www.cafetinnova.org

ISSN 0974-5904, Volume 10, No. 02

DOI:10.21276/ijee.2017.10.0243

International Journal of Earth Sciences and Engineering

April 2017, P.P. 418-426

Effect of Corner Configuration on Wind Pressure Distribution on Tall Buildings

ADAL MENGESHA YIMER[1] AND ASHOK KUMAR AHUJA[2]

[1]*Structural Engineering, IIT Roorkee, Roorkee-247667, Uttarakhand, INDIA*

[2]*Wind Engineering, IIT Roorkee, Roorkee-247667, Uttarakhand, INDIA*

***Email:** adalmengesha123@gmail.com,ahujashok@gmail.com*

Abstract: *Tall buildings have been traditionally designed to be symmetric rectangular, square, triangular as well as circular in plan, in order to avoid excessive seismic-induced torsional vibrations due to eccentricity, in seismic-prone and highly wind induced regions. But, due to architectural and structural requirements, complicated tall and slender buildings with various corner configuration and cross-sectional shapes are emerged now a day, which are difficult to design using the existing wind load standards only. The principal aim of this study is to investigate the effect of chamfered edged configuration on wind pressure distribution on tall buildings experimentally using open circuit wind tunnel. The test is conducted under a mean wind velocity profile of approaching flow 9.61m/sec. A total of 2 rigid Perspex sheet models of equal height are prepared at scale of 1:100, for this study, one with rectangular cross-section and another with chamfered vertical edges. Wind pressure values at many pressure points on the model wall surfaces are measured and wind pressure coefficients are calculated under varying wind incidence angles from 0^0 to 90^0 for rectangular shape and from 0^0 to 180^0 for chamfered edges at 30^0 interval. The surface and cross sectional variations of mean pressure coefficient are presented in this paper. From this study, it is observed that chamfering vertical edges and wind incidence angle have great effect in altering wind load magnitude.*

Keywords: *Rigid Model, Corner Configuration, Velocity Profile, Pressure Coefficient.*

1. Introduction

In designing conventional tall buildings for wind load in wind prone areas, designers refer internationally relevant standards on winds like Indian, American and Asian codes to obtain design requirements. For example, Indian standard on wind loads IS: 875, Part-3-2015 gives external pressure coefficient values on square and rectangular plan shape clad buildings at limited wind incidence angle. Since there is no Codal information available for the design of unconventional tall building with various corner configuration and cross-sectional shape, numerous experimental wind tunnel study have done to obtain design pressure coefficients.

1.1. Literature Review

Kwok et al. (1988) assessed the effectiveness of building edge modification in reducing along-wind and cross-wind response on rectangular, slotted and chamfered corner models. Szalay (1989) investigated drags on several polygonal cylinder shape tall buildings under controlled velocity of 20m/s. Jamieson, N.J. et al.**,** (1992) investigated the effect of corner configuration on the magnitude and distribution of peak pressure coefficient at 2/3 height of square, beveled, rounded and recessed corners tall building and was reported that minimum peak Cp for each corner ranges from -3.4 for large bevels to -4.8 for two different sizes of curved corners. Kawai (1998) investigated the effect of corner cut, recession and roundness on aeroelastic instabilities such as vortex induced excitation and galloping oscillation for square and rectangular prisms. Bhatnagar (2011) investigated the effect of wind direction and calculate total wind load on a square plan building with rectangular, cut and chamfered corners.

2. Experimental Procedure

Before experimental readings are taken Perspex sheet pressure model are prepared, calibration and adjustment of equipments are done, required flow conditions inside the test section is established by placing flow roughening devices in the upstream of the test section, installation of the model and data recording is done.

2.1. Wind Tunnel Set Up

The tests are conducted in an open circuit rectangular boundary layer wind tunnel with cross-section of 2m*2m and length of 15m at IIT Roorkee. Flow roughening devices such as vortex generators, barrier wall, cubical blocks are used on the upstream end of the test section to achieve the mean wind velocity profile of approaching flow corresponding to terrain category-2 of IS: 875, Part-3-2015.

2.2. Flow Conditions

The test is conducted at mean free stream wind velocity profile of approaching flow 9.61m/sec. The maximum mean turbulence intensity inside the test section is 8.94% which occurs at 20mm above the test

Received: December 09, 2016; Accepted: February 14, 2017; Published: April 26, 2017

International Journal of Earth Sciences and Engineering, 10(02), 418-426, 2017, DOI:10.21276/ijee.2017.10.0243

floor. The maximum blockage ratio calculated is 3.75%.

2.3. Model Description

The prototype principal tall building is assumed to have 50m height and 20m*30m plan dimension. The chamfered model is prepared by chamfering vertically the longer side of rectangular building. The models are made of Perspex sheet at a scale of 1:100. The cross-sectional dimension of models are given in ''mm'' in the following figure.

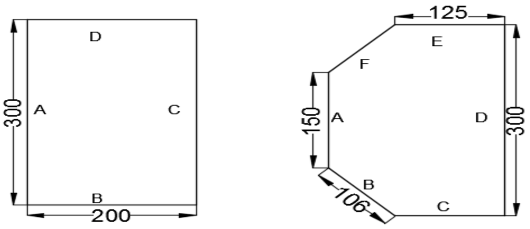


Figure1: *Crossectional dimensions of models*

3. Measurement Techniques

Experimental observations are recorded for 60 seconds for 0^0 to 90^0 wind incidence angle for rectangular model with sharp corners, where as for chamfered model from 0^0 to 180^0 wind incidence angle at an interval of 30^0. A rectangular model with sharp corner has a total of 128 pressure points and the chamfered model has 175 total pressure points. Surface pressures at each pressure-taps on both models are measured by connecting each pressure point one by one to storage banks on scanivalve equipment. This equipment has two storage banks **Banka** and **Bankb** in which each bank can store 64 readings at a time. Measured surface pressures obtained from the equipment is in the form of N/m^2. The Pressure coefficient, **Cp** at each pressure point on the walls of each model is given by:

$$C_p = \frac{P}{0.6 * Vref2} \tag{1}$$

Table 1: *Pressure points on wall surfaces of model*

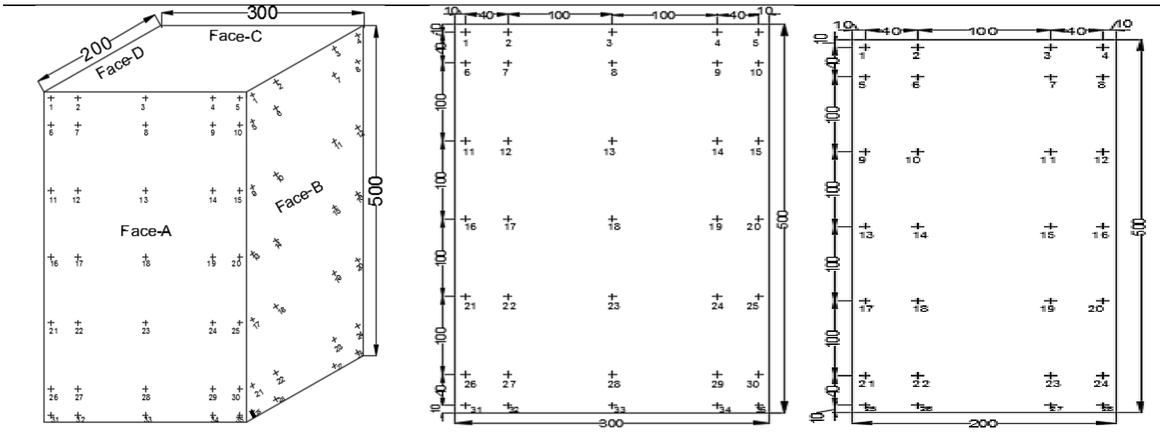
Model-1		Model-2	
Faces	Pressure points	Faces	Pressure points
A	28	A	35
B	28	B	28
C	28	C	35
D	35	D	28
E	28		
F	28		
Total	175		128

4. Experimental Analysis and Results

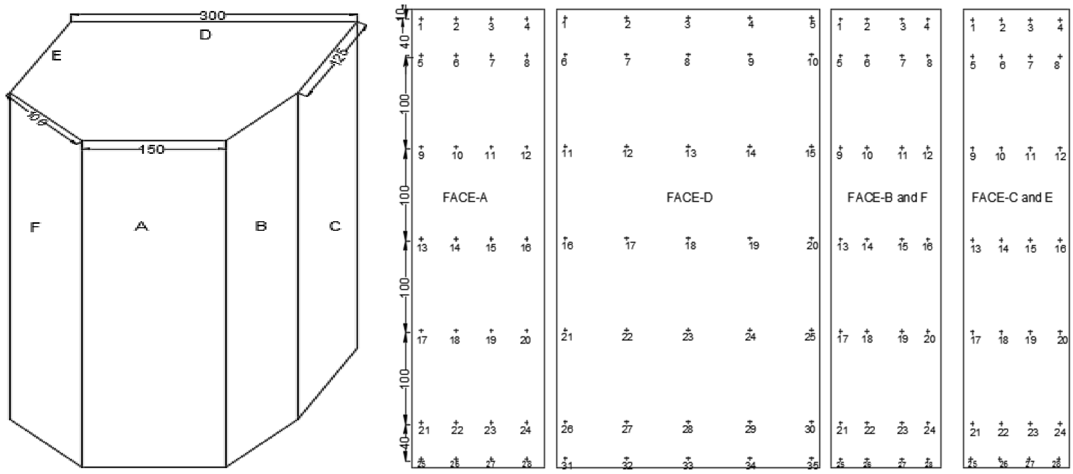
The mean pressure is calculated from readings taken from experimental study and then the mean pressure coefficient is calculated using the above equation. The results of this study can be presented in two ways. The first is by pressure contour, which shows the variation of mean pressure coefficients on the wall surfaces of models. The second is by, cross-sectional variation of mean pressure coefficients at a particular section at which pressure points are defined.

Table 2: *Values of total mean pressure coefficients on the walls of the two models*

Wind incidence	Rectangular model				Chamfered Edged model					
	Face A	Face B	Face C	Face D	Face A	Face B	Face C	Face D	Face E	Face F
0	0.26	-0.91	-0.62	-0.86	0.57	0.06	-0.69	-0.53	-0.70	-0.09
30	0.36	-0.12	-0.41	-0.51	0.22	0.53	-0.11	-0.52	-0.65	-0.79
60	-0.06	0.41	-0.49	-0.38	-0.23	0.48	0.42	-0.55	-0.49	-0.44
90	-0.53	0.42	-0.53	-0.20	-0.53	0.07	0.54	-0.56	-0.29	-0.32
120					-0.42	-0.67	0.28	0.14	-0.37	-0.38
150					-0.47	-0.50	-0.46	0.44	-0.46	-0.45
180					-0.51	-0.60	-0.62	0.43	-0.74	-0.61



(a) Isometric view (b) Face A and C (c) Face B and D
Figure 2: *Location of pressure points on rectangular model wall surfaces*



Note: All dimensions are in ''mm''

Figure 3: *Location of pressure points on chamfered edged rectangular model wall surfaces*

4.1. Rectangular Model with Sharp Corner

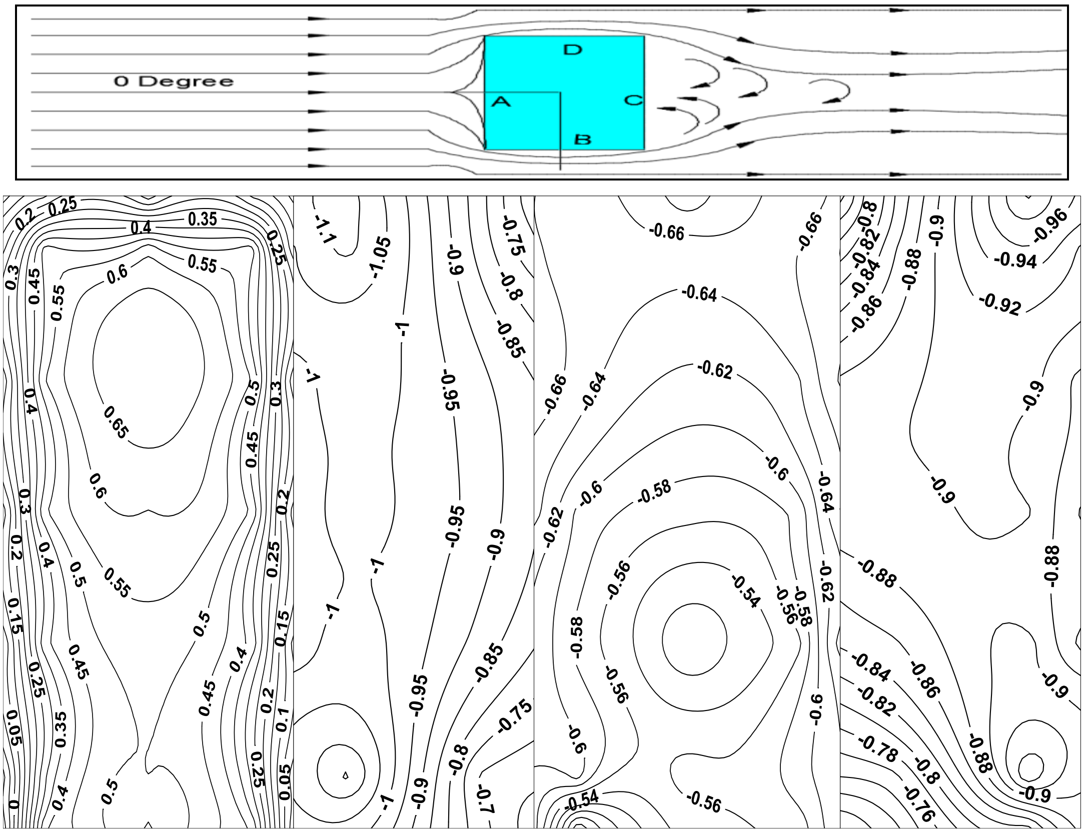


Figure 4: *Mean pressure coefficients, Cp on faces A to D of rectangular model*

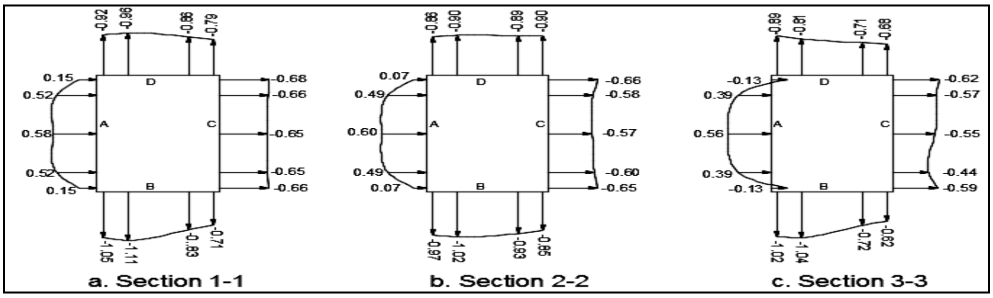


Figure 5: *Variation of pressure coefficients, Cp at section 50mm (a), 250mm (b) and 490mm(c) from top of model*

At 0⁰wind incidence angle (Fig.4), front surface (face-A) is subjected to varying pressure with maximum Cp of 0.66 at furthest top edge. Leeward surface (face-C) is subjected to suction with minimum Cp of -0.69 at bottom edge. Face-B is subjected to completely suction and minimum value is -1.16near to bottom edges. Face-D is subjected to varying suction with minimum Cp of -1.0 at the top nearest edge. Face-A is subjected to pressure and suctions at furthest edges whereas face-B, face-C and Face –D are all subjected to suction.

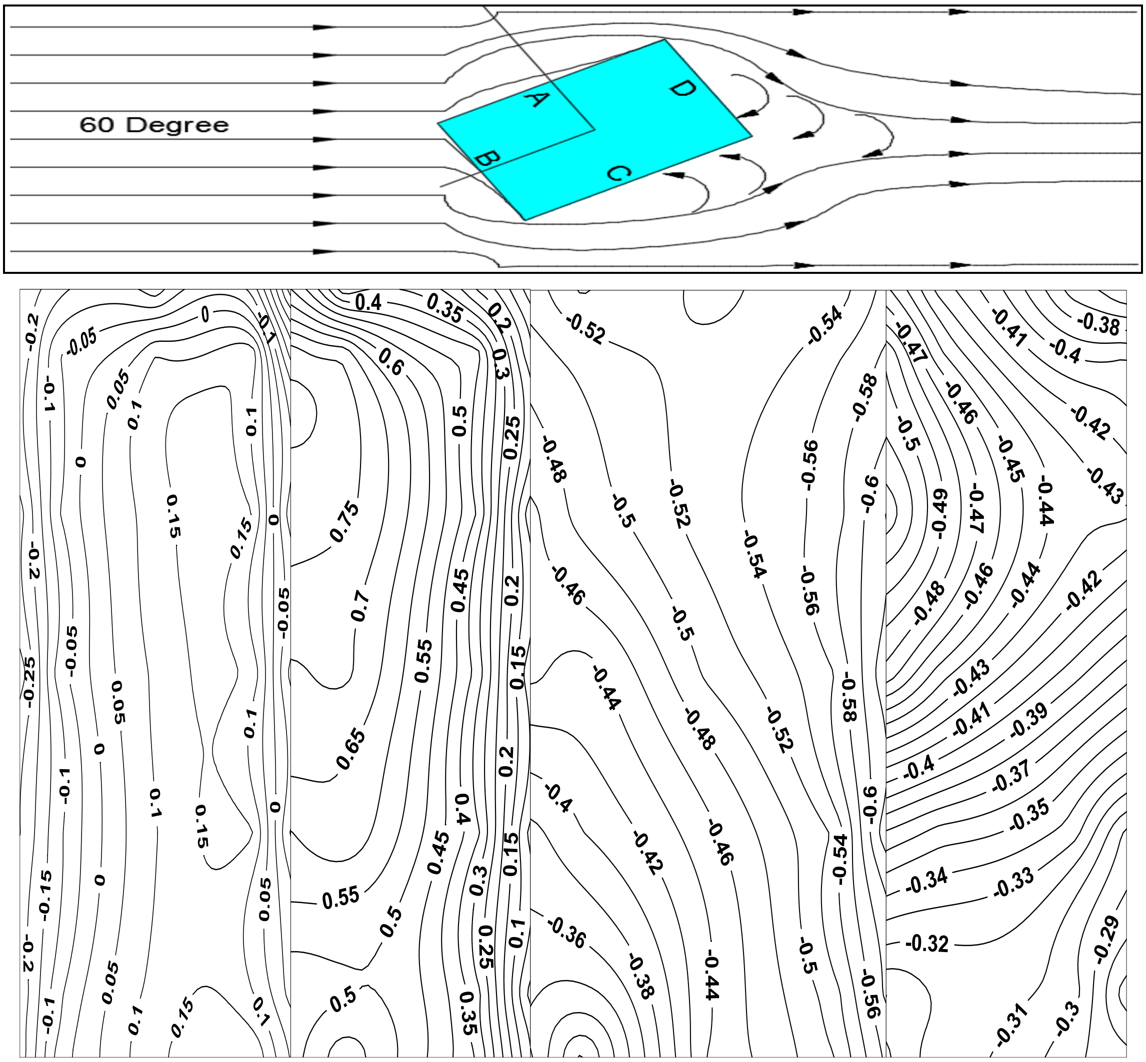


Figure 6: *Mean pressure coefficients, Cp on faces A to D of rectangular Model*

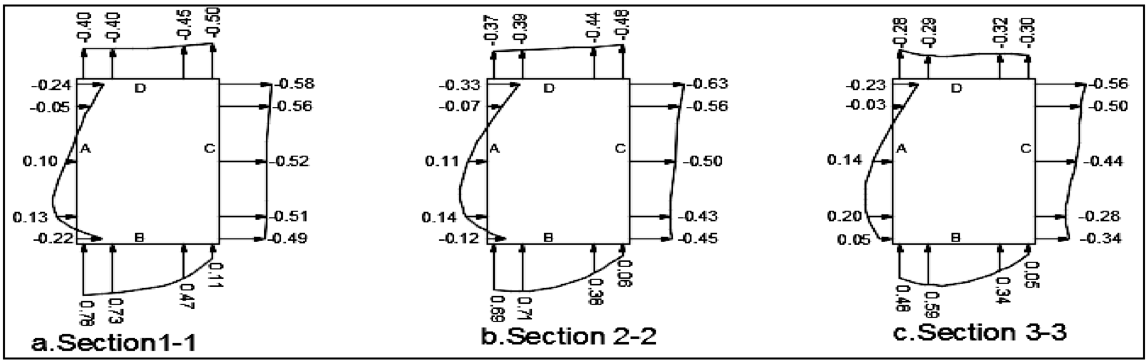


Figure 7: *Variation of pressure coefficients, Cp at section 50mm (a), 250mm (b) and 490mm(c) from top of model*

At 60⁰ wind incidence angle (Fig.6), face-A is subjected to varying pressure with maximum Cp of 0.2 around center edges. Leeward surface (face-B) is subjected to a maximum pressure Cp of 0.78 at top edge. Face-C is subjected to maximum suction near to bottom edge. Face-D is subjected to minimum Cp of -

0.53 around central edge. Face A is subjected to pressure and section; face-B is subjected to purely pressure while face-C and face-D are subjected to suction.

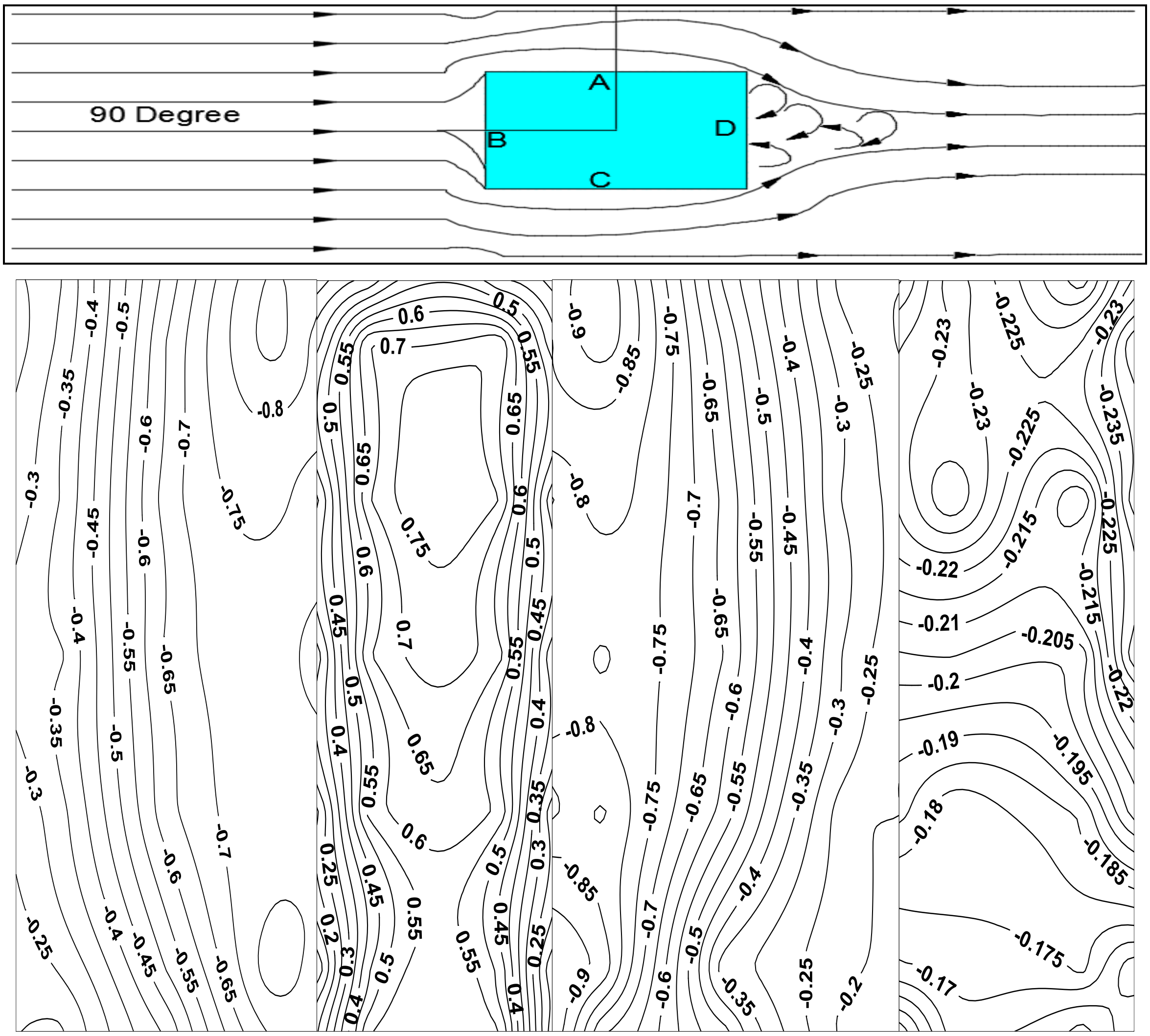


Figure 8: *Mean pressure coefficients, Cp on faces A to D of rectangular model*

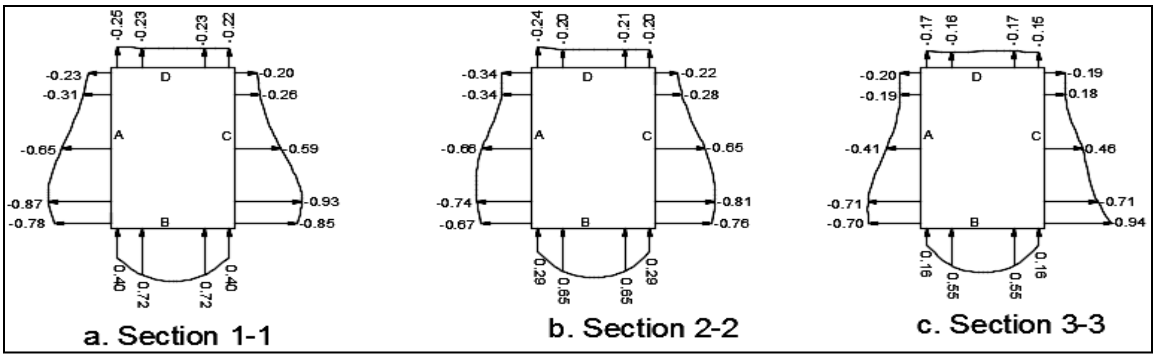


Figure 9: *Variation of pressure coefficients, Cp at section 50mm (a), 250mm (b) and 490mm(c) from top of model*

At 90^0wind incidence angle (Fig.8), face-A is subjected to varying suction with minimum Cp of -0.87 at nearest top edge. Windward surface (face-B) is subjected to pressure with maximum Cp of 0.72 at top near edge. Face-C is subjected to completely suction and minimum value is -0.94 near to bottom edges. Leeward surface, (face-D) is subjected to varying suction with minimum Cp of -0.25 at the top of nearest edge. Face-B is subjected to pressure whereas face-A, face-C and Face –D are all subjected to suction (Negative mean pressure coefficient, Cp) only.

4.2. Rectangular model with vertically chamfered edge (75*75) mm

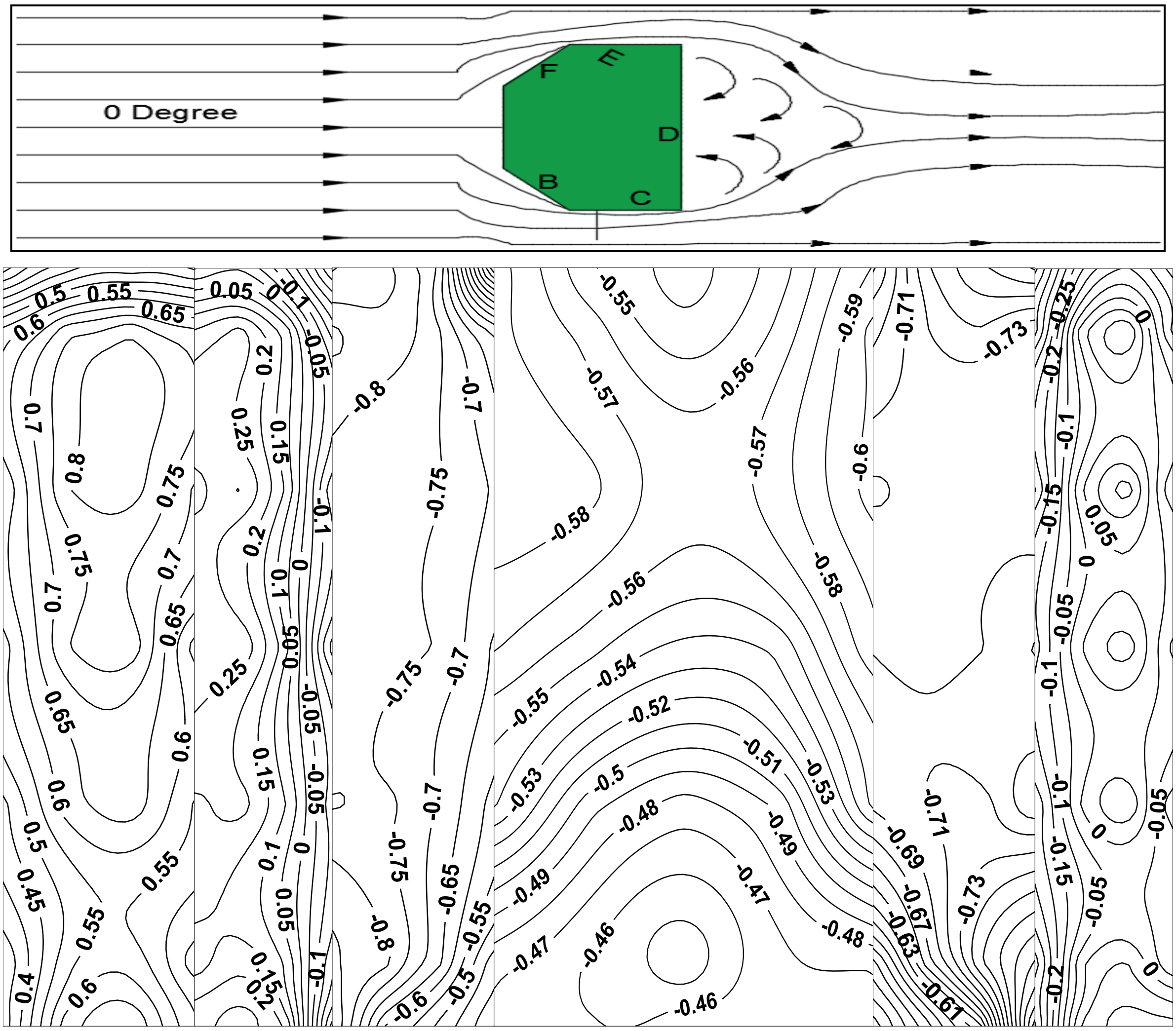


Figure 10: *Mean pressure coefficients, Cp on faces A to D of chamfered edged model*

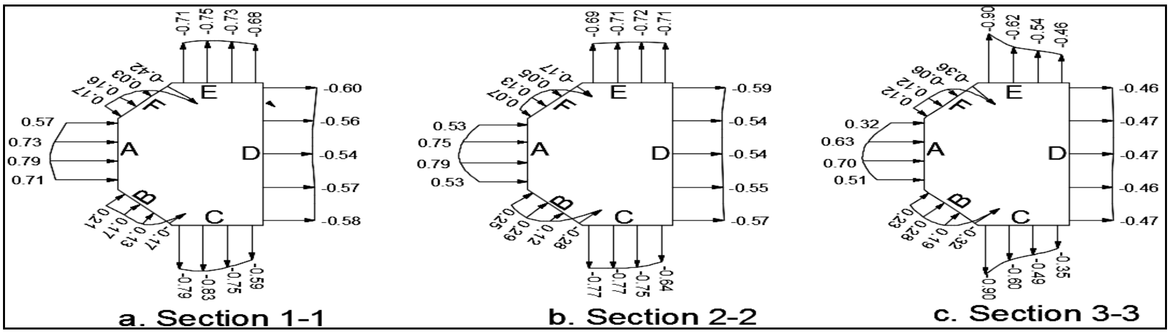


Figure 11: *Variation of pressure coefficients, Cp at section 50mm (a), 250mm (b) and 490mm(c) from top of model*

At 0^0wind incidence angle (Fig.10), face-A is subjected to varying pressure with maximum Cp of 0.82aroundcentral. Face-B is subjected to both varying pressure and suctions with maximum pressure Cp of 0.31around the center. Face-C is subjected to completely suction with minimum value is -0.9near to bottom edges. Face-D is subjected to completely suction with minimum Cp of -0.6near to central edges. Face-E is subjected to completely suction with minimum Cp of -0.9at the bottom edge. Face-F is subjected to both varying pressure and suctions with maximum pressure Cp of 0.18around the center of the instrumented model.

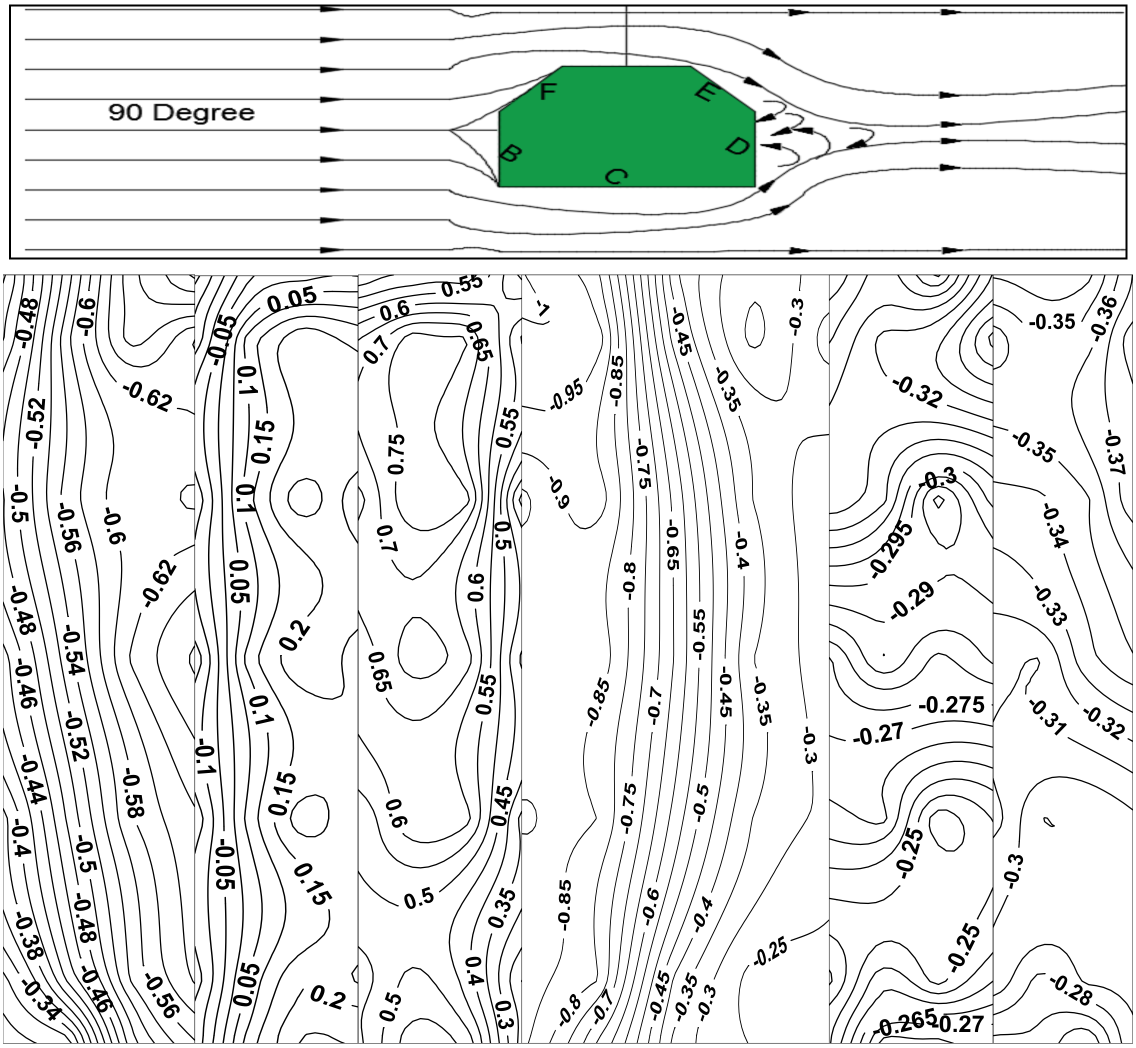


Figure 12: *Mean pressure coefficients, Cp on faces A to D of chamfered edged model*

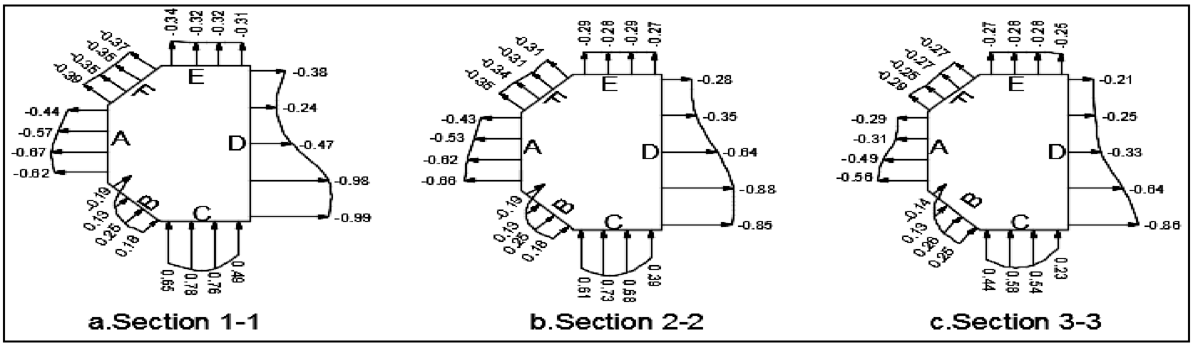


Figure 13: *Variation of pressure coefficients, Cp at section 50mm (a), 250mm (b) and 490mm(c) from top of model*

At 90^0wind incidence angle (Fig.12), face-A is subjected to varying suction with minimum Cp of -0.73 at top near edge. Face-B is subjected to both varying pressure and suctions with maximum pressure Cp of 0.29around the center. Face-C is subjected to completely pressure with maximum value of 0.8 at furthest top edges. Face-D is subjected to completely suction with minimum Cp of -1.0near to top edge. Face-E is subjected to completely suction with minimum Cp of -0.34at the top edge. Face-F is subjected to completely varying suction with minimum Cp of -0.39 around the top edges of the instrumented model.

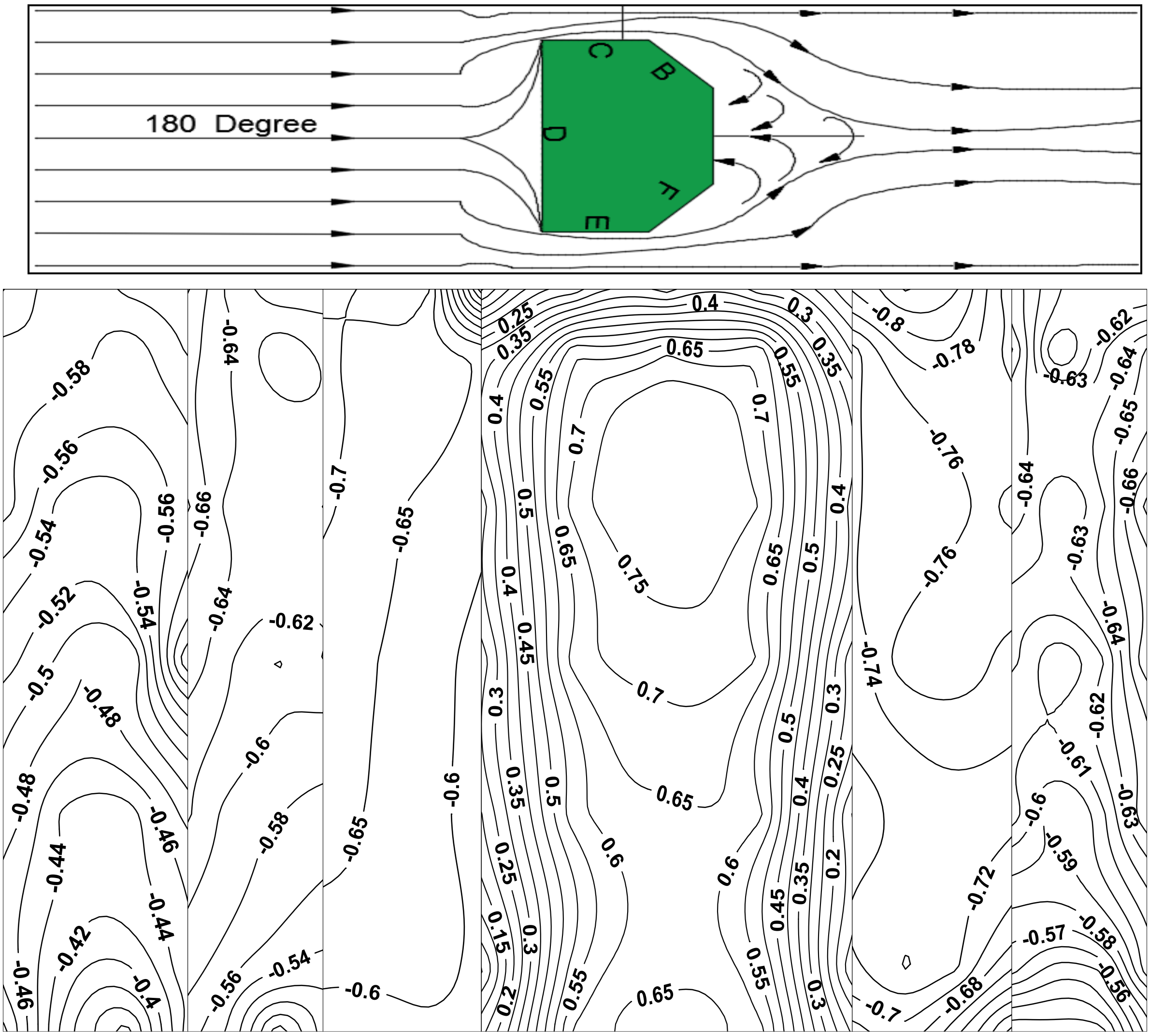


Figure 14: *Mean pressure coefficients, Cp on faces A to D of chamfered edged model*

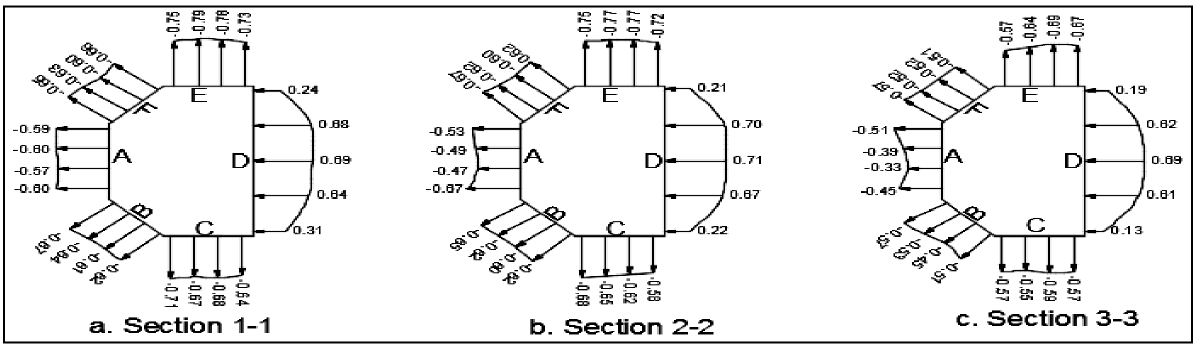


Figure 15: *Variation of pressure coefficients, Cp at section 50mm (a), 250mm (b) and 490mm(c) from top of model*

At 180^0wind incidence angle (Fig.14), face-A is subjected to varying suction with minimum Cp of -0.64 at near to central edges. Face-B is subjected varying suction with minimum suction Cp of -0.64near to the top edges. Face-C is subjected to completely suction with minimum value of -0.72at nearest top edges. Face-D is subjected to both suction and pressures with maximum Cp of 0.77around the center. Face-E is subjected to completely suction with minimum Cp of –0.84 at the top edge. Face-F is subjected to completely varying suction with minimum Cp of -0.68 around the central edges of the instrumented model.

5. Comparison of Pressure Coefficients

The maximum and minimum pressure coefficients on the surfaces of the two models at different wind incidence angle are compared in the following graphs.

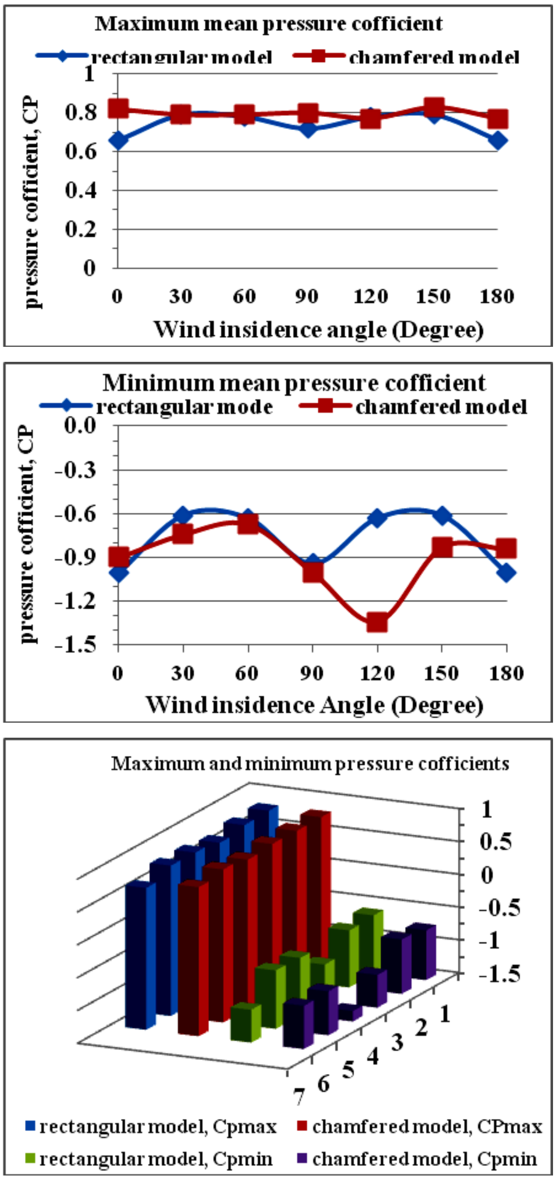


Figure16: *Variation of maximum and minimum Cp*

6. Conclusions

Results of this experiment shows wind ward face is subjected to Pressure whereas the leeward face is subjected to Suction. Compared to rectangular model the pressure Coefficient in chamfered models increases. The minimum suction pressure coefficient is observed in chamfered model at 30^0 wind incidence angle which is -1.44 where as the maximum positive pressure coefficient is observed in rectangular model at120^0 which is 0.79. The pressure coefficient of rectangular model obtained from experimental study has a good Agreement with pressure coefficient value in table 5, IS: 875-part-3 (2015). As wind incidence angle as well as chamfering size varies, the values and distribution of pressure coefficients on model surfaces vary. Generally Wind incidence angle and chamfering size has great effect on distribution of pressure and the Maximum and minimum mean pressure coefficients Cp, mostly occurs around the top and bottom corners of model surface.

Acknowledgment

The work presented in this paper is part of research work done by the first author for M.Tech. Degree under the supervision of the second author. The first author deeply acknowledged the second author for his continuous guidance to effectively accomplish this paper.

References

[1] ASCE: 7-02 (2002), “Minimum Design Loads for Buildings and Other Structures”.

[2] AS/NZS: 1170.2 (2002), “Structural Design Actions, Part 2 - Wind Actions”.

[3] Bhatnagar, N.K. (2011), ‘’Effect of Geometrical Shapes on Wind Loads on Buildings’’ Indian Institute of Technology Roorkee, India, September 2011.

[4] IS: 875-part-3 (2015) ‘’Code of practice for design loads (other Than earth quack) for Building and Structure-Wind loads’’.

[5] Kawai, H. (1998) ‘’Effect of corner modifications on aero elastic Instabilities of Tall buildings,’’ Journal of Wind Engineering & Industrial Aerodynamics 74-76,719-729.

[6] Kwok, K.C.S., Wilhelm, P.A., Wilkie, B.G. (1988) ‘’Effects of Edge configuration on wind induced responses of tall buildings’’ Engineering Structure, Vol.10pp.135-390.uct.

[7] Jamieson, N.J., Carpenter P. and Cenek P.D, (1992) ‘’wind induced external pressure on a tall building with various corner Configuration’’41-44 (1992) 2401-2412.

[8] National conference on wind tunnel testing (NCWT-05) at IIT madras Chennai, India march 16-17, 2017.