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Effects of wind load on 'E' plan shaped tall building under interference conditions

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Abstract. In this study, a Wind Tunnel test was performed to determine the variation of Force and Moment Coefficients on the Symmetric E-plan-shaped tall building in isolated conditions, as well as numerically using Computational Fluid Dynamics (CFD). This investigation further clarifies the effects of interference on a Symmetric E-plan-shaped tall building due to the presence of two interfering buildings using computational fluid dynamics (CFD). These interfering buildings are located at distances of 100 mm, 200 mm, 300 mm, 500 mm, 1000 mm, 1500 mm, 2500 mm & 3000 mm from the principal building, and a scale factor of 1:300 has been taken. The analysis considers wind incidence angles ranging from 0° to 180° at 30° intervals for the wind tunnel test in isolated conditions and 15° intervals for numerical simulations in interference conditions. The maximum force coefficients (0.99) and moment coefficients (0.90) at 0° angle of attack were experimentally determined in a symmetrical E-plan-shaped tall building. The maximum positive value (2.72) of the interference factor (I.F.) for a 30° degree angle of attack on Face J of the principal building at an interfering distances 300 mm and the negative value (-1.23) of the interference factor (I.F.) for a 150° degree angle of attack on Face L of the principal building at an interfering distances 100 mm from edge of principle building. The interference factor (pressure or force) is near about 1 at interfering distances of 3000 mm, and it indicates that the interfering building does not affect the principal building.

Keywords: Wind Tunnel, Force Coefficient, Moment Coefficient, Computational fluid dynamics (CFD), Interference factor.

1. Introduction

In the 1960s, wind engineering tools were developed with a primary focus on understanding the fluid flow behavior of the structure. Tall buildings are crucial solution for habitable with the population continues grow and non-availability space of land in town. In recent days, a substantial increase in the construction of tall buildings has been observed, which can have either regular or irregular shapes, due to limited land availability in large cities and a growing population. A Tall building is defined as per IS875 (Part-III):2015; if the height is equal to or more than 50 m or has height to least lateral dimension of more than 6, it is called High Rise Building (Tall Building). Also observed as per IS16700:2017, If the building height is more than 50 m but less than or equal to 250 m, it is called a Tall building. According to IS 16700 :2017, for buildings (i)Height more than 150 m or ii) with complex geometry iii) Complex topography with interference

effects or iv) whose natural time period is more than 5sec, Wind effects should determine using wind tunnel test. So much information and standard codes are available in above codes for symmetric planar-shaped structures. However, wind pressure in isolated cases and interference factors due to interference effects variations on the twelve faces of symmetric planar-shaped buildings are also uncommon. Therefore, with the advancement of construction technologies, it is very important to carry out the study on the on high-rise building due to the effects of interference. According to the Indian code of practices for estimating wind load (IS:875(Part-III):2015), unable to determine the wind-load design parameter of the building of such an irregular plan shaped high rise building i.e., 'U,' 'V,' 'Y,' 'L,' 'T' 'Z,' '+,' 'H' 'E' plan shaped tall buildings. Building design considers wind load to be a widespread phenomenon in structural engineering. This article presents an experimental study to determine the Force and Moment Coefficients on a symmetric E-plan-shaped building under isolated conditions using a wind tunnel, as well as numerically through Computational Fluid Dynamics (CFD). This investigation further clarifies the effects of interference on Symmetric 'E' plan-shaped tall building due to the presence of two interfering buildings utilizing

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computational fluid dynamics (CFD). Present study, the Interference Factors (I.F.), Force Coefficients (C_f), and Mean Pressure Coefficients (C_p) are Determined numerically utilizing Computational Fluid Dynamics (CFD) analysis, considering two interfering square (i.e., 100 mm $\times$ 100 mm) shaped tall buildings in interference conditions. These buildings are located at distances of 100 mm (first case), then 200 mm, 300 mm, 500 mm, 1000 mm, 1500 mm, 2500 mm & 3000 mm from the edge of the principal building. This numerical study provides detailed information regarding the wind flow parameters under better-controlled in isolated and interference conditions. The precision of numerical computational fluid dynamics (CFD) analysis is validated with an experimental study, kinetic-eddy model was used for numerical analysis. The interference effect between tall buildings should be analyzed (Computational Fluid Dynamics) secondly, as there is no way of predicting the actual behavior of a building under various interfering conditions. Thepmongkorn et al. (2002) examine wind tunnel tests to investigate the effects of interference resulting from wind-induced coupled translational–torsional motion of buildings. Bhattacharyya and Dalui (2014) examined along-wind as well as across-wind effects on an irregularly shaped tall building under wind excitation. Bhattacharyya and Dalui (2018) evaluated the mean wind pressures on ‘E’-plan-shaped tall buildings using both numerical and experimental methods. Bhattacharyya and Dalui (2020)

conducted an experimental and numerical study on the pressure distribution of irregularly shaped tall buildings under wind excitation. Akram et al. (2024) analyzed the static wind effects on a Y-plan-shaped tall building under interference conditions. The present study was conducted to investigate the pressure, force, and moment variations on the twelve faces of the primary(main) building under both in an isolated conditions and interference conditions, with a scale factor of 1:300.

2. Details of building model

In this study, numerical analysis done by computational fluid dynamics (CFD) was performed to clarify the influence of pressure and force on the faces of the principal building (i.e., 350 mm $\times$ 250 mm), considering two interfering square-shaped tall buildings (i.e., 100 mm $\times$ 100 mm). Building Limb width has been taken 50 mm, and the precise distances between limbs are 100 mm. In this study, A height of 500 mm has been considered for principal(main) building as well as interfering buildings. These interfering buildings are at a distance of (i.e., “d”) 100 mm, 200 mm, 300 mm, 500 mm, 1000 mm, 1500 mm, 2500 mm & 3000 mm from edge of the principal building, and a geometric length scale factor of 1:300 has been taken in this study. The analysis was done on wind angles of attack ranging from 0° to 180°, with a 15° angle interval. The figure below shows the geometrical details of the principal and interfering buildings **Fig. 1**.

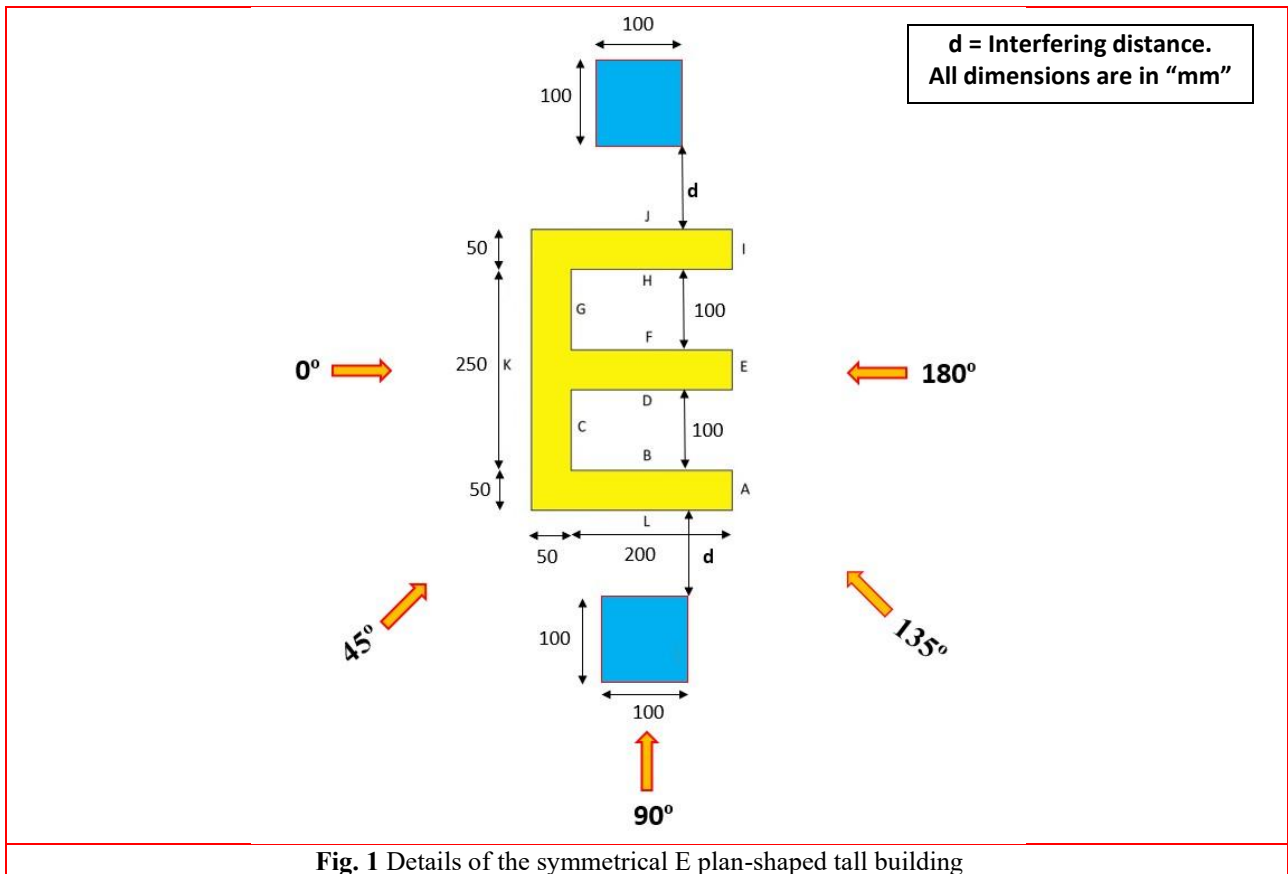


Fig. 1 Details of the symmetrical E plan-shaped tall building

3. Research Gap

Based on the literature survey, the following critical observations may be made. A Lot of work has been done on isolated buildings (L, T, U, E, +, Y, Z, Pentagon, Setback, H, V-shaped, etc.). Also, it was found that interference effects on (square, rectangular, circular, Pentagonal, Hexagonal, octagonal, cross, U, L, T) shaped buildings have been experienced. After reviewing the literature, It must be noted that few works have been done on E-plan-shaped tall buildings, and very few experimental wind tunnel investigations have been conducted to evaluate force and moment coefficients in isolated conditions on E-Plan shaped tall building. Additionally, very few studies have addressed the effects of interference on E-Plan shaped tall buildings.

4. Experimental study

The experimental study was done in an open circuit boundary layer wind tunnel (**Fig. 2**) at the Wind Engineering Centre, Department of Civil Engineering, Indian Institute of Technology (IIT) Roorkee, India. The wind tunnel test was done with a terrain category II according to IS 875 (Part iii): 2015. Wind tunnel cross-section was 2 m (w)×2 m (h) and length consider as a 38 m. To ensure uniform airflow within the wind tunnel, a 6 m × 6 m ((i.e., square section) honeycomb section with a thickness of 1 m was positioned at the inlet of the tunnel. The elliptical effuse profile has a length of 6 m, and the contraction ratio consider as 9:5:1, which was used, and is located immediately downstream of the honeycomb in the inlet to ensure the airflow within the

tunnel. A turntable is set up in the wind tunnel to measure wind design parameters, and it is located 12 m away from the elliptical effuse. The pressure measurement model was setup at the center of the turntable. The pitot tube used to detect the wind speed into the wind tunnel. Wind speed has been taken to be 10 m/s, and a scale factor of 1:5 has been applied in this study.

4.1 Details of model

In this study, models are constructed from 6 mm thick plywood at a length scale of 1:300. Different faces and isometric views of the model and load cell, along with detailed images, are presented in **Fig. 2**. Weights are applied to the structure using a pulley and hanger arrangement. The analysis was done on wind angles of attack ranging from 0° to 180°, with a 30° angle interval. The suction fan operates with a turntable rotating at 500 revolutions per minute, ensuring efficient airflow and smooth mechanical performance.

4.2 Boundary condition

The wind tunnel experiment was conducted with a wind speed of 10 m/s. To generate the boundary-layer flow, a vortex generator was used; additionally, cubic blocks were installed upstream to measure the surface roughness. In the velocity profile, the power law distribution exponent is considered as $\alpha = 0.133$. The building model was set up at the center of the turntable and situated 12 m downstream of the elliptical effuse.



Fig. 2 Force Model Setup for Wind-Tunnel Experiment

5. Numerical study

The current study was done utilizing numerical simulations of computational fluid dynamics (CFD) methods. The standard Reynolds-averaged Navier-Stokes equations (RANS) kinetic-eddy turbulence model has been taken for modeling, because it provides better accuracy as well as efficiency, and the modified continuity equation and momentum equation are represented after including two other variables i.e., k and ε are

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho U_j)}{\partial x_j} = 0 \quad (1)$$

$$\frac{\partial \rho U_i}{\partial t} + \frac{\partial(\rho U_i U_j)}{\partial x_j} = -\frac{\partial p'}{\partial x_i} + \frac{\partial}{\partial x_j} \left[\mu_{eff} \left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i} \right) \right] + S_M \quad (2)$$

Where S_M represent the sum of body forces, μ_{eff} is the effective viscosity, ρ denote density and U represent velocity of air respectively. Also, p' represent the modified pressure

As per eddy viscosity concept, so that

$$\mu_{eff} = \mu + \mu_t \quad (3)$$

where μ_t represent the turbulence viscosity and μ is the mean viscosity,

The relations between turbulence viscosity, kinetic energy, and eddy dissipation of turbulence through the momentum and Continuity equations are below.

$$\mu_t = C_\mu \rho \frac{k^2}{\varepsilon} \quad (4)$$

The values of kinetic-eddy (i.e., k - ε) come directly from the governing differential equations the transport of turbulence kinetic energy and dissipation rate:

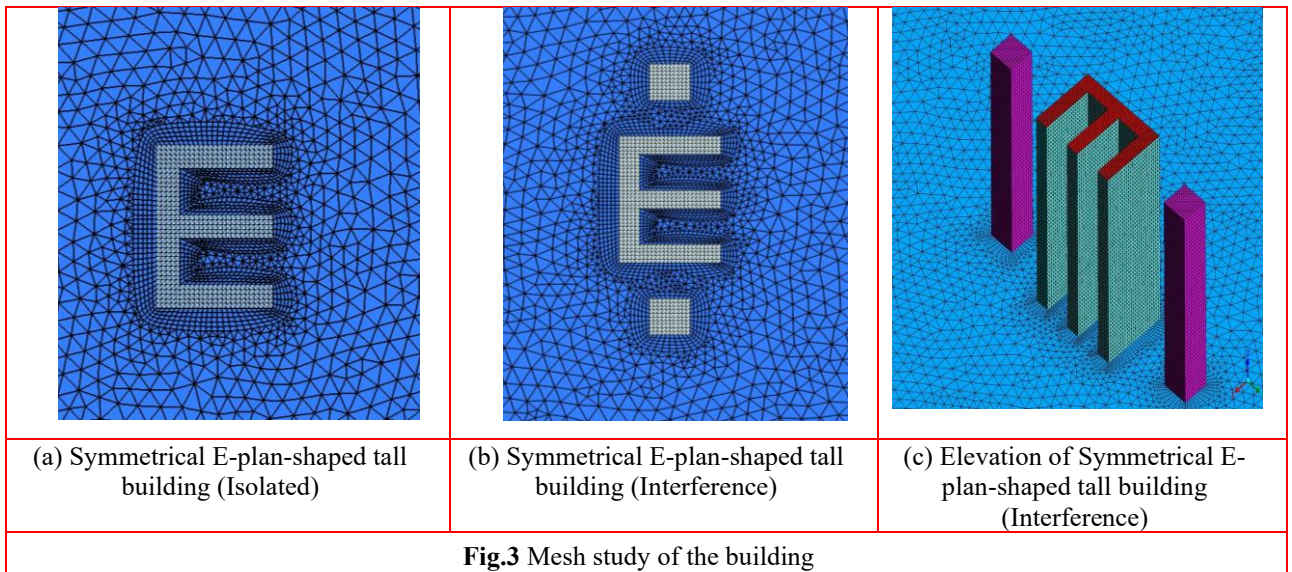
$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k U_j)}{\partial x_j} = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + P_k + P_{kb} - \rho \varepsilon \quad (5)$$

$$\frac{\partial(\rho \varepsilon)}{\partial t} + \frac{\partial(\rho \varepsilon U_j)}{\partial x_j} = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon} \right) \frac{\partial \varepsilon}{\partial x_j} \right] + \frac{\varepsilon}{k} (C_{\varepsilon 1} P_k - C_{\varepsilon 2} \rho \varepsilon + C_{\varepsilon 1} P_{\varepsilon b}) \quad (6)$$

Where C_μ has been taken 0.09 in this study, P_k denotes the turbulence kinetic energy, Density of air in the model denote by ρ and the density of air and it is taken as 1.224 kg/m³. Also, turbulence model constant $C_{\varepsilon 1} = 1.44$ & $C_{\varepsilon 2} = 1.92$ are taken, σ_k consider 1.0 and it is Represent turbulence model constants. The μ is represented as a dynamic viscosity and μ_t are represented as a turbulent viscosity. Turbulence intensity has been considered to be 10%, and the building is treated as a bluff body in computational fluid dynamics (CFD).

5.1 Domain and meshing

The domain size has been taken according to Franke et al. (2004). Computation domain of the CFD simulation is shown in the **Fig. 4**. The upstream clearance is considered as 5 times of principal building height (i.e., H) from the outer edge of the principle building and the downstream clearance maintained 15 times of principal building height from the edge of the principle building both in isolated conditions and interference conditions; Left and right side clearance is taken as 5 times of principal building height from the nearest edge interfering building, and vertical clearance is also taken as 5 times of principal building height from the top surface of the principle building. Where H is the height of the main (i.e., primary) building. A larger domain facilitates vortex formation on the leeward side of the building while also helping to prevent wind backflow. In this study Tetrahedral elements has been taken shown in the **Fig.3** Mesh study of the building.



5.2 Boundary condition

The boundary limitations were taken as per Chakraborty et al. (2014). Similar types of boundary conditions were also used in Bhattacharyya and Dalui (2018). The Wind flow from the inlet side is generated using the Power law as given in Eq.7 and the coefficient (α) is taken as 0.133 which was found from the experiment.

$$\frac{U(z)}{U_0} = \left(\frac{z}{Z_0}\right)^\alpha \quad (7)$$

where U_0 represents the basic wind speed and the basic wind speed 10 m/sec has been taken in this study, 1:5

scale factor has been considered and Z_0 Represent the height of the boundary layer, which is 1 m, similar to the wind tunnel test. Convergence is achieved when the residuals fall below 1×10^{-5} . The velocity in the rest of the directions is set to 0. The left and right side consider as free slip. Similarly, the top surfaces of the domain have been considered as free slip, and All surfaces of the principal buildings, interfering buildings, and the ground surface of the domain are considered as no-slip conditions to estimate the contour of pressure accurately.

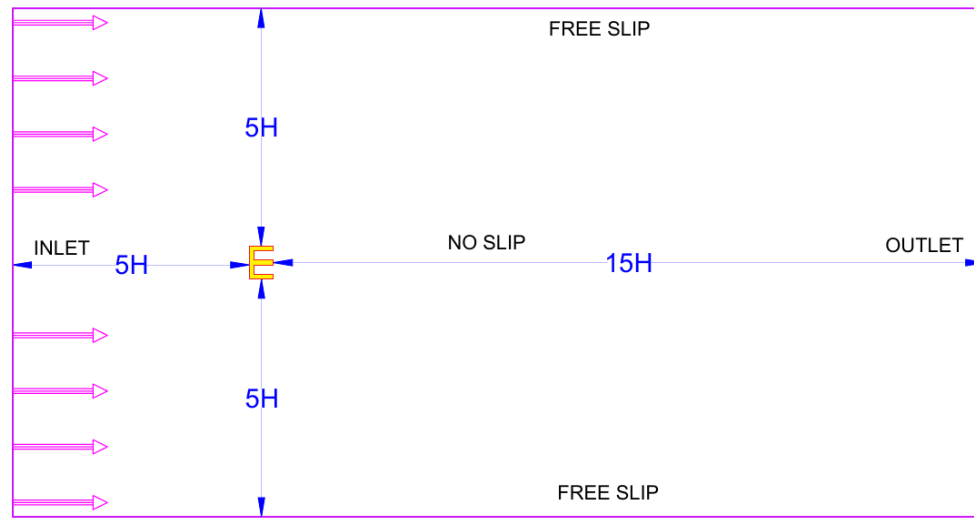


Fig. 4 Computation domain for CFD simulation

6. Results & Discussion

Table 1. Mean pressure coefficient principal building at 0° AOA in interference conditions

GRID	Number of Elements	C _p means at Different Faces in an interference condition											
		Face A	Face B	Face C	Face D	Face E	Face F	Face G	Face H	Face I	Face J	Face K	Face L
GRID 1	10136255	-0.29	-0.27	-0.27	-0.28	-0.25	-0.29	-0.28	-0.28	-0.30	-0.53	0.66	-0.53
GRID 2	12399974	-0.30	-0.28	-0.28	-0.29	-0.25	-0.28	-0.28	-0.28	-0.30	-0.53	0.64	-0.54
GRID 3	15792408	-0.31	-0.29	-0.29	-0.30	-0.26	-0.29	-0.28	-0.29	-0.31	-0.54	0.64	-0.54
GRID 4	18666059	-0.33	-0.30	-0.30	-0.31	-0.27	-0.30	-0.28	-0.30	-0.30	-0.54	0.66	-0.57
GRID 5	22992134	-0.30	-0.30	-0.28	-0.30	-0.26	-0.31	-0.29	-0.30	-0.30	-0.53	0.64	-0.54
GRID 6	29635016	-0.31	-0.32	-0.31	-0.32	-0.28	-0.32	-0.31	-0.31	-0.31	-0.55	0.66	-0.55
GRID 7	41187054	-0.31	-0.31	-0.31	-0.32	-0.28	-0.32	-0.31	-0.31	-0.31	-0.54	0.66	-0.54

6.1 Grid Sensitivity

The grid sensitivity analysis done to ensure the accurate and independent of mesh resolution. This analysis is done on tall principal building in Interference conditions to calculate mean pressure coefficients for a 0° angle of attack at different element sizes, and the mean pressure coefficients (C_p) at different Twelve faces (i.e., From Face A to Face L) are shown in **Table 1**. It was observed from this grid sensitivity study that Grid-6 is almost similar to Grid-7. So, Grid-6 is considered for analysis. So, we can decrease the computational cost as well as computational time.

6.2 Validation

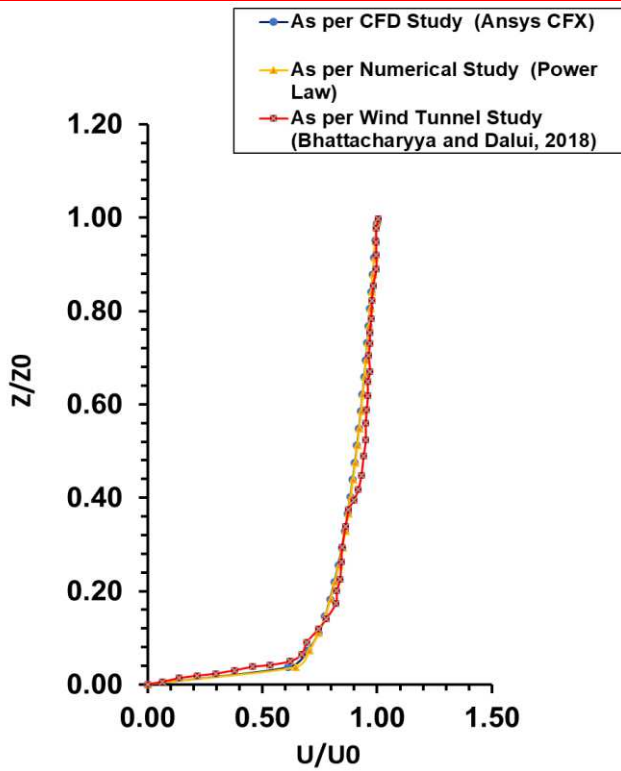


Fig. 5 Velocity profile as per as per Experimental study and as per present study

The Validation is done by Computational fluid dynamics (CFD) using the kinetic-eddy model in isolated conditions to determine the Mean pressure coefficient, and it is compared with experimental data. The coefficients for all twelve faces of the principal (primary) building have been validated with the computational results by Bhattacharyya and Dalui (2018) through experimental results for 0° and 90° wind angles shown in the **Fig. 6**. Some faces are almost similar to the Experimental (wind tunnel) data, and the error is less than 15 % in all twelve faces of the principal tall building, hitting the wind at 0° and 90° attack. Also, the velocity profile graph (Shown in the **Fig. 5**) will be validated (by Mean pressure Coefficients) using wind tunnel test experimental results as by Bhattacharyya and Dalui (2018). Similarly, compared with numerically power Law results. The numerical simulation has been comprehensively validated through comparison with experimental studies, as well as through numerical analyses (power law) that demonstrate its accurately estimate the wind-induced responses of the structures.

The coefficient of mean pressure (C_p) is calculated by the formula

$$\text{Coefficient of mean pressure } (C_p) = \frac{P}{\frac{1}{2}\rho v^2} \quad (8)$$

Where, ρ is represent the density of air,

v is Streamline line velocity, P is the mean pressure.

In this study air density is taken 1.224 kg/m³.

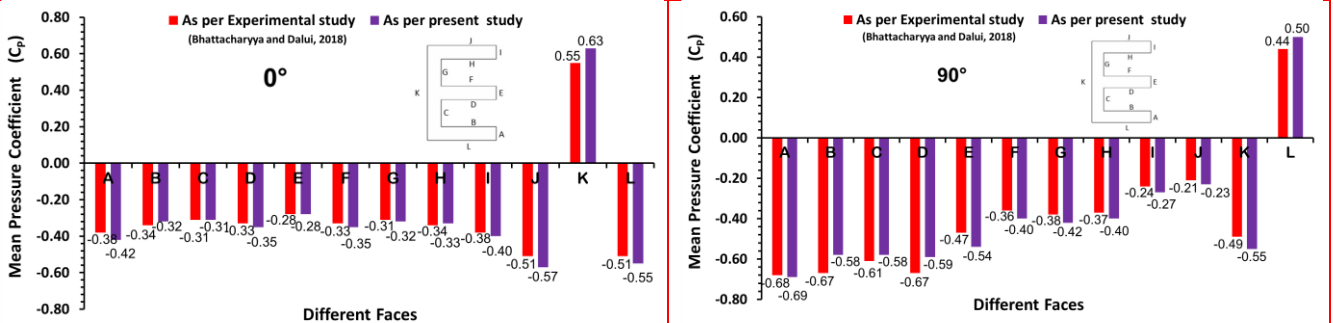


Fig. 6 Mean pressure coefficient for 0° & 90° AOA

6.3 Force and Moment coefficient t(Experimental)

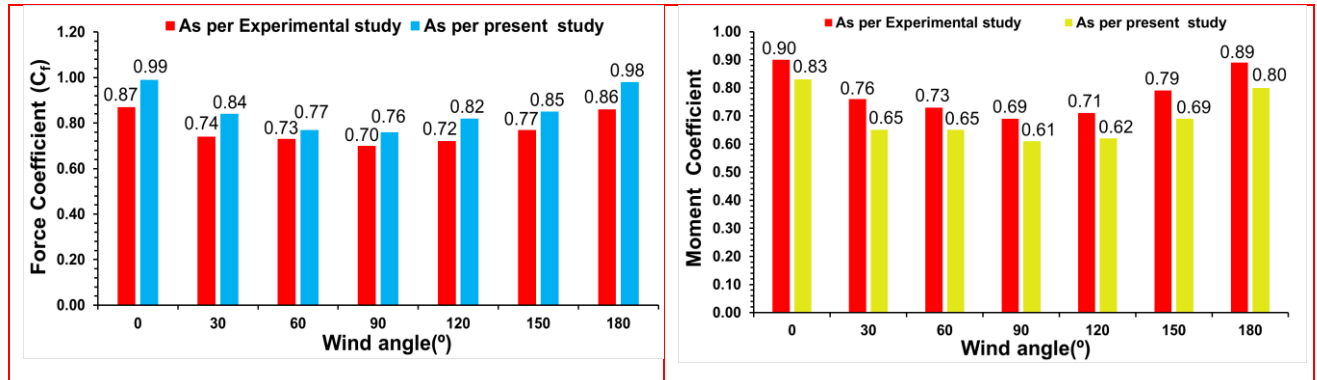


Fig. 7 Force and Moment coefficient for Symmetrical E-plan-shaped tall building

$$\text{Force coefficient } (C_f) = \frac{F}{\frac{1}{2}\rho V^2 A} \quad (9)$$

$$C_{M(x \text{ or } y)} = \frac{M(x \text{ or } y)}{\frac{1}{2}\rho V^2 A * \text{Lever arm}} \quad (10)$$

$$\text{where } C_M = (C_{Mx} + C_{My})^{0.5}$$

In this investigation, the force and moment coefficients were calculated experimentally using wind tunnel tests and numerically using the CFD of the Symmetrical E-plan-shaped tall building. The analysis considers wind angles ranging from 0° to 180° at an interval of 30°. The error between the experimental study and the numerical analysis is less than 15 %. The accuracy of the numerical analysis results is compared with experimental results, and it seems to agree strongly with the experimental wind tunnel test results. Also, The results show that the maximum force coefficient (0.87 experimentally and 0.99 Numerically simulations) and moment coefficient (0.90 experimentally and 0.83 Numerically simulations) at 0° angle of attack were experimentally as well as numerically determined in E-plan shapes of building and the minimum force coefficient (0.70 experimentally and 0.76 Numerically simulations) and moment coefficient (0.69 experimentally and 0.61 Numerically simulations) at 90° angle of attack were experimentally as well as numerically determined in symmetrical E-plan-shaped tall building as shown in the Fig. 7.

6.4 Interference factor

In interference effect, the wind pressure acting on a structure may be affected by surrounding buildings. The interference factor represents the interference effects of surrounding buildings. This interference factor is expressed as the ratio of wind-induced response (for example, pressure or force) on a structure in the presence of nearby obstructions to that on the same structure when isolated. It helps with the increased or decreased wind loads and ensures accurate design for safety and

structural performance under real environmental conditions.

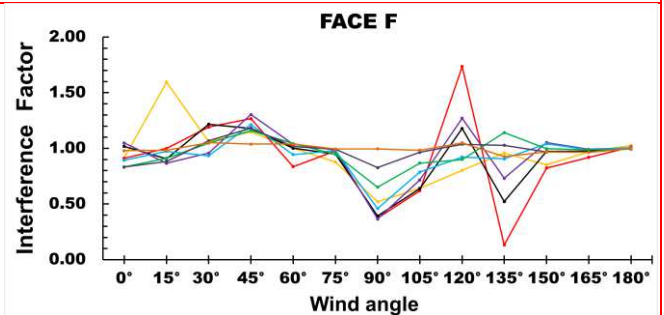
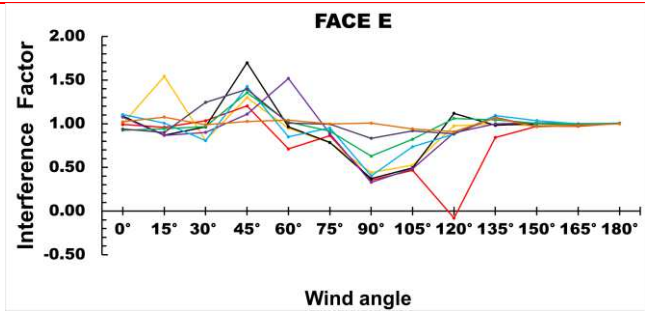
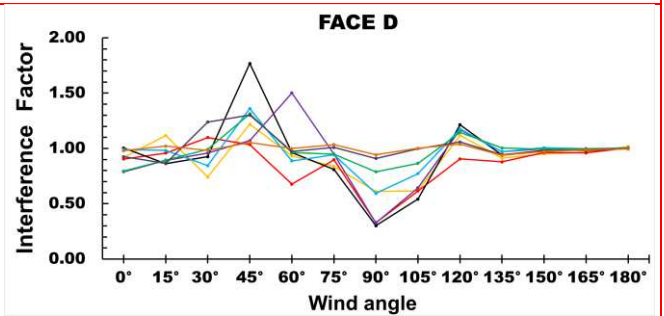
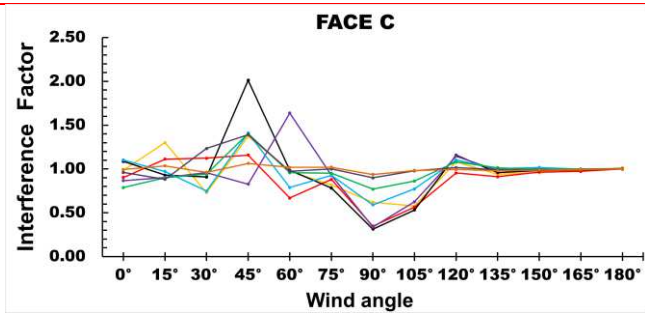
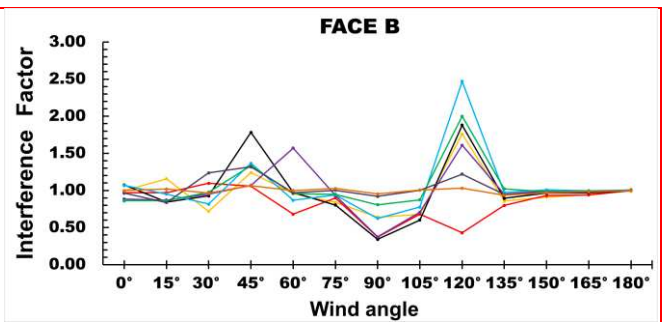
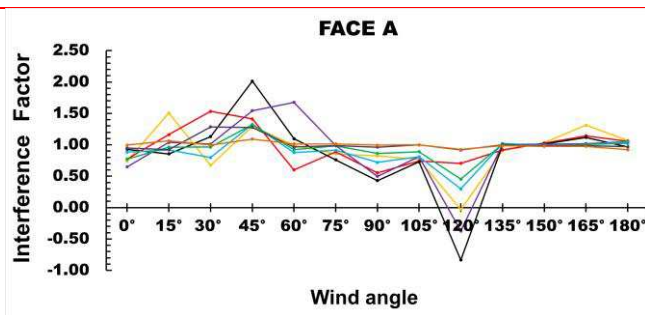
The interference factor represented by:
Interference Factor

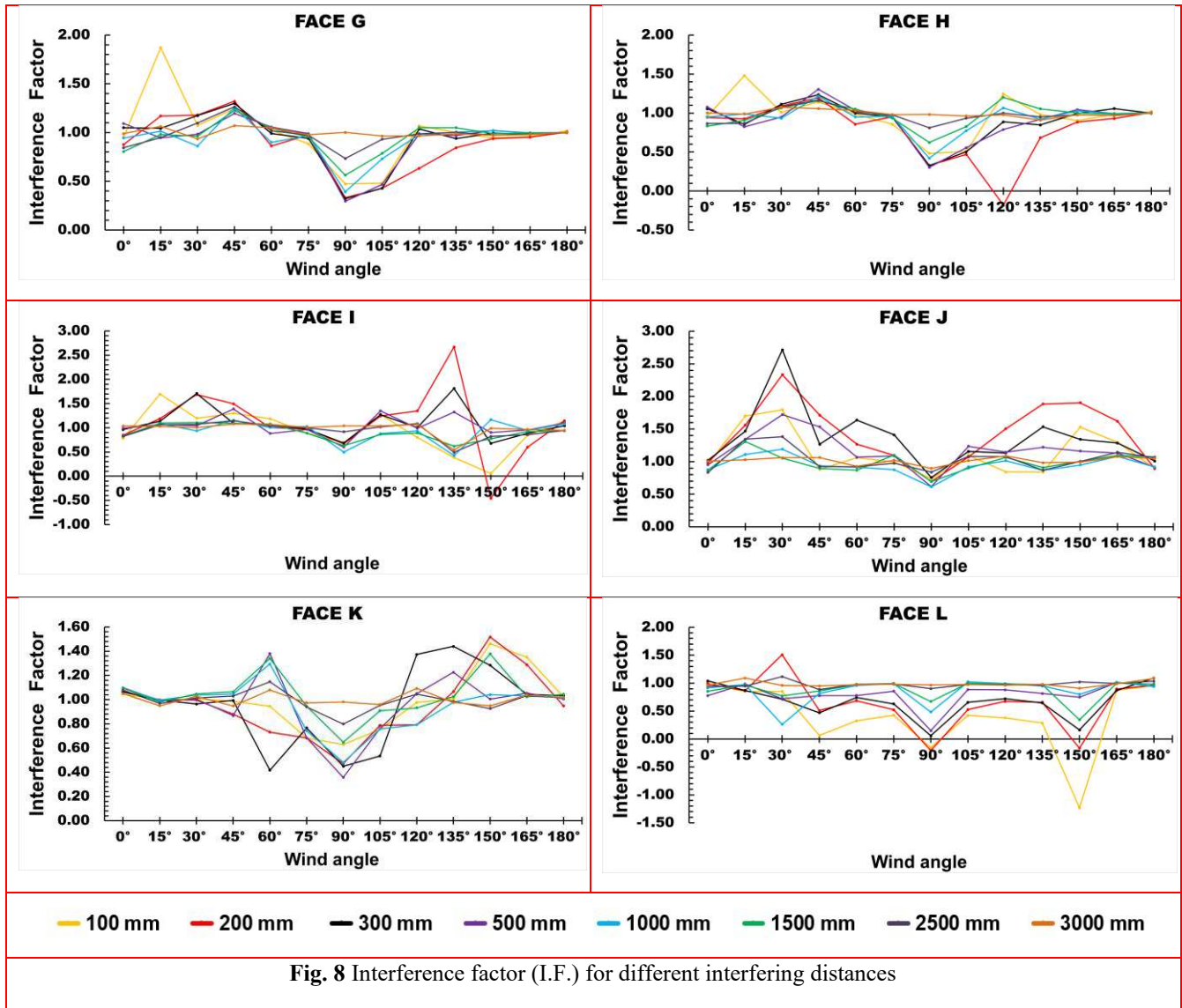
$$= \frac{\text{The enhanced pressure in the Interference conditions}}{\text{The corresponding pressure in Isolated conditions}}$$

The interfering buildings are located at distances of 100 mm, 200 mm, 300 mm, 500mm, 1000mm, 1500mm, 2500mm & 3000mm from the principal building, and a scale factor of 1:300 has been taken in this study. The analysis considers wind angles ranging from 0° to 180° at an interval of 15°. The maximum positive value (2.72) of the interference factor (I.F.) for a 30° degree angle of attack on Face J of the principal building at an interfering distances 300 mm from edge of principle building and the negative value (-1.23) of the interference factor (I.F.) for a 150° degree angle of attack on Face L of the principal building at an interfering distances 100 mm from edge of primary building. The interference factor is near about 1 at interfering distances 3000 mm (i.e., 12b) from the principal building shown in the Table 2, and It indicates that it does not affect the main building. Also observed that negative values are displayed on the Face E & Face H for a 120° angle of attack at an interfering distance of 200mm from the principal building shown in the Fig. 8. Similarly, negative values are shown on Face I at a distance of 200 mm from the main building for a 150° angle of attack. Also found negative values on Face A for 120° angle of attack at an interfering distances 100mm, 300mm & 500 mm, It indicates that suction occurs on the particular faces of interference distances due to the interfering building. Faces B, Face C, Face D, Face F, Face G, Face J & Face K showed positive interfering values, meaning no suction occurs due to interfering buildings on the particular faces for wind incidence angles ranging from 0° to 180° at an interval of 15° at any interfering distances. Increasing or decreasing the distance between the principal building and the interfering building will change the wind effects.

Table 2 Interference factors (I.F.) for different AOA of wind for 3000 mm interfering distance on different faces

AOA FACE	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
A	1.00	1.06	1.00	1.09	1.02	1.02	1.00	1.00	0.93	0.99	0.98	0.98	0.92
B	1.00	1.02	0.97	1.06	1.00	1.03	0.95	1.01	1.03	0.94	0.97	0.98	0.99
C	0.99	1.04	0.96	1.06	1.02	1.02	0.94	0.98	0.99	0.98	0.99	0.99	1.00
D	0.98	1.02	0.98	1.05	1.00	1.04	0.94	1.00	1.04	0.94	0.97	0.99	0.99
E	1.02	1.08	0.99	1.03	1.04	1.00	1.01	0.94	0.91	1.07	0.97	0.98	1.00
F	0.98	0.98	1.05	1.04	1.04	0.99	1.00	0.98	1.05	0.93	0.97	0.96	1.00
G	0.99	1.06	0.94	1.07	1.05	0.98	1.00	0.97	0.97	0.99	0.97	0.98	1.00
H	1.00	0.99	1.08	1.06	1.04	0.98	0.98	0.96	0.98	0.91	0.98	0.97	1.00
I	1.04	1.03	1.01	1.08	1.07	1.01	1.04	1.04	1.07	0.54	0.99	0.97	0.95
J	1.01	1.03	1.06	1.06	0.93	1.02	0.90	1.01	1.09	0.98	0.99	1.08	1.05
K	1.05	0.95	1.03	0.95	1.08	0.97	0.98	0.96	1.09	0.98	0.95	1.04	1.02
L	0.96	1.09	0.96	0.95	0.97	0.98	0.97	0.97	0.96	0.98	0.91	0.99	1.08

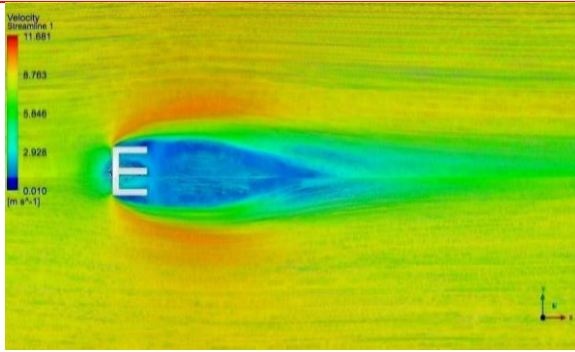




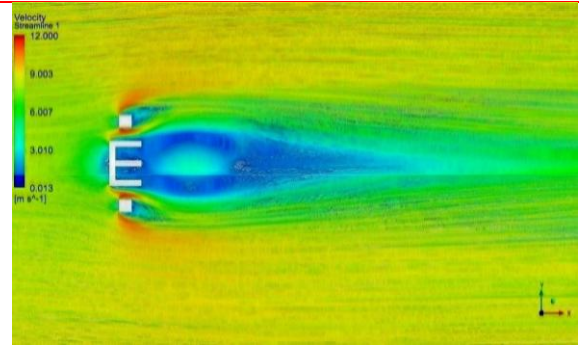
6.5 Streamline velocity

The flow streamlines for the isolated and interference case with interfering distance 100 mm for 0°, 30° and 60° and 90° wind angles have been shown in **Fig. 9** Comparison study for Velocity streamline(3D) both in an isolated and interference case; while the streamlines for different interfering distances for 0° & 45° angle of attack for 100 mm, 500 mm, 1000 mm & 3000 mm interfering distances have been shown in **Fig. 10**. This comparison is used to evaluate the effects of interference on flow separation and wake formation around the building. It is observed that for a 90° wind angle of incidence, in the interference condition, wind directly hits the interfering building; therefore, wind flow is less

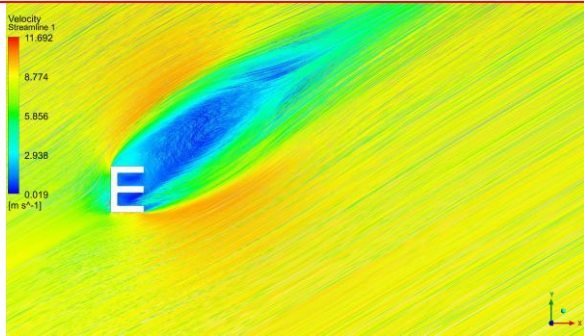
just behind the primary building, but since there is no interfering building in isolated case, hence wind directly hit the principle building and wind flow and its leeward side wind pressure just behind the building is heavy. Due to the interfering building, channeling effects are observed in the streamline velocity shown in the figure, a velocity increase by 0.319 m/sec for a 0° angle of attack. Similarly, due to the blockage of an interfering building, a decrease of 0.025 m/sec in the streamline velocity, at a 90° angle of attack. Also observed from Fig. 10, the channeling effects decreases with increasing distances between interfering buildings and principal building. Also observed from streamlining, that shielding effects occur due to the obstruction or interfering buildings, which is a reduction in wind pressure and force experienced by a structure.



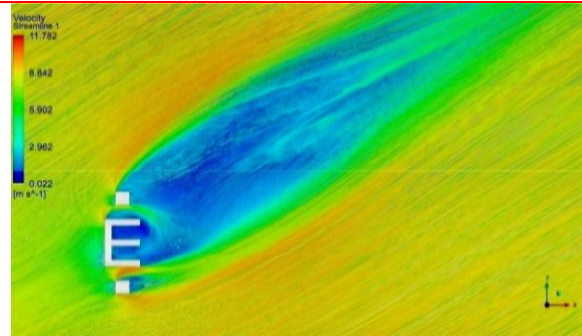
(a) Isolated case at 0° angle



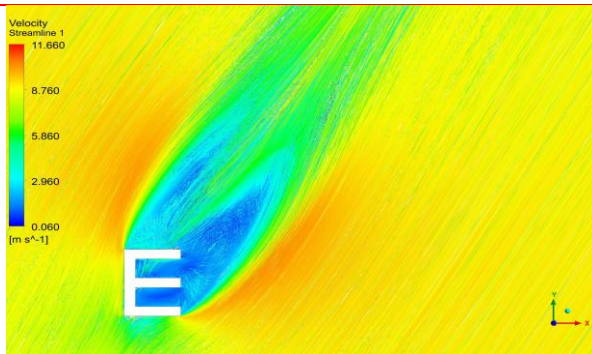
(b) Interference case at 0° angle



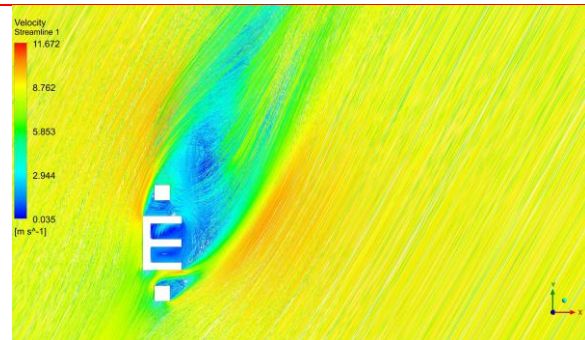
(c) Isolated case at 30° angle



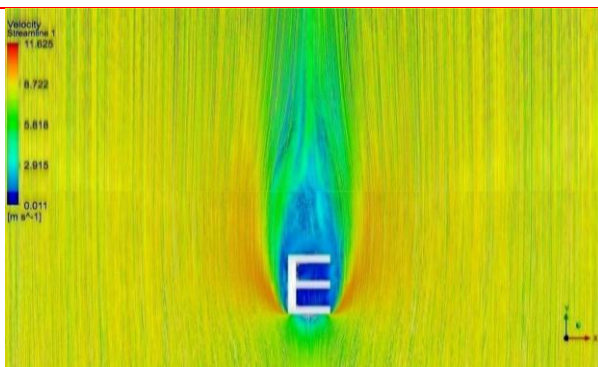
(d) Interference case at 30° angle



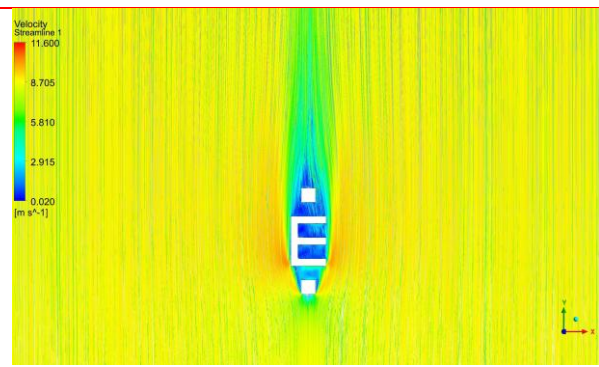
(e) Isolated case at 60° angle



(f) Interference case at 60° angle



(g) Isolated case at 90° angle



(h) Interference case at 90° angle

Fig. 9 Comparison study for Velocity streamline(3D) both in an isolated and interference case

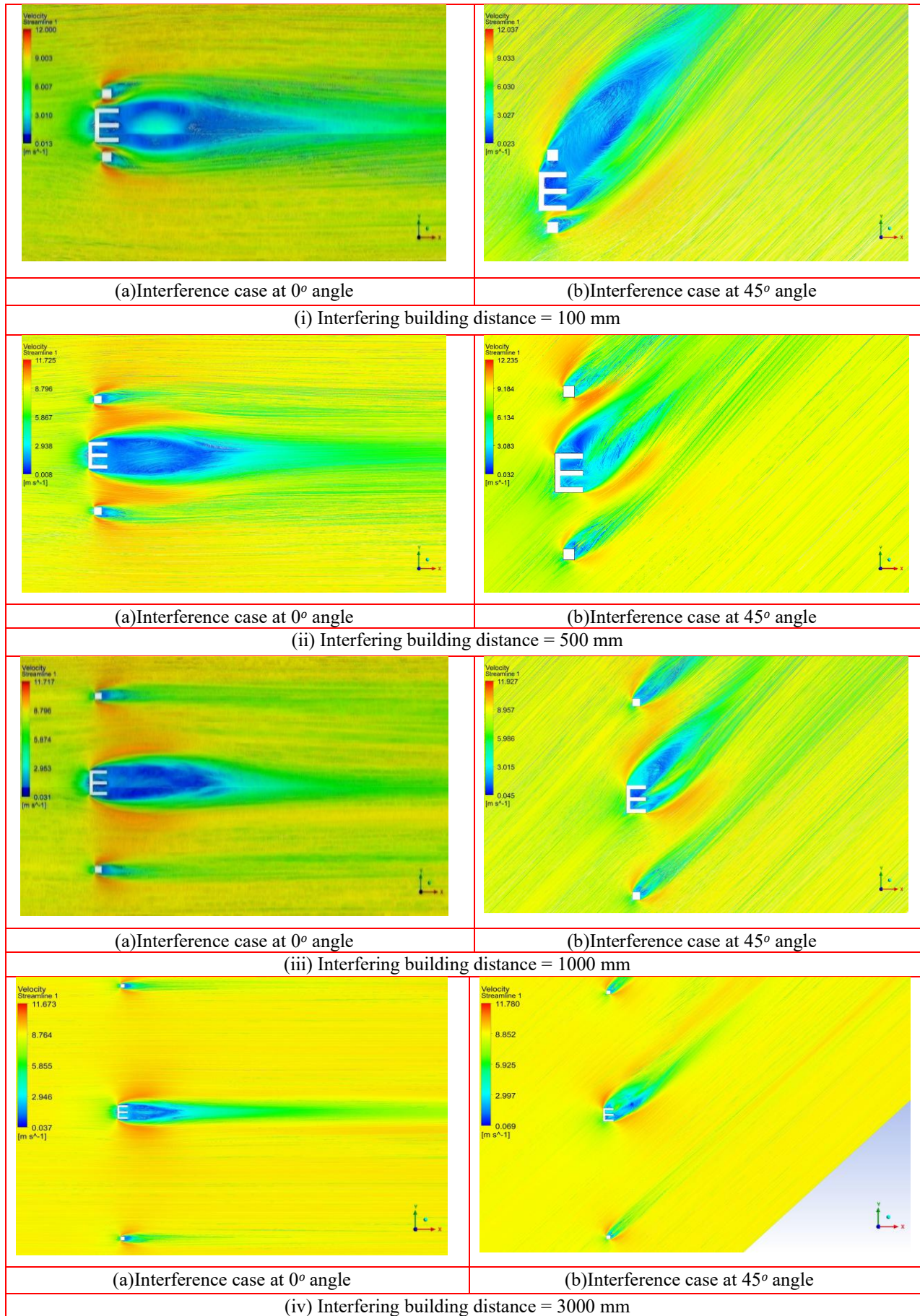


Fig. 10 Velocity streamlines(3D) at different interfering building distances

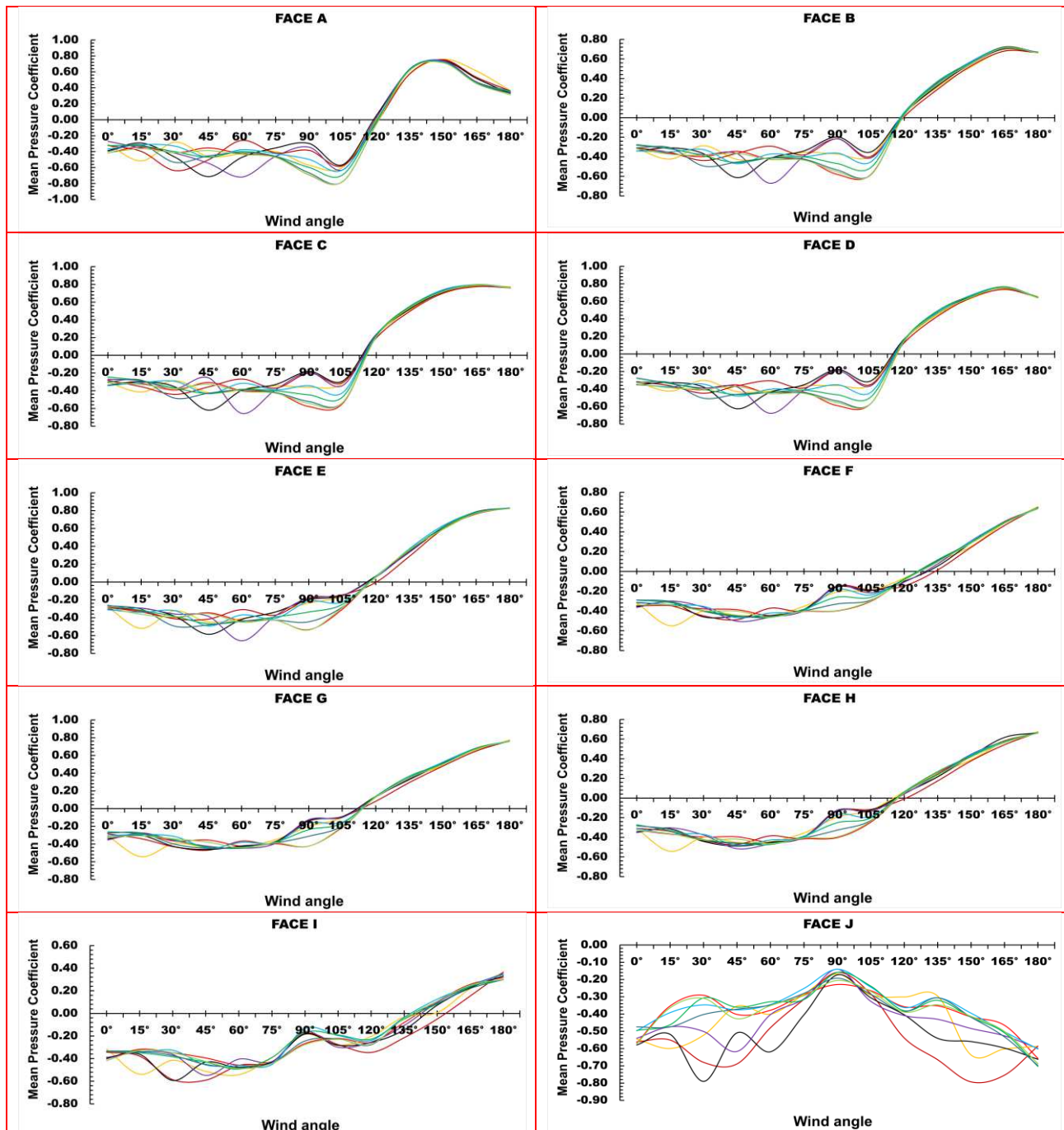
6.6 Pressure variation

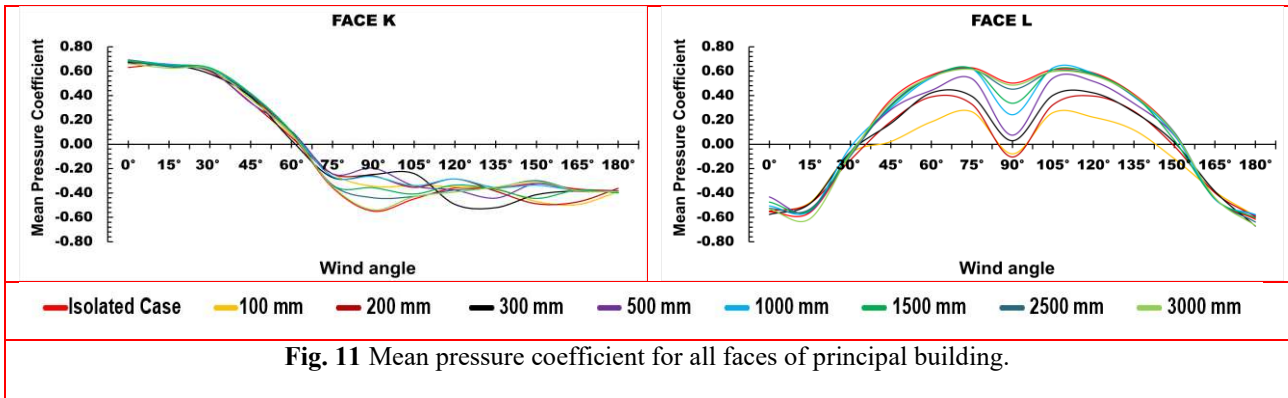
The coefficient of mean pressure (C_p) is calculated by the formula

$$\text{Coefficient of mean pressure } (C_p) = \frac{P}{\frac{1}{2}\rho v^2} \quad (11)$$

Where, ρ is the density of air, v is Streamline line velocity, P is the mean pressure. In this study Air density is taken 1.224 kg/m³. The mean pressure variations for all twelve faces of the primary (main) building with

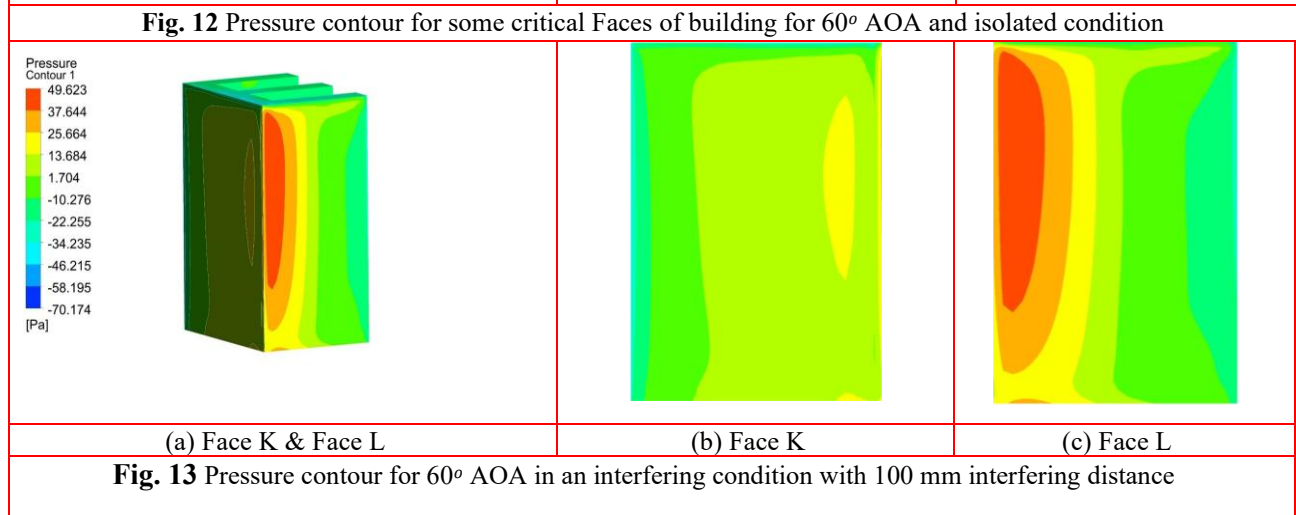
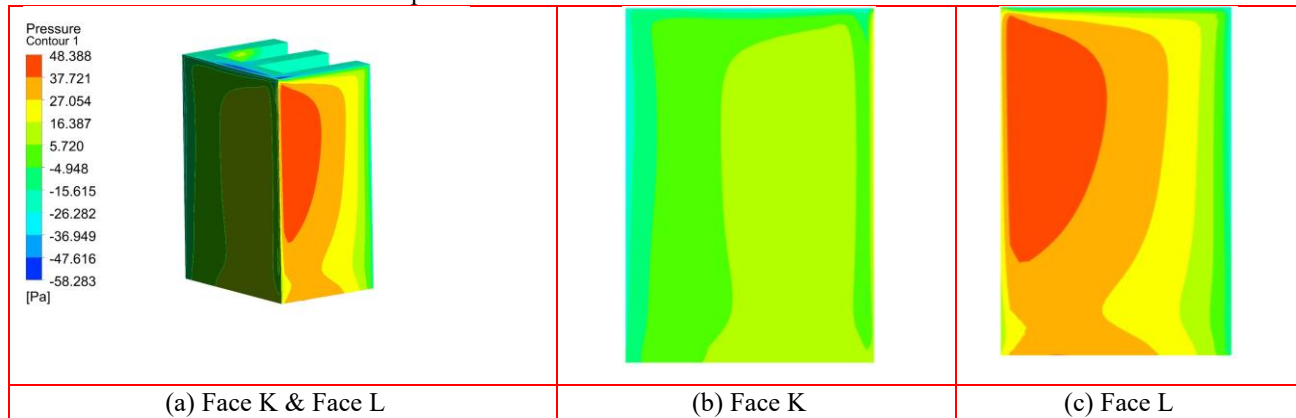
respect to different wind incidence angles for the isolated and different interfering distance cases are shown in the **Fig. 11**; The mean pressure values showed negative values isolated conditions. Still, positive mean pressure coefficient values were observed on Face A in interference conditions at an interfering distance of 100mm, 300mm & 500 mm from principle building for 120° angle of attack. Also, Positive mean pressure coefficient observed on Face B, C, D, E & G for 120°, 135°, 150°, 165° & 180° in an both in isolated condition and interfering condition cases.





Positive mean pressure coefficient observed on Face A, F & H for 135°, 150°, 165° & 180° in isolated condition as well as interfering condition Cases. In isolated conditions, mean pressure values showed positive values but negative mean pressure coefficient values were observed on Face H for 120° and Face I for 150° in interference conditions at an interfering distance of 200 mm only. Negative values (mean pressure coefficient) observed on Face J for any angle of attack both in isolated condition and interfering condition cases. Mean pressure coefficient values showed positive for 0° to 60° angle of attack. Still, negative mean pressure coefficient values were observed on Face K for 75° to 180° angle of attack in interference conditions as well as isolated conditions. Similarly, Some critical observations on Face L for the coefficient of mean pressure variation

values showed positive values in isolated conditions; however, in interference condition cases, the values were negative at interference distances of 100 and 200 mm. Pressure changes can also be visualized using contour maps, as shown in **Fig. 12** Pressure contour for some critical Faces of building for 60° AOA and isolated condition (Isolated conditions) and **Fig. 13** (Interference conditions with interfering distances of 100 mm), provided below. The face on the principal building experiences more pressure at a 60-degree angle of attack in interference conditions than in isolated conditions. Pressure increases to 1.235 Pa under interfering conditions.



6.7 Force coefficient variation

It is noted that the obstruction of the interfering building reduces the force coefficient of the primary building to its minimum (**Fig. 14** Comparison of force coefficients between different distances of interfering buildings) for 90° AOA at interfering distances of 200 mm. Still, at distances of 3000 mm, the value of the force coefficient is almost the same as in isolated conditions. Since, the interference factor is about 1 at interfering

distances 3000 mm (i.e., 12b) from the principal building as shown in **Table 3**, and It indicates that it does not affect the primary building due to the interfering building.

Interference Factor (I. F) =

$$\frac{\text{The enhanced Force in the Interference conditions}}{\text{The corresponding Force in isolated conditions}}$$

Table 3 Interference factors (I.F.) for different AOA

WIND ANGLE	Interference Factor (I.F.)							
	100 mm I.D.	200 mm I.D.	300 mm I.D.	500 mm I.D.	1000 mm I.D.	1500 mm I.D.	2500 mm I.D.	3000 mm I.D.
0°	1.02	1.03	1.08	1.06	1.08	1.02	1.04	1.05
30°	1.00	1.16	1.12	1.03	0.97	1.02	1.07	1.00
60°	0.78	0.86	1.02	1.05	0.93	0.98	0.98	0.99
90°	0.17	0.14	0.35	0.36	0.58	0.72	0.91	0.99
120°	0.72	0.95	1.03	1.02	0.97	1.02	1.03	1.03
150°	1.10	1.20	1.08	1.01	1.00	1.09	0.96	1.01
180°	1.12	1.08	1.10	1.10	1.10	1.11	1.09	1.09

*I.D.: Interference Distance; AOA: Angle of attack

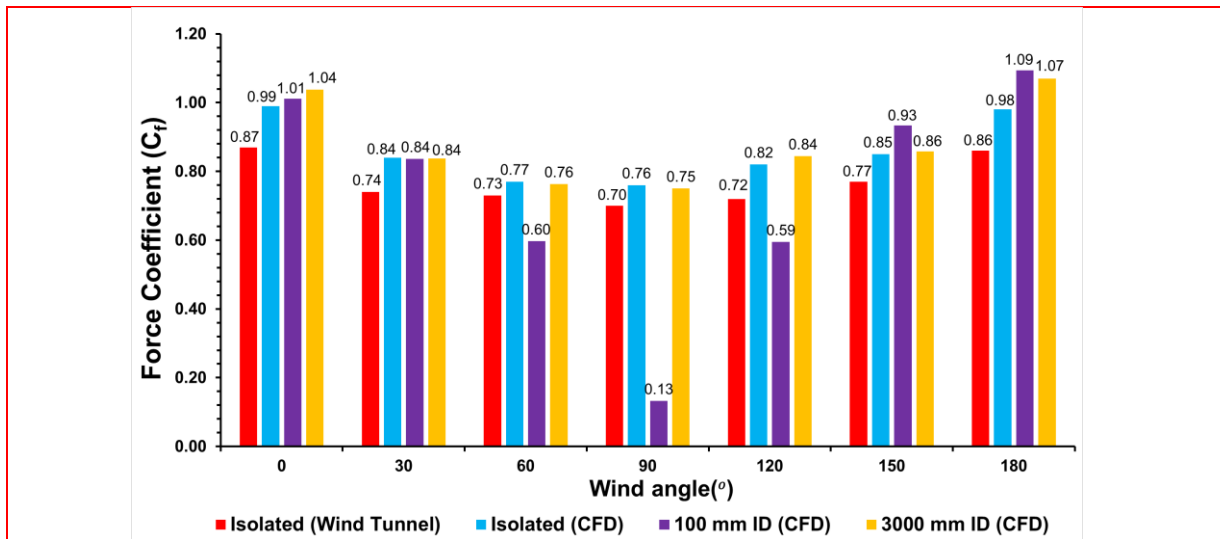


Fig. 14 Comparison of force coefficients between different distances of interfering buildings

7. Conclusions

This study focuses on an 'E' plan-shaped tall building to calculate the Force Coefficient and Moment Coefficient numerically and experimentally due to wind excitation. This study further investigates the variation of Pressure, Force, streamline velocity, pressure contour and interference factor of the principal (E-plan-shaped tall building) building through numerically simulations in the presence of two square-shaped tall interfering buildings (i.e., 100 mm × 100 mm). From this study, some critical observations are

- The above table shows that Grids-6 & 7 have almost the same CP means at Different Faces, since Grid-6 has been taken for the CFD analysis.

- The Validation is done numerically by Computational fluid dynamics (CFD) using the kinetic-eddy model in isolated conditions to determine the Mean pressure coefficient, and it is compared with experimental data by Bhattacharyya and Dalui (2018) for 0° and 90° wind angles. There is an error of less than 15 % in all twelve faces of the principal tall building. Additionally, the velocity profile graph will be validated using wind tunnel test experimental results, as reported by Bhattacharyya and Dalui (2018), and with numerically derived power Law results. This demonstrates determinate the accuracy of wind-structure interaction responses of the structures.
- In an experimental study (wind tunnel test), the

results showed that the maximum force coefficient (0.87 experimentally and 0.99 numerically) and moment coefficient (0.90 experimentally and 0.83 numerically) at a 0° angle of attack were experimentally and numerically determined for E-plan shapes tall building.

- Similarly, in an experimental study (wind tunnel test), the minimum force coefficient (0.70 experimentally and 0.76 numerically) and moment coefficient (0.69 experimentally and 0.61 numerically) at 90° angle of attack were experimentally as well as numerically determined in a symmetrical E-plan-shaped tall building. The accuracy of the numerical analysis results is compared with experimental results, and it seems to agree strongly with the experimental wind tunnel test results.
- From numerical study (Interference conditions), The analysis considers wind angles ranging from 0° to 180° at an interval of 15°. The maximum positive value (2.72) of the interference factor (I.F.) for a 30° degree angle of attack on Face J of the principal building at an interfering distances 300 mm from edge of principle building and the negative value (-1.23) of the interference factor (I.F.) for a 150° degree angle of attack on Face L of the principal building at an interfering distances 100 mm from edge of principle building.
- The interference factor (pressure) is about 1 at interfering distances 3000 mm (i.e., 12b) from the main building and it indicates that the interfering building does not affect the principal building. Also observed that negative values (I.F.) are displayed on the Face E & Face H for a 120° angle of attack at an interfering distance of 200mm from the principal building.
- Similarly, negative values are shown on Face I at a distance of 200 mm from the primary building for a 150° angle of attack. Also found negative values (I.F.) on Face A for 120° angle of attack at an interfering distances 100mm, 300mm & 500 mm, it's indicates that suction occurs on the particular faces of interference distances due to the interfering building.
- Faces B, Face C, Face D, Face F, Face G, Face J & Face K showed positive interfering values, meaning no suction occurs due to interfering buildings on the particular faces for wind angles ranging from 0° to 180° at an interval of 15° at any interfering distances.
- Also, observed from flow streamlines, due to channeling effects, is an increase in streamline velocity of 0.319 m/s for a 0° angle of attack. Similarly, due to the blockage of an interfering building, a decrease of 0.025 m/s in the streamline velocity occurred at a 90° angle of attack. Also observed from Fig. 10, the channeling effects decrease with increasing distances between interfering buildings and the principal building.
- In isolated conditions, mean pressure values

showed negative values. Still, positive mean pressure coefficient values were observed on Face A in interference conditions at an interfering distance of 100mm, 300mm & 500 mm from principle building for 120° angle of attack. In isolated conditions, mean pressure values showed positive values but negative mean pressure coefficient values were observed on Face H for 120° and Face I for 150° in interference conditions at an interfering distance of 200 mm only.

- Similarly, some critical observations on Face L for the coefficient of mean pressure variation values showed positive values in isolated conditions; however, in interference condition cases, the values were negative at interference distances of 100 and 200 mm.
- It is observed that as a result of the blockage of the interfering building, the force coefficient of the principal building is minimum (0.13) for 90° AOA at interfering distances of 100 mm. Still, at distances of 3000 mm, the value of the force coefficient is almost the same as in isolated conditions.
- The interference factor (force) is near about 1 at interfering distances 3000 mm (i.e., 12b) from the principal building, and it indicates that the interfering building does not affect the principal building.

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