Interference effects on wind pressures on low-rise and high-rise square structures in side-by-side arrangement

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In this paper, the effects of interference on three-dimensional bluff bodies with square cross-section placed in side-by-side arrangement for a low-rise body and a high-rise body have been investigated experimentally. The extent of interference effects are brought out by varying the spacing between the bodies. The pressure distributions on the surfaces of the bodies are measured to bring out the severity of interference due to another body adjacent to it. The bodies are exposed to an air stream with a velocity profile satisfying the $1/7^{th}$ power law. It is seen that the pressure distribution on rear side and interference side is greatly affected for low-rise body when interfered by a high-rise body in close proximity.

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Wind loading codes have been developed on the basis of wind-tunnel tests on isolated models in different wind environments, which adequately cover the response of the majority of buildings. However, the wind loads on buildings in realistic environments may be considerably different from those measured on isolated buildings. Buildings are in general considered as three-dimensional prismatic structures, since they have finite dimensions of length ($l$), width ($b$) and height ($h$). Further, they have well-defined edges and are fixed to the ground. Depending on the height, buildings are classified as high-rise or low-rise structures; if the height is more than three times the width, it is a high-rise structure and if the height is less than $3b$ it is considered as a low-rise structure. The distribution and magnitude of wind pressure on various faces of a building can be expected to be strongly dependent on the approach flow conditions, building geometry and the relative dimensions. Another aspect, which would significantly influence the wind loading on any structure, is the ‘interference’ effects. Interference effects of one building located in the vicinity of another can be expected to significantly influence wind pressure distribution over the building considered.

There are several investigations in the past, which deal with the measurement of wind loads on buildings exposed to different approach conditions. For example, Baines, Castro and Robins and Sakamoto et al. have investigated the wind pressure distribution on the various faces of three-dimensional bluff bodies of different sizes exposed to different wind conditions. Meroney has reviewed the flow around simple rectangular shaped bodies; wind tunnel studies of mean surface pressure patterns were conducted which suggested the need to document the pressure measurements on the surface of buildings with different sizes, exposed to different approach flow conditions. Gowda and Sitheeq have investigated the interference effects on wind pressure distribution on prismatic bodies in tandem arrangement. Gowda et al. studied the wind pressure distribution on low-rise and high-rise prismatic bodies due to mutual interference effects in tandem arrangement. The results indicated that the interference effects could be very severe on the shorter body due to the presence of a tall body in close proximity, with a possibility of negative drag. The mean pressure on the roof of different cubical bodies exposed to boundary layer type of velocity profile were measured by Bachlin et al. with a power-law exponent ranging from 0.1 to 0.25 and for various ratios of building height to boundary layer thickness ranging from 0.22 to 1.0. They concluded that for bodies with height less than the boundary layer thickness, the position of the maximum pressure on the roof depends only on the building shape and the approach flow. Narasimhan et al. studied wind pressure distribution on three high-rise prismatic bodies in tandem arrangement and concluded that the interference effects on the middle body are quite considerable as compared to those on the front and rear bodies. But it appears that there is...
practically no information in the case of two bodies with different relative heights kept in side-by-side arrangement. Hence, there is a need to study systematically the effects of one body over the other, in different side-by-side arrangement.

In the present study, two prismatic three-dimensional bluff bodies with square cross-section are kept in side-by-side arrangement in the test section of a wind tunnel and exposed to an air stream with a boundary layer type of velocity profile satisfying the $1/7$th power law and the interference effects are investigated. The wind pressures on various faces of a low-rise body ($h/b = 1$) are measured when another body ($h/b = 1, 3$ or $5$) is interfering and on a tall body ($h/b = 5$) when interfered with a body of $h/b = 1, 3$ or $5$, where $h$ is the height and $b$ is the side of the square prismatic body. The cases considered for the present investigation on two prismatic square bodies kept in side-by-side arrangement are given in Table 1.

### Experimental Procedure

Static pressure measurements are carried out in the low speed, straight through, blower-type wind tunnel of the Fluid Mechanics Laboratory, Indian Institute of Technology, Madras. The general layout of the wind tunnel facility is shown in Fig. 1. A 15 kW AC motor, running at a constant speed of 1460 rpm, drives the blower using a belt-drive causing air to be blown into the test section. The settling chamber is 3490 mm long and has a cross-section of $1500 \text{ mm} \times 1064 \text{ mm}$. The contraction cone has an overall area ratio of 4.19. A shear-velocity profile satisfying the power law with an exponent $n = 1/7$ is generated using a grid of suitably spaced, smooth mild steel rods of 10 mm diameter. The technique is based on the method originally described by Cowdrey. The $1/7$th law velocity profile has its significance of representing the atmospheric boundary layer over an open country terrain with grasslands, according to Davenport. During measurements, the tunnel wall-static pressure at 200 mm behind the grid is continuously monitored by using a Betz manometer for maintaining a constant flow rate. The $1/7$th law velocity profile was first realized at a distance of 450 mm downstream of the grid and the shape of the profile remains the same from this station onwards. The two dimensionality of the flow field in the test section was examined by measuring the velocity profile on the centre-line and at two span-wise locations $\pm 150 \text{ mm}$ on either side of the centre-line at a section $450 \text{ mm}$ away from the grid. The three velocity profiles are found to be almost identical, indicating the two-dimensionality of the flow in the domain of the present investigations. For the measurements of the mean velocity, a standard Pitot–static tube with a tip diameter of 3 mm was used. To check the self-similarity, the Pitot-static

<table>
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<td>$h/b=1$</td>
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<td>$h/b=5$</td>
<td>$h/b=1, 3, 5$</td>
<td>1.25, 1.5, 2.0, 2.5 and 3.0</td>
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Fig. 1 — Wind tunnel facility used for measurements
probe is traversed along the central plane at three different locations (namely 450 mm, 1000 mm and 1500 mm from the grid). These velocity profiles showed that the flow is self-similar. The turbulence level in the test section of the wind tunnel is of the order of 5 per cent.

All the models in the present study are made out of 10 mm thick perspex sheet. Six models with square cross-section of side \( b = 60 \text{ mm} \) and \( h/b = 1, 3 \) and 5 (two models of each size) with sharp edges are fabricated out of 10 mm thick perspex sheet. Two sets of models are made, namely, one set (called the ‘Principal Body’ - PB) with surface pressure taps for measuring the static pressure and the other set (called the ‘Interfering Body’ - IB) without any pressure taps used as dummy body in the interference studies. The pressure taps (1 mm in diameter) are provided in horizontal direction, vertical direction and on top along the centerlines of the faces. The principal body is hollow to facilitate easy communication of PVC tubes connecting the different pressure taps to various ports of a scanning box (FC091, made by Furnace controls, UK). The scanning box is in turn connected to a digital micro-manometer (FC012), which can record pressure with an accuracy of 0.01 mm water column. The sequential directions of measuring the pressures on various faces are named as A, B, C, D, E, F, A’, B’, C’, and D’.

The bodies are placed in side-by-side arrangement in the flow as shown in Fig. 2. The center-to-center distance between two bodies is denoted by \( t \). The bodies are kept at a distance of 1000 mm from the grid for all test cases so that they are in the region of flow satisfying the \( 1/7 \)th law velocity profile. The PB (with pressure taps) is kept at a specified location with a constant distance of 90 mm from the tunnel centreline in the test section and the IB is suitably placed at various locations relative to the PB, so as to obtain \( t/b = 1.25, 1.5, 2.0, 2.5 \) and 3.0 respectively thus varying the gap between the PB and the IB systematically. For the sake of convenience, the height of the principal body and that of the interfering body are henceforth represented as \( h_p \) and \( h_i \) respectively. The pressure coefficient \( C_p \) is calculated from the static pressure sensed by the pressure taps on the principal body on all its faces (except the base).

The values of \( C_p \) are plotted along the centerlines on each face of the body. The variations of \( C_p \) on each face along the horizontal and vertical centerlines of the principal body when another interfering body is placed in the air stream on one side of it are compared with those obtained when only the principal body is present in the air stream (as a single body – SB). All the tests were carried out at a free stream velocity \( U_\infty = 9.7 \text{ m/s} \). At this velocity, the Reynolds number \( Re \) based on the free stream velocity and width \( b \) of the body is found to be \( 3.88 \times 10^4 \). As sharp-edged prismatic bodies are used and \( Re \) is more than \( 10^4 \), there will be no influence of \( Re \) as observed by Bearman and Obasaju and the results presented are applicable to practical situations.

**Results**

The mean velocity distribution in the test section of the wind tunnel has been measured by a Pitot-static probe traverse in the central plane of the tunnel. This is done at a distance of 1000 mm from the grid (without any body kept in the test section) and is shown in Fig. 3 and compared with the \( 1/7 \)th law profile calculated using the equation

\[
U/U_\infty = (z/\delta)^{1/7}
\]

where, \( U \) is the local mean velocity at a vertical distance \( z \), \( \delta \) is the boundary layer thickness and \( U_\infty = 9.7 \text{ m/s} \). The pressure coefficient \( C_p \) on the surface of the body is defined as

\[
C_p = (P_b - P_i)/(\rho U_h^2/2)
\]

where, \( P_b \) is the pressure at any point on the face of the body and \( P_i \) is the free stream reference static pressure, \( U_h \) is the velocity in the undisturbed flow (i.e., without the presence of the bodies) at the height of the principal body and \( \rho \) is the air density.
Blockage corrections were made for $C_p$ on all faces of the body depending on the blockage ratio as proposed by Cooper et al. The variations of $C_p$ thus obtained along centre-lines on each face of the PB are shown plotted for different $t/b$ values for the six cases in Figs 4-9.

Interference factor (IF), is a measure of the intensity of interference and is defined as the magnitude of the ratio of the change in $C_{p_{\text{max}}}$ value due to interference to the value for isolated case and given by

$$IF = \frac{|C_{p_{\text{max}}}(C_{p_{\text{max}}})_0|}{(C_{p_{\text{max}}})_0}$$

...\(3\)

Fig. 3 — Mean velocity profile in wind tunnel at a section 1000 mm from the grid

![Mean velocity profile](image)

Fig. 4 — Variation of $C_p$ on different faces of the principal body for $h_p/b = 1$, $h_i/b = 1$ (a) Faces A, B and C, (b) Faces D, E and F, (c) Faces $A'$, $B'$, $C'$ and $D'$
where, \((C_{p_{\text{max}}})_o\) is the maximum value of \(C_p\) on the corresponding face for an isolated body under similar flow conditions. The variations of IF are plotted against \(t/b\) values for various faces of the bodies in Figs 10 and 11.

**Interference effects on PB with \(h_p/b = 1\)**

**Case (i): \(h_p/h_i = 1/1\)**

Here, the principal body is a low-rise body with \(h_p/b = 1\) and the interfering body is also low-rise body with \(h_i/b = 1\). The variations of \(C_p\) along the centerlines on various faces of the PB for this case are shown in Fig. 4. There is hardly any effect of the IB on the pressure distribution over the front face in both vertical and horizontal directions (A, Fig. 4a and A', Fig. 4c) of PB. On the roof along the flow direction (B, Fig. 4a), the \(C_p\) variation follows the same trend as in the case of single body with marginal changes in the \(C_p\) values for all \(x/b\) values. On the roof, across the flow direction (E, Fig. 4b), there is a decrease in the \(C_p\) value with increase in \(t/b\) value till 2.00 and after that there is an increase in \(C_p\) values and tending towards the value for the single body case. On the rear face both in C (Fig. 4a) and C' (Fig. 4c) directions, the \(C_p\) variation follows the same trends as in the case of...
single body with marginal decrement in the $C_p$ values. On the interfering face in vertical direction (F, Fig. 4b), for $t/b$ values 1.25 and 1.50, $C_p$ values are more than that of the isolated body case. On the interfering face, in the horizontal direction ($B'$, Fig. 4c), till $x/b = 0.5$, $C_p$ values are more than that of the single body case and after this location $C_p$ values are more than that of the single body case. When $x/b$ is less than 0.4, the $C_p$ value increases steeply from $-2.0$ to $-0.8$ (i.e., becomes less negative). At $x/b \approx 0.02$ for $t/b = 1.25$, the $C_p$ values are as much as 4 times less than that of single body case. On the outer face, in vertical and horizontal directions ($D$ and $D'$) for all $t/b$ values, the same trends as for the single body case are followed but the magnitudes of the $C_p$ values are less than that of the single body case.

Case (ii) $h_p / h_i = 1/3$

The results for this case, when the interfering body has $h_i / b = 3$, are shown in Fig. 5. The $C_p$ variations on the front face in vertical direction (A, Fig. 5a), are practically not affected by the interference with the IB for all $t/b$ values, as compared to the isolated body.

Fig. 6 — Variation of $C_p$ on different faces of the principal body for $h_p/b = 1$, $h_i/b = 5$ (a) Faces A, B and C, (b) Faces D, E and F, (c) Faces $A'$, $B'$, $C'$ and $D'$
However, in the horizontal direction (A', Fig. 5c), for all t/b values, the \(C_p\) value starts from a lower value (\(\leq 0.3\)) at \(y/b = 0\), increases to a maximum (\(\approx 0.9\)) at about \(y/b \approx 0.85\) and then steeply decreases to a lower value near the edge of the interfering side (\(y/b = 1\)). Further, as \(t/b\) increases, the curve for \(C_p\) versus \(y/b\) tends to the isolated body case. The maximum \(C_p\) value, which corresponds to stagnation point on the front face, is shifted towards the interfering side from \(y/b = 0.5\) for single body case to \(y/b \approx 0.85\) with interference. On the roof along the flow direction (B, Fig. 5a), for \(t/b\) values of 1.25 and 1.50, \(C_p\) values are less when compared to single body case and the difference is maximum when \(x/b = 0.3\). When \(t/b\) is greater than 1.5, from \(x/b = 0.2\) onwards up to \(x/b = 0.85\), the \(C_p\) values are tending towards those for the single body case and the \(C_p\) values are increasing rapidly. On the roof across the flow direction (E, Fig. 5b), \(C_p\) values are less than those of single body case and the value increases with increase in \(y/b\) value. On the rear side in vertical direction (C, Fig. 5a) and in horizontal direction (C', Fig. 5c), when the spacing between the bodies (\(t/b\)) is 1.5, similar trends are followed but \(C_p\) values are lesser as much as three times those of single body case. On the

Fig. 7 — Variation of \(C_p\) on different faces of the principal body for \(h_p/b = 5, h_i/b = 1\) (a) Faces A, B and C, (b) Faces D, E and F, (c) Faces A', B', C' and D'
interfering face in vertical direction (F, Fig. 5b), for $t/b = 1.25$ and 1.5, the $C_p$ value is less than that of single body case whereas for $t/b$ greater than 1.5, the $C_p$ values are more than the values for single body case. However, on the interfering side in horizontal direction (B', Fig. 5c), for $t/b$ values less than 1.5, the $C_p$ value is less than that of single body case while for $t/b$ greater than 1.5, $C_p$ values are more than that of the single body case when $x/b$ is greater than 0.5. On the outer face in vertical direction (D, Fig. 5b), and in horizontal direction (D', Fig. 5c), similar trends are observed as for the single body case, the magnitude of $C_p$ values being less when compared to the single body case, and the minimum $C_p$ values are occurring when $t/b$ is equal to 1.5.

Case (iii) $h_p/h_t = 1/5$
In this case, the principal body is a low-rise body with $h_p/b = 1$ while the interfering body is a high-rise body with $h_t/b = 5$. The variation of $C_p$ along various faces of the PB is shown plotted for different $t/b$ values in Fig. 6. There is hardly any effect of the IB on the pressure distribution over the front face of PB in vertical direction (A, Fig. 6a), whereas in horizontal direction (A', Fig. 6c), for the values of $t/b$
equal to 1.5 and 2.0, $C_p$ values are less than those of single body case and negative pressures are also seen when $y/b \approx 0.02$. The stagnation points on the front face of the body are shifted towards the interfering side, to a location at $y/b \approx 0.8$. For $t/b$ values of 1.25, 1.5 and 2.0, on the roof along the flow direction (B, Fig. 6a), from $x/b \approx 0.02$ to $x/b \approx 0.2$, the $C_p$ values are decreased with increase in $x/b$, after which the $C_p$ values increase very steeply with $x/b$ from $x/b = 0.2$ to $x/b = 0.6$. Once $x/b$ value becomes more than 0.6, the decrease in $C_p$ values can be seen. However, for $t/b$ values of 2.5 and 3.0, the $C_p$ values are relatively lower than single body case but similar trends are followed. The maximum $C_p$ value is equal to $-3.0$ for $t/b = 1.25$ and it is three times the value for the single body case on that face. On the roof across the flow direction (E, Fig. 6b), for $t/b$ values of 1.25, 1.5 and 2.0, $C_p$ values are increased till $y/b \approx 0.5$; after that a decrease in the values of $C_p$ is seen. However, for $t/b$ values of 2.5 and 3.0, a constant value of $C_p$ is observed till $y/b \approx 0.6$, after which an increase in $C_p$ value is seen. In this case of $h_p/h_i = 1/5$, the effect of

![Fig. 9 — Variation of $C_p$ on different faces of the principal body for $h_p/b = 5$, $h_i/b = 5$ (a) Faces A, B and C, (b) Faces D, E and F, (c) Faces A', B', C' and D']
the separating shear flow from the IB enveloping the roof of the shorter PB causes less \( C_p \) values for smaller \( t/b \) values both along and across the flow directions on the roof. On the interfering side along vertical direction (F, Fig. 6b), for \( t/b \) values of 1.25 and 1.5, the \( C_p \) values are less than those of single body, whereas for \( t/b \) greater than 1.5, the \( C_p \) values are more than those of single body case. On the interfering side along horizontal direction (B', Fig. 6c), for \( t/b \) values of 1.25 and 1.5, \( C_p \) value increases till \( x/b \approx 0.2 \) after which the decreasing trend in \( C_p \) value is seen with increase in \( x/b \) value. For the case of \( t/b = 2.0 \), the \( C_p \) value increases (from \(-1.7 \) to \(-0.7\)) with \( x/b \) till \( x/b = 0.5 \) and then starts decreasing to a value of \(-1.0\) near the rear edge (\( x/b \approx 1.0 \)). For \( t/b \) values of 2.5 and 3.0, the \( C_p \) values are increased with increase in \( x/b \) value till \( x/b \approx 0.65 \). On the rear side in vertical direction (C, Fig. 6a), and in horizontal direction (C', Fig. 6c), for \( t/b \) values of 1.25 and 1.5, \( C_p \) values are three times less than those of single body case. With increase in \( t/b \) values, the \( C_p \) values are tending towards the values for the single body case. On the outer side along vertical direction (D, Fig. 6b), and horizontal direction (D', Fig. 6c), \( C_p \) values are nearly 2.5 times less than those of the values for the single body, and the trends are similar to the case of single body, for \( t/b = 1.25 \) and 1.5.

**Interference effects on PB with \( h_p/b = 5 \)**

Here, the principal body is a high-rise body with \( h_p/b = 5 \) and three different cases are considered depending upon the height of the interfering body, namely, the case (iv) with \( h_p/h_i = 5/1 \), the case (v) with \( h_p/h_i = 5/3 \) and the case (vi) with \( h_p/h_i = 5/5 \) respectively. For the sake of brevity, the common features of these three cases are briefly dealt with and then the characteristic features of each of these three cases will be discussed in detail.

The variations of \( C_p \) along the centerlines of different faces of the principal body are shown in Figs 7, 8 and 9 respectively for the cases (iv), (v) and (vi). On the front face of the body along the vertical direction A, (Figs 7a, 8a and 9a), and along the horizontal direction A', (Figs 7c, 8c and 9c), there is practically no effect due to increase in \( t/b \) values, for all the \( h_i/b \) values, except that the \( C_p \) values are slightly more with the interference than those for the single body case. On the rear side along the vertical direction C, (Figs 7a, 8a and 9a), and along the horizontal direction C', (Figs 7c, 8c and 9c), similar trends are followed as in the case of the single body.
but with marginally lesser $C_p$ values for all $t/b$ values for cases (iv) and (v) and about 25% to 30% lesser $C_p$ values for the case (vi) for all $t/b$ values.

On the roof in the flow direction B, (Figs 7a, 8a and 9a), and across the flow direction E, (Figs 7b, 8b and 9b), the behaviour of $C_p$ variation is the same as that of the single body case. Further one can see that in this case the gap flow effect is predominant since higher $t/b$ values cause lower $C_p$ values on the roof both along and across the flow directions. The $t/b$ values of 2.5 and 3.0 result in the least values of $C_p$ while $t/b = 1.25$ and 1.5 cause the higher $C_p$ values for all the three cases. On the outer side face in vertical direction D, (Figs 7b, 8b and 9b), and in horizontal direction B', (Figs 7c, 8c and 9c), similar trends are followed as in the case of single body. The $C_p$ values for $t/b = 1.25$ and $h/b = 1$, are seen to be more or less following the results of the single body case thus showing that the low-rise IB ($h/b = 1$) with least spacing ($t/b = 1.25$) has negligible interference effect on high-rise PB with $h/b = 5$. It is also seen that for $h/b = 5$, the interference effect is predominant as compared to the single body case for all $t/b$ values. On the interfering side, both in the vertical direction, F (Figs 7b, 8b and 9b), and in the horizontal direction B' (Figs 7c, 8c and 9c), the $C_p$ values with interference are, (except for $t/b = 1.25$), in general, much lower as compared to that of the single body case. Further, it is seen that generally, the $C_p$ values decrease with increase in $t/b$ value as compared to single body case.

For the two cases (v) with $h/b = 3$ and (vi) with $h/b = 5$, there is no specific trend in the variation of $C_p$ values on the interfering face both in the vertical direction F, (Figs 8b and 9b), as well as in the horizontal direction B', (Figs 8c and 9c). The maximum value of $C_p$ is found to be about $-1.95$ and $-2.45$ respectively occurring at $x/b = 0.2$ in the direction B' (as seen from Figs 8c and 9c) for $t/b = 1.5$ so that the magnitude of $C_p$ at $x/b = 0.2$ is almost 2.5 times that of the single body case at the same point.

Interference factor (IF)

The interference factor, which is an index of the severity of the interference effects, can be calculated on each face of the building along the vertical and horizontal directions using Eq. (3). Figure 10 shows the plot of IF versus $t/b$ values for a low-rise structure PB (i.e., body with $h/b = 1$), on various faces of the building due to the interference of another low-rise or high-rise structure (IB). The maximum interference factor is observed on the rear side of the building. $IF_{\text{max}}$ has a value of 3.2 and 3.8 in the directions C and $C'$ (Fig. 10), respectively on the rear face of the building (PB with $h/b = 1$), when interfered by a high-rise building with $h/b = 5$ in close proximity, (i.e., at $t/b = 1.5$). For all the faces, IF is approaching zero with increased spacing ($t/b$) between the bodies, except on the interfering face along the vertical direction (F), for which case, the value tends to reach about 1.8. The plot of IF versus $t/b$ values for a high-rise structure with $h/b = 5$, on various faces of the building due to the interference of a low-rise or high-rise building is depicted in Fig. 11. The general trend of higher IF value with increased height of the IB is seen in this case also. Further, maximum interference is felt on the interfering face along horizontal direction (B'), where $IF_{\text{max}}$ is equal to 1.4 at $t/b = 1.5$ when interfered with a similar high-rise building ($h/b = 5$).

Discussion

The general trends in the variation of $C_p$ on different faces of the PB for various cases may be explained in the following manner: The observed trends of the pressure distribution on various faces of the PB are influenced by the relative size of the IB and the spacing between PB and IB. Two primary effects can be identified due to interference: (i) the gap flow effect and (ii) influence of the shear layers separating from the IB particularly for the cases when $h_p \neq h_i$.

Considering the gap flow effect, the magnitude of the velocity in the gap between PB and IB can be expected to be considerably larger at lower $t/b$ values ($t/b = 1.25$ and 1.5) as compared to that at larger $t/b$ values. However, this appears not to be the case for all relative sizes of the PB and IB. For example, when we consider the PB with $h/b = 1$ for the case $h_p/h_i = 1/1$ the pressure on the interfering face in vertical direction (F, Fig. 4b), which is on the gap side is relieved, i.e., the $C_p$ magnitudes are larger (or less negative) as compared to the isolated body case. However, for $h_p/h_i = 1/3$ (Fig. 5b) and $h_p/h_i = 1/5$ (Fig. 6b), the trends in the pressure distribution along the direction F are completely different from those for $h_p/h_i = 1/1$. This shows that a linear correlation between the magnitude of the gap and $C_p$ distribution cannot be made. The separating shear layers from IB within the gap area up to the height of the shorter body will also have considerable influence on the pressure distribution. A very complex flow field can be expected within the gap between the bodies for various values of $h_p/h_i$. 
Considering the influence of the shear layers, particularly those separating from the IB and for \( h_p/h_i \) different from 1/1, very interesting and complex features can be inferred. For example, considering PB of \( h/b = 1 \) and \( h_p/h_i = 1/3 \) and 1/5 respectively, the shear layers separating from the portions of the IB above the roof height of PB appear to have considerable influence on the roof pressures of the PB. The gap ratio \( t/b \) will have a further influence. This becomes evident when the \( C_p \) distributions on the roof along the direction B for \( h/b = 1 \) for cases \( h_p/h_i = 1/1 \) (Fig. 4a), \( h_p/h_i = 1/3 \) (Fig. 5a) and \( h_p/h_i = 1/5 \) (Fig. 6a) are considered. In the case when \( h_p/h_i \) is different from 1/1, the extent of the shear layer separating from the IB over the top of PB depends on the height of IB and also the value of \( t/b \). Higher the value of \( h_i \), larger is the depth of the shear layer over the roof top of the PB. Hence, for the case of \( h_p/h_i = 1/5 \), the interference effects can be expected to be more severe compared to those of the case \( h_p/h_i = 1/3 \). This is evident from Figs 5a and 6a, which show that for \( h_p/h_i = 1/3 \), \( C_{p_{max}} \) on roof along the direction B is nearly equal to - 2.6, whereas for \( h_p/h_i = 1/5 \) (Fig. 6a), \( C_{p_{max}} \) value on this face is nearly - 3.0 and also steeper gradients are seen in the latter case. Due to the above reasons, one can expect higher interference effects on the shorter bodies due to taller bodies and an opposite effect, i.e., decreased interference effects on the taller bodies due to shorter bodies.

Another interesting feature observed is in the \( C_p \) distribution on the outer face in the vertical direction D, particularly for the low-rise body with \( h/b = 1 \). The face D is on the other side of the gap and normally one would expect a pressure distribution very similar to the single body case, even with interference. However, this is not so, as can be seen from Fig. 4b (\( h_p/h_i = 1/1 \)), Fig. 5b (\( h_p/h_i = 1/3 \)) and Fig. 6b (\( h_p/h_i = 1/5 \)). It is seen for the cases when \( h_p/h_i \) is different from 1/1, the taller bodies have a predominant influence on the pressure distribution over face D. It appears that there is flow spillage to the sides from the separating shear layers of the interfering tall bodies which almost envelope the shorter body. This results in considerable reduction of the \( C_p \) value on the face D particularly at lower \( t/b \) values. Thus, it is once again seen that the interfering effects on the low-rise body due to taller bodies present in close proximity are very severe.

The \( C_p \) distribution in addition to indicating the magnitude of the wind loading, also gives information on the possible wind motion on the various faces of the body. The pressure gradients become stronger due to interference, with the possibility of stronger wind motion. For example, on the low-rise body with interference, stronger pressure gradients occur on the roof surface along the flow direction (B) and on the interfering surface in horizontal direction (B’). It is also observed that these gradients become steeper with increase in the height of the IB in Figs 4-6. As an example, if Fig. 6a is considered, it is seen that there is a possibility of strong reverse flow on the roof surface (B) for \( t/b = 1.5 \) and 2.0. For larger \( t/b \) values, i.e., \( t/b = 2.5 \) and 3.0, the pressure variation indicates a different flow pattern similar to that for the single body case. When the pressure distribution for the side (B’) is considered in Fig. 6c, the gradients in pressures show a much more complex variation with \( t/b \).

The pressure gradients on various faces of the taller body are not affected to the same extent as the low-rise PB. However, even in the case of the taller body, steep pressure gradients are seen to occur in the direction B’ (Fig. 9c). Thus, it is seen that the interference effects are found to influence not only the magnitude of the wind pressures but also the wind motion on the faces of the body.

**Conclusions**

The interference effects are seen to influence not only the magnitude of the wind loads but also the wind movement on the surfaces of a prismatic body. Very steep pressure gradient occurs on a low-rise body, particularly on the roof and the side surface due to interference from a high-rise body. The wind pressure gradients are not affected to the same severity on a high-rise body due to the interference from a shorter body.

The interference effects are very much pronounced for low-rise structures (\( h/b = 1 \)) on the rear face (IF_{max} = 3.2 for vertical direction, C and IF_{max} = 3.8 for horizontal direction, C’) and on the interfering face (IF_{max} = 2.4 for the vertical direction, F). In the case of the high-rise structures (\( h/b = 5 \)), the effects are predominant on the interfering face (IF_{max} = 1.4 for the horizontal direction, B’), as compared to the effects on the other faces, for all \( t/b \) values. Low-rise structures are more vulnerable to interference effects from high-rise structures as compared to the high-rise structures when interfered by the low-rise or high-rise structures.
Nomenclature

\( b \) = width of the body (mm)
\( h \) = height of the body (mm)
\( C_p \) = static pressure coefficient
\( C_{p_{\text{max}}} \) = maximum value of \( C_p \)
\( h_i \) = height of IB (mm)
\( h_p \) = height of PB (mm)
\( \text{IB} \) = interfering body
\( \text{IF} \) = interference factor
\( n \) = exponent in the power law for velocity profile.
\( \text{PB} \) = principal body
\( P_b \) = pressure at any point on a face of the body (N/m\(^2\))
\( P_s \) = free stream reference static pressure (N/m\(^2\))
\( \text{Re} \) = Reynolds number based on \( U_\infty \) and \( b \)
\( \text{SB} \) = single (or isolated) body
\( t \) = centre-to-centre distance between two bodies (mm)
\( U \) = local mean velocity (m/s)
\( U_h \) = undisturbed flow velocity at the height of PB (m/s)
\( U_\infty \) = free stream velocity (m/s)
\( x \) = coordinate along the flow direction (mm)
\( y \) = coordinate in transverse (across the flow) direction (mm)
\( z \) = coordinate in vertical direction (mm)
\( \delta \) = boundary layer thickness (mm)
\( \rho \) = air density (kg/m\(^3\))

References