Wind Engineering Joint Usage/Research Center
FY2019 Research Result Report

Research Field: Wind Hazard Mitigation/Wind Resistant design
Research Year: FY2019
Research Number: 19192001
Research Theme: Researches on tornado flow characteristics and their effects on wind loadings

Representative Researcher: Dr. Sabareesh Geetha Rajasekharan

Budget [FY2019]: 400000JPY Yen + Tornado simulator, 10 days (estimated facility cost 1000000JPY: 100000JPY/day x 10 days*2)

There is no limitation of the number of pages of this report.
*Figures can be included to the report and they can also be colored.
*Submitted reports will be uploaded to the JURC Homepage.

1. Research Aim

The present research is part of a global initiative in benchmarking the tornado induced wind loads obtained using different tornado-simulators world-wide. Considering the unpredictability and danger associated with tornado, real time studies on tornadoes are very rare. In the past researchers have attempted to simulate tornado-like flow in a laboratory using tornado-like flow simulators. But these tornado simulators were distinct in its types and constructional features.

The comparison between wind loads obtained through different 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 study it is believed to establish a benchmark between the wind loads calculated using different simulators with a common understanding between world-wide 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.

2. Research Method

The methodology involves, constructing a scaled building model with pressure taps on the roof and walls. Exposing it to a translating tornado and measuring the fluctuating pressures and velocity using cobra probes/hot wire anemometers. Varying the parameters such as swirl ratio, aspect ratio, building size ratios and obtaining the time varying pressures. Further in post processing pressure coefficients will be calculated and compared with identical cases obtained under identical conditions in other simulators.

The results obtained through these studies will provide greater insight into simulating tornado-induced wind loads using tornado-simulators and extending it to understand the real time wind loads acting on structures under an actual tornado.

3. Research Result

As part of the benchmarking between different simulators, a set of parameters were identified and the broad range of agreement between different simulators required was agreed upon between the participating researchers. The table -1 shows the achieved values when compared to the broad range of values agreed and proposed by the participating laboratories.

Table:1 Comparison of Proposed Simulated-Tornado Parameters with actual values obtained at TPU, Japan

Simulated-Tornado Parameters	Proposed	Actual
Terrain	Smooth	Smooth
Tornado Type	Two-celled	Single-celled
Core radius, r_c	0.10 to 0.50 m	0.1 m
Elevation, z_c	0.01-0.15m	0.01 m
Vane Angle, θ_v	45^0-60^0	60^0
Maximum Horizontal Wind Speed, V_H at z_c	5-12.5m/s	7.2 m/s
Tornado Translation Speed, V_t	0.25 to 0.50 m/s	0.25 m/s
Radial Reynolds Number, Re_r	> 2 x 10^4	3 x 10^4

Target Field Tornado Parameters		
Core radius of EF3 tornado	45-225 m	
Maximum horizontal velocity (EF3)	50 m/s (mean hourly) or 73.8 m/s (3-sec gust)	
Translation speed	2-5 m/s	
Similarities	**Proposed**	**Actual**
Length scale, λ_L	1:100 to 1:450	1 : 223.3
Velocity scale, λ_v	1:4 to 1:10	1 : 10.25
Time scale, λ_t	1:10 to 1:100	1 : 21.78
Frequency scale, λ_f	10:1 to 100:1	21.78 : 1
Swirl Ratio (S_c)	>0.20	Yet to be calculated
Swirl Ratio (S_{vane})	>0.50	0. 54
Swirl Ratio (S_{local})	>0.10	Yet to be calculated

The translating tornado-like flow simulator at TPU is shown in Figure.1

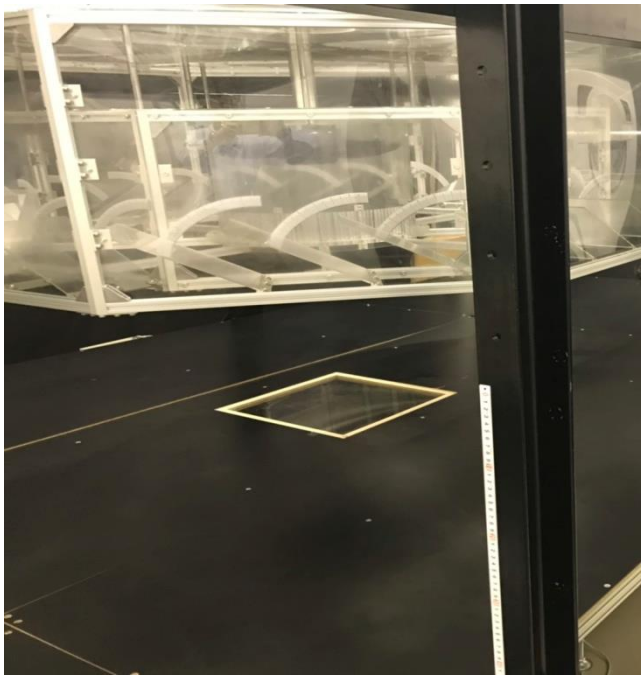

Figure:1 Tornado-like flow simulator at TPU

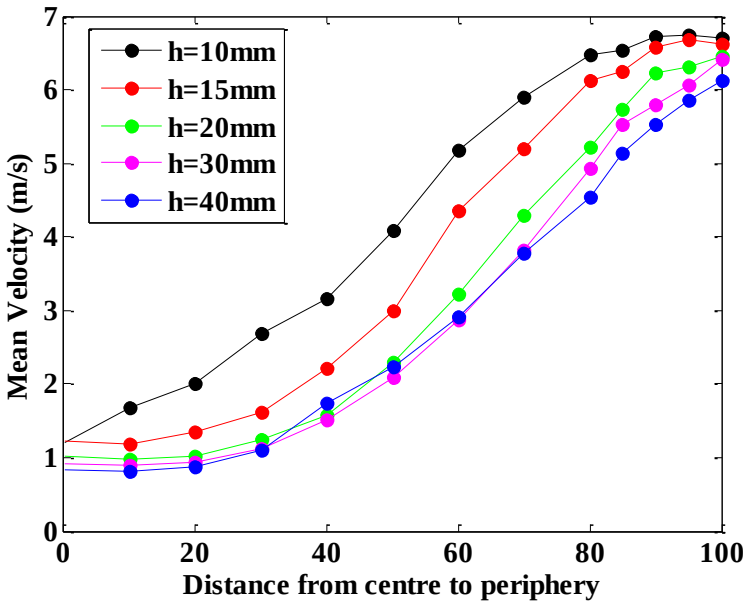

Figure:2 Mean Velocity vs distance from centre of periphery of tornado simulator

A rectangular building model of length scale 1: 223 instrumented with pressure taps was used for determining the pressure coefficients. The same is plotted for different locations of building model as contour plots on the exploded face of the building model Few contour plots at selected locations are shown. " rc" refers the location of core radius

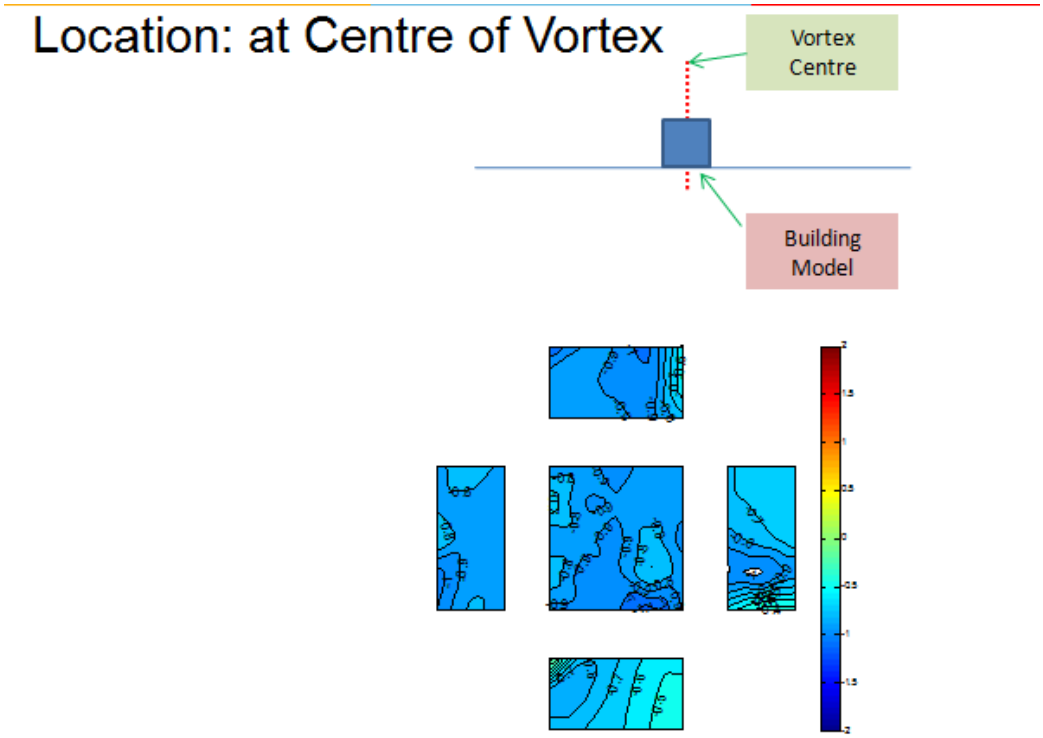

Figure:3 Mean Pressure Coefficients as building model is located at vortex centre

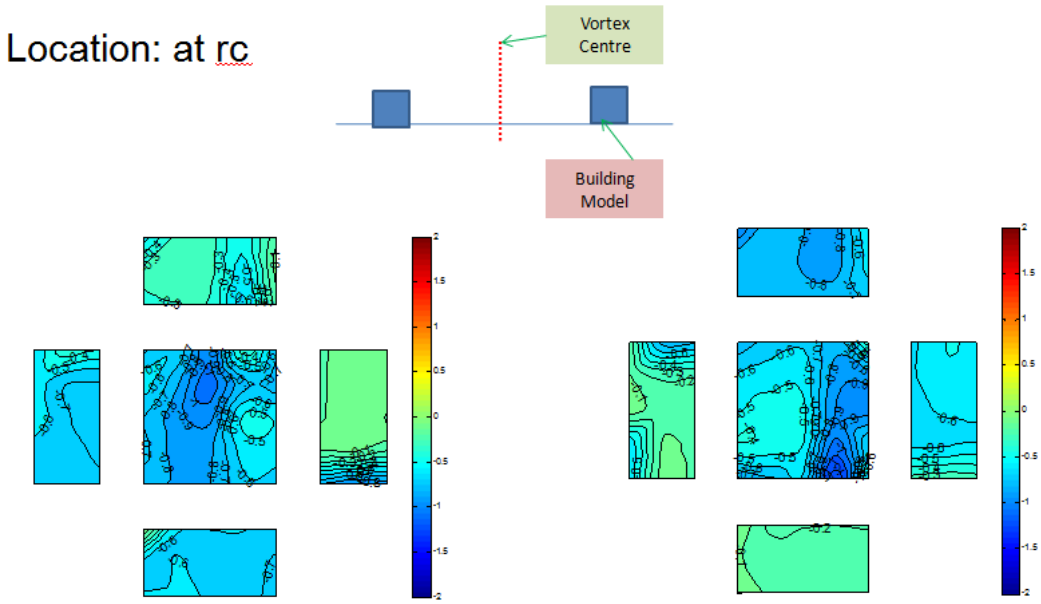

Figure:4 Mean Pressure Coefficients as building model is located at core radius

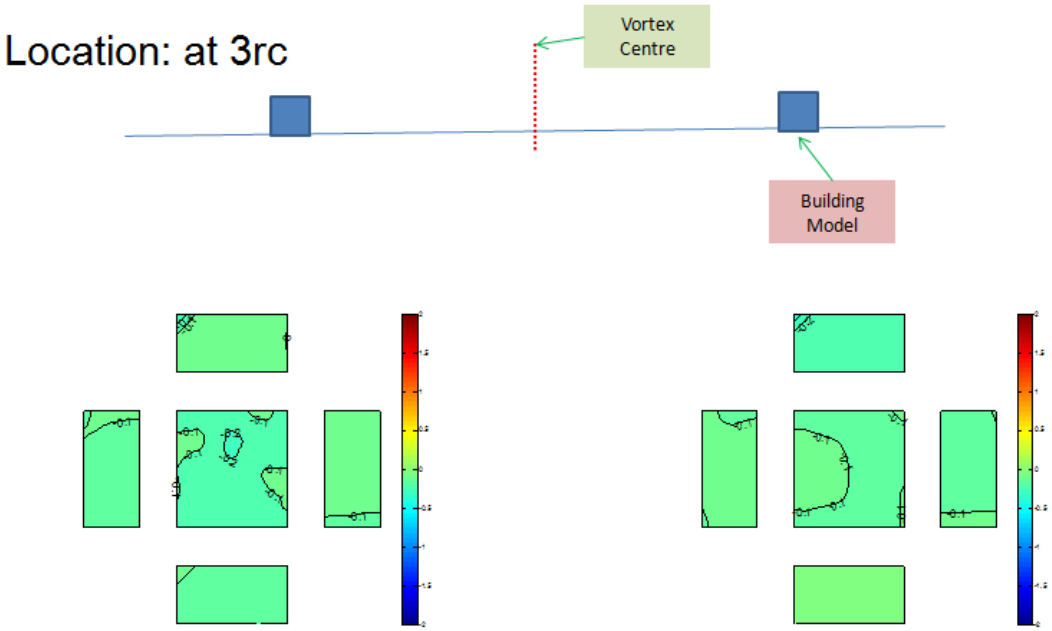

Figure:4 Mean Pressure Coefficients as building model is located at three times core radius

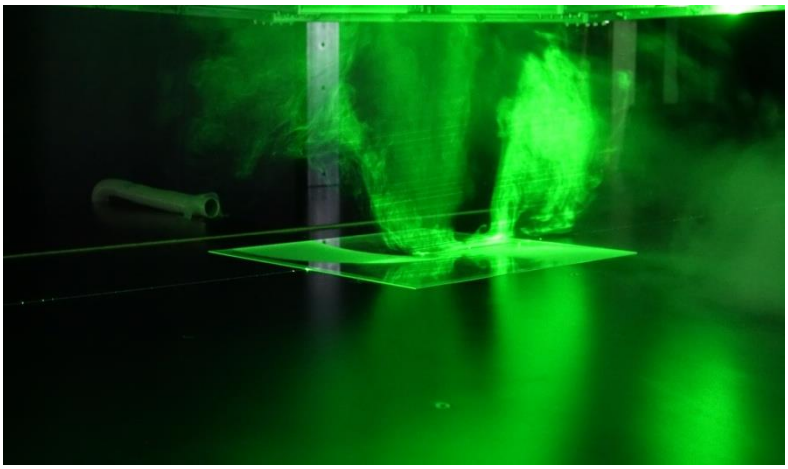

Figure:5 Flow Visualization Studies on tornado-like flow

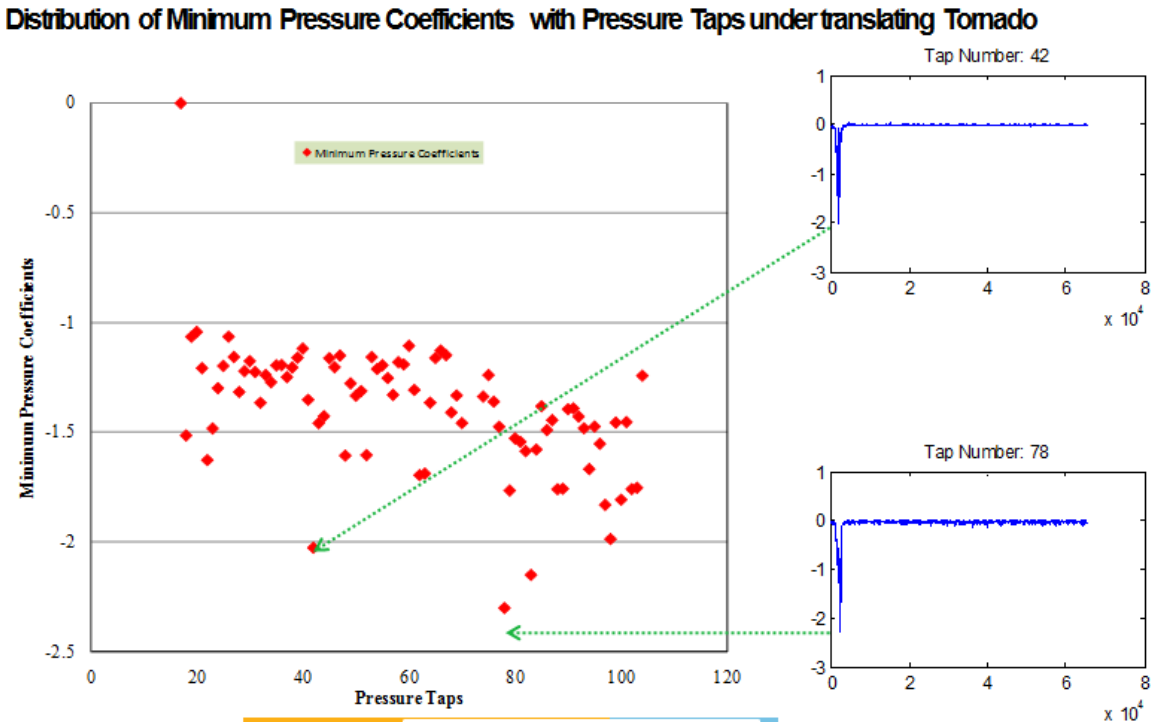

Figure:6 Minimum pressure coefficients on surface of building model under translating tornado

Summary of the research

- Flow field in the TPU Simulator was characterised
- Mean Velocity and Turbulence Intensity variation were determined
- Pressure Coefficients on Cube Model of Building was obtained.
- Similar studies using TTU Building model is being performed at Tongji University and Iowa State University
- Results from these simulators will be compared

4. Published Paper etc.
[Underline the representative researcher and collaborate researchers]

[Published papers]
1. Nil
2.

[Presentations at academic societies]
1. Nil
2.

[Published books]
1. Nil
2.

[Other]
Intellectual property rights, Homepage etc.

5. Research Group

1. Representative Researcher: Dr.Sabareesh Geetha Rajasekharan

2. Collaborate Researchers

1. 1. Prof. Yukio Tamura (Co-Researcher) Professor, School of Civil Engineering, Chongqing University No.83 North St., Shapingba District, Chongqing, CHINA / Program Coordinator, Wind Engineering JURC, Tokyo Polytechnic University, Atsugi, Kanagawa, JAPAN
2. **Prof. Masahiro Matsui, (TPU/WERC member, PI),** Professor, Wind Engineering Research Center, JURC Programme, Tokyo Polytechnic University, Atsugi, Kanagawa, JAPAN Tokyo Polytechnic University
3. Prof. Akihito Yoshida (TPU/WERC member**)** Professor, Wind Engineering Research Center, Tokyo Polytechnic University, Atsugi, Kanagawa, JAPAN Tokyo Polytechnic University
4. Prof. Yongchul Kim, (TPU/WERC member) Professor, Wind Engineering Research Center, Tokyo Polytechnic University, Atsugi, Kanagawa, JAPAN Tokyo Polytechnic University
5. Prof.Partha.P.Sarkar (Co-Researcher), Professor, Iowa State University, Department of Aerospace Engineering United States
6. Prof.Shuyang Cao (Co-Researcher), Professor, State Key Laboratory for Disaster Risk Reduction, Tongji University, China

6. Abstract (half page)

Research Theme: **Researches on tornado flow characteristics and their effects on wind loadings**

Representative Researcher (Affiliation): Dr Sabareesh Geetha Rajasekharan (BITS-Pilani, Hyderabad Campus)

Experiments were conducted by exposing a rectangular building model to a tornado -like flow simulator at Tokyo Polytechnic University and velocity field was characterized. Pressure coefficients were obtained on the surface of these models at different locations with respect to the tornado vortex. Also peak minimum pressure coefficients on building model when exposed to translating tornado -like flow was also obtained. The same will be benchmarked with results of identical cases obtained from ISU, USA and Tongji University, China results. Figure.1 shows the flow visualization depicting tornado-like flow and Fig.2 depicts the pressure coefficients on the building model when placed at same location on both sides of the vortex.

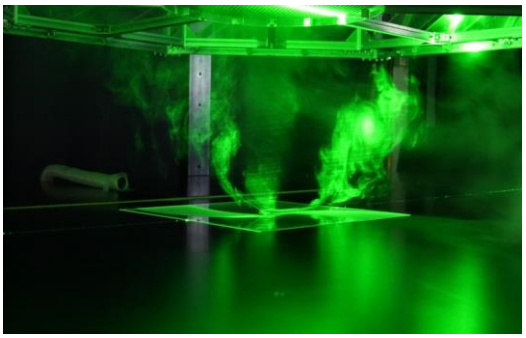

Fig.1 Flow Visualization of tornado-like vortex

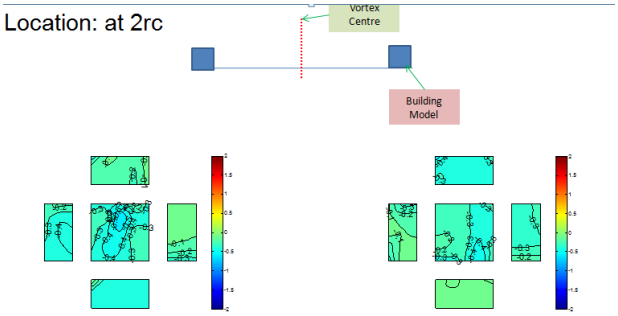

Fig.2. Pressure coefficients on exploded face of building model