Wind Engineering Joint Usage/Research Center
FY2020 Research Result Report

Research Field: Wind Hazard Mitigation/Wind Resistant design
Research Year: FY2020
Research Number: 20202003
Research Theme: “DETERMINATION OF WIND LOADS ACTING ON DIFFERENT STANDARD BUILDING MODELS AND COMPARISON WITH IDENTICAL SCENARIOS OBTAINED USING RESULTS FROM OTHER TORNADO SIMULATORS”
Representative Researcher: Dr. Sabareesh Geetha Rajasekharan

Budget [FY2020]: 550000JPY (including 100000JPY as a travel budget*1)
Facility you use: Tornado simulator, 20 days (estimated facility cost 2000000JPY: 100000JPY/day x 20 days*2) Yen

(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.

2. Research Method

The present research aims at comparison of external pressures experienced by building models exposed to tornado-like flow simulators placed at different simulators world wide. As a first step, the external pressures on an exploded face of a building model were presented in the FY 2019-20 results. Further to the same, the pressures on another scaled model which has dimensions scaled from the Texas Tech University (TTU) model which is considered in many benchmarking studies reported earlier were captured. Both Mean and RMS pressure coefficients were used. The same is defined in the present studies as below

- Pressure coefficients, C_{P_j} are defined as follows.
- $C_{P_j} = \frac{P_j - P_\infty}{q_H}$
- where
  - $P_j - P_\infty$: measured differential pressures between pressure tap location and ambient pressure far from the swirl -flow.
  - $q_H \left(= \frac{1}{2}\rho u_\theta^2\right)$: estimated dynamic pressure with maximum tangential wind speed u_θ and air density ρ.

In the present year , a comparison of the above mentioned models as shown below were made

Model-I

Rectangular Model: 50mm x 50 mm x 25mm

Figure: 1

Model-II (TTU Mode): 60mm x 40mm x 17.5mm

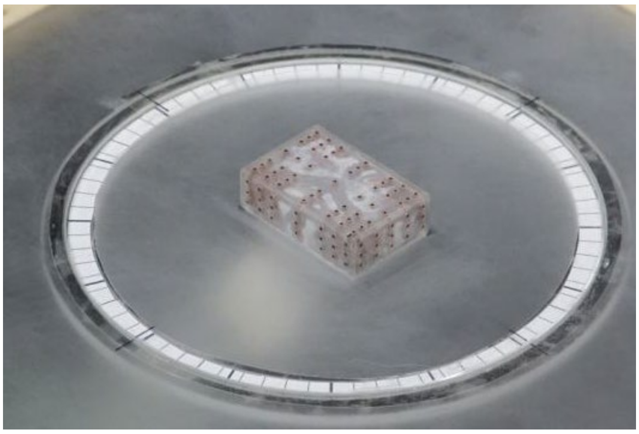

Figure: 2

The pressure coefficients were captured at different location from the tornado vortex. In the present scheme, the following locations were identified
centre of vortex, 0.5 rc, rc, 2rc, 3 rc, where rc refers to the radius of vortex.

Further the results from the flow field characterization of ISU and Tonji simulators were presented.

3. Research Result

Comparison of flow field characterized between different simulators

Simulated-Tornado Parameters	**Proposed (ISU)**	**TPU**	**Tongji University**
Terrain	Smooth	Smooth	Smooth
Tornado Type	Two-celled	Two-celled	Uncertain

Core radius, r_c	0.10 to 0.50 m	0.1m	0.045 to 0.065 m
Elevation, z_c	0.01-0.15 m	0.01	0.01 to 0.015 m
Vane Angle, θ_v	45^0-60^0	60deg	20^0 - 60^0
Tornado Translation Speed, V_t	0.25 to 0.50 m/s	0.25 m/s	Maximum 0.4 m/s
	> 1.5 x 10^5	3 x 10^4	Approximate 1 x 10^5

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 (ISU)	TPU	Tongji University
Length scale, λ_L	1:100 to 1:200	1:100 to 1:200	1:300
Velocity scale, λ_v	1:4 to 1:5	1:10.25	1:5
Time scale, λ_t	1:20 to 1:50	1:21.78	1:60
Frequency scale, λ_f	20:1 to 50:1	21.78:1	60:1
Swirl Ratio (S_c)	>0.20	0.28	Approximate 0.15 (60°)
Swirl Ratio (S_{vane})	>0.50	0.54	0.52 (40°), 0.74 (50°), 1.08 (60°)
Swirl Ratio (S_{local})	>0.05	0.34	Approximate 1
Aspect Ratio (a)	0.5-1.0	1.6	0.8
Local Aspect Ratio (a_c)	>5	2	Approximate 3

Given below are the comparison of results between two building models mentioned above(for selected cases)

(1)Location at centre of vortex- Mean Pressure Coefficients

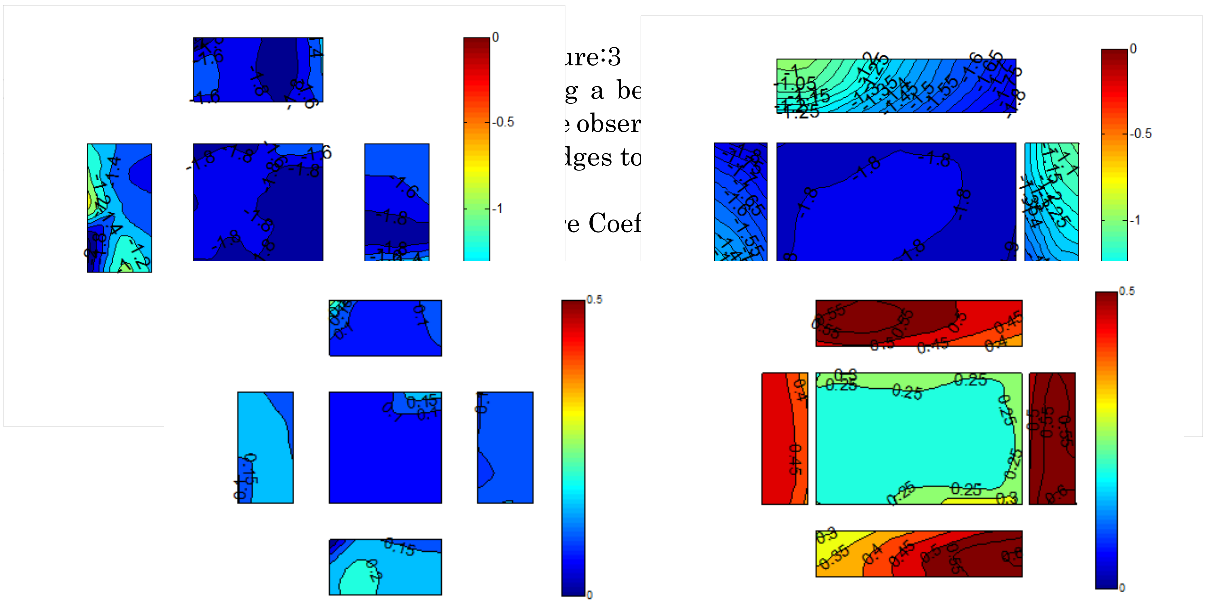

Figure: 4

The leading edges were experiencing higher fluctuations as seen from Figure 4, when the model was completely immersed in the vortex.

(3) Location at radius of maximum winds- Mean Pressure Coefficients

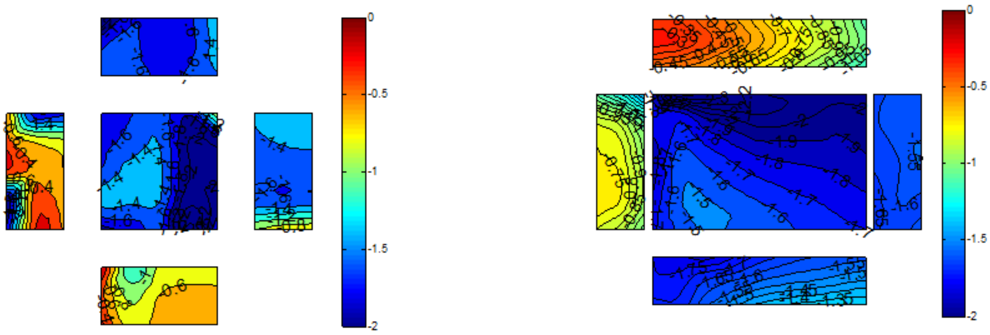

Figure:5

As the location of model shifts to the radius of maximum winds, the faces exposed to tornado vortex experiences higher negative pressures as can be seen from Figure 5.

(4) Location at radius of maximum winds- RMS Pressure Coefficients

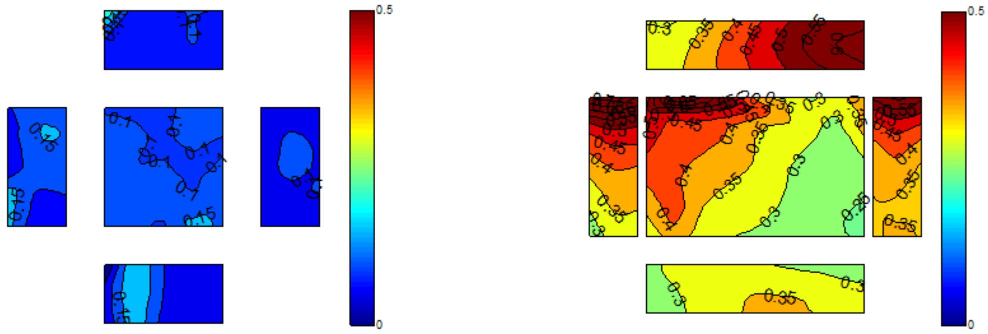

Figure: 6

The fluctuations were more predominant across the roof edges and building corners as can be seen from Figure 6.

(5) Mean pressures at location at three times the core radius

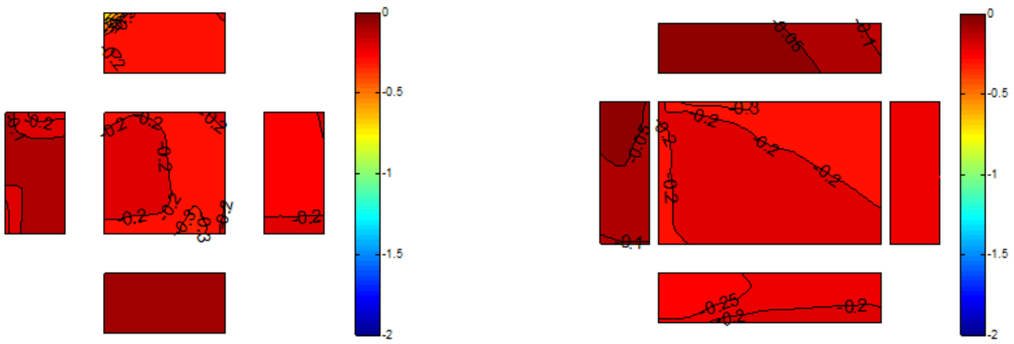

Figure:7

At locations far away from the vortex, the magnitude of pressure coefficients decrease on different faces as can be seen from Figure.7 where the effect of rotating flow is least experienced

(6) Instantaneous surface pressure variation

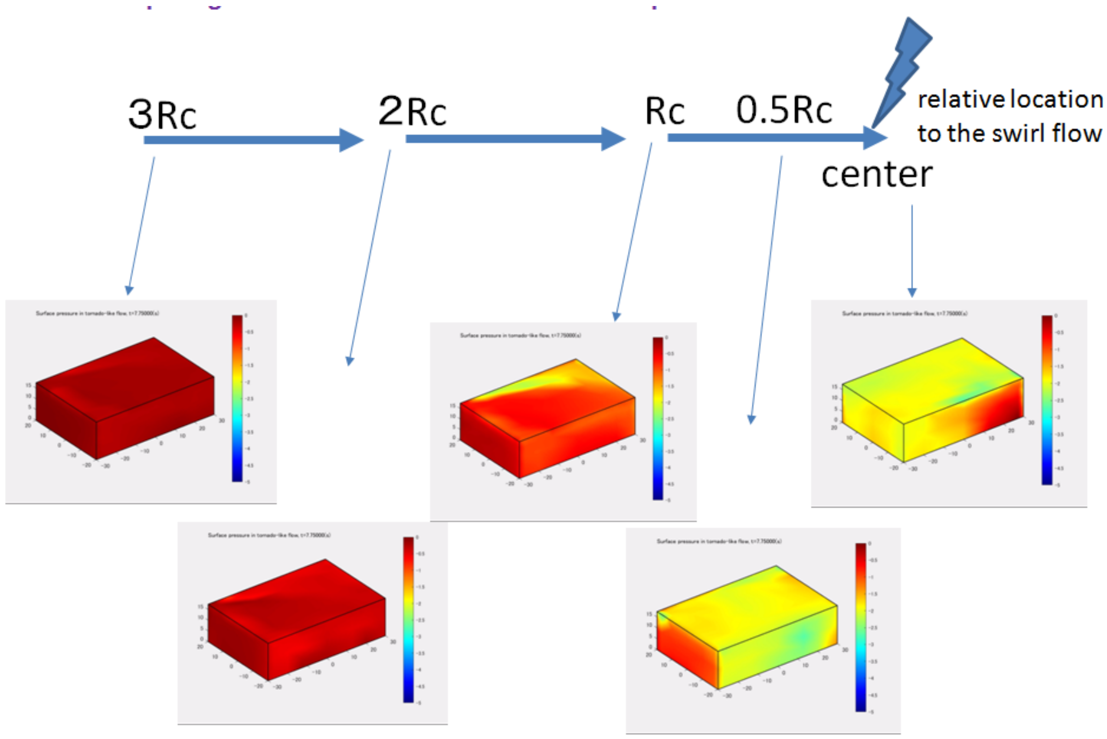

Figure: 8

Figure: 8 depicts the instantaneous pressure acting at different locations on surface of the rectangular model-II when exposed to tornado like vortex.

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

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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

Exposure of building models to tornado-like flows often proves fatal, resulting in massive destruction of property and structures. The effect of disasters can be minimized by understanding the nature of fluid-structure interactions which results when a tornado hits a building on its path. There are many simulators worldwide and there is a need to benchmark the results between the different simulators world wide. As a first step, through the present work two models were identified to understand the external pressure coefficients both mean as well as RMS values and instantaneous pressure on the building faces. Also the flow field in three simulators were characterized. The present report discusses on the comparison between pressure coefficients of two such models tested at Tokyo Polytechnic University Simulator. The results will be compared further with identical models tested using simulators at Tongji University, China and Iowa state University, USA. The results of these and findings from these will serve as a benchmark for parameters to be looked for while simulating tornado like flow in laboratory simulators.

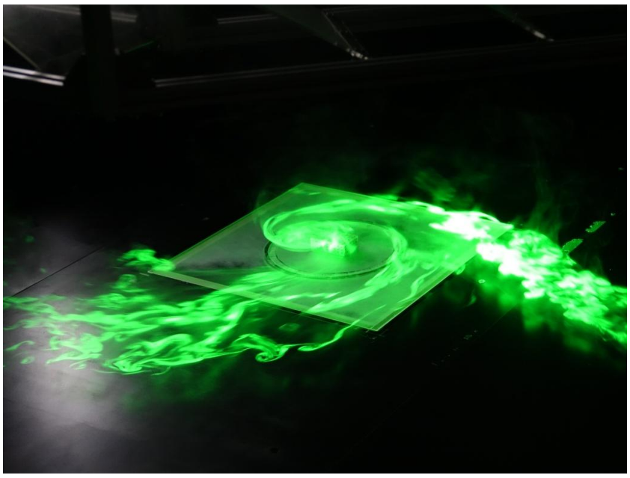

Figure: Flow visualization depicting tornado like flow in presence of building model