# WIND LOADS ON WALLS OF LOW-RISE BUILDING

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**3 authors**, including:

Amrit Kumar Roy
National Institute of Technology, Hamirpur

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# WIND LOADS ON WALLS OF LOW-RISE BUILDING

*A. D. John[1)], A. K. Roy[2)] and A. Gairola[3)]

[1)] Department of Civil Engineering, Galgotias University, Greater Noida, India
[2)] Efficiency of Building Division, Central Building Research Institute, Roorkee, India
[3)] Department of Civil Engineering, Indian Institute of Technology Roorkee, India

## ABSTRACT

A wind-tunnel study has been carried out to assess wind loads on walls of 25° low-rise gable building due to interference with freestanding boundary wall placed on the upstream side at different locations. Mean and fluctuating pressures were measured on wall surfaces of the building prepared at a geometric scale of 1:25. Critical values of positive and negative pressures measured on the isolated gable building agree well with design pressures specified in wind standards. Based on the wind tunnel experiment, it has found that at different distances of interfering wall, pressure coefficients on building reduce significantly i.e. shielding occurs.

Keywords: Low-rise building; wind loads; interference.

## 1. INTRODUCTION

Wind loads on low-rise gable buildings mostly obtained through experimental investigations conducted on the common types of gable-buildings for isolated condition. Studies have shown that corner regions of roof and walls are subjected to high suction and high pressure at oblique wind directions during windstorm (Yasushi and Nicholas 1998, Stathopoulos 2001).

Boundary wall can play an important role for shielding against these wind loads on wall of low-rise buildings; especially at the corner regions, where wind force is dominant component of load. A few studies for buildings with interference of other structures are described below.

Studies to determine the effect of four nearby octagonal structures on the wind pressure along the circumference of a central circular structure building in the immediate vicinity were undertaken early by Peterka and Cermak (1976). It was observed that adverse effects can be encountered depending on the relative placement of structures in the approaching wind. Introducing variations in building geometry may decrease these effects. Ho et al. (1991) studied the effect of surroundings on wind loads on flat roof low buildings. They considered several cases with different types of immediate surroundings, and concluded that with increase in the surrounding obstructions the mean wind pressure acting on the building decreased (as expected), while unsteady pressure increased. Stathopoulos (1984) studied the effect of a tall nearby building on the wind loading of low buildings (5, 7.5 and 10 m high) with gable roofs in a wind tunnel at 1:250 geometric scale in two different terrain conditions. The results indicate significant increase of the pressure coefficients under conditions of buffeting caused by a tall building. He further concluded that the complexity of the problem of evaluation of wind loads on low buildings under buffeting conditions indicates that, with the present state-of-the-art, it would be extremely difficult to treat this nearby building situation with any degree of generality. Kumar (1994) studied the interference effect on a gable pitched roof building of a similar building and found that the effect of interference is maximum when the spacing between the two buildings is between 0.25 and 0.50 of the width of the building. Holmes (1983,

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[1)] Assistant Professor
[2)] Scientist Fellow
[3)] Associate Professor

1994) studied the effect of grouping of houses in characteristic suburban street patterns. A significant increase in the magnitude of the negative roof pressures occurred when added with one extra half row of houses was added to each side of an isolated low-set house. It also concluded that the shielding effect of upwind buildings is dependent strongly on the ratio of building spacing to height.

Tsutsumiet al. (1992), Ho et al. (1990) and John (2009) also reported the significant effect of surrounding structures on wind pressures on low-rise buildings. Khanduri et al. (1998), in their state-of-the-art paper, have discussed enormous possible interference effects in low as well as in high-rise structures.

Since numerous situations are possible amongst the possible surroundings for a building or group thereof, generalization of results for the effect of interference is difficult. The best that can be expected from more study is a widened database with possibly some kind of generalization for different “categories” of situations. In the present study, following two objectives have been undertaken. First, to determine wind pressures on wall surface of isolated building and compare the experimental values with codal provisions. Second is to study the variation of wind pressure on wall surfaces of building due to the interference of boundary wall on upstream side.

## 2. EXPERIMENTAL SETUP

The experiment has been carried out in an open circuit atmospheric Boundary Layer Wind Tunnel at Indian Institute of technology Roorkee (IITR). The working section of the tunnel is 15 m long and 2.1 m wide. The height of the working section is approximately 2.0 m. The wind speed of the reference height (z = 80 cm) is 11.55 m/s.

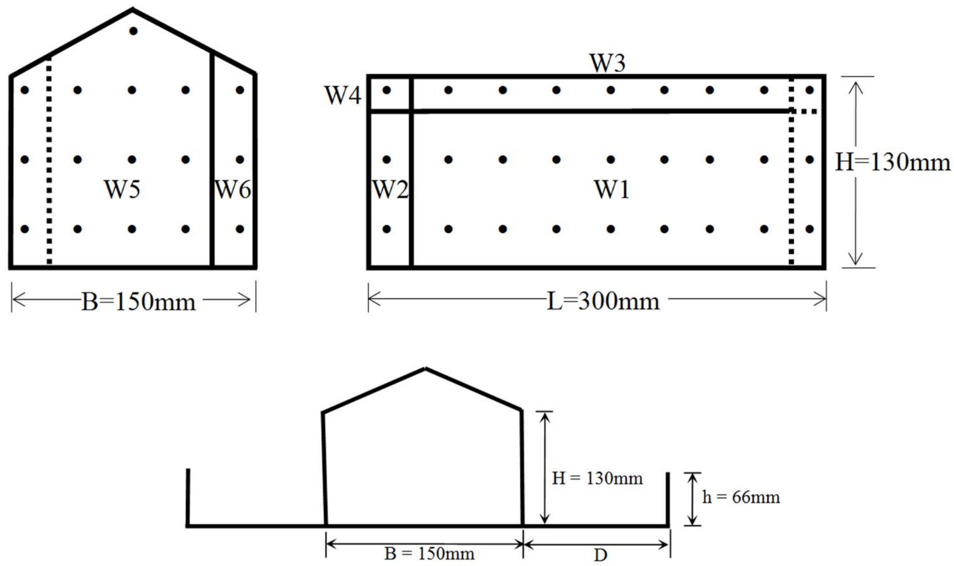


Fig. 1. Schematic of tap locations on different zones on walls of building model.

### 2.1 Model building

A 25° gable-building model of geometric scale of 1:25 was fabricated representing a building with height (H) and width (B) of 3.25 x 3.75 m. The lengths (L) of the buildings were 7.5 m. These building are regarded as simplified model of typical low-rise building for warehouses and residential houses. Experiment was performed for 0° to 90° at an interval of 15° angle of wind attack. The lay out of pressure taps for walls is shown in Figure 1. Particular attention has been paid to the position of the pressure taps near to the edge and corner of the walls of building, where the separation of flow may occur to form a region of high velocity gradient with high local turbulence and vortices.

2.2 Wind Tunnel Flows

The mean velocity and longitudinal turbulence intensity profile are simulated in the wind tunnel for the desired terrain condition. The velocity profile has a power law exponent (α = 0.14). The values of mean velocity and longitudinal turbulence intensity at the eave height (H) of the model have been found to be 9.2 m/s and 18% respectively as shown in Figure 2. Assuming the boundary layer scale of 1:400 and the velocity scale of 1:4, the time scale was determined as 1:100.

2.3 Pressure Measurement and Data Analysis

Pressure taps 10 mm long, 1.3 mm external diameter and 1 mm internal diameter of stainless steel tube were inserted into the holes drilled in the Perspex sheet with one end of the tap flush with the wall surface. The tubing for measuring the surface pressure consisted of 500 mm vinyl tube with a 20 mm restrictor placed at 200 mm from the pressure point. Pressure measurements were carried out by using a scanivalve ZOC12, a 32-port pressure scanner having a linear response up to 200 Hz. The sampling rate was kept at 500 samples per second per channel and the duration of each run was 16 seconds.

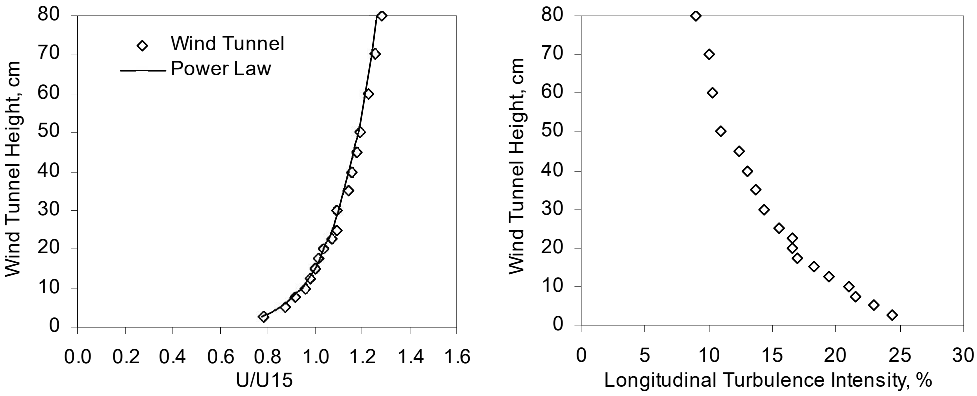


**Fig. 2.** Upstream profiles of mean wind speed and longitudinal turbulence intensity.

Wind pressures measured on the building models are expressed in the form of a non-dimensional pressure coefficients defined as follows:

$$C_p = \frac{p_i - p_0}{1/2\rho U^2}$$

where, $p_0$ = static (ambient, atmospheric) reference pressure, $p_i$ = instantaneous surface pressure, $\rho$ = air density, $U$ = mean wind velocity measured at eaves height of the model. Since pressure at any point on wall of the building is fluctuating with time, the pressure coefficient can also be treated as time varying quantity. Following statistical quantities of pressure coefficient $C_p$ were obtained from sampled time history.

Mean value = $C_{pmean} = \frac{1}{N}\sum_{i=1}^{N} C_{p(i)}$ , where N is the total number of samples.

$C_{pmin}$ = minimum of $C_p$, $C_{pmax}$ = maximum of $C_p$

Standard deviation of $C_p$, $C_{psd} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}[C_{p(i)} - C_{pmean}]^2}$ , variance = $\sigma_x = (C_{psd})^2$

Design pressure coefficient, $C_{pq} = C_{pmean} + (C_{psd} \times \text{peak factor})$, where peak factor is the ratio of maximum and mean value of $C_p$. The average value of peak factor is estimated as 3.0.

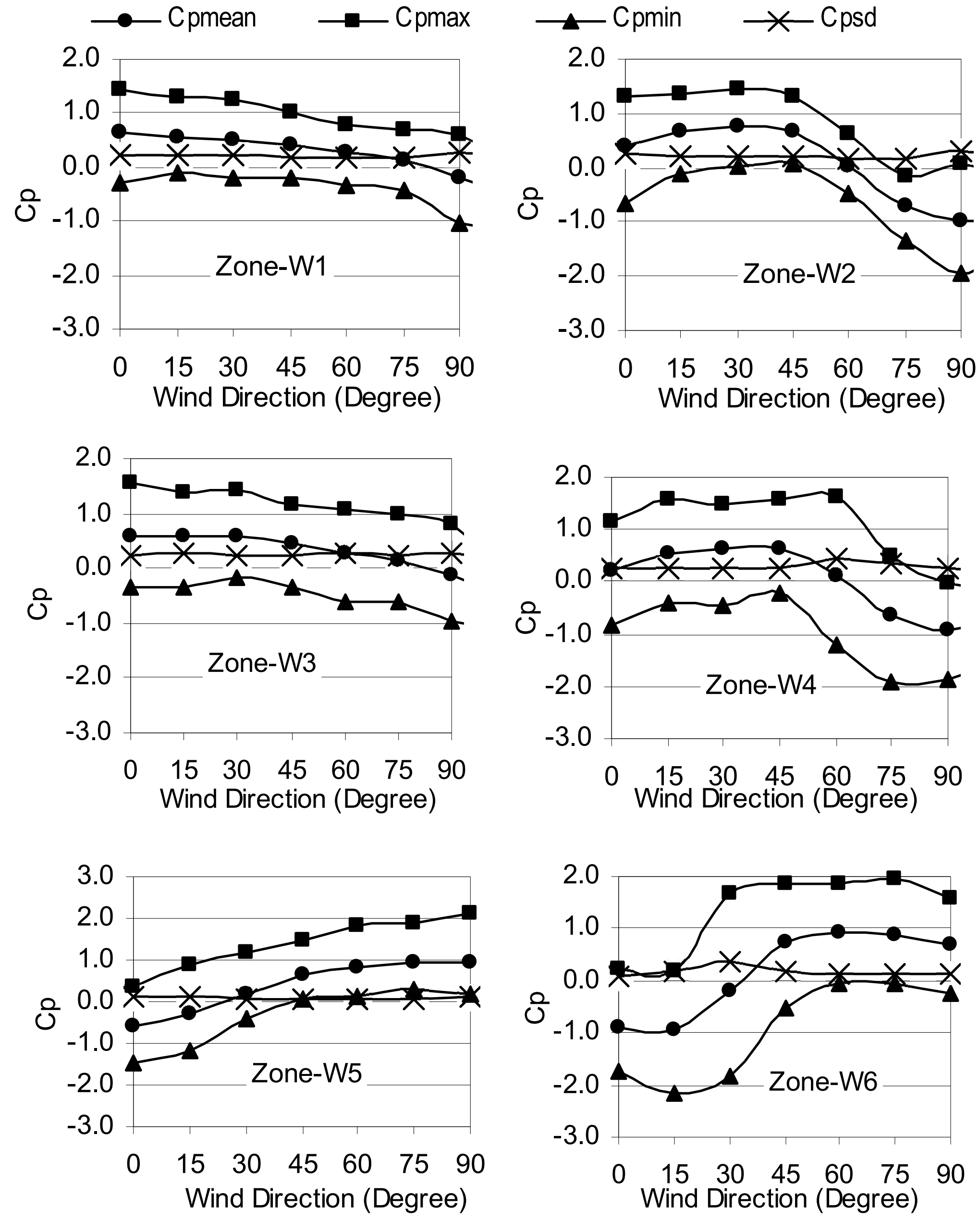


**Fig. 3.** Variation of $C_p$ for different zones of wall surface of building

## 3. RESULTS AND DISCUSSION

3.1 Variation of Instantaneous Pressure Distribution with Time

The basic wind pressure coefficients, $C_{pmean}$, $C_{pmax}$, $C_{pmin}$ and $C_{psd}$ for different zones of wall of gable building for wind incidence angles of $0^o$ to $90^o$ at an interval of $15^o$ are given in Figure 3. Corresponding values of design pressure coefficients are given in Table 1. Positive pressure on walls is found to be maximum for the corner zones W2, W4 and W6, when angle between wind direction and wall surface of building is $120^o$. While for central zones W1, W3 and W5 it has occurred when wind direction is perpendicular to the wall of building i.e. $\theta = 0^o$.

3.2 Comparison with Codal Provisions

The values of design pressure coefficient obtained experimentally corresponds to 3-sec gust ($C_{pq*}$) are given in Table 1. The positive and negative values of $C_{pq*}$ of wall surfaces of building for isolated building are compared with the various Design Codes; IS 875 (Part 3) - 1987, ASCE 7-05, AS/NZS 1170.2:2002 and HK-2004.

The negative $C_{pq*}$ obtained by AS/NZS 1170.2:2002 Code is -0.65 while the same value by experimental observation for zone W2 is -0.76 which is 15% higher than the codal values. The results while compared with IS 875 Part-3 shows that the values of $C_{pq*}$ are on the conservative side compared to the experimental values. Also, comparing the experimental values of $C_{pq*}$ on gable and longitudinal wall surface with the ASCE 7-05 and HK-2004, it was found that the codal values are conservative.

3.3 Interference Effect of Freestanding Wall on Building Walls

The mean pressure coefficients for all the six zones (W1 to W6) of wall surfaces of building in presence of boundary wall at different locations are shown in Figure 4. From these figures, it is observed that with an increase in the distance between the building and the boundary wall, initially there is a significant decrease in the magnitude of positive and negative pressure coefficients on the wall surface of the building and then the effect tapers off.

**Table 1** Comparison of $C_{pq*}$ for wall surface of building with codal values

| Wall Zones | Experimental $C_{pq*}$ | IS: 875 Pt-3 1987 | ASCE 7-05 | AU/NZ 1170.2:2002 | HK-2004 |
|---|---|---|---|---|---|
| W1 | 0.55 | 0.70 | 1.00 | 0.70 | 1.00 |
| | -0.36 | -0.50 | -1.10 | -0.50 | -1.00 |
| W2 | 0.56 | 0.70 | 1.00 | 0.70 | 1.00 |
| | -0.76 | -0.80 | -1.40 | -0.65 | -1.40 |
| W3 | 0.51 | 0.70 | 1.00 | 0.70 | 1.00 |
| | -0.34 | -0.50 | -1.10 | -0.50 | -1.00 |
| W4 | 0.57 | 0.70 | 1.00 | 0.70 | 1.00 |
| | -0.76 | -0.80 | -1.40 | -0.65 | -1.40 |
| W5 | 0.69 | 0.70 | 1.00 | 0.70 | 1.00 |
| | -0.5 | -0.70 | -1.10 | -0.50 | -1.00 |
| W6 | 0.67 | 0.70 | 1.00 | 0.70 | 1.00 |
| | -0.67 | -1.10 | -1.40 | -0.65 | -1.40 |

The central zone of the longitudinal wall W1 is subjected to maximum positive pressure when wind blows perpendicular to ridge ($0^o$ angle of wind incidence) for isolated condition. For $0^o$ wind incidence, positive pressure changes to negative when boundary wall is located at D = 1.5H from the face of building.

The edge zone W2 is subjected to high negative pressure when wind blows parallel to ridge (at $90^o$ angle of wind incidence) for isolated building. However, at $90^o$ angle of wind incidence, negative pressure reduces significantly due to boundary wall. The $C_{pq*}$ values reduce up to 30% as distance D, increases up to 3H. Further increase in the distance of boundary wall, reduces the effect on negative pressure coefficients.

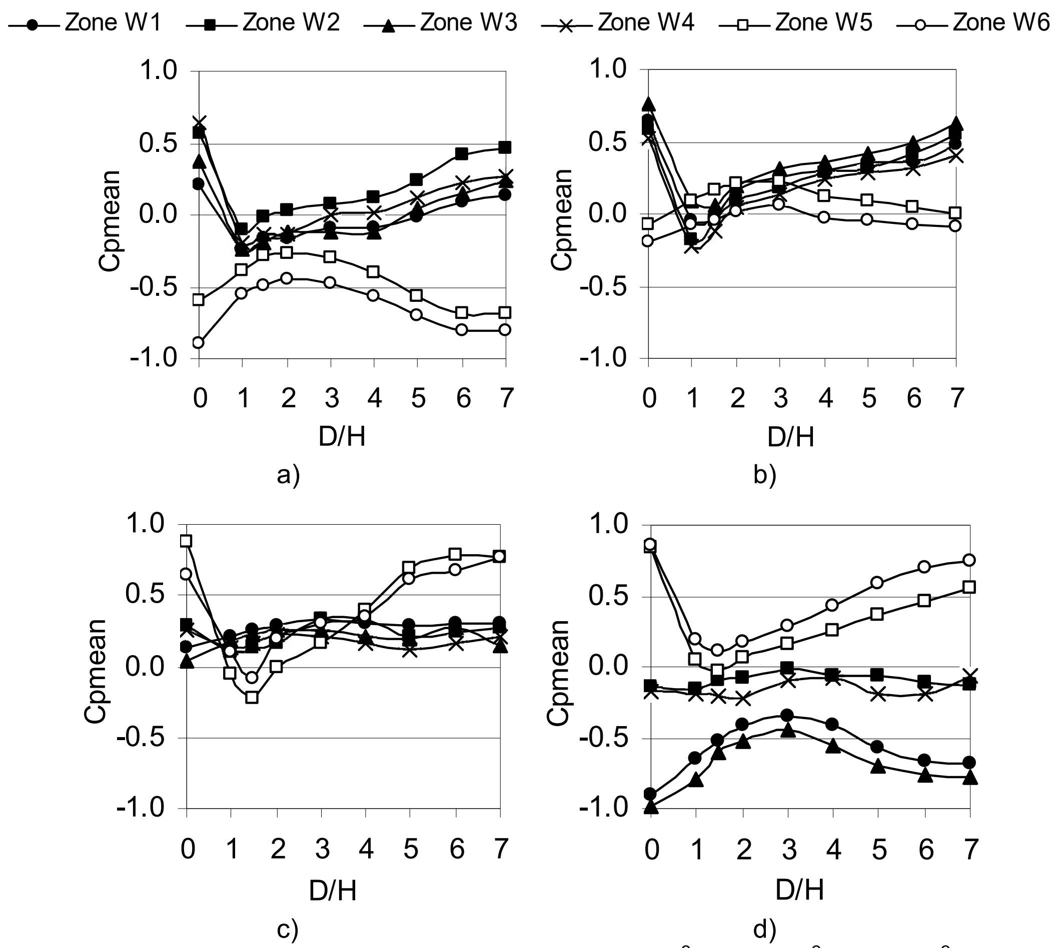


**Fig. 4**. Variation of $C_p$ mean on wall surface of building a) θ = 0°, b) θ = 30°, c) θ = 60° , d) θ = 90°

The corner zone W4 is subjected to high fluctuating positive as well as negative pressure coefficients because of high local turbulence and vortices. For isolated building, the negative $C_{pq*}$ value is -0.76 and this values reduce to -0.48 when boundary wall is located at 3H from the building wall. Positive values of $C_{pq*}$ for the same buildings have been found to be 0.58 for isolated condition and these reduced up to 0.41 at D = 1.5H. Contours of mean pressure coefficients for the wall surface of building are presented in Figure 5.

The central zone of gable wall W5 is subjected to high negative pressure when wind blows perpendicular to ridge (0° angle of wind incidence) for isolated condition and the values is -0.50. It reduces up to 16%. Likewise the positive $C_{pq*}$ values of 0.64 is reduced by 42% when boundary wall is located at D = 1H.

The maximum positive values of $C_{pq*}$ for edge zone W6 are found to be 0.67. Due to shielding effect this values is decreased by 45% when the distance between building and boundary wall is 1H. The negative value of $C_{pq*}$ for isolated building is -0.67, this value changes to -0.54 when D = 2H.

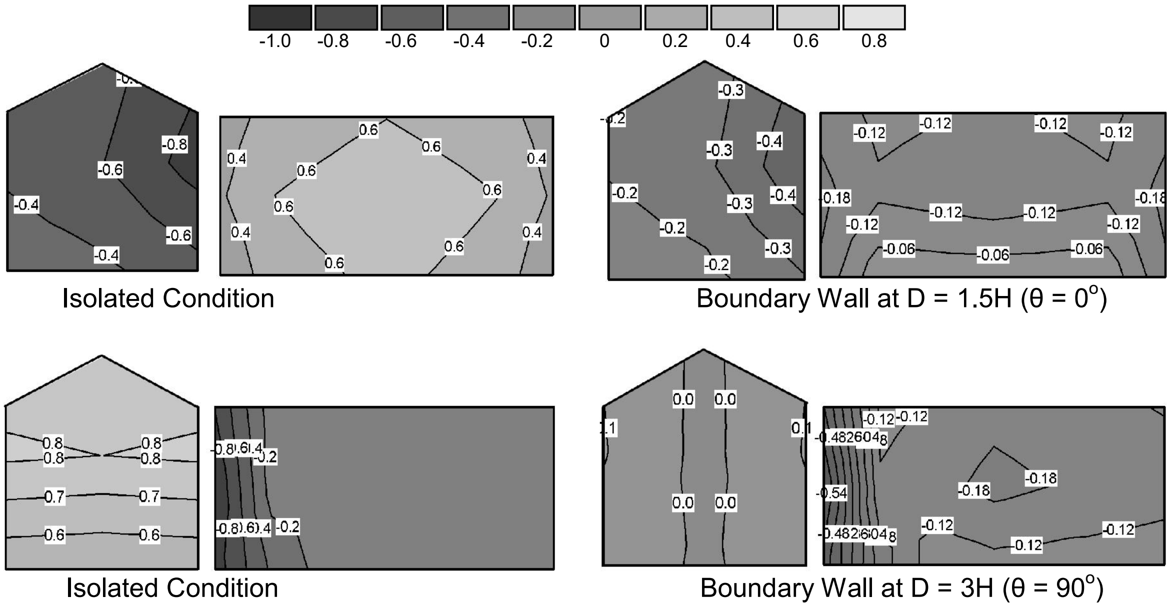


**Fig. 5.** Variation of mean pressure distribution on wall surface of building

## CONCLUSIONS

In this paper, information based on the experimental studies has been provided on wind load variations on wall surface of a gable building. The objective of this investigation is to develop the better understanding on wind load on wall surface of building due to interference effect of boundary wall located on upstream side of building. It is observed that the maximum shielding for positive design pressure coefficients in various zones occurred when the spacing between the building and the boundary wall is 1.5 times the height of building wall. Negative pressure values for the building wall reduce significantly when wall position is at two to three times the height of building wall. Further increase the distance of boundary wall tapers off the shielding effect on wall surface of building.

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