Wind Engineering Joint Usage/Research Center
FY2019 Research Result Report

Research Field: Wind Hazard Mitigation
Research Year: FY2019
Research Number: 19192005
Research Theme: Impact of Tornado Vortex Induced Aerodynamic Loads on Structural Projections in Low Rise Buildings

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Budget [FY2019]: Yen

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*Figures can be included to the report and they can also be colored.
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1) Aim of Research

a) To evaluate the damage of projections in low rise structure due to aerodynamic loads caused by tornadoes.

To enhance the wind pressure database of low-rise buildings with attached projections

2. Research Method

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 -2 shows the different measurement of model and bare ground with different position of tornado flow.

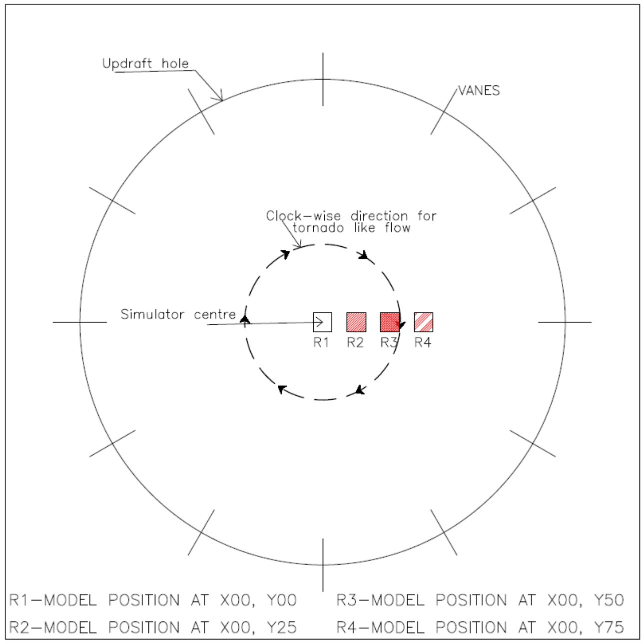

FIGURE 2 Building Model position on simulator floor

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 surrounding to the building, a square area of 80 m x 80 m was considered. Figure-3 shows the schematic diagram of prototype of building and surrounding ground.

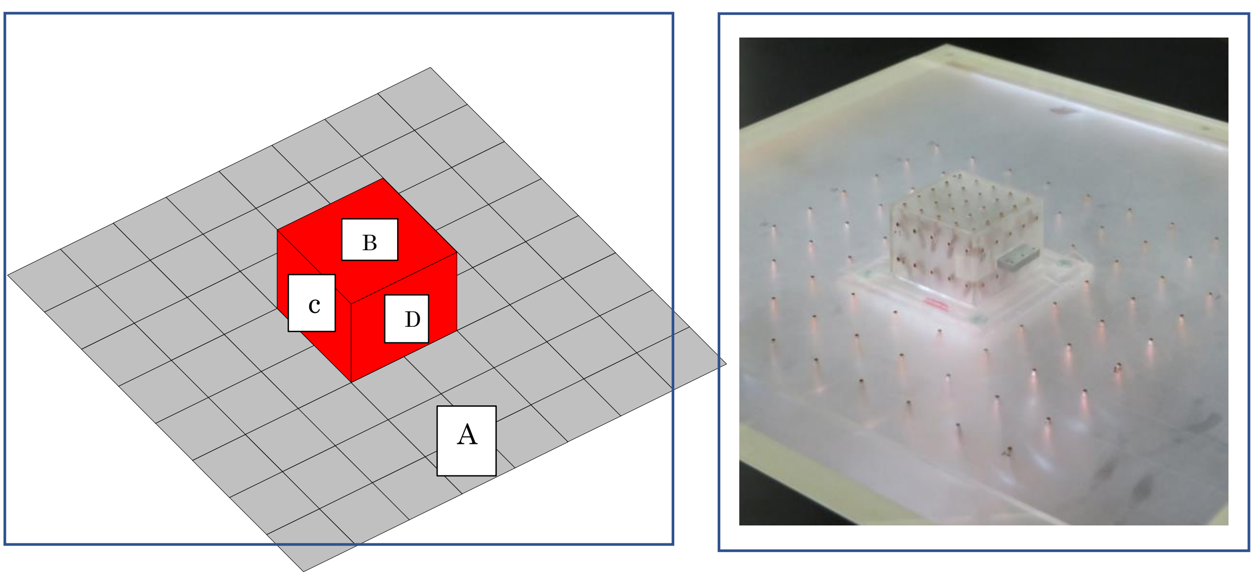

Figure-3 shows the schematic diagram of prototype of building and surrounding ground.

2.2 Model Scale

Models were prepared as geometric similar model of prototype on a scale of 1:400 refer to table -1 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.

Table -1 Model Size, Scale and Parameters of Canopy to be studied

Item	Prototype (m)	Model (mm)	Remarks
Length	20m	50mm	
Breadth	20m	50mm	
Height of building	10m	25mm	
Height Of canopy	5.00m	12.5mm,	
Width of canopy	3.6m	9mm	
Length of canopy	7.6m, 11.92m	19mm, 29.8mm	
Slope of canopy	0° - 30°		At an interval of 10°
F1 Tornado path width (core radii)	16–36 m	40mm -90mm	Actual F1 radius range from (16m to 50)

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-2 shows number of pressure points provided on different surfaces. Figure-4 shows the location of pressure points with their dimensions.

Table-2- shows number of pressure points provided on different surfaces

Structural Element	Number of pressure points	remarks
Flat roof	25	
Sides (4 sides)	40	10 points on each side
Canopy of length 7.6m (model length 19mm)	6	3 Top and

		3 Bottom
Canopy of length 11.92m (model length 29.8mm)	8	4 Top and 4 Bottom

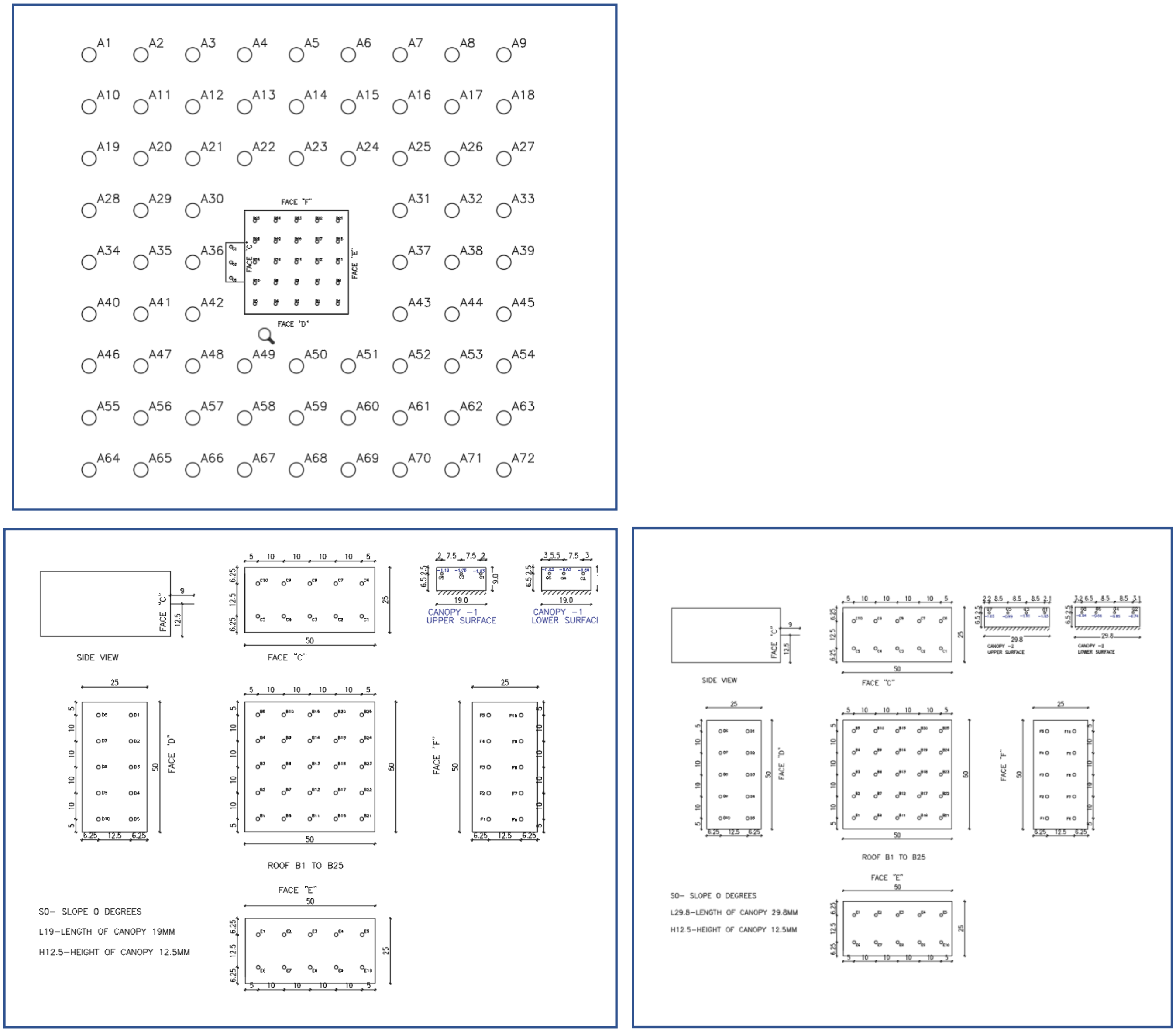

FIGURE 4 | Exploded view of the pressure points of base plate, model surface and canopy

3. Experimental Setup

3.1 Tornado Simulator

The experimental setup used for the present investigation comprises of a translating tornado-like flow simulator as shown in Figure 5. It comprises of an updraft system equipped with an axial flow fan capable of diverting the surrounding air into the confluence region, which gets converged together at the center of vortex before ascending up. Convection region houses a honey comb structure that removes the vortices as the flow ascends up. Updraft system has two layers which enables the flow that ascends up to return as a rear flank downdraft.

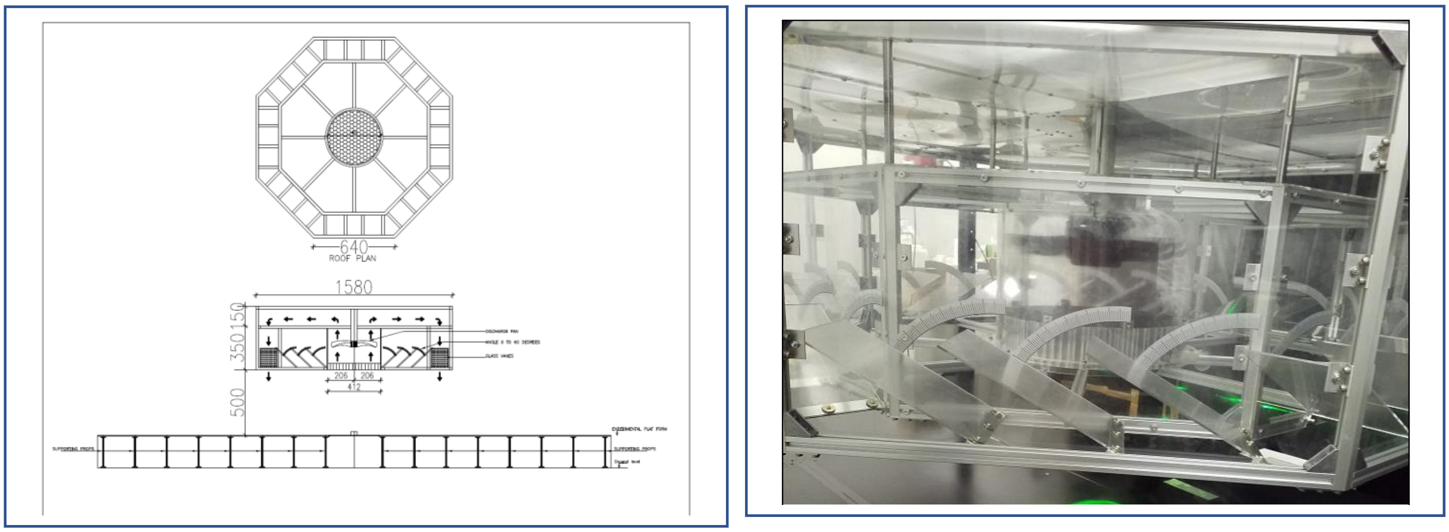

FIGURE 5| Translating tornado-like flow simulator at Tokyo Polytechnic University and schematic showing the dimensions

The outer diameter of the updraft system was 1,580 mm. The required angular momentum for the inflow is provided by the guide vanes at the periphery of the updraft system. The swirl ratio, which characterizes the strength of the generated vortices, is obtained as in Equation (1) Frequency of 50 Hz.

Swirl ratio $S = (R/2h) \tan \theta$ .... (1)

$\theta = 60$ degrees, $R = 206$mm, $h = 500$mm

$S = 0.36$ for the actual tornado conditions,

Radius of tornado = 1 to 3km,

Height of tornado 0.5km to 2km

Here, "θ" corresponds to the guide vane angle and h/R is the aspect ratio 2.42. "H" is the inflow height and "R" is the radius of updraft hole.

3.2 Velocity Measurement System

During the experiments, PIV measurements were conducted to quantify the characteristics of the tornado-like vortex generated by the tornado simulator before the building models were mounted on the ground plane. While the cinema sequence of instantaneous PIV measurement results revealed clearly that the tornado-like vortex are highly turbulent with varying vortex sizes and vortex center from one frame to another, time-averaged PIV measurement results were presented in the study to characterize the time-averaged behavior of the tornado-like vortex. The time averaged PIV measurement results (i.e., velocity distributions and the corresponding streamlines) to reveal the 3-D flow structures of the tornado-like vortex. Axisymmetric flow pattern in the form of a well-defined single counter-clockwise vortex structure can be seen clearly in the horizontal planes. The streamlines in the vertical plane passing the center of the time averaged vortex reveal clearly that air streams near the ground far away from the vortex center would flow towards the vortex core and turn upward abruptly before reaching the vortex core. It indicates a radial and upward vertical flow appearing in the region outside the vortex core, as it is expected. An interesting flow feature is seen in the vortex core region, where flow is found to be a downdraft jet impacting the ground. As the downdraft jet approaching the ground in the vortex core, it would move outwards radially and contact with the radial inflow from outside, both branches will join and move upward. See Table 3 for wind speed varying distance from center.

Table-3- Average operating Frequency

Frequency (Hz)	50 Hz										
Distance from Centre (M)	0	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
Wind speed (m/s	2.22	2.34	3.34	3.95	5.73	6.65	6.7	6.43	6.75	7.36	7.8
Flow rate Q (m3/s)	0.0007	0.00588	0.01679	0.02978	0.0576	0.08357	0.10103	0.11312	0.13572	0.16648	0.15526
Average upward flow velocity W (m/s)	6.49531										
Flow ratio	0.3148	0.3603	0.5142	0.6081	0.8822	1.0238	1.0315	0.9899	1.0392	1.1331	1.2009

Frequency (Hz)	10 Hz

Distance from Centre (M)	0	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
Wind speed (m/s	0.43	0.41	0.8	0.91	0.99	1.02	0.99	0.95	1.04	1.16	1.38
Flow rate Q (m3/s)	0.00014	0.00103	0.00402	0.00686	0.00995	0.01282	0.01493	0.01671	0.02091	0.02624	0.02747
Average upward flow velocity W (m/s)	1.05822										
Flow ratio	0.4063	0.3874	0.755	0.8599	0.9355	0.9639	0.9355	0.8977	0.9828	1.0962	1.3041

Um= 1.26m/s at height 15mm Vm = 7.735m/s

4. Research Results

To understand the building effects on the near-surface tornado flow field, it is important to first consider the flow field of the translating tornado on flat terrain, to form a basis for a comparison of the results of the tornado flow field over more complex topographies.

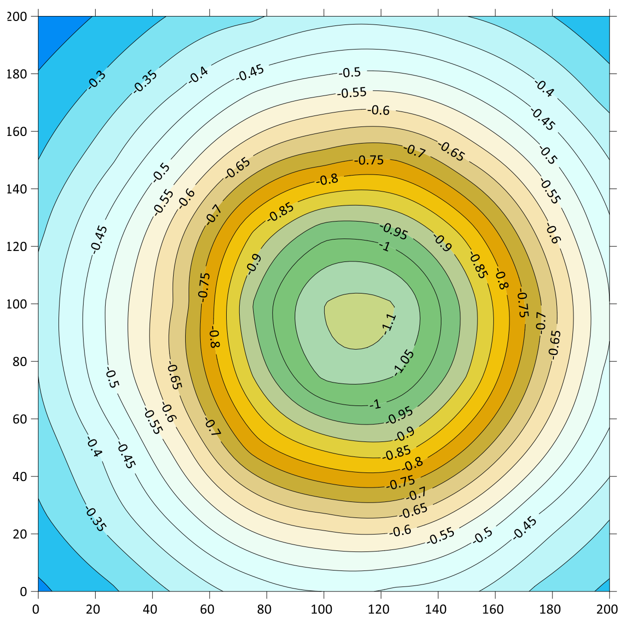

FIGURE 6| tornado at center

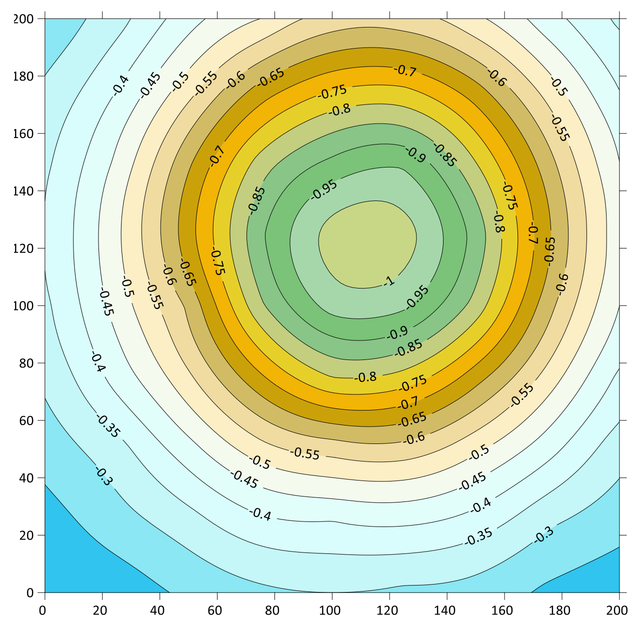

FIGURE 7| tornado at 10m

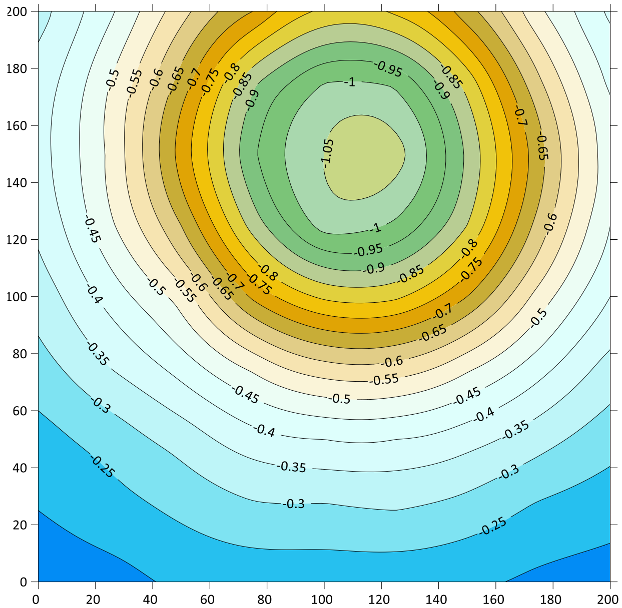

FIGURE 8| tornado at 20m

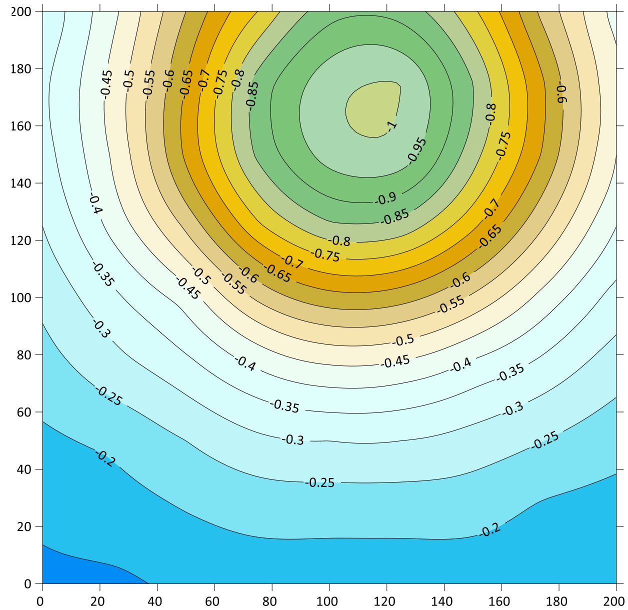

FIGURE 9| tornado at 30m

It can also be observed that the radius of the maximum horizontal wind speed (r mw) is not constant around the tornado center as shown in figures 6 to 9. Maximum horizontal wind speeds are closest to the tornado center on the leading edge (smallest r mw), and r mw increases helically in a clockwise direction from the point on the leading edge of the tornado center until the point at the exact left side of the tornado center is reached. The importance of the increase of r mw in the translation direction is that it increases the duration of exposure to high wind speeds and low pressures for the structure over which it translates. Similarly, an increase in r mw in the direction normal to the translation direction (y-direction) increases the damage width because a greater number of structures will be exposed to the maximum wind speeds and low pressures. Figure 9 shows distribution pressure coefficients along the x- and y-direction passing through the center of the stationary tornado.

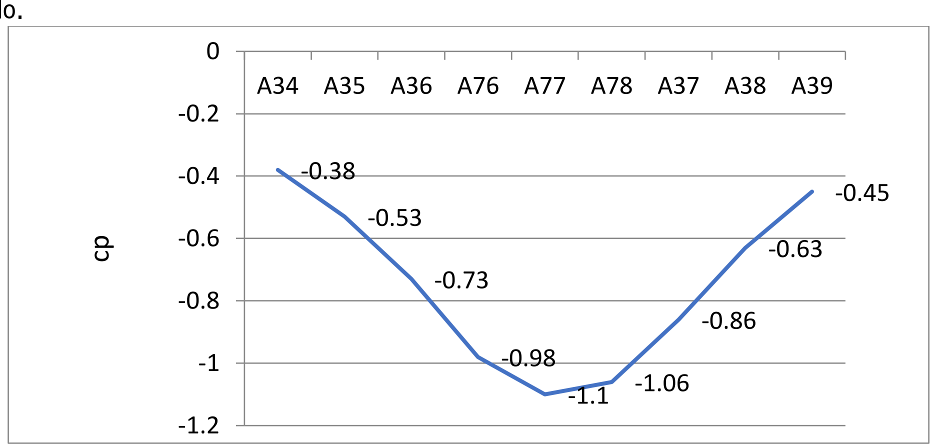

FIGURE 10| Radial distribution of the surface pressure coefficient along the x- and y-direction passing through the center of the stationary tornado.

The control parameters used to simulate the stationary tornado are given in Eqs. 1 and the pressure coefficient at the ground is calculated using

$$Cp = (P - Po)/ (0.5 \times \rho \times V2)$$

Where Cp is the pressure coefficient and Po is the pressure deficit from the far-field static pressure, taken as the room pressure in the laboratory. ρ is the density of air and V is the reference velocity, which is average radial velocity at the inlet. The pressure distribution on the ground along the two lines (x- and y-directions) that pass through the Centre of the stationary tornado is shown in Fig.10. The region of maximum pressure deficit around the tornado Centre can be seen, with a maximum pressure coefficient of –1.1

<u>4.1 effect on terrain and model surface with the change of location</u>

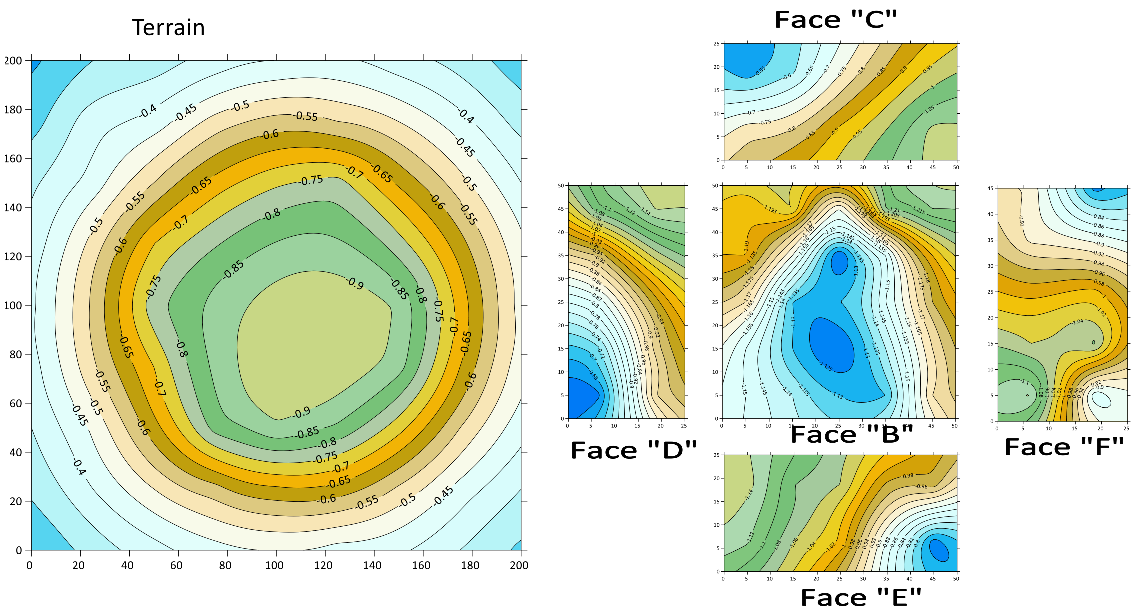

FIGURE 11|- Pressure coefficients on terrain and model surface tornado location at center of model

For the location at the core center, the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient varies from -0.4 to -0.9 as it is governed by the high angular momentum primarily, as shown in figure -11 the pressure coefficients on the roof of model varies from -1.125 to -1.195 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.55 to -1.05, Cp on the surface “D” varies from -0.68 to -1.14, Cp on the surface “E” varies from -0. 8 to -1.14, Cp on the surface “F” varies from -0.84 to -1.1.

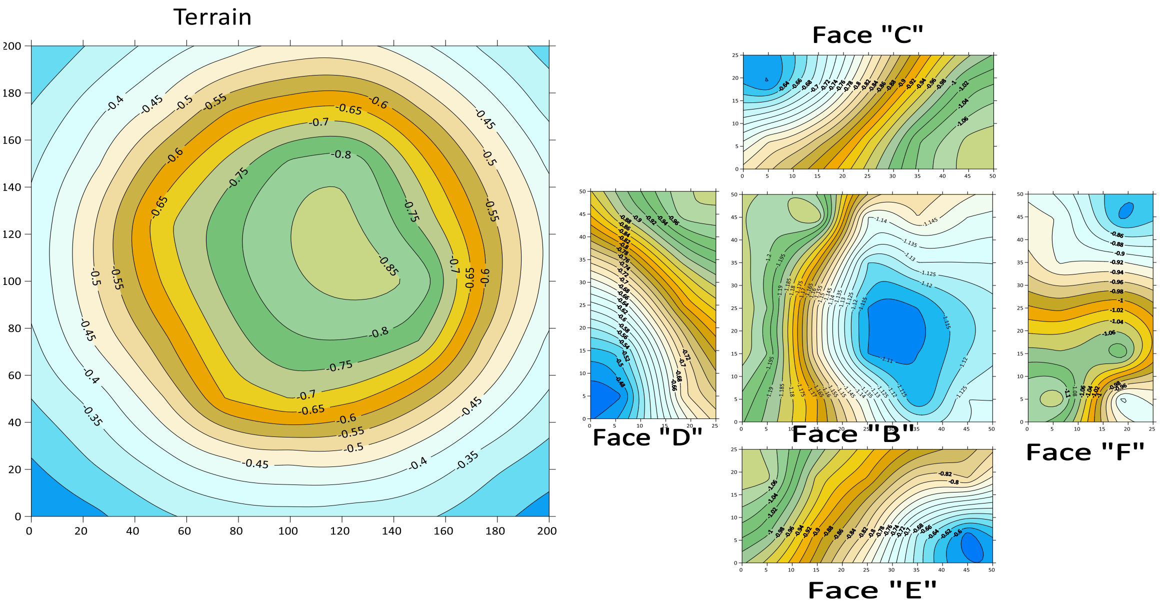

FIGURE 12- Pressure coefficients on terrain and model surface tornado location at 10m.

For the location at the core at 10m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.35 to -0.85 as it is governed by the high angular momentum primarily, As shown in figure -12 the pressure coefficients on the roof of model varies from -1.11 to -1.2 whereas on pressure coefficient at the center of core without model was -1.1, Cp on the surface “C” varies from -0.64 to -1.06, Cp on the surface “D” varies from -0.48 to-0.96, Cp on the surface “E” varies from -0. 6 to -1.06, Cp on the surface “F” varies from -0.86 to -1.1.

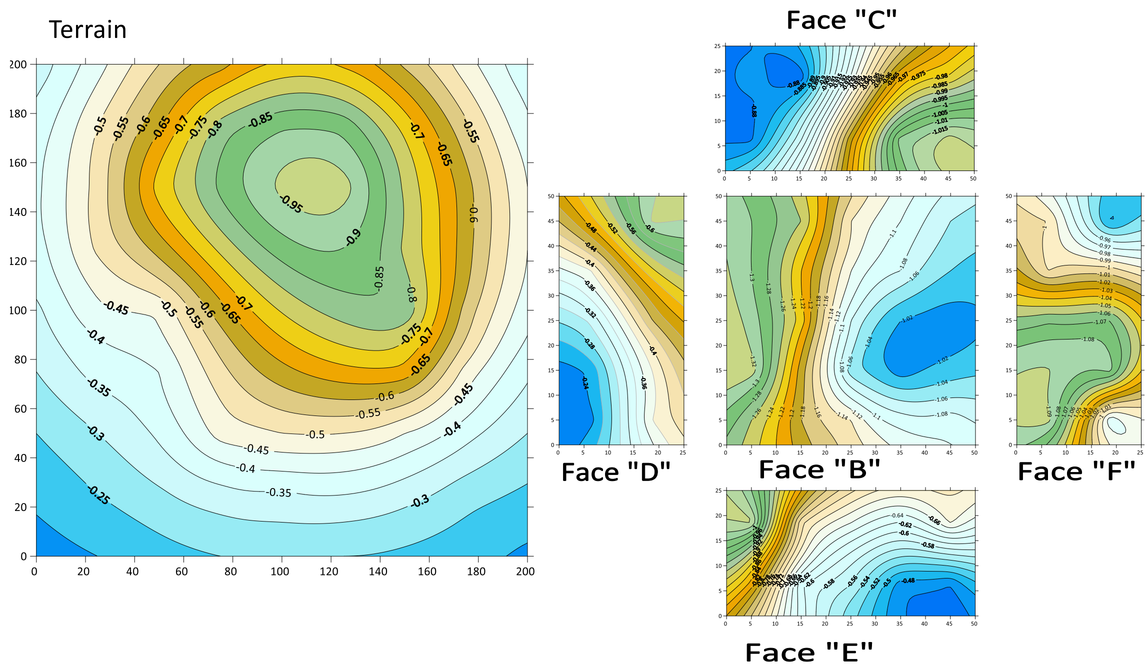

FIGURE 13- Pressure coefficients on terrain and model surface tornado location at 20m.

For the location at the core at 20m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.25

to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -13 the pressure coefficients on the roof of model varies from -1.02 to -1.32 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.88 to -1.15, Cp on the surface “D” varies from -0.24 to-0.6, Cp on the surface “E” varies from -0. 6 to -1.06, Cp on the surface “F” varies from -0.86 to -1.1. As shown in figure -12

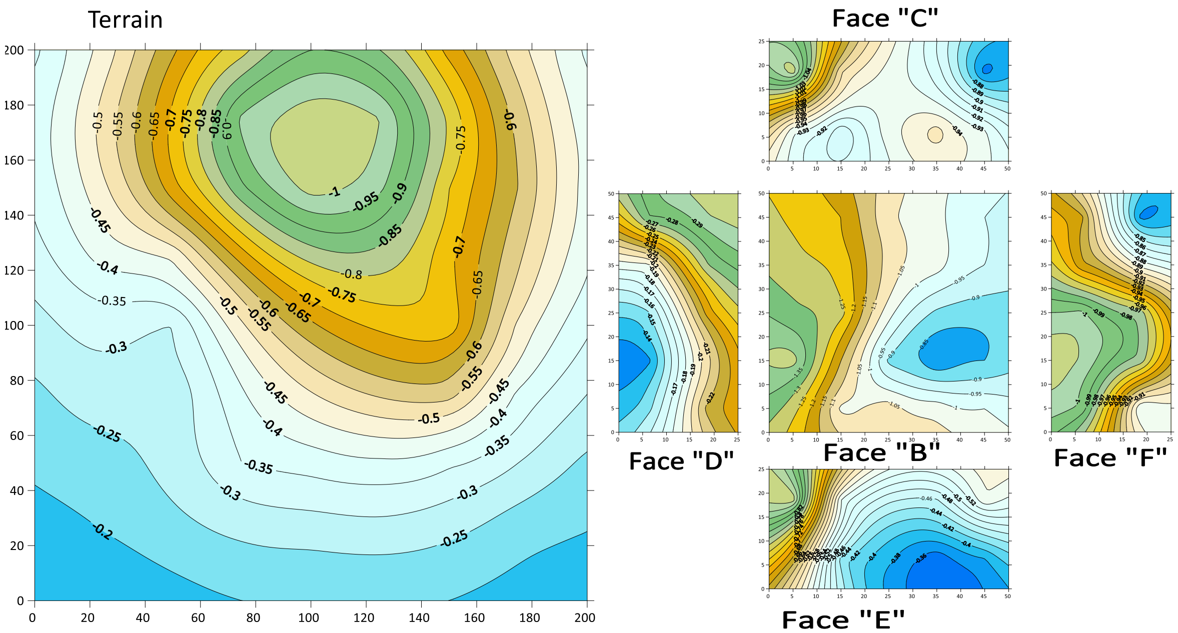

FIGURE 14 Pressure coefficients on terrain and model surface tornado location at 30m.

For the location at the core at 30m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.2 to 1 as it is governed by the high angular momentum primarily, As shown in figure -14 the pressure coefficients on the roof of model varies from -0.85 to -1.35 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.88 to -1.04, Cp on the surface “D” varies from -0.14 to-0.29, Cp on the surface “E” varies from -0. 36 to -0.82, Cp on the surface “F” varies from -0.85 to -1.0.

4.2 effect on terrain and model surface with a canopy 7.6m with the change of location

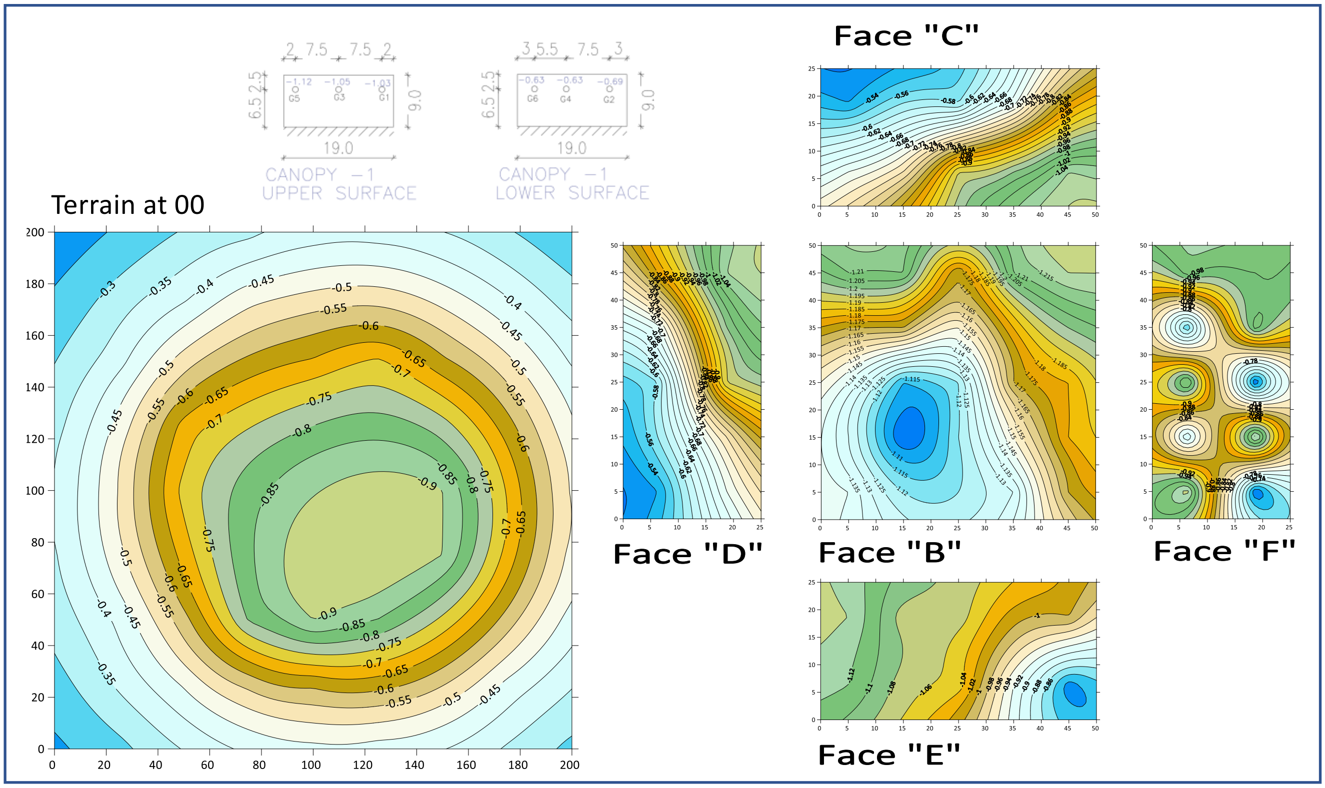

FIGURE 15 Pressure coefficients on terrain and model surface tornado location at 00m.

For the location at the core center, the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient varies from -0.3 to -0.9 as it is governed by the high angular momentum primarily, as shown in figure -15 the pressure coefficients on the roof of model varies from -1.115 to -1.215 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface "C" varies from –0.54 to -1.04, Cp on the surface "D" varies from –0.54 to -1.04, Cp on the surface "E" varies from -0. 86 to -1.12, Cp on the surface "F" varies from -0.6 to -0.98, and Cp on the upper surface of canopy varies from -1.03 to -1.12 , Cp on the lower surface of canopy varies from -0.63 to -0.69 ,

For the location at the core at 10m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.30 to -0.9 as it is governed by the high angular momentum primarily, As shown in figure -16 the pressure coefficients on the roof of model varies from -1.11 to -1.26 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface "C" varies from –0.9 to -1.14, Cp on the surface "D" varies from 0.9 to -1.14, Cp on the surface "E" varies from -0. 6 to -1.12, Cp on the surface "F" varies from -0.94 to -1.15, and Cp on the upper surface of canopy varies from -1.12 to -1.17 , Cp on the lower surface of canopy varies from -0.95 to -1.01.

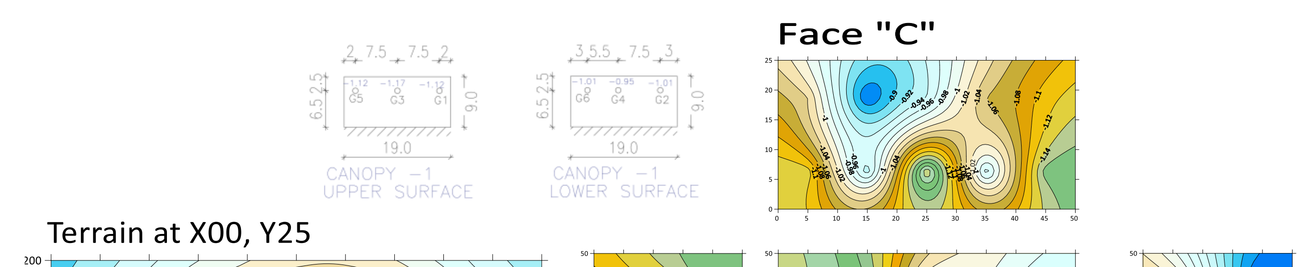

FIGURE 16 Pressure coefficients on terrain and model surface tornado location at 10 m in Y-direction

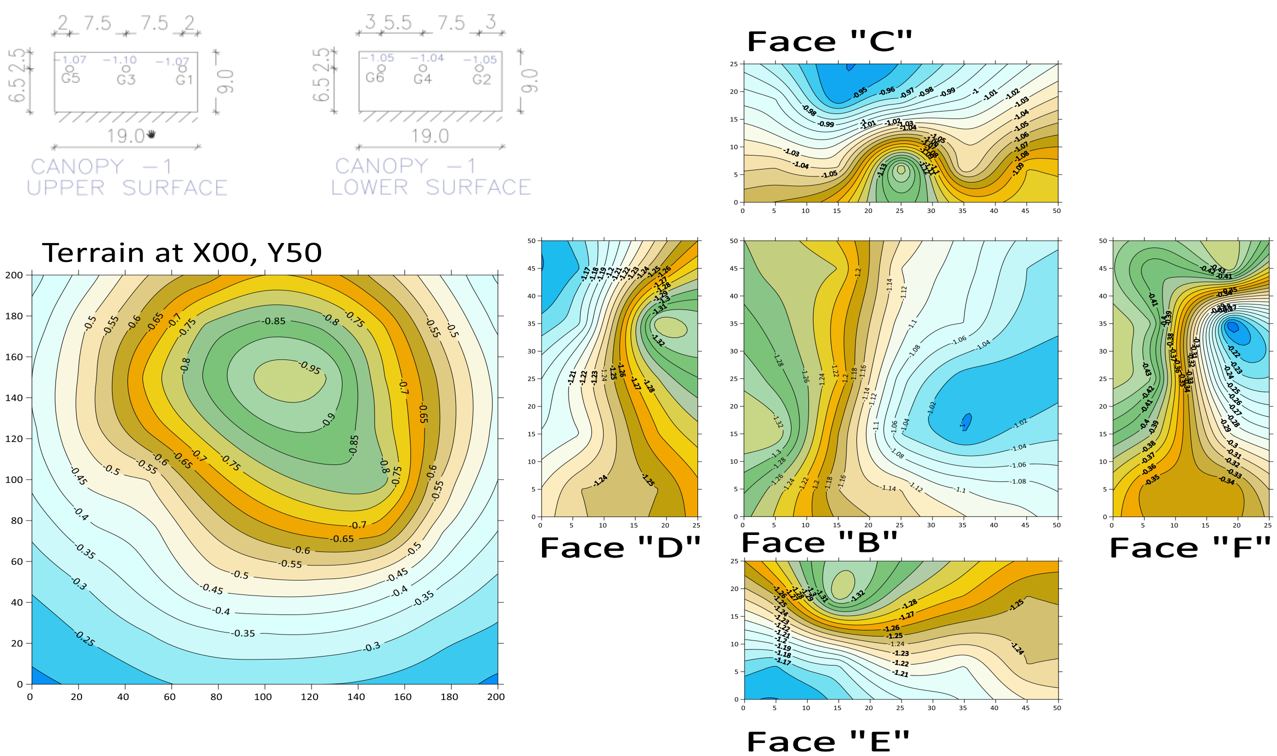

FIGURE 17 Pressure coefficients on terrain and model surface tornado location at 20 m

For the location at the core at 20m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.25 to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -17 the pressure coefficients on the roof of model varies from -1.0 to -1.32 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.95 to -1.13, Cp on the surface “D” varies from 1.17 to -1.32, Cp on the surface “E” varies from -1.17 to -1.32, Cp on the surface “F” varies from -.22 to -.43, and Cp on the upper surface of canopy varies from -1.07 to -1.1, Cp on the lower surface of canopy varies from -1.04 to -1.05.

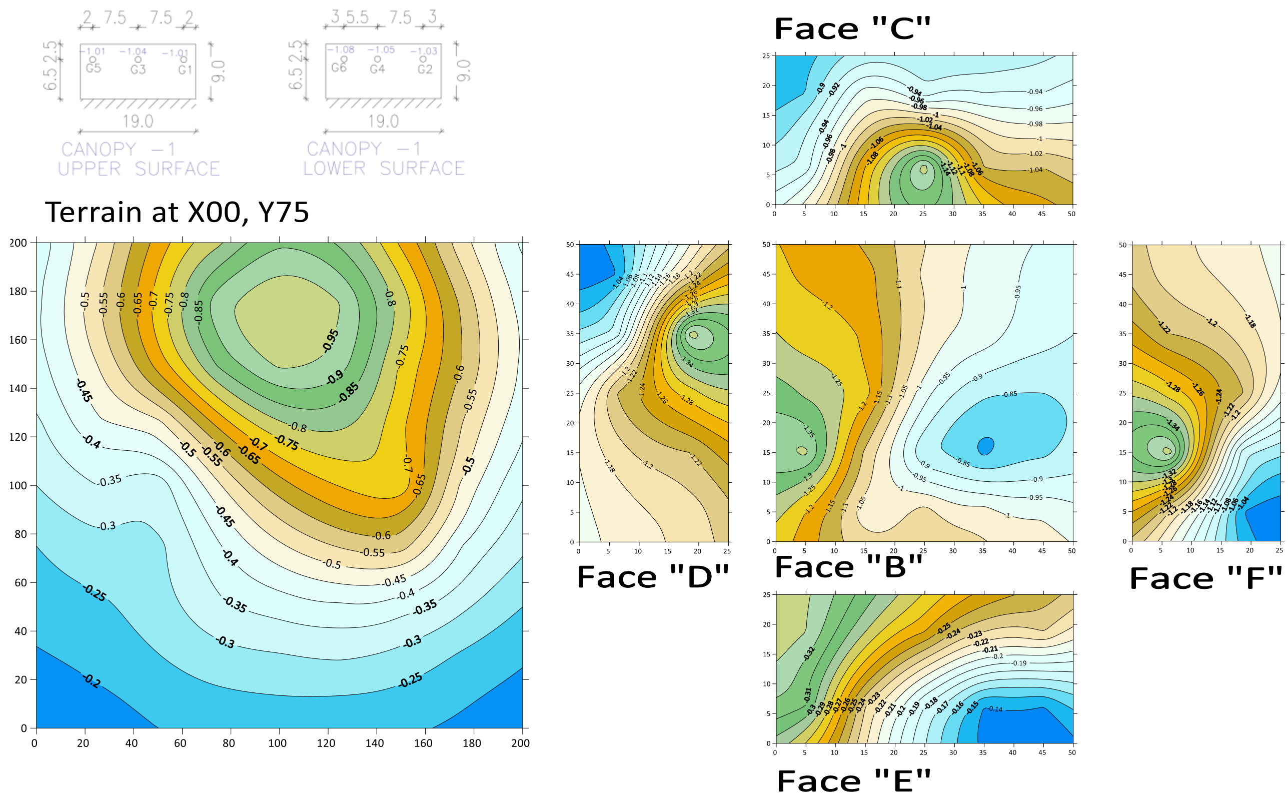

FIGURE 18 Pressure coefficients on terrain and model surface tornado location at 30 m

For the location at the core at 30m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.20 to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -17 the pressure coefficients on the roof of model varies from -0.85 to -1.35 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.90 to -1.14, Cp on the surface “D” varies from 1.04 to -1.34, Cp on the surface “E” varies from -0.14 to -0.32, Cp on the surface “F” varies from -1.04 to -1.34, and Cp on the upper surface of canopy varies from -1.01 to -1.04, Cp on the lower surface of canopy varies from -1.03 to -1.05.

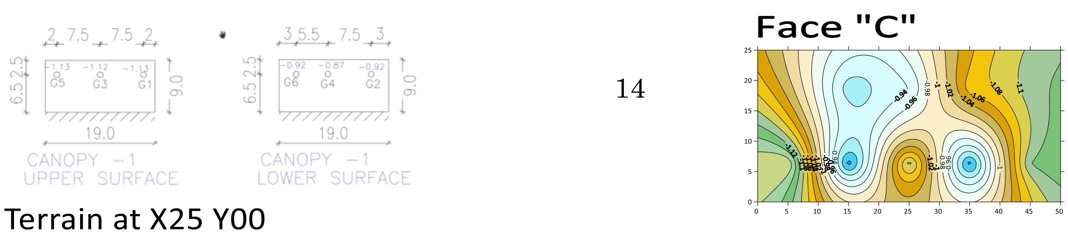

FIGURE 19 Pressure coefficients on terrain and model surface tornado location at 10 m in X-direction

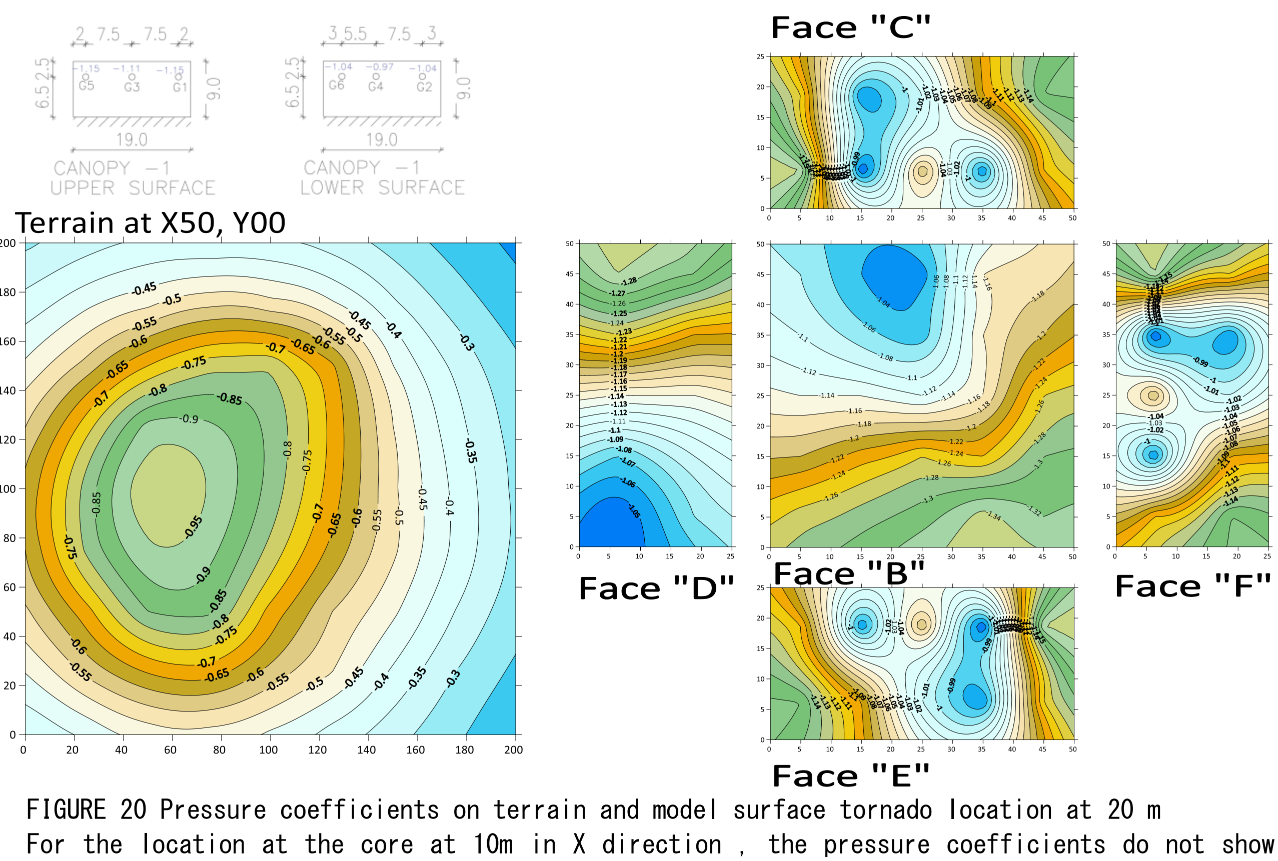

FIGURE 20 Pressure coefficients on terrain and model surface tornado location at 20 m

For the location at the core at 10m in X direction , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.30 to -0.9 as it is governed by the high angular momentum primarily, As shown in figure -19 the pressure coefficients on the roof of model varies from -1.115 to -1.24 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.94 to -1.12, Cp on the surface “D” varies from -1.125 to -1.185, Cp on the surface “E” varies from -0. 58 to -1.04, Cp on the surface “F” varies from -0.5 to -1.0, and Cp on the upper surface of canopy varies from -1.12 to -1.13 , Cp on the lower surface of canopy varies from -0.87 to -0.92.

For the location at the core at 20m in X direction , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.30 to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -20 the pressure coefficients on the roof of model varies from -1.04 to -1.34 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -1.0 to -1.15, Cp on the surface “D” varies from -1.05 to -1.28, Cp on the surface “E” varies from -0. 99 to -1.14, Cp on the surface “F” varies from -0.99 to -1.14, and Cp on the upper surface of canopy varies from -1.11 to -1.13 , Cp on the lower surface of canopy varies from -0.97 to -1.04.

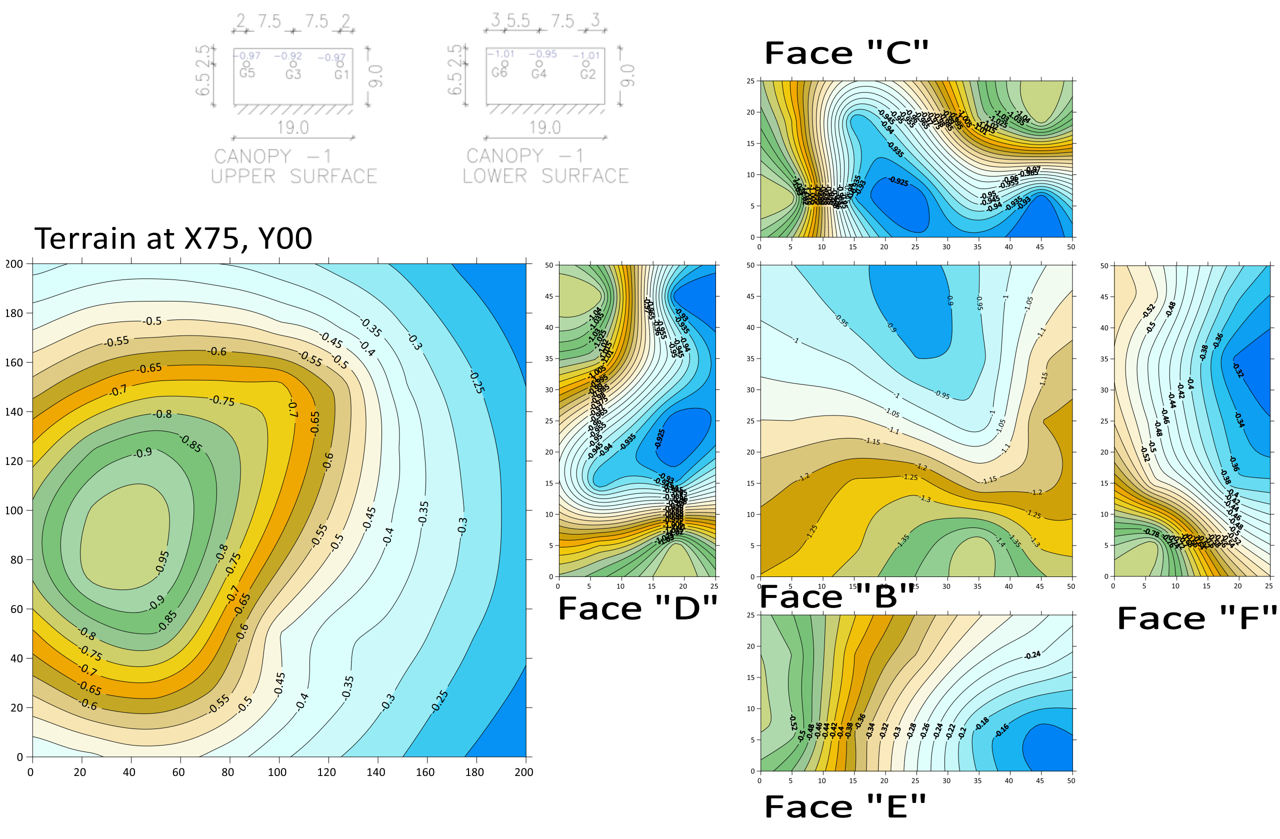

FIGURE 21 Pressure coefficients on terrain and model surface tornado location at 30 m

For the location at the core at 20m in X direction , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.25 to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -21 the pressure coefficients on the roof of model varies from -0.9 to -1.4 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.93 to -1.04, Cp on the surface “D” varies from -0.925 to -1.04, Cp on the surface “E” varies from -0. 16 to -0.52, Cp on the surface “F” varies from -0.32 to -0.78, and Cp on the upper surface of canopy varies from -0.92 to -0.97, Cp on the lower surface of canopy varies from -0.95 to -1.01.

4.3 effect on terrain and model surface with a canopy 11.92m with the change of location

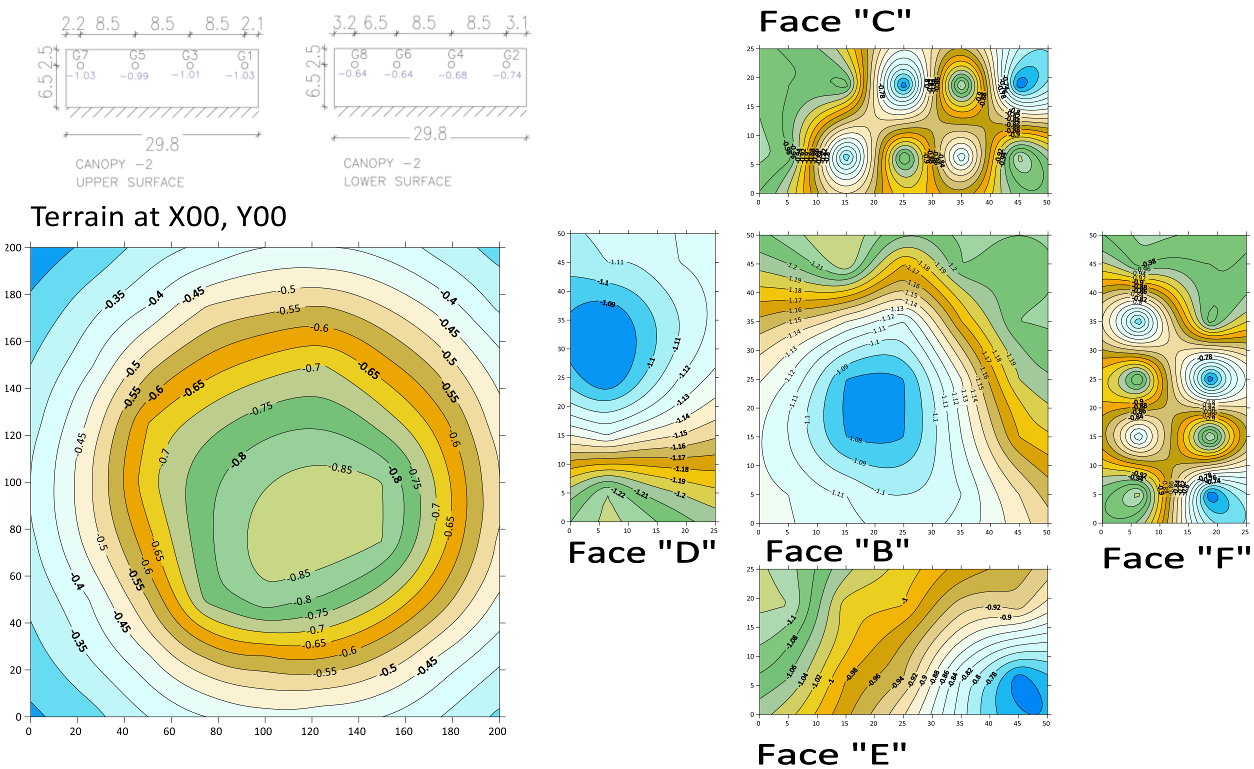

FIGURE 22 Pressure coefficients on terrain and model surface tornado location at 00m.

For the location at the core center, the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient varies from -0.35 to -0.85 as it is governed by the high angular momentum primarily, as shown in figure -22 the pressure coefficients on the roof of model varies from -1.08 to -1.21 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0..74 to -0.98, Cp on the surface “D” varies from -1.09 to -1.22, Cp on the surface “E” varies from -0. 78 to -1.10, Cp on the surface “F” varies from -0.78 to -0.98, and Cp on the upper surface of canopy varies from -0.99 to -1.03 , Cp on the lower surface of canopy varies from -0.64 to -0.74 ,

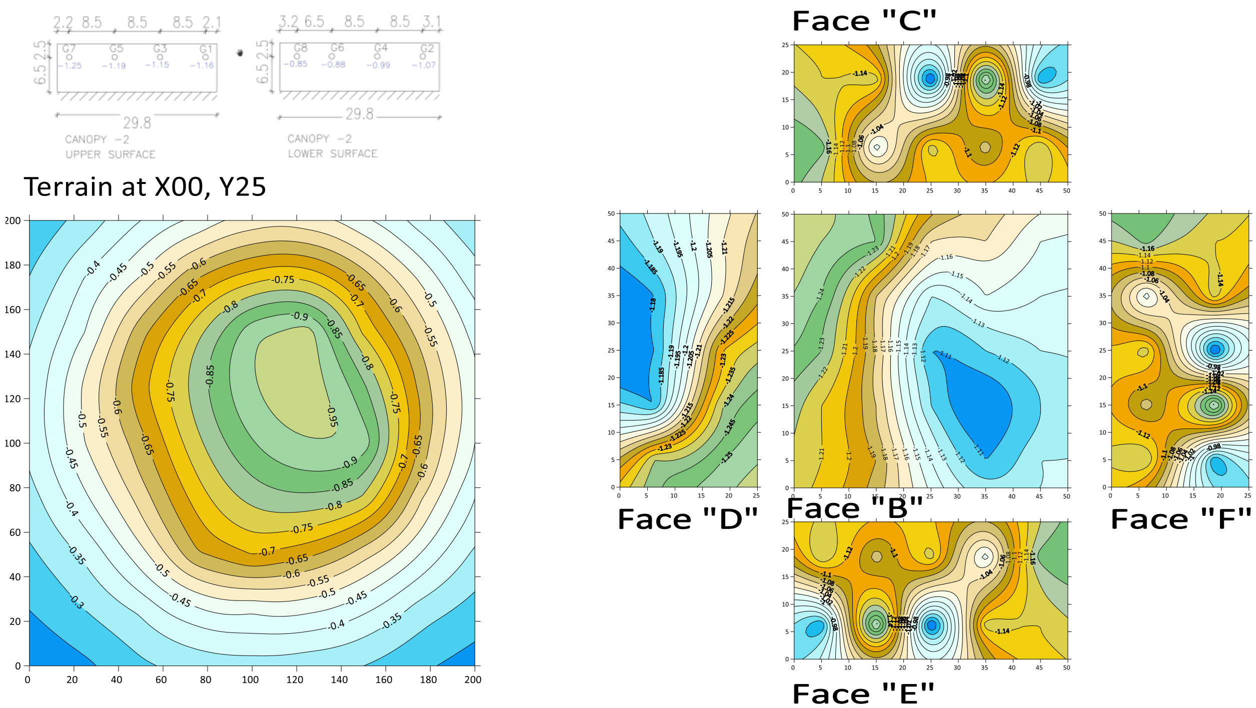

FIGURE 23 Pressure coefficients on terrain and model surface tornado location at 10m.

For the location at the core at 10m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.35 to -0.9 as it is governed by the high angular momentum primarily, As shown in figure -23 the pressure coefficients on the roof of model varies from -1.11 to -1.26 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.98 to -1.16, Cp on the surface “D” varies from -1.18to -1.25, Cp on the surface “E” varies from -1.04 to -1.12, Cp on the surface “F” varies from -0.98 to -1.16, and Cp on the upper surface of canopy varies from -1.15 to -1.19 , Cp on the lower surface of canopy varies from -0.85 to -1.07.

For the location at the core at 20m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.25 to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -24 the pressure coefficients on the roof of model varies from -0.98 to -1.3 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -1 to -1.1, Cp on the surface “D” varies from -1.0 to -1.1, Cp on the surface “E” varies from -0.46 to -1.0, Cp on the surface “F” varies from -0.87 to -1.09., and Cp on the upper surface of canopy varies from -1.09 to -1.26, Cp on the lower surface of canopy varies from -0.95 to -1.06.

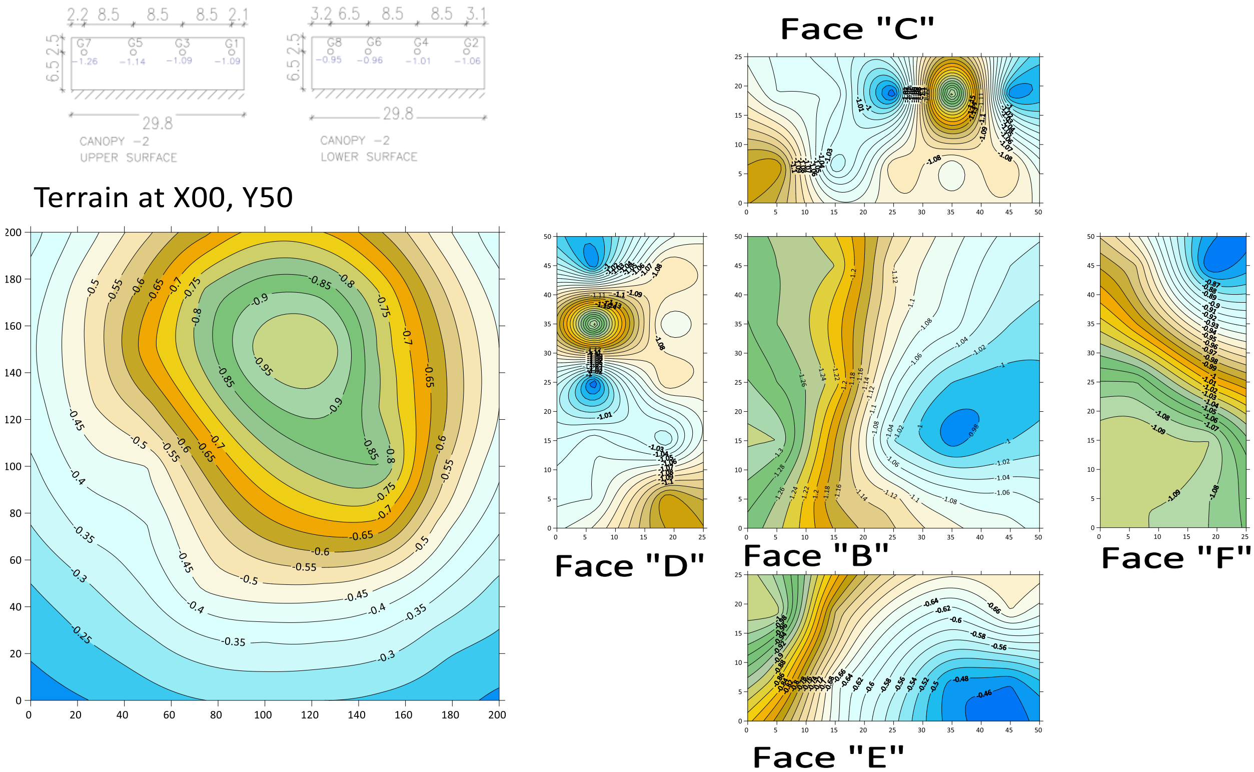

FIGURE 24 Pressure coefficients on terrain and model surface tornado location at 20m.

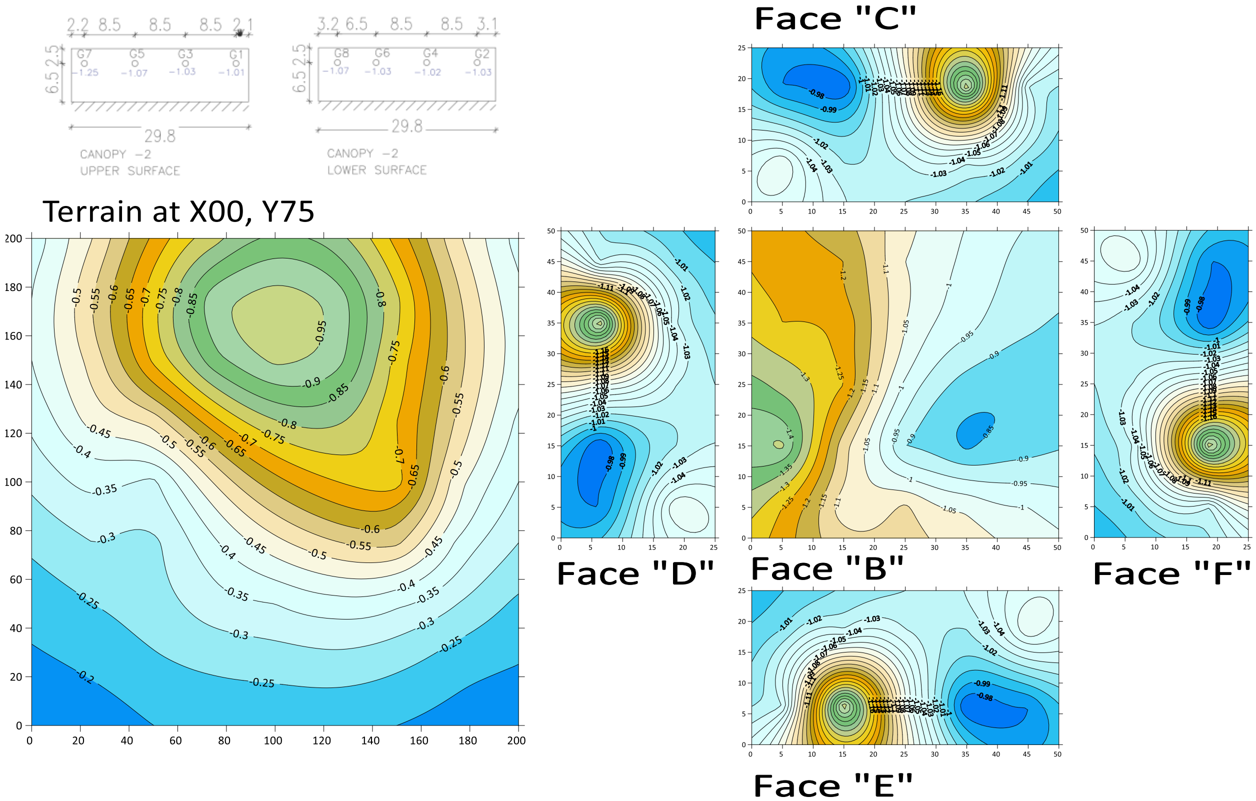

FIGURE 25 Pressure coefficients on terrain and model surface tornado location at 30m.

For the location at the core at 30m , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.20 to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -25 the pressure coefficients on the roof of model varies from -0.85 to -1.40 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface "C" varies from -0.98 to -1.11, Cp on the surface "D" varies from 0.98 to -1.16, Cp on the surface "E" varies from -0.98 to -1.16, Cp on the surface "F" varies from --0.98 to -1.16, and Cp on the upper surface of canopy varies from -1.01 to -1.25, Cp on the lower surface of canopy varies from -1.02 to -1.07.

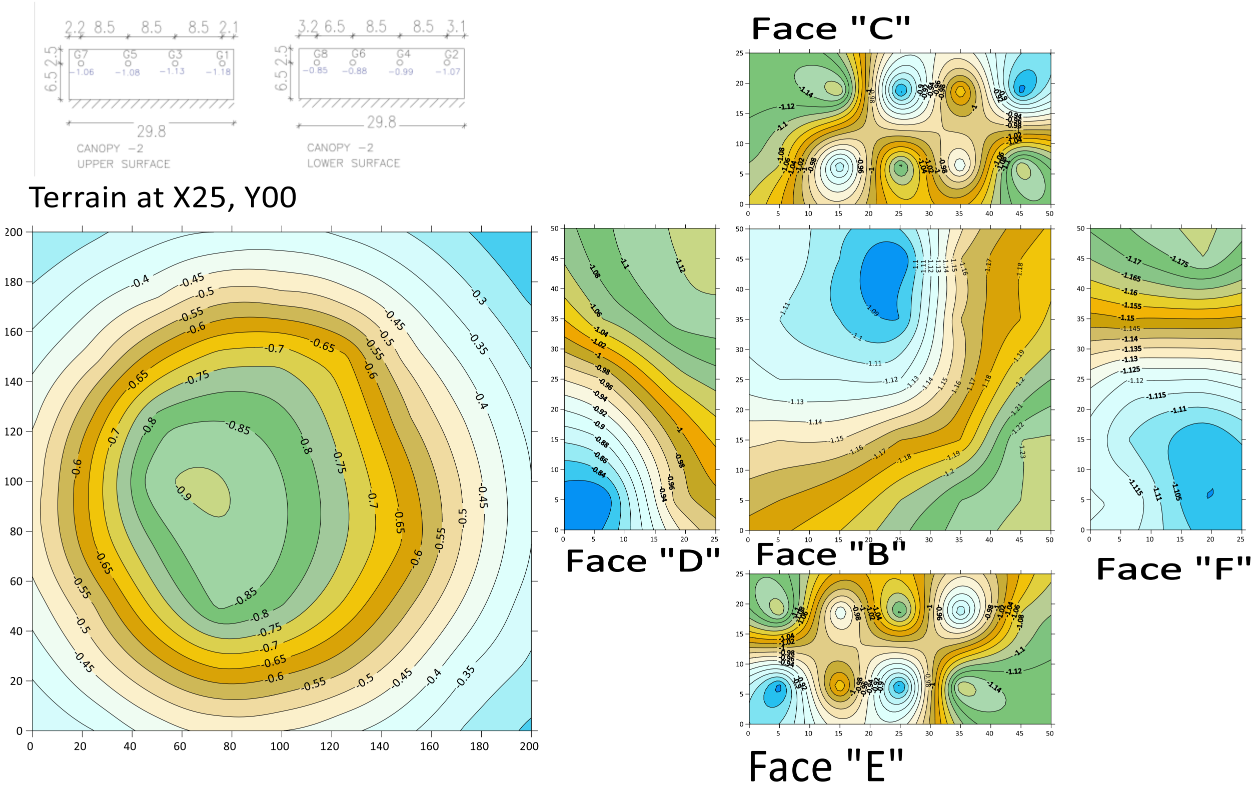

FIGURE 26 Pressure coefficients on terrain and model surface tornado location at 10m in X direction.

For the location at the core at 10m in X direction , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.30 to -0.9 as it is governed by the high angular momentum primarily, As shown in figure -26 the pressure coefficients on the roof of model varies from -1.09 to -1.23 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface "C" varies from -0.90 to -1.14, Cp on the surface "D" varies from -0.84 to -1.1, Cp on the surface "E" varies from -0. 9 to -1.14, Cp on the surface "F" varies from -1.105 to -1.175, and Cp on the upper surface of canopy varies from -1.06 to -1.18 , Cp on the lower surface of canopy varies from -0.85 to -1.07.

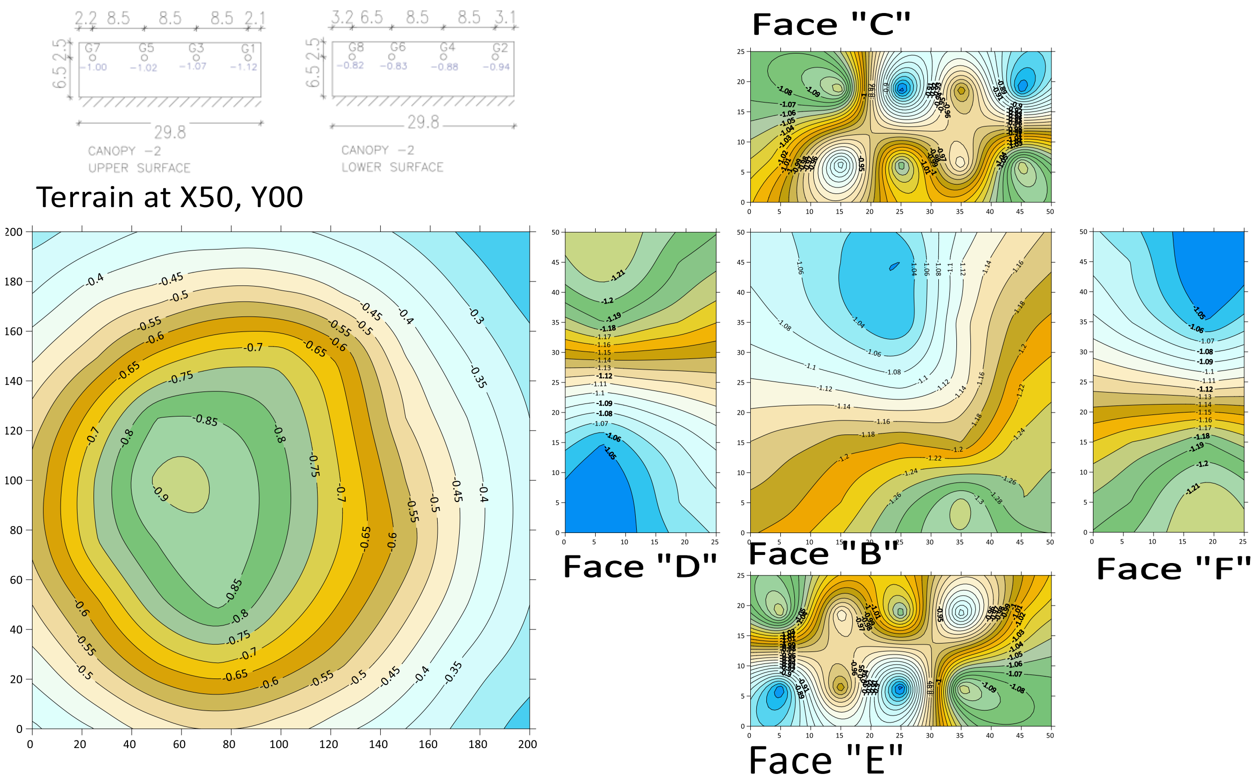

FIGURE 27 Pressure coefficients on terrain and model surface tornado location at 20m in X direction.

For the location at the core at 20m in X direction , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.30 to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -27 the pressure coefficients on the roof of model varies from -1.04 to -1.3 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.9 to -1.09, Cp on the surface “D” varies from -1.05 to -1.21, Cp on the surface “E” varies from -0. 95 to -1.05, Cp on the surface “F” varies from -1.05 to -1.21, and Cp on the upper surface of canopy varies from -1.00 to -1.12 , Cp on the lower surface of canopy varies from -0.82 to -0.94.

For the location at the core at 30m in X direction , the pressure coefficients do not show significant variation in all terrain surface on outer edges the pressure coefficient changes from -0.25 to -0.95 as it is governed by the high angular momentum primarily, As shown in figure -28 the pressure coefficients on the roof of model varies from -0.85 to -1.5 whereas on pressure coefficient at the center of core without model was -1.1,Cp on the surface “C” varies from -0.86 to -1.00, Cp on the surface “D” varies from -0.86 to -1.00, Cp on the surface “E” varies from -0. 14 to -0.52, Cp on the surface “F” varies from -0.86 to -1.00, and Cp on the upper surface of canopy varies from -0.87 to -1.00, Cp on the lower surface of canopy varies from -0.87 to -0.98.

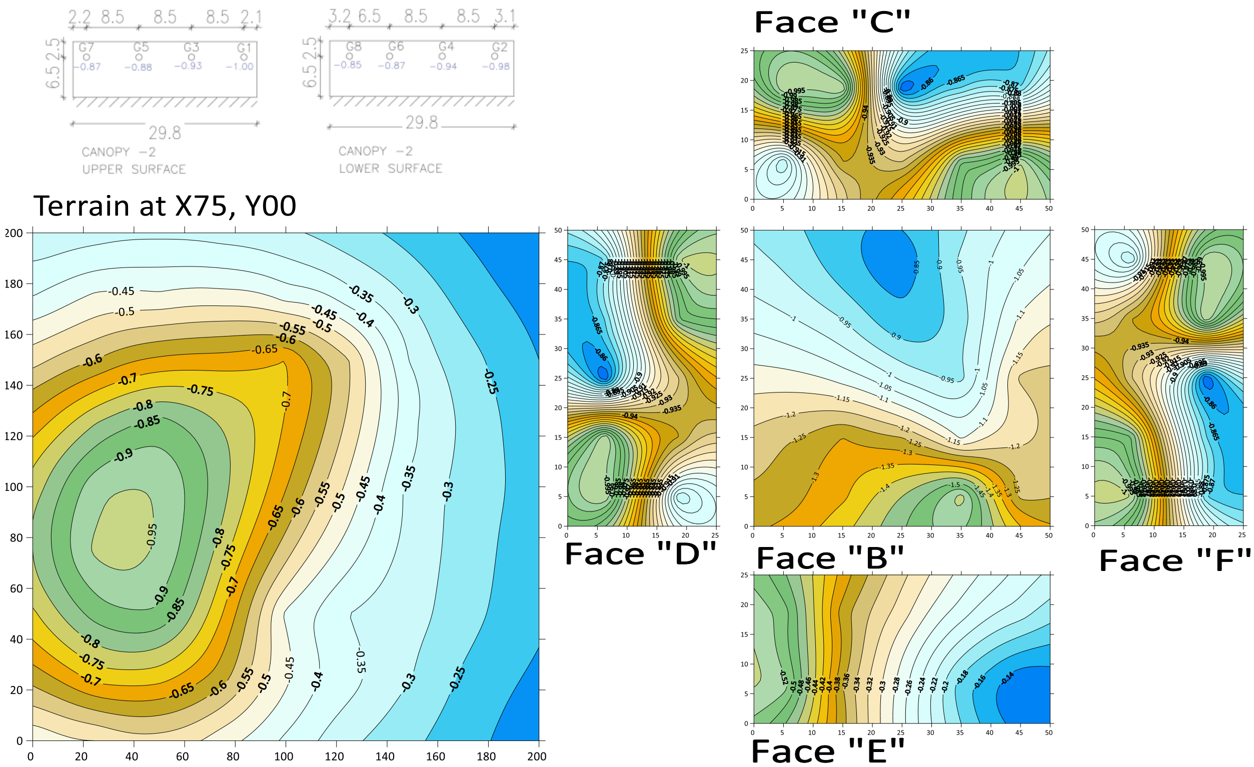

FIGURE 28 Pressure coefficients on terrain and model surface tornado location at 30m in X direction

<u>4.4 Roof surface pressure coefficients without a canopy, with canopy 7.6m, with canopy 11.92m with the change of location</u>

Table -4 Roof surface pressure coefficients

	surface B without canopy				surface B with canopy 19mm (7.6m)							surface B with canopy 29.8mm (11.92m)						
	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00
B1	-1.15	-1.17	-1.26	-1.08	-1.14	-1.23	-1.25	-1.2	-1.19	-1.27	-1.24	-1.12	-1.21	-1.26	-1.25	-1.17	-1.19	-1.27
B2	-1.15	-1.21	-1.14	-0.89	-1.13	-1.25	-1.34	-1.41	-1.15	-1.2	-1.2	-1.11	-1.21	-1.32	-1.46	-1.15	-1.17	-1.24
B3	-1.17	-1.14	-1.05	-1.02	-1.14	-1.25	-1.29	-1.29	-1.14	-1.14	-1.1	-1.12	-1.23	-1.28	-1.33	-1.12	-1.12	-1.12
B4	-1.19	-1.11	-1.08	-1.08	-1.17	-1.26	-1.27	-1.22	-1.14	-1.1	-1.02	-1.15	-1.24	-1.26	-1.25	-1.11	-1.08	-1.01
B5	-1.19	-1.11	-1.12	-1.06	-1.21	-1.26	-1.25	-1.19	-1.14	-1.08	-0.97	-1.2	-1.25	-1.26	-1.22	-1.12	-1.07	-0.94
B6	-1.14	-1.12	-1.14	-1.03	-1.12	-1.21	-1.16	-1.02	-1.19	-1.29	-1.29	-1.11	-1.19	-1.16	-1.07	-1.18	-1.22	-1.34
B7	-1.13	-1.14	-1.09	-0.81	-1.10	-1.2	-1.18	-1.09	-1.16	-1.23	-1.26	-1.08	-1.18	-1.18	-1.12	-1.15	-1.19	-1.3
B8	-1.13	-1.11	-1.01	-0.89	-1.11	-1.2	-1.22	-1.22	-1.13	-1.14	-1.11	-1.08	-1.18	-1.23	-1.25	-1.12	-1.11	-1.08
B9	-1.16	-1.11	-1.02	-1.02	-1.17	-1.2	-1.21	-1.19	-1.13	-1.07	-0.99	-1.13	-1.18	-1.21	-1.23	-1.1	-1.05	-0.95
B10	-1.2	-1.11	-1.08	-1.01	-1.21	-1.24	-1.24	-1.17	-1.12	-1.04	-0.92	-1.23	-1.24	-1.24	-1.2	-1.1	-1.04	-0.87
B11	-1.13	-1.13	-1.10	-1.00	-1.12	-1.16	-1.14	-1.07	-1.2	-1.31	-1.37	-1.1	-1.14	-1.13	-1.11	-1.2	-1.27	-1.45
B12	-1.12	-1.15	-1.09	-0.85	-1.12	-1.13	-1.04	-0.86	-1.18	-1.26	-1.28	-1.08	-1.12	-1.02	-0.9	-1.17	-1.2	-1.25
B13	-1.13	-1.13	-1.03	-0.87	-1.12	-1.12	-1.07	-0.97	-1.13	-1.12	-1.04	-1.08	-1.11	-1.07	-0.99	-1.12	-1.09	-0.99
B14	-1.12	-1.12	-1.01	-0.95	-1.15	-1.14	-1.11	-1.04	-1.12	-1.05	-0.9	-1.11	-1.13	-1.11	-1.05	-1.09	-1.02	-0.86
B15	-1.16	-1.12	-1.04	-0.95	-1.17	-1.16	-1.12	-1.04	-1.11	-1.03	-0.86	-1.17	-1.17	-1.12	-1.05	-1.08	-1.02	-0.82
B16	-1.13	-1.13	-1.06	-0.94	-1.13	-1.13	-1.1	-1.02	-1.22	-1.35	-1.5	-1.11	-1.11	-1.08	-1.04	-1.22	-1.33	-1.62
B17	-1.14	-1.14	-1.03	-0.96	-1.15	-1.11	-1	-0.79	-1.19	-1.24	-1.15	-1.12	-1.1	-0.97	-0.84	-1.18	-1.18	-1.09
B18	-1.15	-1.09	-1.02	-0.94	-1.17	-1.11	-1.01	-0.86	-1.18	-1.16	-0.96	-1.13	-1.12	-1	-0.88	-1.16	-1.13	-0.94
B19	-1.15	-1.04	-0.97	-0.91	-1.18	-1.13	-1.08	-0.98	-1.19	-1.16	-0.93	-1.17	-1.15	-1.07	-0.97	-1.16	-1.13	-0.93
B20	-1.21	-0.94	-0.91	-0.94	-1.21	-1.16	-1.09	-0.98	-1.19	-1.16	-0.95	-1.21	-1.17	-1.08	-0.99	-1.16	-1.12	-0.96
B21	-1.17	-0.85	-0.88	-0.86	-1.17	-1.14	-1.09	-0.99	-1.24	-1.32	-1.29	-1.14	-1.13	-1.07	-1	-1.23	-1.26	-1.24
B22	-1.17	-0.80	-0.99	-0.92	-1.18	-1.12	-1.03	-0.84	-1.24	-1.3	-1.18	-1.17	-1.12	-1	-0.88	-1.23	-1.25	-1.19
B23	-1.18	-1.03	-0.97	-0.94	-1.18	-1.11	-1.01	-0.85	-1.22	-1.26	-1.2	-1.19	-1.13	-0.99	-0.86	-1.2	-1.22	-1.21
B24	-1.19	-0.94	-0.93	-0.97	-1.20	-1.12	-1.03	-0.92	-1.2	-1.2	-1.14	-1.21	-1.14	-1.02	-0.91	-1.18	-1.19	-1.11
B25	-1.22	-0.83	-0.88	-1.09	-1.22	-1.14	-1.04	-0.93	-1.2	-1.17	-1.07	-1.2	-1.15	-1.04	-0.93	-1.18	-1.16	-1.04

From the table- 4 Pressure coefficients on roof varies from -0.80 to -1.26 without canopy maximum pressure cp is -1.26 when tornado is 20m away from center in Y direction, Pressure coefficients on roof varies from -0.79 to -1.5 with canopy of 7.6m maximum pressure cp is -1.5 when tornado is 30m away from center in X direction, Pressure coefficients on roof varies from -0.82to -1.62 with canopy of 11.92m maximum pressure cp is -1.62 when tornado is 30m away from center in X direction, pressure coefficients increases as tornado away from the center 20m to 30m and also pressure coefficients increases with increase in length of canopy from 7.6m to 11.92m

4.5 Face "C" surface pressure coefficients without a canopy, with canopy 7.6m, with canopy 11.92m with the change of location

Table -5 Face "C" surface pressure coefficients

	surface C without canopy				surface C with canopy 19mm (7.6m)							surface C with canopy 29.8mm (11.92m)						
	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00
C1	-1.12	-1.09	-0.94	-1.03	-1.06	-1.17	-1.1	-1.04	-1.12	-1.11	-0.92	-1.03	-1.16	-1.09	-1.01	-1.18	-1.12	-1
C2	-1.01	-1.04	-0.96	-1.02	-0.98	-0.95	-1.04	-1.04	-0.87	-0.97	-0.95	-0.74	-1.07	-1.06	-1.03	-0.92	-0.94	-0.98
C3	-0.92	-0.94	-0.94	-0.97	-0.94	-1.24	-1.18	-1.21	-1.11	-1.08	-0.92	-1.01	-1.15	-1.09	-1.03	-1.13	-1.07	-0.93
C4	-0.81	-0.85	-0.91	-0.91	-0.76	-0.93	-1.04	-1.08	-0.87	-0.96	-0.93	-0.68	-0.99	-1.01	-1.02	-0.86	-0.88	-0.94
C5	-0.79	-0.8	-0.94	-0.88	-0.70	-1.13	-1.05	-0.93	-1.18	-1.18	-1.05	-0.99	-1.19	-1.14	-1.07	-1.08	-1.02	-0.88
C6	-0.97	-1.03	-0.86	-0.99	-0.86	-1.11	-1.03	-0.94	-1.11	-1.16	-1.05	-0.64	-0.88	-0.96	-1.03	-0.81	-0.83	-0.87
C7	-0.87	-0.94	-0.92	-0.97	-0.69	-1.06	-1	-0.94	-1.07	-1.1	-1.02	-1.03	-1.25	-1.26	-1.25	-1.06	-1	-0.87
C8	-0.75	-0.83	-0.94	-0.93	-0.58	-0.94	-0.97	-0.93	-0.94	-1.01	-0.96	-0.64	-0.85	-0.95	-1.07	-0.81	-0.82	-0.85
C9	-0.6	-0.7	-0.97	-0.88	-0.58	-0.86	-0.94	-0.97	-0.91	-0.97	-0.93	-0.99	-1.15	-1.05	-0.97	-1.18	-1.12	-1
C10	-0.53	-0.6	-1.09	-0.89	-0.52	-1.04	-1	-0.88	-1.03	-1.12	-1.01	-0.98	-1.14	-1.05	-0.98	-1.13	-1.08	-1

From the table- 5 Pressure coefficients on Face "C" varies from -0.53 to -1.12 without canopy maximum pressure cp is -1.12 when tornado is center of Model, Pressure coefficients on Face "C" varies from -0.52 to -1.24 with canopy of 7.6m maximum pressure cp is -1.24 when tornado is 10m away from center in Y direction, Pressure coefficients on Face "C" varies from -0.64to -1.26 with canopy of 11.92m maximum pressure cp is -1.26 when tornado is 20m away from center in Y direction, pressure coefficients increases as tornado away from the center 0m to 20m and also pressure coefficients increases with increase in length of canopy from 7.6m to 11.92m

4.6 Face "D" surface pressure coefficients without a canopy, with canopy 7.6m, with canopy 11.92m with the change of location

Table -6 Face "D" surface pressure coefficients

	surface "D" without canopy				surface "D" with canopy 19mm (7.6m)							surface "D" with canopy 29.8mm (11.92m)						
	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00
D1	-1.16	-0.99	-0.62	-0.3	-1.15	-0.97	-0.65	-0.33	-1.16	-1.12	-0.99	-1.01	-0.96	-0.58	-0.36	-1.12	-1.1	-1.07
D2	-1.05	-0.89	-0.52	-0.27	-1.06	-0.86	-0.58	-0.29	-1.14	-1.13	-1.02	-0.95	-0.89	-0.52	-0.31	-1.11	-1.1	-1.08
D3	-0.95	-0.8	-0.44	-0.23	-0.95	-0.74	-0.48	-0.26	-1.08	-1.11	-1.03	-0.85	-0.78	-0.45	-0.25	-1.05	-1.06	-1.08
D4	-0.91	-0.72	-0.38	-0.21	-0.89	-0.66	-0.41	-0.23	-1.03	-1.08	-1.05	-0.78	-0.69	-0.4	-0.21	-0.99	-1.01	-1.09
D5	-0.9	-0.69	-0.38	-0.22	-0.88	-0.64	-0.39	-0.23	-1.02	-1.08	-1.14	-0.79	-0.68	-0.39	-0.21	-0.97	-0.99	-1.11
D6	-1.09	-0.89	-0.49	-0.28	-1.11	-0.83	-0.56	-0.31	-1.14	-1.09	-0.96	-0.96	-0.89	-0.49	-0.33	-1.09	-1.06	-1.02
D7	-0.92	-0.75	-0.38	-0.19	-0.94	-0.67	-0.45	-0.23	-1.08	-1.08	-0.98	-0.85	-0.71	-0.4	-0.25	-1.06	-1.05	-1.03
D8	-0.8	-0.62	-0.3	-0.15	-0.80	-0.54	-0.35	-0.18	-0.99	-1.04	-0.99	-0.73	-0.58	-0.32	-0.18	-0.96	-0.97	-1.01
D9	-0.71	-0.51	-0.25	-0.13	-0.69	-0.43	-0.27	-0.14	-0.93	-1.02	-1.06	-0.64	-0.46	-0.26	-0.13	-0.88	-0.93	-1.04
D10	-0.65	-0.46	-0.23	-0.15	-0.62	-0.39	-0.24	-0.14	-0.86	-0.97	-1.11	-0.58	-0.41	-0.25	-0.13	-0.8	-0.87	-1.04

From the table- 6 Pressure coefficients on Face "D" varies from -0.13 to -1.16 without canopy maximum pressure cp is -1.16 when tornado is center of Model, Pressure coefficients on Face "D" varies from -0.14 to -1.16 with canopy of 7.6m maximum pressure cp is -1.16 when tornado is 10m away from center in x direction, Pressure coefficients on Face "D" varies from -0.13to -1.12 with canopy of 11.92m maximum pressure cp is -1.12 when tornado is 10m away from center in X direction, pressure coefficients increases as tornado away from the center 0m to 10m.

4.7 Face "E" surface pressure coefficients without a canopy, with canopy 7.6m, With canopy 11.92m with the change of location

Table -7 Face "E" surface pressure coefficients

	surface "E" without canopy				surface "E" with canopy 19mm (7.6m)							surface "E" with canopy 29.8mm (11.92m)						
	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00
E1	-1.15	-1.09	-1.04	-0.91	-1.14	-1.15	-1.04	-0.88	-1.07	-0.87	-0.52	-1.12	-1.2	-1.03	-0.84	-1.02	-0.9	-0.51
E2	-1.08	-0.95	-0.73	-0.54	-1.07	-0.97	-0.73	-0.52	-0.95	-0.72	-0.4	-1.01	-1.04	-0.76	-0.49	-0.89	-0.78	-0.37
E3	-1.06	-0.9	-0.66	-0.47	-1.07	-0.9	-0.65	-0.47	-0.9	-0.64	-0.34	-1	-0.94	-0.66	-0.45	-0.85	-0.74	-0.31
E4	-0.98	-0.82	-0.62	-0.46	-1.01	-0.82	-0.6	-0.46	-0.79	-0.53	-0.27	-0.93	-0.85	-0.61	-0.44	-0.75	-0.66	-0.25
E5	-0.97	-0.82	-0.68	-0.56	-1.00	-0.84	-0.67	-0.55	-0.75	-0.48	-0.24	-0.93	-0.86	-0.68	-0.53	-0.72	-0.62	-0.21
E6	-1.12	-1	-0.83	-0.68	-1.12	-1.05	-0.82	-0.63	-1	-0.77	-0.53	-1.06	-1.14	-0.86	-0.56	-0.94	-0.83	-0.53
E7	-1.06	-0.89	-0.6	-0.43	-1.07	-0.88	-0.6	-0.42	-0.9	-0.65	-0.36	-0.98	-0.94	-0.65	-0.39	-0.86	-0.74	-0.36
E8	-1.01	-0.81	-0.56	-0.39	-1.05	-0.8	-0.52	-0.39	-0.81	-0.55	-0.27	-0.94	-0.83	-0.57	-0.37	-0.79	-0.68	-0.27
E9	-0.87	-0.66	-0.47	-0.35	-0.92	-0.65	-0.44	-0.36	-0.65	-0.4	-0.17	-0.82	-0.64	-0.47	-0.35	-0.64	-0.55	-0.17
E10	-0.75	-0.57	-0.46	-0.38	-0.81	-0.57	-0.44	-0.39	-0.52	-0.3	-0.13	-0.73	-0.56	-0.46	-0.39	-0.53	-0.46	-0.12

From the table- 7 Pressure coefficients on Face “E” varies from -0.35 to -1.15 without canopy maximum pressure cp is -1.15 when tornado is center of Model, Pressure coefficients on Face “E” varies from -0.13 to -1.15 with canopy of 7.6m maximum pressure cp is -1.15 when tornado is 10m away from center in Y direction, Pressure coefficients on Face “E” varies from -0.12to -1.2 with canopy of 11.92m maximum pressure cp is -1.2 when tornado is 10m away from center in Y direction, pressure coefficients increases as tornado away from the center 0m to 10m.

<u>4.8 Face “F” surface pressure coefficients without a canopy, with canopy 7.6m, With canopy 11.92m with the change of location</u>

Table -8 Face “F” surface pressure coefficients

	surface "F" without canopy				surface "F" with canopy 19mm (7.6m)							surface "F" with canopy 29.8mm (11.92m)						
	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00
F1	-1.12	-1.13	-1.09	-1	-1.10	-1.16	-1.11	-0.99	-1.09	-0.98	-0.86	-1.06	-1.19	-1.09	-1.01	-1.01	-0.92	-0.71
F2	-1.04	-1.06	-1.09	-1.01	-1.03	-1.14	-1.11	-1.01	-0.91	-0.75	-0.53	-0.99	-1.17	-1.1	-1.03	-0.85	-0.75	-0.45
F3	-0.99	-0.99	-1.07	-1	-0.97	-1.1	-1.08	-1.01	-0.81	-0.66	-0.49	-0.92	-1.13	-1.07	-1.02	-0.76	-0.66	-0.42
F4	-0.92	-0.92	-1	-0.93	-0.88	-1.04	-1	-0.94	-0.72	-0.6	-0.47	-0.83	-1.06	-1	-0.93	-0.66	-0.59	-0.4
F5	-0.92	-0.92	-1	-0.93	-0.82	-1.02	-0.97	-0.89	-0.69	-0.63	-0.53	-0.79	-1.04	-0.97	-0.89	-0.65	-0.6	-0.47
F6	-0.87	-0.89	-0.97	-0.88	-1.05	-1.15	-1.1	-0.96	-0.9	-0.72	-0.54	-1	-1.18	-1.08	-0.98	-0.83	-0.73	-0.41
F7	-1.06	-1.1	-1.08	-0.98	-1.00	-1.12	-1.09	-0.98	-0.75	-0.56	-0.37	-0.94	-1.15	-1.09	-1	-0.72	-0.6	-0.3
F8	-1.01	-1.02	-1.07	-0.97	-0.90	-1.06	-1	-0.88	-0.63	-0.48	-0.35	-0.85	-1.08	-1.01	-0.88	-0.61	-0.51	-0.29
F9	-0.89	-0.92	-1.01	-0.89	-0.77	-0.98	-0.91	-0.8	-0.5	-0.41	-0.32	-0.74	-0.99	-0.93	-0.79	-0.48	-0.42	-0.29
F10	-0.77	-0.81	-0.93	-0.82	-0.68	-0.91	-0.84	-0.76	-0.45	-0.41	-0.37	-0.66	-0.87	-0.84	-0.72	-0.4	-0.38	-0.31

From the table- 8 Pressure coefficients on Face “F” varies from -0.77 to -1.13 without canopy maximum pressure cp is -1.13 when tornado is 10m away from the center in Y direction , Pressure coefficients on Face “F” varies from -0.32 to -1.16 with canopy of 7.6m maximum pressure cp is -1.16 when tornado is 10m away from center in Y direction, Pressure coefficients on Face “F” varies from -0.29to -1.19 with canopy of 11.92m maximum pressure cp is -1.19 when tornado is 10m away from center in Y direction, pressure coefficients increases as tornado away from the center 0m to 10m and also pressure coefficients increases with increase in length of canopy from 7.6m to 11.92m.

<u>4.8 Face “G” surface pressure coefficients with canopy 7.6m, with canopy 11.92m with the change of location</u>

Table -9 Face “G” Upper and lower surface pressure coefficients

	Upper surface "F" with canopy 19mm (7.6m)							Upper surface "F" with canopy 29.8mm (11.92m)						
	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00	X00, Y00	X00, Y25	X00, Y50	X00, Y75	X25, Y00	X50, Y00	X75, Y00
G1	-1.03	-1.12	-1.07	-1.01	-1.13	-1.15	-0.97	-1.03	-1.16	-1.09	-1.01	-1.18	-1.12	-1
G3	-1.05	-1.17	-1.1	-1.04	-1.12	-1.11	-0.92	-1.01	-1.15	-1.09	-1.03	-1.13	-1.07	-0.93
G5	-1.08	-1.12	-1.07	-1.01	-1.13	-1.15	-0.97	-0.99	-1.19	-1.14	-1.07	-1.08	-1.02	-0.88
G7								-1.03	-1.25	-1.26	-1.25	-1.06	-1	-0.87
	Lower surface "F" with canopy 19mm (7.6m)							Lower surface "F" with canopy 29.8mm (11.92m)						
G2	-0.69	-1.01	-1.05	-1.03	-0.92	-1.04	-1.01	-0.74	-1.07	-1.06	-1.03	-0.92	-0.94	-0.98
G4	-0.63	-0.95	-1.04	-1.05	-0.87	-0.97	-0.95	-0.68	-0.99	-1.01	-1.02	-0.86	-0.88	-0.94
G6	-0.63	-1.01	-1.05	-1.08	-0.92	-1.04	-1.01	-0.64	-0.88	-0.96	-1.03	-0.81	-0.83	-0.87
G8								-0.64	-0.85	-0.95	-1.07	-0.81	-0.82	-0.85

From the table- 9 Pressure coefficients on Face “G” upper surface of canopy varies from -0.92 to -1.17 with canopy 7.6m maximum pressure cp is -1.17 when tornado is 10m away from the center in Y direction, Pressure coefficients on Face “G” upper surface of canopy varies from -0.87 to -1.26 with canopy of 11.92m maximum pressure cp is -1.26 when tornado is 20m away from center in Y direction,

Pressure coefficients on Face “G” Lower surface of canopy varies from -0.63 to -1.08 with canopy 7.6m maximum pressure cp is -1.08 when tornado is 30m away from the center in Y direction, Pressure coefficients on Face “G” lower surface of canopy varies from -0.64 to -1.07 with canopy of 11.92m maximum pressure cp is -1.07 when tornado is 10m away from center in Y direction,

The pressure coefficients are higher on upper surface compared to lower surface. Pressure coefficients increase with the increase of canopy length on upper surface whereas length of canopy has no effect on lower surface of canopy.

5. Research Outcome

a) 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.
b) The tornado pressure on terrain is not affected significantly by the presence of the building
c) Roof experienced higher pressure coefficient compering with the walls.
d) Anti-symmetry was observed in pressure distribution on opposite sides.
e) Roof center experience lesser pressure coefficients compared with the roof edges when the tornado is center of model.
f) Roof center pressure increase as the tornado move away from the center of building model.
g) Maximum pressure coefficient on roof experienced when tornado is 30m away from the center of building.
h) with the attachment of canopy Pressure coefficients of roof increases as tornado away from the center 0m to 20m and also pressure coefficients increases with increase in length of canopy .
i) Surface with canopy Pressure coefficients increases as tornado away from the center 0m to 20m and also pressure coefficients increases with increase in length of canopy.
j) Anti-symmetry was observed in pressure distribution on opposite sides with the attachment of canopy.
k) The pressure coefficients are higher on upper surface of canopy compared to lower surface of canopy. Pressure coefficients increase with the increase of canopy length on upper surface whereas length of canopy has no effect on lower surface of canopy.

6. Published Paper etc.
[Underline the representative researcher and collaborate researchers]
[Accepted for Publication]
1. Rajesh Goyal Mohammed Moizuddin and Masahiro Matsui "Evaluation of Wind Pressure on the Low-Rise Buildings and Surrounding Terrain under the Influence of Tornado Like Vortex Induced Aerodynamic Loads" International Conference on Climate Change Adaptation: Evidences from Best-Practice in Coastal Area, Proposed to held in Dhaka, Bangladesh. (Funded by DAAD, Germany)

[Presentations at academic societies]
No

[Published books]
No

[Other]
Intellectual property rights, Homepage etc.
No

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The effects of wind loading on buildings due to straight line boundary layer type winds have been studied extensively 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 models of low-rise buildings was 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 were simulated in smooth open terrain with vortex core diameters from 0.46 m to 1.06 m. A 1:400 scale model of a building of dimensions of 20m x 20m x 10 m were prepared using flexi glass. An arrangement was 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.

Building models with and without attached canopies were tested in the tornado like flow simulator of wind engineering research center of Tokyo Polytechnic University, Japan. The testing was carried out for different parameters of attached canopy and also for application of tornado at different location of building models. A comprehensive conclusions of the present study was drawn which will be helpful for same design of such projection under the influence of tornado flows on the buildings.