World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:8, No:6, 2014

Wind Interference Effect on Tall Building

Atul K. Desai, Jigar K. Sevalia, Sandip A. Vasanwala

***Abstract*—**When a building is located in an urban area, it is exposed to a wind of different characteristics then wind over an open terrain. This is development of turbulent wake region behind an upstream building. The interaction with upstream building can produce significant changes in the response of the tall building. Here, in this paper, an attempt has been made to study wind induced interference effects on tall building. In order to study wind induced interference effect (IF) on Tall Building, initially a tall building (which is termed as Principal Building now on wards) with square plan shape has been considered with different Height to Width Ratio and total drag force is obtained considering different terrain conditions as well as different incident wind direction. Then total drag force on Principal Building is obtained by considering adjacent building which is termed as Interfering Building now on wards with different terrain conditions and incident wind angle. To execute study, Computational Fluid Dynamics (CFD) Code namely Fluent and Gambit have been used.

***Keywords*—**Computational Fluid Dynamics, Tall Building, Turbulent, Wake Region, Wind.

I. Introduction

WHEN a building is located in an urban area, it is exposed to a wind of different characteristics then wind over an open terrain. This is development of turbulent wake region behind an upstream building. The interaction with upstream building can produce significant changes in the response of the tall building. Buffeting and interaction from upstream building in an urban situation can produce strong changes in the dynamic response of tall building. Neighboring structures may either increase or decrease the flow induced forces on building, depending mainly on geometry and arrangement of these structures, their orientation with respect to the direction of the flow and terrain conditions. Therefore, this effect, commonly known as Interference must properly be assessed by designers and planners. The main parameters affecting interaction between adjacent buildings are the types of terrain, size and shape of the building, the incident wind direction and last but not least the building arrangement and spacing.

Reference [1] have tried to study the interference effect on the building model with extended overhang having 25º roofs slope which is widely used in coastal zones in India. An interference effect due to the presence of single similar building has been studied. The design pressure coefficients obtained for the interfering cases are normalized by those for the isolated case thus obtaining the Interference Factor (IF). It has been concluded by them that the wake produced by the interfering building changes the wind flow separation points on the principal building, which leads to a changed pressure distribution on the roof, causing either shielding or amplification. Reference [2] has tried to discuss a comprehensive wind tunnel test program which was conducted to investigate interference effects between two tall rectangular buildings. They concluded that the interference effect is found to be predominant, when the height of the interfering building is in range from 67% to 150% of the height of the principal building. Reference [3] has studied the mean interference effects between two and among three tall buildings by a series of wind tunnel tests. Both the shielding and channeling effects are discussed to understand the complexity of the multiple-building effects. The results show that the upstream interfering buildings cause certain shielding effects by decreasing the mean wind load on the downstream principal building. Reference [4] has discussed an estimate of the extent of shielding provided by the upstream structure to the downstream building. The effect of shielding is to lower the drag force on the downstream building. As expected, the closer the two buildings, the higher is the level of shielding. At a distance of about twice the building width, there is practically no drag force on the building, and at still lower spacing, a negative shielding (suction) is experienced by the downstream building. Reference [5] has discussed the practical and theoretical knowledge that can be found in scientific literature. Most of the knowledge has been acquired by wind tunnel experiments regarding scale models.

Modeling the wind atmosphere associated with proposed or existing buildings is of great importance for the Wind Engineering as well as Structural Engineering Sectors. The potential market for wind engineering studies around buildings is very large. Computational Wind Engineering (CWE) as a branch of Computational Fluid Dynamics (CFD) has been developed rapidly over the last three decades to evaluate the interaction between wind and structures numerically, offering an alternative technique for practical applications [6]. CFD simulations can provide information on all flow parameters in the entire computational domain. Moreover, a reliable numerical evaluation of the interaction between fluids namely winds and buildings can be achieved with CFD modeling in a time- saving as well as economic manner. Thus, CFD can offer more flexibility when exploring a variety of building designs and modifications and their impact on the flow around them.

Here, in this paper an attempt has been made to study wind induced interference effect (IF) on Tall Building and for that initially a tall building (which is termed as Principal Building now on wards) with square plan shape has been considered

Atul K. Desai is with Sardar Vallabhbhai National Institute of Technology, Surat, Gujarat, India (phone: +91-261-2799390; fax: +91-261-2227334; e-mail: atuldesai61@gmail.com, akd@amd.svnit.ac.in).
Jigar K. Sevalia is Ph. D. Research Scholar at Sardar Vallabhbhai National Institute of Technology, Surat, Gujarat, India (e-mail: jigar.sevalia@yahoo.co.in).
Sandip A. Vasanwala is with Sardar Vallabhbhai National Institute of Technology, Surat, Gujarat, India (e-mail: sav@amd.svnit.ac.in).

with different Height to Width Ratio and total drag force is obtained considering different terrain conditions as well as different incident wind direction. Then total drag force on Principal Building is obtained by considering adjacent building which is termed as Interfering Building now on wards with different terrain conditions and incident wind angle. To execute study, Computational Fluid Dynamics Code namely Fluent and Gambit have been used.

II. Methodology

In this numerical study, initially tall building units (Both Principal and Interfering Building Units) with square geometric plan shape having dimensions as tabulated in Table I have been considered. The height of building unit is considered to be 300m.

TABLE I
GEOMETRIC DIMENSIONS OF TALL BUILDING UNITS

Plan Dimensions (B) Of Building Unit (M X M)	Height of Building Unit (m) - H	Height / Width Ratio (H/B)
75 x 75	300	4
37.5 x 37.5	300	8
25 x 25	300	12

Under this condition, total drag force on Principal Building is obtained considering different terrain conditions (α) as well as different incident wind direction (θ).

Then again total drag force on Principal Building (PB) is obtained by considering adjacent Interfering Building (IB) with different terrain conditions and incident wind angle.

After having results of drag force on Principal Building with and without interfering building, they are compared to study the interference effects.

Relative position of adjacent Interfering Building with respect to Principal Building for H/B Ratio = 4 is as shown in Table II.

TABLE II
DETAILS OF PRINCIPAL AND INTERFERING BUILDING WITH THEIR RELATIVE POSITION FOR (H/B) = 4

Particulars	Value			
Plan Dimension(B X B)	75 X 75			
Height (H) In (M)	300			
Ratio (H/B)	4			
Ratio (S/B)	2	3	4	5
Relative Spacing (S) In Meter	150	225	300	375
Wind Angle (Θ)	0°, 15°, 30°, 45°			

Typical relative position of interfering building with respect to principal building for Height to Breadth (H/B) ratio 4 is as shown in Fig. 1.

III. Governing equations

The approaching wind was created from a power-law model to approximate the mean velocity profile [7], [8]:

$$U(Z) = U_G * \left[\frac{Z}{Z_G}\right]^{\alpha}$$

The gradient height Z_G was assumed to be 900 m and the mean wind velocity U_G at the gradient height is as tabulated below in Table III for different roughness of terrain.

TABLE III
TYPE OF TERRAIN, POWER LAW EXPONENTS AND GRADIENT VELOCITY

Type Of Terrain	Power Law Exponent (A)	Gradient Velocity (M/S) - U_g
Coastal Area	0.10	49.11
Open Terrain	0.15	51.88
Suburban Terrain	0.25	57.91
Centre Of Large Cities	0.35	64.63

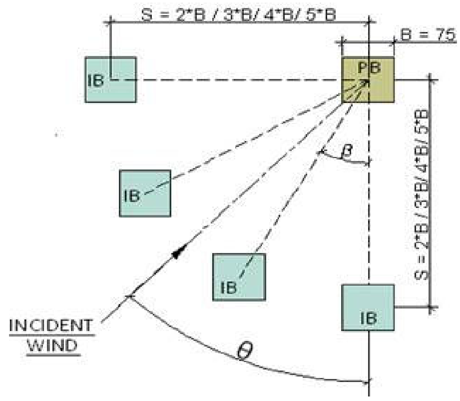


Fig. 1 Relative Position of Interfering Building with respect to Principal Building for (H/B) Ratio = 4

IV. Boundary Conditions

The boundary conditions for the computing domain are considered as follows [7]-[9],

- The ground at the bottom of the computing domain was simulated with no slip boundary condition
- The free slip boundary conditions are applied to top and side surfaces of computing domain. The flux normal to the boundary is considered zero.
- The no slip boundary conditions are applied to the surfaces of models.

V. Domain Size and Meshing

There are no explicit rules dictating the size of a computing domain [6]. For this study, the size of the computational domain considered is 2235m X 1635m X 900m in the longitudinal (X), lateral (Z), and vertical (Y) directions, respectively.

The location of the building units in computational domain is as shown in Figs. 2 to 4. The height of building unit in this study is 300 meter. Thus the height to width ratio of building unit considered is 4, 8, 12 and 16.

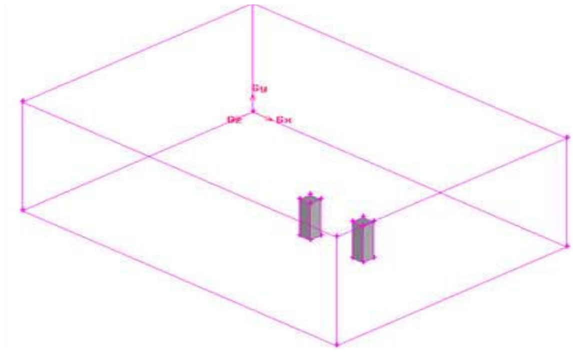


Fig. 2 Location of the building units in Computational Domain

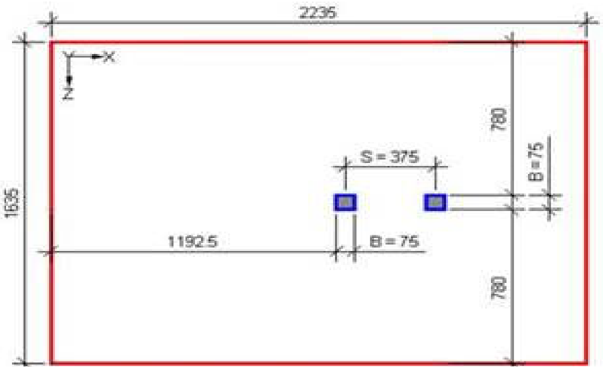


Fig. 3 View of Computational Domain in X-Z Plane (Horizontal Plane) When Incident Wind Angle θ = 0°

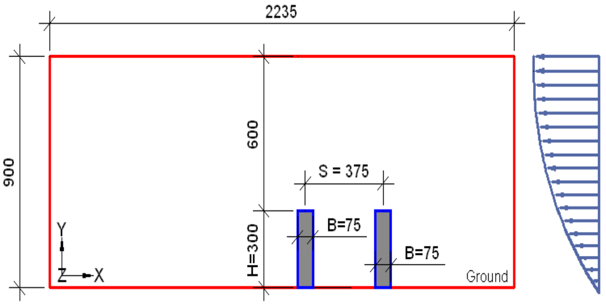


Fig. 4 View of Computational Domain in X-Y Plane (Vertical Plane)

3-D Structured grids are created in the testing domains and 3-D unstructured meshes are arranged in the vicinity of Building Model. The grids in vertical plane are closely spaced near ground and coarser mesh is providing away from ground. The Computational Grid Patterns for the Building Unit is shown below in Figs. 5 to 8.

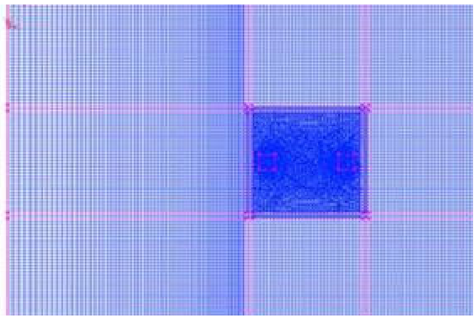


Fig. 5 Computational Grids in X-Z Plane (Horizontal Plane)

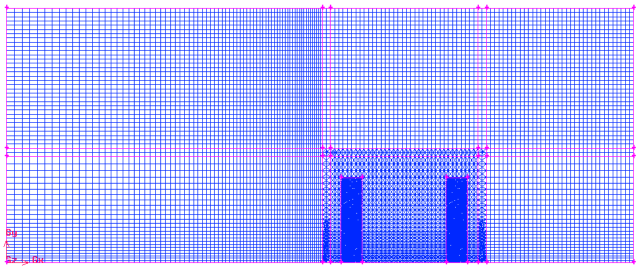


Fig. 6 Computational Grids in X-Y Plane (Vertical Plane)

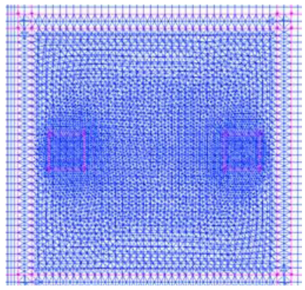


Fig. 7 Enlarged Views of Computational Grids Around Building Model (H/B = 4, β = 0° and θ = 0°) in X-Z Plane

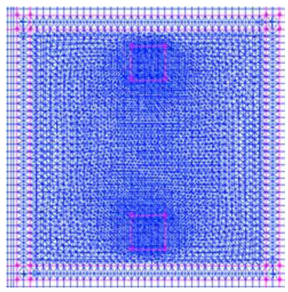


Fig. 8 Enlarged Views of Computational Grids Around Building Model (H/B = 4, β = 90° and θ = 0°) in X-Z Plane

VI. Results and Discussions

The results consist of variation of Interference Factor (IF) for Tall Principal Building. Initially a tall building namely Principal Building with square plan shape has been considered with different Height to Width Ratio (i.e. H/B = 4, 8, 12, 16) and total drag force is obtained considering different terrain conditions (α = 0.1, 0.15, 0.25, 0.35) as well as different incident wind direction (θ = 0°, 15°, 30°, 45°). Then total drag force on Principal Building is obtained by considering adjacent building namely Interfering Building with different position of interfering building with respect to principal building (β), terrain conditions (α) and different incident wind angle (θ). To execute study, Computational Fluid Dynamics Code namely Fluent and Gambit have been used. The Height of each Building Unit is 300 meter and Plan dimensions of tall building unit are as shown in Table I so that Height (H) to Breadth (B) Ratio is 4, 8, 12 and 16. The temperature of Air is considered to be 30°C and accordingly different properties of air have been considered in post processing using Fluent.

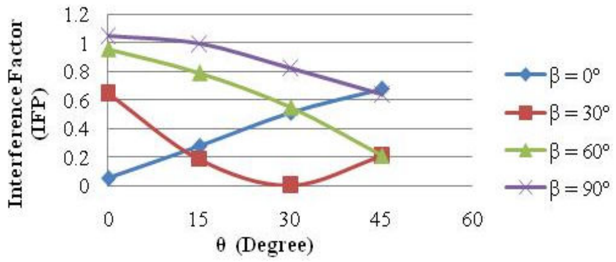


Fig. 9 Effect of (θ) on Interference Factor (IFP) for different (S/B) Ratio considering α = 0.10, (H/B) = 4 and (S/B) = 2

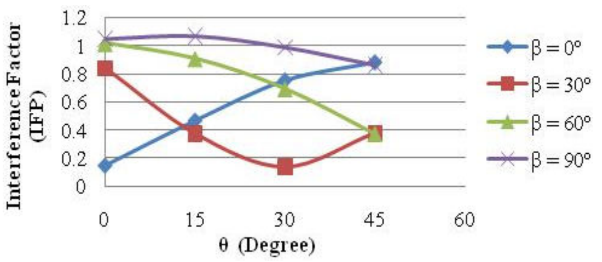


Fig. 10 Effect of (θ) on Interference Factor (IFP) for different (S/B) Ratio considering α = 0.10, (H/B) = 4 and (S/B) = 3

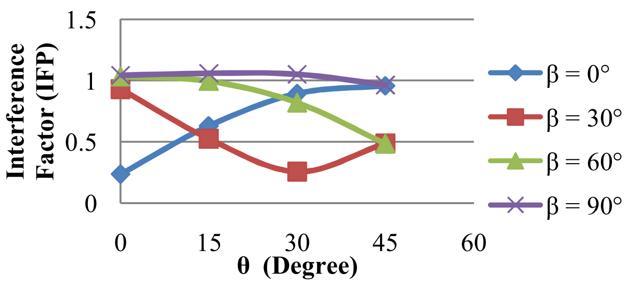


Fig. 11 Effect of (θ) on Interference Factor (IFP) for different (S/B) Ratio considering α = 0.10, (H/B) = 4 and (S/B) = 4

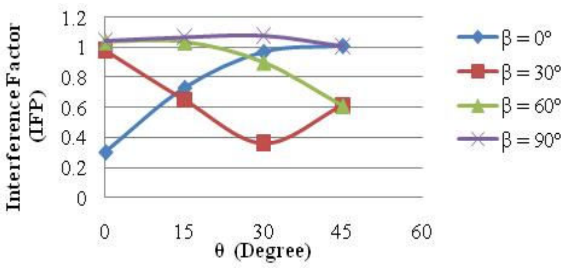


Fig. 12 Effect of (θ) Factor on Interference Factor (IFP) for different (S/B) Ratio [α = 0.10, (H/B) = 4 and (S/B) = 5]

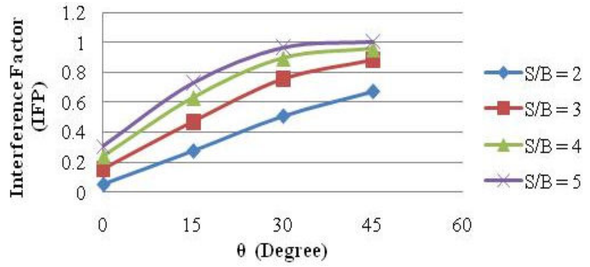


Fig. 13 Effect of (θ) on Interference Factor (IFP) for different (β) Factor [α = 0.10, (H/B) = 4 and (β) = 0°]

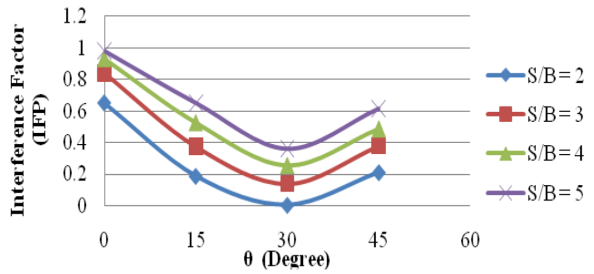


Fig. 14 Effect of (θ) on Interference Factor (IFP) for different (β) Factor [α = 0.10, (H/B) = 4 and (β) = 30°]

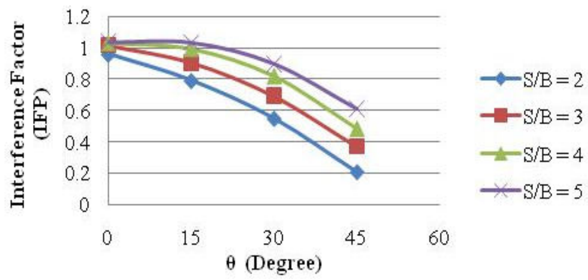


Fig. 15 Effect of (θ) on Interference Factor (IFP) for different (β) Factor [α = 0.10, (H/B) = 4 and (β) = 60°]

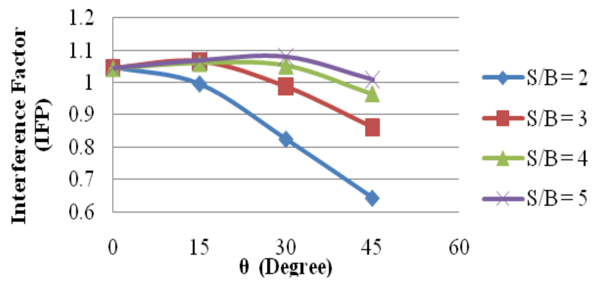


Fig. 16 Effect of (θ) on Interference Factor (IFP) for different (β) Factor [α = 0.10, (H/B) = 4 and (β) = 60°]

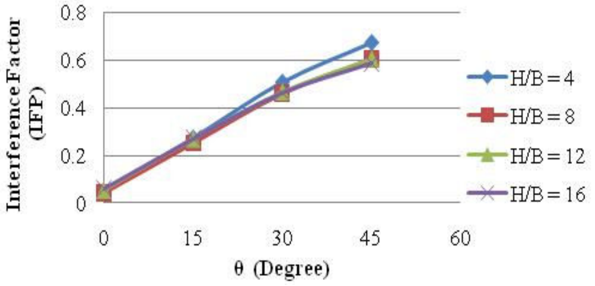


Fig. 17 Effect of (θ) Factor on Interference Factor (IFP) for different (S/B) Ratio [α = 0.10, (β) = 0° and (S/B) = 2]

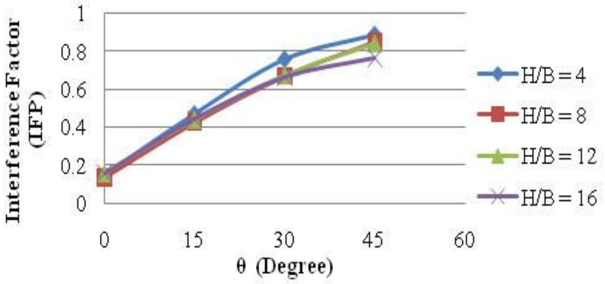


Fig. 18 Effect of (θ) Factor on Interference Factor (IFP) for different (S/B) Ratio [α = 0.10, (β) = 0° and (S/B) = 3]

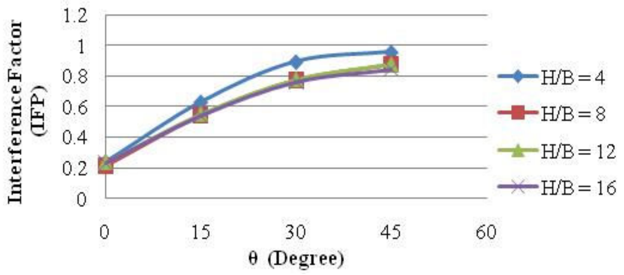


Fig. 19 Effect of (θ) Factor on Interference Factor (IFP) for different (S/B) Ratio [α = 0.10, (β) = 0° and (S/B) = 4]

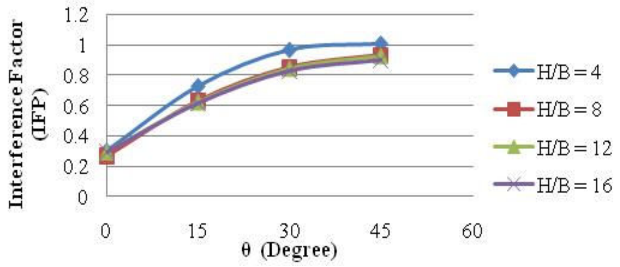


Fig. 20 Effect of (θ) Factor on Interference Factor (IFP) for different (S/B) Ratio [α = 0.10, (β) = 0° and (S/B) = 5]

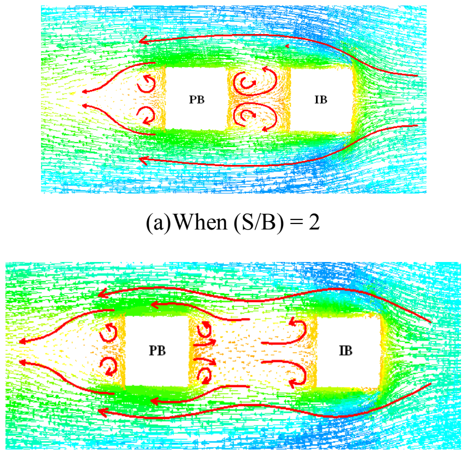
From Figs. 13 to 16, it can be seen that interference effect is more on principal building due to interference building when spacing to breadth ratio(S/B) is less for any value to Height to Breadth ratio (H/B). When (S/B) ratio is 2.0, the minimum value of interference factor is found and when (S/B) ratio is 5, the maximum value of interference factor is found.

From Fig. 21, it can be visualized that when (S/B) ratio is 2, the velocity vectors are striking the windward face of interfering building and getting deflected on both sides. The deflected vectors are directly passing through both sides of principal building with creation of strong vortices in between principal and interfering building. As the spacing between two buildings is less, velocity vectors don't have space to strike windward face of principal building. After passing through both sides of principal building, they get deflected inward with creation of vortices on leeward face of principal building.

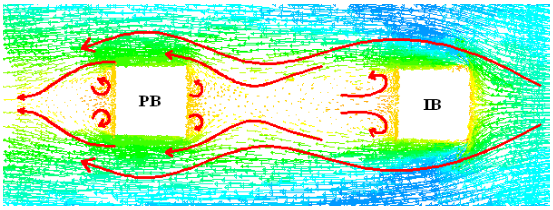
From Figs. 9 to 12, it can be seen that when value of incident wind direction (θ) coincide with the value of position of interfering building with respect to principal building (β), the value of interference factor is minimum. This is happening due to reason that almost full width of principal building in under direct shadow of interfering building and hence velocity vectors are not directly striking the principal building and hence wind pressure on principal building reduces. As the value of (β) Factor goes away from Incident Wind Direction (θ), the shadow effect of interfering building reduces on principal building and hence winds pressure on principal building increases gradually.

From Figs. 22 and 23, it can be seen that when θ = 0° and β = 0°, the principal building is under direct shadow of interfering building. Due to which, velocity vectors are directly striking the interfering building and don't have space to strike windward face of principal building. The deflected velocity vectors on both sides of interfering building are moving ahead from sides of principal building also and then get deflected inward on leeward side of principal building with the development of weak vortices in wake region of principal building. The strong vortices are developing in the space in between two building.

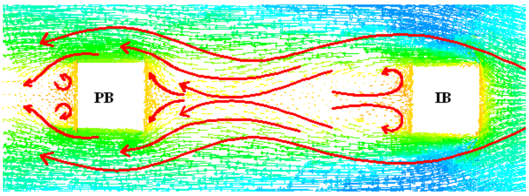
From Figs. 17 to 20, it can be seen that interference effect on principal building due to interference building for different value of height to breadth ratio is differing by small magnitude and its behavior is almost same for any value of (S/B) ratio and incident wind direction (θ). It has been observed that for the value of Height to Breadth ratio 4, the value of Interference factor is more as compared to other ratio. It indicates that if height to breadth ratio of building is less, interference effect of interfering building is less on principal building.



(b) When (S/B) = 3

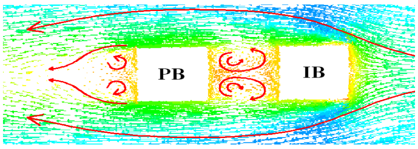


(c)When (S/B) = 4

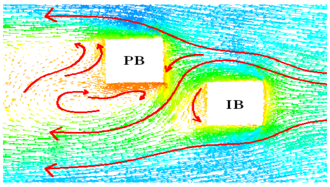


(d) When (S/B) = 5

Fig. 21 Velocity Vector Distribution Diagrams when θ = 0°, β = 0°, H/B = 4 and S/B = 2, 3, 4, 5

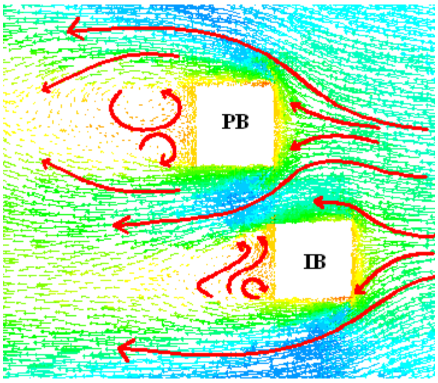


(a) When θ = 0° and β = 0°

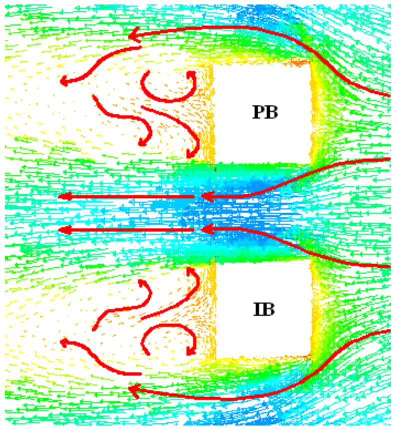


(b) When θ = 0° and β = 30°

Fig. 22 Velocity Vector Distribution Diagrams when θ = 0°, β = 0°, 30°, H/B = 4 and S/B = 2

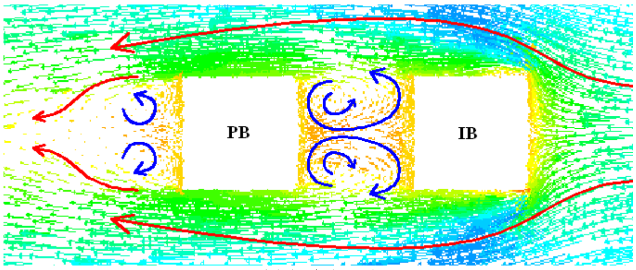


(a) When θ = 0° and β = 60°

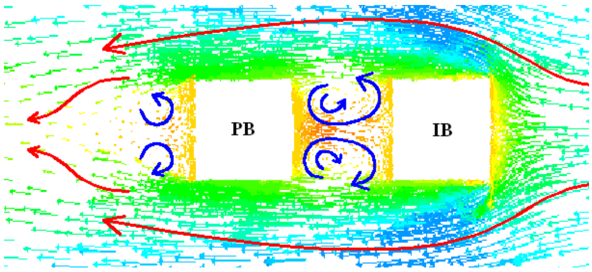


(b) When θ = 0° and β = 90°

Fig. 23 Velocity Vector Distribution Diagrams when θ = 0°, β = 60°, 90°, H/B = 4 and S/B = 2



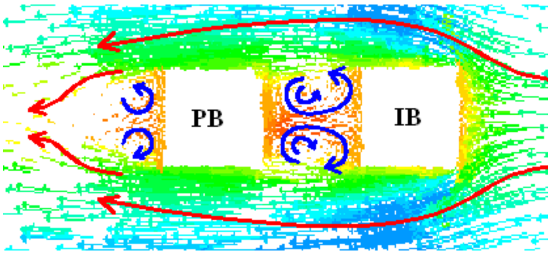
(a)(H/B) = 4



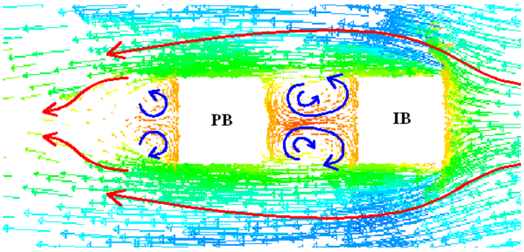
(b) (H/B) = 8

Fig. 24 Velocity Vectors Distribution when θ = 0°, β = 0°, H/B = 4, 8

From Figs. 24 and 25, it can be seen that the structure of wind flow pattern is almost same in all cases of (H/B) ratio. There is development of wake region with strong vortices between two buildings and development of weak vortices behind principal buildings. The wind is not striking directly principal building but it is under the action of deflected velocity vectors emanating from interfering building. The difference in all cases of (H/B) ratio is that level of strength of vortices in wake region between two buildings is differing in magnitude negligibly. When (H/B) ratio is 4, the suction effect on principal building is very less as compared to other (H/B) ratio of 8, 12, and 16. As the suction effect is less, the drag force acting on principal building is high when (H/B) ratio is 4.



(a) (H/B) = 12



(b) (H/B) = 16

Fig. 25 Velocity Vectors Distribution when θ = 0°, β = 0°, H/B = 12, 16 and S/B = 2

VII. Conclusions

Interference effect is more on principal building due to interference building when spacing to breadth ratio(S/B) is less for any value to Height to Breadth ratio (H/B). When (S/B) ratio is 2.0, the minimum value of interference factor is found and when (S/B) ratio is 5, the maximum value of interference factor is found. It has been observed that in tandem arrangement, the total drag force is only 5 % when (S/B) ratio is 2 and it is 30 % when (S/B) ratio is 5.

It is found that when value of incident wind direction (θ) coincides with the value of position of interfering building with respect to principal building (β) i.e. θ = β, the value of interference factor is minimum. This is happening due to reason that almost full width of principal building in under direct shadow of interfering building and hence velocity vectors are not directly striking the principal building and hence wind pressure on principal building reduces. As the value of (β) Factor goes away from Incident Wind Direction (θ), the shadow effect of interfering building reduces on principal building and hence winds pressure on principal building increases gradually. It has been observed that when θ – β = 30°, the total drag force on principal building is increasing by 60 % as compared to θ = β for any (S/B) ratio. When θ – β = 60°, the total drag force on principal building is increasing by 90 % as compared to θ = β for (S/B) ratio = 2 and increasing by 70% when (S/B) ratio = 5.

It has been deduced that effect of interfering building starts reducing on principal building when incident wind direction (θ) and relative position of interfering building with respect to principal building (β) differs by value 30°.

It had been revealed from this study that interference effect on principal building due to interference building for different value of height to breadth ratio is different and its behavior is almost same for any value of (S/B) ratio. It has been observed that when (H/B) ratio is 4, the value of Interference factor is more as compared to (H/B) ratio of 8, 12 and 16. It indicates that if height to breadth ratio of building is less, interference effect of interfering building is less on principal building. The value of Interference factor is almost same for (H/B) ratio of 8, 12 and 16. It has been observed that the value of interference factor is 5 % more in case of (H/B) ratio 4 as compared to other ratio for (S/B) ratio 2 and value of interference factor is 10 % more in case of (H/B) ratio 4 as compared to other ratio for (S/B) ratio 5.

References

[1] Narayan K. and Gairola A., “Wind Interference on Single Similar Gable Roof Building with Overhangs”, International Journal of Advanced Engineering Technology, Vol.III, Issue I/January-March 2012, pp. 04-12.
[2] Nikhil Agrawal, Achal Kr. Mittal, V. K. Gupta, “Along-Wind Interference Effects on Tall Buildings”, VI National Conference on Wind Engineering, December 2012, pp. 193-204.
[3] Xie Z. N., Gu M., “Mean interference effects among tall buildings”, Engineering Structures 26 (2004), pp. 1173–1183.
[4] Khanduri, A. C., Stathopoulos, T. and Bedard, C., “Wind induced interference effects on buildings: A review of the state of the art”, Engg. Structures, 20 (7), 1998, pp. 617 – 630.
[5] Van Uffelen G. M., “Wind Induced Building Interference: Increase of Wind Loads on existing buildings after erection of new high-rises”, EACWE 5, Florence, Italy, July 2009.
[6] Huang, S., Li, Q.S. and Xu, S., “Numerical evaluation of wind effects on a tall steel building by CFD”, J. of Constru. Steel Res. 2007, 63, 612–627.
[7] Cheng-Hu Hu and Fan Wang, “Using a CFD approach for the study of street-level winds in a built-up area”, Building and Environment 40 (2005), pp. 617-631.
[8] Robert H. Scanlan and Emil Simiu, “Wind Effects on Structures – Fundamentals and Applications to Design”, 3rd Edition, John Wiley & Sons Publication.
[9] Gloria Gomes M., Moret Rodrigues A. and Pedro Mendes, “Experimental and numerical study of wind pressures on irregular-plan shapes”, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 93 (2005), pp. 741–756.