenon which cause damage to life and property globally. In the past researchers have attempted to address the issue of tornado-structure interaction, through laboratory studies by exposing scaled building models to tornado-like flow generated in simulators. It is noted that the results thus obtained depend on the type of simulator employed. There have been different types of simulators developed over the years. Scaled building models are exposed to these simulators to capture the external and internal pressure to determine the wind load acting on these structures when exposed to tornado-like flow. The present investigation is part of an effort to benchmark the results obtained by exposing the same building model to different types of tornado-simulators worldwide- namely the ISU (Iowa State University Simulator, TPU (Tokyo Polytechnic University) Simulator and Tongji University Simulator.

Keywords: Tornado -like flow, tornado-simulator, pressure coefficient, wind loads

1. GENERAL INSTRUCTIONS

Tornadoes are the deadliest among all wind phenomenon causing havoc to life and property. Every year world over there are many tornadoes reported resulting in loss of life, crops and building structures. Many early studies on tornadoes and its effects on structures were restricted to post-tornado damage surveys. Further with development of tornado-like flow simulators, scaled building models were exposed to tornado-like flow and the wind loads were estimated. The earlier tornado-simulators were stationary in nature in the sense that the translational effects of tornado-like flow couldn't be simulated. Further in the last decade the tornado-like flow with combined translational and rotational nature could be simulated, which could better mimic the nature of actual tornadoes on the ground. More recently computational fluid dynamic studies are also being undertaken to investigate the effect of the tornado like flow on building structures. It has been observed that there is a requirement to benchmark the wind loads estimated between different simulators world-wide. Protocol for conducting wind tunnel model tests in boundary-layer wind tunnels for assessing wind loads on civil structures subject to straight-line wind is well established. However, this cannot be asserted for assessing tornado-induced wind loads on civil structures

using laboratory tornado simulators because the protocol for specifying the tornado parameters, model test specifications and wind loads vary between laboratory facilities making it difficult to make a comparison between data sets and assess their accuracy. The accuracy of the laboratory data sets cannot be ascertained because the selection of the simulated tornado parameters, methodology to simulate the tornado and collect data, and selection of model scales because of simulator size, vary between different studies.

The comparison between wind loads obtained through different tornado simulators is quite challenging considering the fact that there are wide differences in the definition of governing parameters of a tornado-like flow such as swirl ratio, aspect ratio etc. This necessitates further study to agree on common platforms and parameters under which the study needs to be performed for better agreement on the results.

As part of the proposed benchmark study, it is proposed to establish a benchmark between the wind loads assessed using different simulators with a common understanding between acceptable parameters used for characterizing the tornado flow such as aspect ratio, definition of swirl ratio, building size, etc. Keeping these parameters in an agreeable range between the simulators, the tornado induced wind loads will be determined and compared.

This benchmark study will be the first of its kind that aims at studying the following aspects related to assessing tornado-induced wind loads on low-rise buildings based on laboratory model studies using tornado simulators: (a) formulate specifications for laboratory tornado simulation and model tests, (b) compare the wind flow field of the simulations and wind pressures/loads data of a low-rise building model between laboratories to help formulate guidelines for future laboratory-based studies.

1.1. Experimental Setup

The tornado-simulators used in the three participating universities are described below.

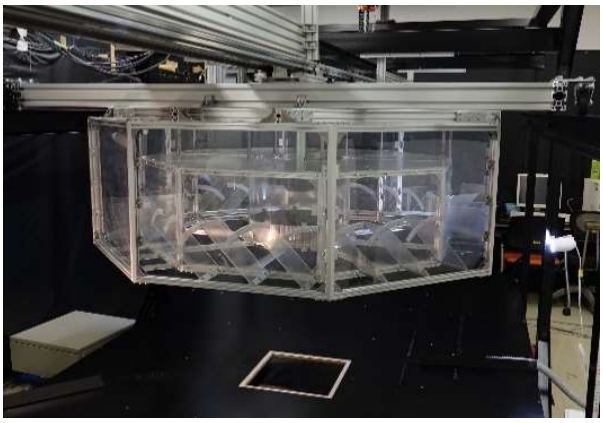


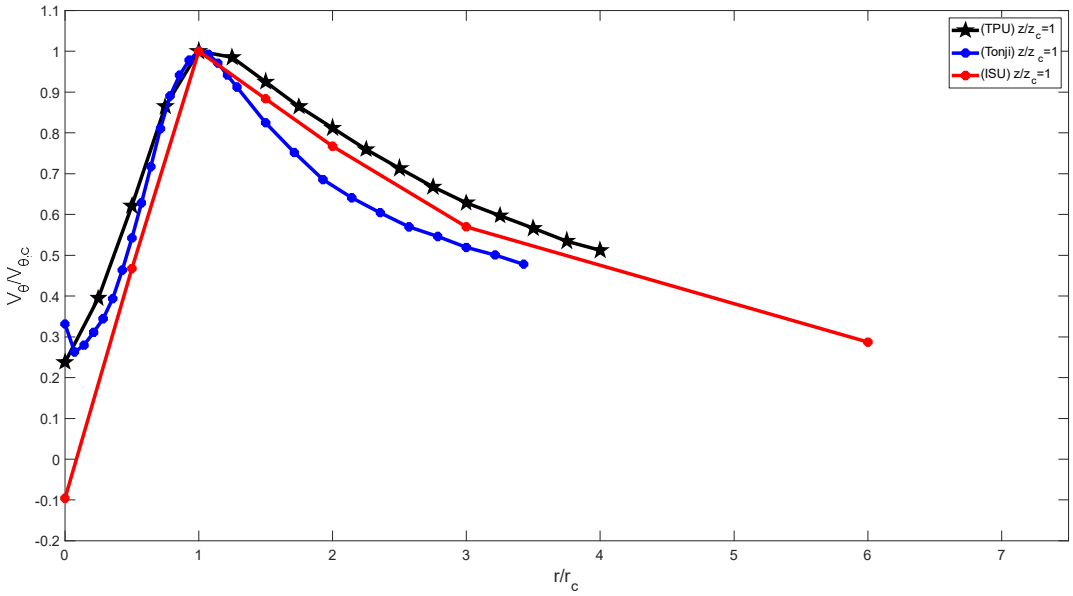
Figure 1. Tornado like-flow simulators at (a) TPU (b) Tongji (c) ISU

All the three simulators used can generate tornado-like flow with both rotational and translational component. The characteristics of tornado-like flow generated are as listed in Table.1.

Simulated-Tornado Parameters	ISU	TPU	Tongji University
Terrain	Smooth	Smooth	Smooth
Tornado Type	Two-celled	Two-celled	Two-Celled
Core radius, r_c	0.41m	0.1m	0.07m
Elevation, z_c	0.03 m	0.01	0.015 m
Vane Angle, θ_v	45^0	60deg	50deg
Tornado Translation Speed, V_t	0.3 m/s	0.25 m/s	0.4 m/s
Radial Reynolds Number, Re_r	2.03×10^5	3×10^4	Approximate 1×10^5

Comparison of other parameters will be presented in the full paper.

The tangential flow velocity obtained at specific height above simulator floor were compared between the different simulator and is as shown in Figure. 2.
External pressure on building model exposed to tornado like flow were estimated at different locations with respect to the tornado core. The angle of attack was varied to have different faces exposed to tornado like flow. Two such cases were analyzed in the present study AOA=0 deg and AOA =90 deg . Force coefficients were estimated for three mutually perpendicular directions.



The full paper will discuss further on the comparison of wind loads obtained in these three simulators.

Conclusions

The different force coefficients were compared between the three simulators namely- Iowa State University(ISU), Tongji University (TPU) and Tokyo Polytechnic University (TPU) . It was observed that the trend in force coefficients followed a behavior akin with the core radius size of the tornado-like flow. Further results will be submitted in the full length paper.

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