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Research Article

Numerical Investigation of the Variations in Velocity and Pressure due to Various Building Design with Pedestrian Wind

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Abstract:
The numerical investigation of the effect of the shape of a high-rise building on pedestrian winds has been done. The study investigates the influence of building shapes on pedestrian-level wind comfort using an Ansys workbench and a virtual fluid domain of 600m×480m×800m. Square, rectangular, circular, hexagonal, and octagonal-shaped buildings have dimensions of (40m×40m×60m), (50m×40m×60m), (40m×60m) (D×H), (20m each side), and (15m each side), respectively. The variations in the shape of different buildings have a constant channel width of 12m. The results were compared to CFD models for the exact different house module using different velocities of wind with Large eddy simulation (LES) model. The study found that increasing the sides of buildings shows favourable pedestrian wind level characteristics. Circular shape offers a comfortable pedestrian level with their small channel space and low separation zone, setting them apart from other shapes like square, rectangular, hexagonal, and octagonal buildings. As a result of having the same width, square-shaped buildings have comparable pedestrian wind velocity in case -1 (C5 – C6 = 12 meters). This is because of the venturi effect, which causes wind speeds to be at their lowest at high space locations. The width of high-rise structures increases. There are a number of factors that influence wind levels in various forms, including wind direction, turbulence, and channel flow. While square and rectangular structures have a significant wind separation, circular buildings provide better walking conditions than their square and rectangular counterparts.

Keywords: *Different shaped buildings, Channel width, Pressure, Air velocity, CFD*

1. Introduction

Buildings have a big effect on things like wind speed and direction, air pollution, ventilation, radiation, and sunshine. High-rise buildings can change the wind speeds and surroundings around them. For example, higher wind speeds can make walking uncomfortable and even dangerous. In many population cities, walking has become the preferred means of transportation. According to information on transportation distribution in Indian cities, it makes up anywhere from 25 to 35 percent of all journeys. All social groups can travel affordably to work, school, recreation, and other daily activities by walking or cycling. According to the Global Status Report on Road Safety 2023, 1.19 million people die in traffic accidents each year.

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The study demonstrates that initiatives to raise road safety are having an effect and that, with the right policies in place, road traffic fatalities may be significantly decreased. Specifically, the propagation of smoke in the RF, which is mathematical calculations, are capable of being performed. The fast development of computational fluid dynamics (CFD) during the past 20 years allowed for substantial advancements in the numerical modelling of wind technology by Haghighat et al. [1]. Cassidy [2], a building standard called Passivhaus was initially created for dwellings. Since then, it has spread over the world and been altered to fit different sorts of buildings, such as offices and schools.

The key characteristics of Passivhaus buildings are their low energy use, especially for heating and cooling, and their focus on occupant comfort and indoor air quality. Lee et al. [3], Computational fluid dynamics (CFD) is used in a variety of building environmental studies. The goal region of the CFD model has been separated into a limited amount of grids in order to facilitate computation. A case study was performed to assess the effectiveness of the suggested approach. The ideal grid resolution rose as the characteristic length did. Singh and Roy [4], the roof form and roof slope both serve as limits for the structural safety to withstand wind load. Through CFD simulation, the current work shows how the wind load affects the pressure distribution on the pyramidal roofs of a low-rise, one-story building with pentagonal and hexagonal plans. Ten alternative building models are created for the current study (five with pentagonal plans and five with hexagonal plans), with roof angles of 20, 25, 30, 35, and 40°. All of the models are simulated for wind directions ranging from 0° to 45° at 15° intervals. In the current work, the pressure coefficient contours for various wind directions and various roof slopes are plotted.

Lu et al. [5] according to an up-to-date investigation on the wind's motion pattern against a high-rise structure, the existence of a defined RF has no impact on the wind field surrounding the structure. Mintz et al. [6], traditional rooftops are severely harmed by high wind-induced suctions, which results in rain infiltration and the loss of internal contents. Harm can include, among several others, the breakdown of tiling or roofs. Singh and Roy [7], through a computational fluid dynamics (CFD) model, the current work illustrates the pressure fluctuation brought on by wind loads on a two-story structure having a plan that is square and an inclined roof. To investigate whether the wind affects the structure, measurements of pressure coefficients have been given for five distinct wind introduction directions. The findings show that as roof gradient increases, so do the maximum positive as well as maximal negatives wind velocity coefficients. Singh and Roy [8], for a building to be safe, its roof design & slope have to be considered, particularly if it is exposed to wind pressures. Whenever the wind stress the coefficients compared to buildings alongside gaps and those with no openings were contrasted, it was discovered that the stress the coefficients for buildings lacking passageways are nearly twice as great as those for buildings with openings, if not nearly three times as high. Andersson et al. [9], an investigation of the exact position of a fishway's opening in a controlled stream using CFD and ADCP, the mathematical models included a fishway entry, & afterwards, attracting water has been evaluated across two approach sites & four approach orientations at various turbine outputs. Marjavaara and Lundström [10], the simulations take place at full size, resulting in a virtual model that is 320 meters long, typically 75 meters wide, typically 10 meters deep, and has a main entrance that can carry a maximum of 1000 m3/s. Fulfilling requirements for a suitable mesh overall and an adequately defined flow structure at sites with significant gradients presents numerical difficulty when working at a big scale. Rivinoja et al. [11], the primary cause for such has to do with the Stornorrfors power station, which stands downstream of the confluence of the regulated rivers Ume and Vindelalven. A significant problem with the generation station occurs when fish migrate up along the old stream mattress, which provides a fishway surrounding the generators, rather than being drawn down the tailrace stream that surrounds the rotors. Arnekleiv and Kraabøl [12], the path that leads into the point of convergence was extremely broad, and the flow rate generated by the generators can frequently be 20 times greater than the discharge velocity through the previous river bed. As a result, there aren't sufficient flow circumstances for the old bottom of the river to draw fish. It has become a regular issue that migratory fish are drawn into the generator tailrace rather than the less strong stream within the fishway.

Huang et al. [13] study regarding the Wind Conditions to Enhance Warm Quality in a Qilou Street's Colonnade Area Using the Comparative Temperature Measure as a basis It turned out that with these methods, the wind-driven conditions of a qilou could be optimised, as the average RWI value dropped by 0.06, voluntarily improving the perimeter of the space's thermal insulation. The results of the study can be used to create a transitional room that is pleasantly warm. Jin et al. [14], the Impact of Housing Zone Building Design upon Outside Air Environment on the Pedestrian Height in China's Extreme Cold Regions, the findings demonstrate that the standard deviation of the wind speed ratio has no significant effect by the relative location of high-rise buildings within multi-high-level diverse housing neighbourhoods, with an absolute variation of 0.04. Khan and Roy [15], it considers when average wind speed and dispersion factors change with altitude above the surface of the earth. Viscardi et al. [16], to reduce the impact of the tidal change in their instance, the velocities were averaged over 2 seconds in each vertical sample, and the velocities correspond to quite accurate values. The primary factors affecting the building's thermal performance are the construction materials and layout, wind direction and speed, location, sun availability, thermal mass, and orientation. Al-Addous and Albatayneh [17] noted that their electiveness has been mostly constrained so far. Prior to building, it is crucial to take into account all the physical, environmental, and social factors. This will enable better energy demand forecasting and result in lower overall operational expenses over the course of the building's life. Yu et al. [18] observed the performance of wind speed at different on high rising building. In this model wind tunnel observation is used and after that it is validated with computational fluid dynamics software. Du et al. [19] observed the comfortable location for pedestrian level. CFD analysis is performed with turbulent model tool for lifting air. It is a study based paper. Kubilay et al. [20] worked on pollutant based study with variations of velocity in fluid as air. The paper contains removable process of pollutant index factor with a linear distribution of pollutant in different places. An analysis took place to determine how the modified corner affects wind conditions. The impact of the ground and temperatures in the air, however, has not been taken under account. A high building's dynamical wind-induced stress assessment has been mimicked and examined [21], but the impact on neighboring minor structures hadn't been taken into account. Numerical modeling has been employed to study metropolitan areas, and improvements to the pedestrians [22] wind condition had been suggested [23]. However, this investigation did not take into account the impact that natural convection. The high-velocity wind-induced gradient in temperature could have an impact on the investigations. The temperature-induced by pedestrians wind was not taken into consideration when reviewing evaluates taken to enhance pedestrian’s thermal well-being, such as shading (through trees as well as buildings [24]), avenue introductions, as well as illustrating substance utilized by buildings. Van Druenen et al. [25] conducted a parametric study using computational fluid dynamics to examine the impact of building geometry modifications on lateral wind speed (PLW) around a high-rise building. The study found that the canopy and podium solutions have a larger effect on PLW speed than the introduction of a permeable floor. Tamura et al. [26] worked on wind-tunnel tests revealed that the Venturi effect and downwash effect contribute to the maximum speed-up ratio R_{max}. Downwash effects are significant, while Venturi effects don't. Two types of downwash effects were found: Type 1 and Type 2. For Case I building models, the maximum speed-up ratio R_{max} increases with building height H, increases with building height H. For Case II, building width decreases, strengthening blocking effects and enhancing both downwash and Venturi effects. Huang et al. [27] studied on wind-tunnel tests found that high-rise buildings during urban renewal decrease pedestrian wind environments in street canyons. The densely distributed traditional apartment buildings had low-speed flow fields, indicating poor urban ventilation quality. The study by Lee and Mak [28] investigates the impact of wind angles on wind velocity and pollutant distribution in two building arrays arranged in 'L' and 'U' shapes. Zou et al. [29] examined the relationship between convective heat loss and wind turbulence in urban green spaces. They measured wind speed and turbulence characteristics at pedestrian heights, finding an average turbulence intensity of 22-48%. Zhong et al. [30] study on pedestrian-level wind simulations over the past five years found that SRANS is the most dominant approach, with 62.3% of 215 CFD studies using it. High-efficiency approaches like hybrid LES-RANS, mass. Hågbo and Giljarhus [31] explores the impact of simulated wind directions on pedestrian wind comfort maps in Niigata, Japan.

The research analysis highlights how various building designs, tall buildings, pedestrian interactions around buildings, wind influences from the environment, and building anchoring all greatly increase the effectiveness of building variants. However, it should be emphasized that this improvement often leads to a significantly greater drop in pressure. Motivated by these results, the present work proposes a unique building geometry with distinct terms of shape that takes pedestrian wind into account, all with the aim of minimizing pressure loss and optimizing thermal efficiency overall. In this exclusive arrangement of the research, the thermal pedestrian simulation is investigated around five distinct building shapes: square, rectangular, circular, hexagonal, and octagonal. In this illustration, the proportions of these designs appear, using a channel spacing that remains constant at 12 meters. During the simulation, wind speeds of 3.5 meters per second are varied, and it makes sure that there has been no interaction with any structures that are already present inside the area. The introduction section, the study is concluding all the literature and also deciding the benchmark for valuable study as well summarizing the simulation setup.

2. Methodology Setup

Since we are interested in the effect of pedestrian level wind on pressure rise nearby structures, a simplified geometry replicating a real-world field scenario was modeled. In order to develop a structure in which the local wind is represented using the least amount of information and complication achievable, a reduced-order wind and airflow model was used in this study. The numerical study is done with the help of Ansys workbench; a virtual fluid domain of 600 m × 480 m × 800 m is taken as shown in Fig. 1. These measurements are constructed since they don't interfere with any of the buildings that were designed inside the domain. The five different types of building shapes are symbolically represented by the subscript letters s, r, c, hex, and oct, which stand for square, rectangular, circular, hexagonal, and octagonal shapes, respectively in Fig. 2 (i, ii, iii, iv, and v) whose dimensions are illustrated in Table 1.

The constant in channel gap are taken as 12 m. with the variations of dimensions of building shapes as Square, rectangular, circular, hexagonal, and octagonal shaped building of are taken (40 m × 40 m × 60 m), (50 m × 40 m × 60 m), (40 m × 60 m) (D x H), (20 m each side), and (15 m each side) respectively where D-diameter and H – height of circular building. The simulation of thermal pedestrian around the five different shapes of building is analysis with using of the different speed of wind of ranges of 3.5 m/s.

Table 1: Parameters are used in Domain

S.NO.	Different shapes of building Parameters	Dimensions
1	Computational Domain	600 m × 480 m × 800m
2	Tall Buildings	
	a) Square shaped(T_s)	40 m × 40 m × 60 m
	b) Rectangular shaped (T_r)	50 m × 40 m × 60 m
	c) Circular shaped (T_c)	40 m × 60 m (D x H)
	d) Hexagon shaped (T_{hex})	20 m each side
	e) Octagon shaped (T_{oct})	15 m each side
3	**Small Buildings**	
	a) Square shaped (S_s)	6 m × 6 m × 8 m
	b) Rectangular shaped (S_r)	8 m × 6 m × 8 m
	c) Circular shaped (S_c)	8 m × 6 m (D x H)
	d) Hexagon shaped (S_{hex})	3 m each side
	e) Octagon shaped (S_{oct}	2 m each side
4	**Fixed Square shaped buildings (Third)**	**20 m × 20 m × 40m**
	a) Channel (C1– C2) Gaps between high rise and tall buildings fixed	8 m
	b) Channel (C3 – C4) fixed gap between third square buildings	12 m
	c) Channel (C5 – C6) width of proper highway	12 m
	d) Inlet wind velocity	3.5 m/s
	e) Ambient Temperature (Ta)	303.2 K

2.1 Boundary and Wall Conditions

Although using double precision will increase accuracy, the solution will take longer than with a single-precision model. The gravity is set to -9.81ms^{-2} (Negative-Z direction) as it is a natural convection scenario, and the solver type is Pressure-Based with absolute velocity formulation in a steady-state condition. The k-SST turbulence model is used to parameterize the energy equations and turbulence. We used the air's density of 1.225 kg/m^3 and thermal expansion coefficient of 0.00367 K^{-1} as the fluid's physical characteristics. According to field data, the inlet us reference input velocity is 3.5 ms-1, and the outside temperature is 300ºK. The temperature of the ground is 303ºK, which is the ideal temperature to evaluate the impact of convection on temperature change caused by wind at street level. The ground surface and the domain sides have a no-slip boundary wall condition, and the outlet boundary is configured to outflow. The numerical modeling was carried out in Fluent with residuals set to 10^{-6}.

The following presumptions are illustrated:
1. A fluctuating wind flow
2. An incompressible fluid
3. A fully completed design model flow
4. Variable fluid parameters include temperature [23] and pressure
5. K-Epsilon modeling analysis results [4]
6. The large-eddy simulation technique

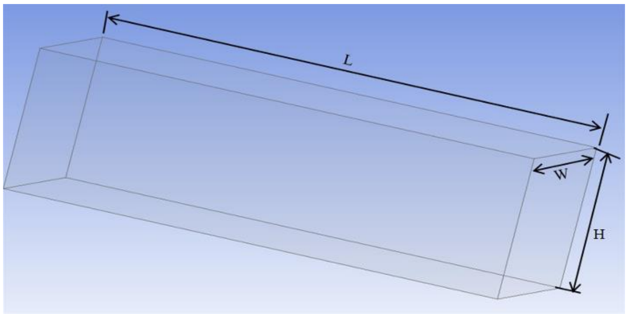
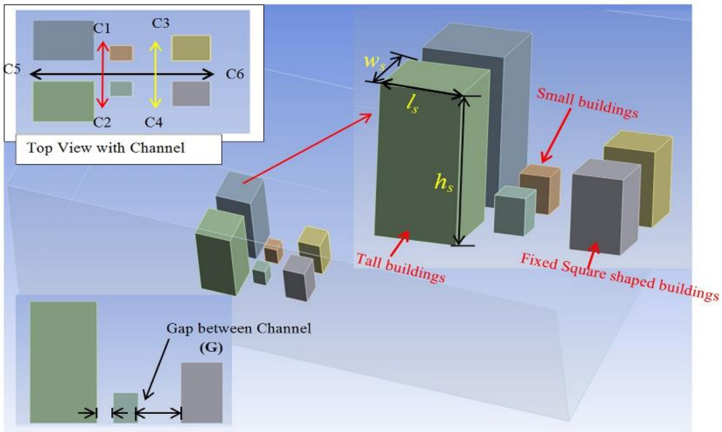
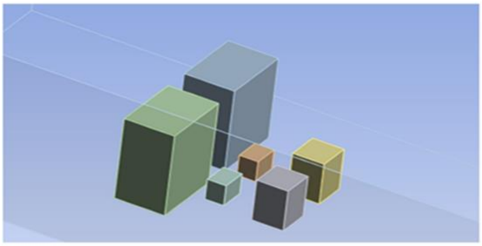


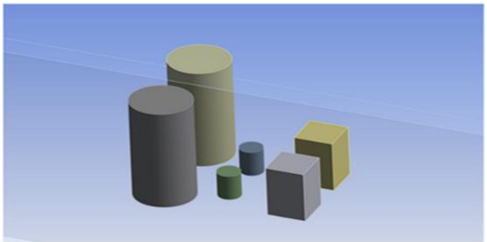
Fig. 1. Geometry of virtual domain.



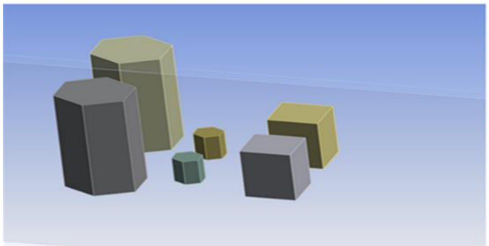
(i) Square shaped buildings



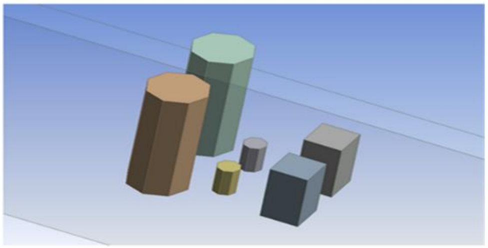
(ii) Rectangular shaped building



(iii) Circular shaped building



(iv) Hexagonal shaped building



(v) Octagonal shaped building

Fig. 2. Structure of different-shaped buildings with varying of geometrics (i, ii, iii, iv and v).

2.2 Meshing of the Domain

A continuous representation that represents the domain represents a mesh. It would be difficult to meet all of these demands simultaneously, thus compromises are required. Mesh creation is used to provide automation, validity, correctness, higher-quality output, and good efficiency. It is also used to produce graded meshes of excellent quality and flexible mesh density control. Tetrahedron meshing, which is the most regular meshing format, and 3-D homogeneous meshing was used for the design. As illustrated in Fig. 3, the center of the spanning angle has a fine, smooth change, is virtual topological, and has an element size of 0.005 m. The design model's finer meshing isolates from time-consuming issues.

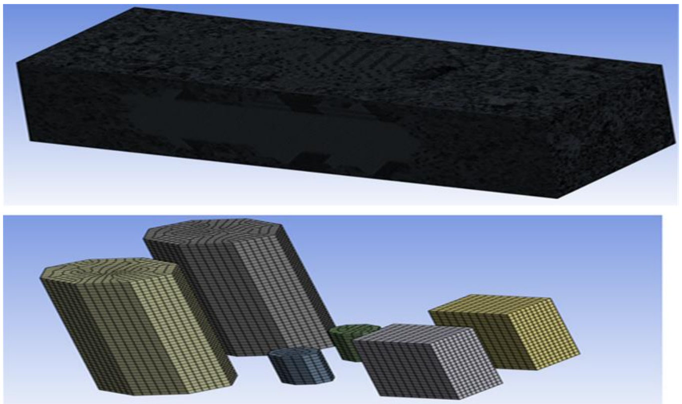


Fig. 3. Meshing of the Domain.

3. Data Processing

3.1 Turbulence Simulation

The "k-ω SST" was a combination model that transforms the k-epsilon version towards the k – w (k-omega) model within the area close over the wall with the k-epsilon version in the totally turbulence sector far from the wall [9]. The equations governing the dynamics of the field of motion, consisting of the consistency, momentum, and transportation equations of k and, can be written as follows:

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_i)}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial(\rho u_i)}{\partial t} + \frac{\partial(\rho u_i u_j)}{\partial x_i} = -\frac{\partial(p)}{\partial x_i} + \frac{\partial\left(\Gamma_U \frac{\partial u_i}{\partial x_j}\right)}{\partial x_j} + S_U \tag{2}$$

$$\frac{\partial(\rho\omega)}{\partial t} + \frac{\partial(\rho u_j \omega)}{\partial x_j} = \frac{\partial\left(\Gamma_\omega \frac{\partial k}{\partial x_j}\right)}{\partial x_j} + G_\omega - Y_\omega + D_\omega + S_\omega \tag{3}$$

where

$$\Gamma_U = \mu + \mu_t, \Gamma_k = \mu + \frac{\mu_k}{\sigma_k}, \Gamma_\omega = \mu + \frac{\mu_\omega}{\sigma_\omega}, \mu_t = \frac{\sigma_k}{\omega} \frac{1}{Max\left[\frac{1\, SF_2}{\alpha^*, \alpha_1 \omega}\right]}$$

The numbers ρ and p show the average density and pressure of the fluid, and the numbers Γ_U, Γ_k, and Γ_ω show the effective diffusivities of the mean fluid speed U (V or W), 'k' the turbulent kinetic energy, and 'ω' the specific dissipation rate. The parameters as σ_k and σ_ω are the turbulent Prandtl values for k and ω, and μ_t indicates turbulent viscosity. The blending function (F_2), model coefficients (α * and α_1), and mean rate-of-strain tensor modulus (S) are defined.

$$\rho\left(\frac{\partial u}{\partial t} + u \cdot \nabla u\right) = -\nabla p + \nabla.\left(\mu(\nabla u + (\nabla u)^T) - \frac{2}{3} u(\nabla \cdot u) I\right) + \rho g \tag{4}$$

The Navier-Stokes equations (4) don't need to be solved in their fully compressible version in order to approximate non-isothermal flow. The approximation is correct when density variations are small because the nonlinearity of the problem is minimized. Where 'u' stands for the fluid's speed. The identity matrix, g, and the sign stand for the identity matrix, the fluid dynamic viscosity, and the fluid dynamic viscosity, respectively. The Boussinesq approximation states that the buoyancy factor (g) is the only part of the equation where differences in density are meaningful.

4. Results and Discussion

4.1 Validation between the Results of CFD Analysis

In this study, a calculation for fully generated flow is made at increasing building heights using various designs meshing with the same design building characteristics. Fig. 4 shows that the velocity rate increases as the height with respect to the grid increases. The validation (Mirzaei and Haghighat [32]) range for wind speed values is from 1% to 3%. Ansys fluent is used to explore and validate each outcome. In Fig. 5, we employed the identical domain parameters and boundary conditions for the K-e RNG, K-w, and LES models to validate our findings. We have plotted the velocity profile and temperature distances within the structure as well as close to the channel from a distance of X (5 to 85 m). According to the figure, velocity increased as a building's height grew as a result of venturi effects in the Channel LES, K-w, and K-e RNG are close to one another with an error of 2-3%, which will be useful in future analyses. The study is validated by [32].

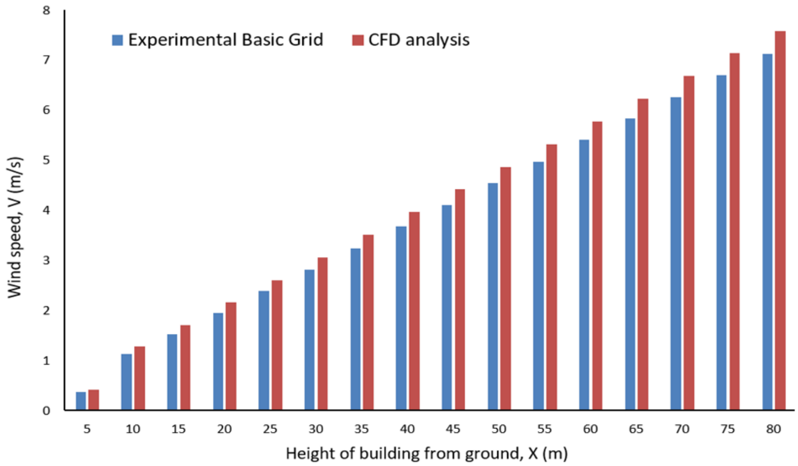


Fig. 4. Comparison of the fine grid between CFD study and Experimental Basic study of wind condition at pedestrian level.

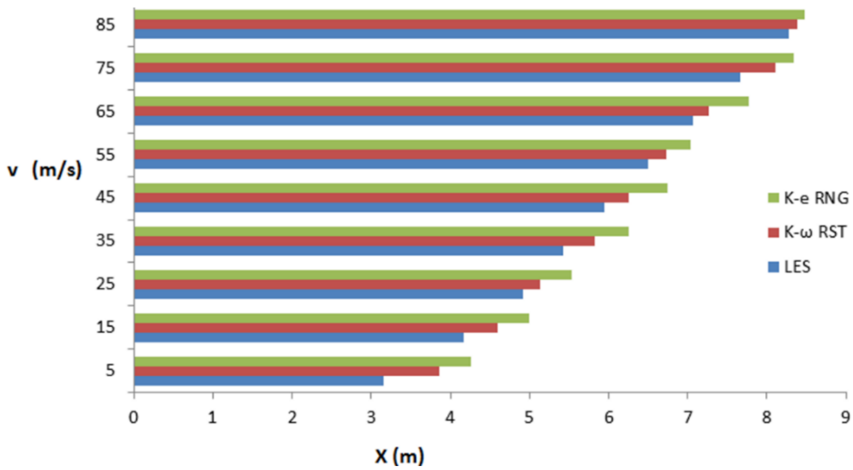


Fig. 5. Comaprison of turbulent model as building's height (m) with respect to velocity (m/s).

4.2 Effect of Shape Change on Pedestrian Wind

In the study, the effects of different shape of buildings on pedestrian level wind comforts are illustrated in case -1 (C5 – C6 = 12 m). The movement of air inside a channel or conduit is referred to as channel flow C1, C2, C3, C4, C5 and C6. The comfort and safety of pedestrians in urban contexts may be impacted by channel flow, which can have a considerable impact on pedestrian-level wind conditions. The figures present the velocity contour justifies the pressure contour for different shaped buildings (first two buildings and third building will be fixed for all cases). These measurements were made 1.4 m above the ground. As can be shown, the venturi effect causes the pedestrian wind velocity to reach its maximum value in the zone C5 - C6 between the high-rise buildings in case-1.

4.2.1 Case – 1: Effect of Channel C5 – C6 = 12 m on Different Shapes of Buildings

In channel C5 – C6, observed maximum speed of wind along the maximum length of channel C5 – C6. The reason behind this increase wind velocity can be explained through venturi effect. Wind can speed up as it moves through small openings or in between structures due to channel flow. The movement of air inside a channel or conduit is referred to as channel flow C1, C2, C3, C4, C5 and C6. The venturi effect is a name for this accelerating force. Wind can be channeled via small spaces between buildings in streets, increasing wind speed near pedestrians level. In Channel C1 – C2, there is no recirculation zone between high rising building and small building and as result no ventilation between these building. This type of problem of channel C1 – C2 faces because of low bluff and early separation of wind. In channel C3 – C4 observed recirculation zone of wind due to large space of channel between the buildings as compared to channel C1- C2. Channel C3 – C4 feels better ventilation condition as compared to C1 – C2 as shown in Fig. 6 (a). In Fig. 6 (b), the velocity of pedestrian wind in channel C5 – C6 is nearly same, since the breadth of square and rectangular shape building is same. The change in pedestrian wind velocity is visible when the breadth of high rising building varies. The ventilation has same condition as square shaped building.

In Fig. 6 (c), the velocity of wind breaks after the separation point because the wind does not find proper channel in C5 – C6 in the hexagonal shaped buildings. In Fig. 6 (c), the velocity of wind reduced because of shaped of hexagonal building. The reduced velocity of wind is comfortable for pedestrian wind level on Channel C1 – C2, C3 – C4 and C5 – C6. The hexagonal shape of small building satisfied for developing and built to withstand any environmental pressures that it might encounter, such as wind pressure, vibrations, and any possible impacts from the surrounding high-rise structure. The pedestrian level is comfort for human as compared to Fig. 6 (a and b) at velocity and pressure level. Fig. 6 (d) presents the comfortable zone for pedestrian level as compared to the Square, Rectangular, and Hexagonal shaped buildings. The pedestrian level is comfortable because of shape of octagonal building, channel space C5 – C6 = 12 m and low separation zone as compared to others buildings (Fig 6 (a, b, and c). In Fig. 6 (d), wind Channel length C5 – C6 is small and break in two channel. Fig. 6 (e) (Circular shaped building) observed maximum comfortable pedestrian level as compared to building of square, rectangular, hexagonal, and octagonal shapes.

In Fig. 7, the statement that has been made on velocity contour could be justified by pressure contour. The Fig. 7 explains the maximum pressure where velocity is low as Fig. 6 (a) according to the Bernoulli principle as shown in Fig. 7. In low-pressure areas, winds may be stronger and more erratic for pedestrians, which can be uncomfortable as shown in Fig. 7. In Fig. 7, Pressure is maximum at starting of the rectangular building as compared to square shaped building. The pressure of hexagonal building is maintained with velocity in Fig. 7. In Fig. 7 pressure satisfies the velocity condition of octagonal building.

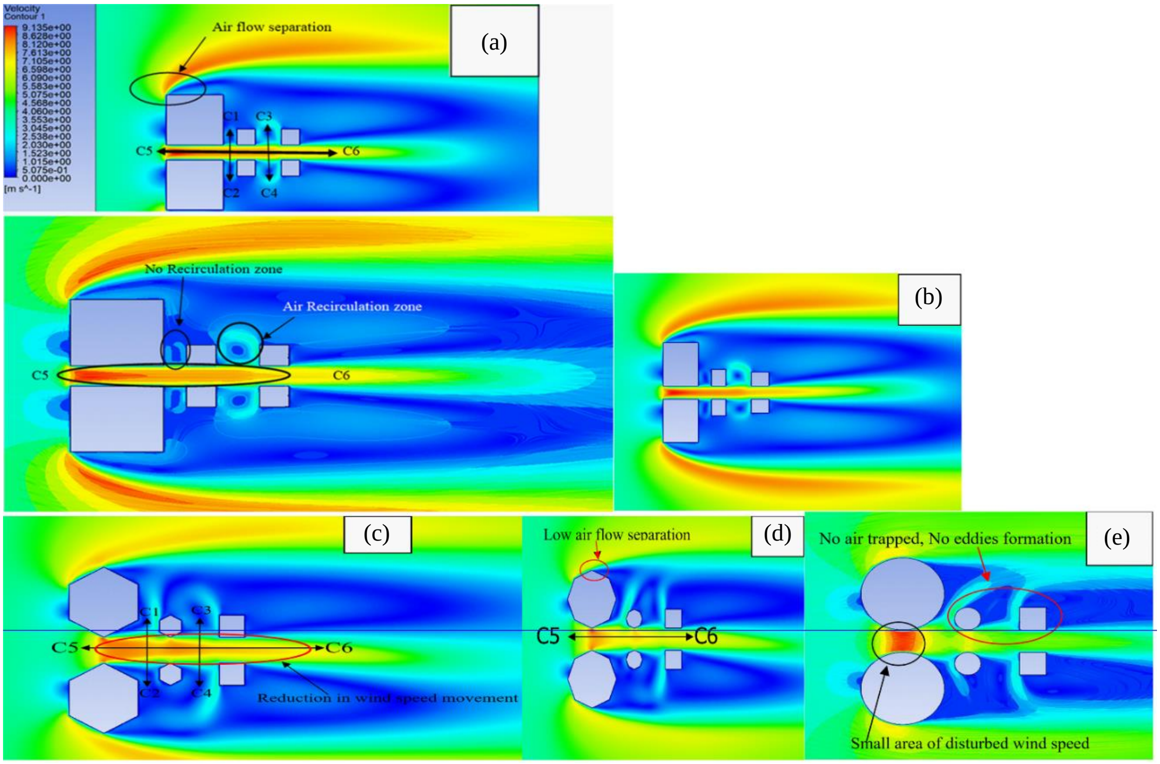


Fig. 6. Presents the justification of comfortable velocity magnitude between (a) Square shaped, (b) Rectangular shaped, (c) Hexagonal shaped, (d) Octagonal shaped and (e) Circle shaped building respectively at C5 – C6 = 12 m.

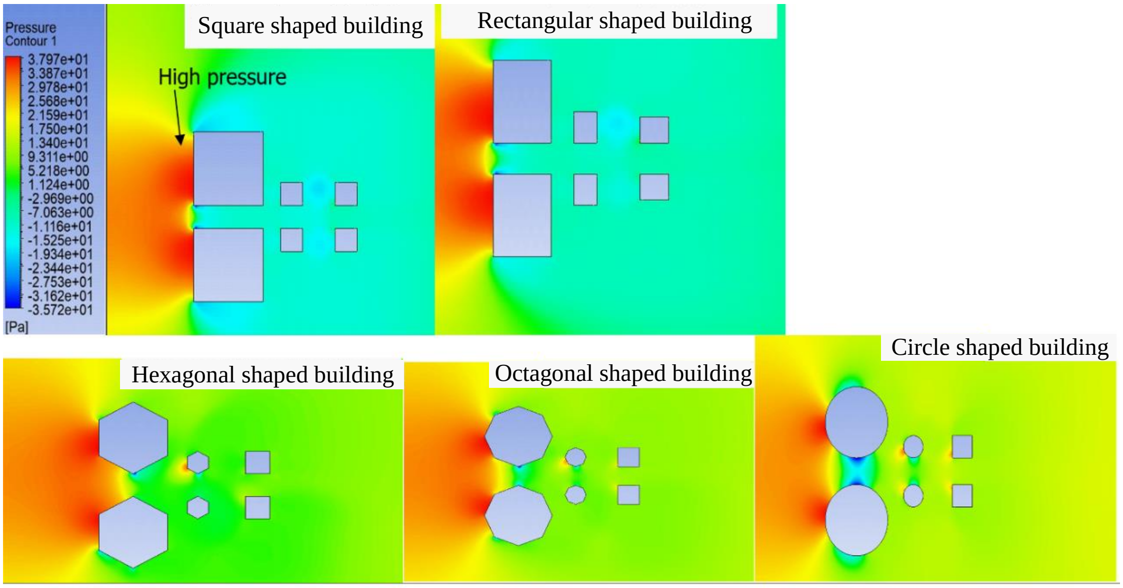


Fig. 7. Pressure contour of different building at C5 – C6 = 12 m.

4.3 Effect of Channel C5 – C6 = 12 m on Different Shapes of Buildings

Wind speeds are frequently minimum in high space locations. In high-channel areas, winds may be lighter and more comfortable for pedestrians due to venture effect. Walking can be easily in strong winds, especially when they are accompanied by wind.

4.3.1 Pressure Effect around the Different Shapes of Buildings

Wind patterns, building designs, and urban layouts significantly influence the pressure effects on pedestrians near structures. Buildings may experience zones with higher and lower air pressure due to wind blowing over and around them. These pressure differences can affect pedestrians, with increased air pressure on the windward side and potential drop on the leeward side. Strong winds caused by pressure differences near buildings can channel or accelerate wind, producing brief bursts of increased wind velocity. This can compromise the comfort and stability of pedestrians, as increased wind forces and turbulence in certain areas can compromise their safety.

4.3.2 Downwash Impact on Buildings

The downward air flow brought on by the interaction of wind with a building or other structure is referred to as the downwash effect, also known as the downwash phenomena. It is especially important near tall buildings because wind flowing over the building causes air to flow downward on the leeward side. Wind flows over and around a tall building when it comes into contact with it.

Areas of higher and lower pressure are produced as a result of the interaction between the wind and the building's surfaces in Fig. 8. There is often a region of higher pressure on the windward side of the building where the wind hits the structure. However, because of the split of the wind flow, the pressure drops on the leeward side as shown in Fig. 8.

From Fig. 8, it is clearly seen in side view; the downward effect is maximum in square and rectangular building while minimum in octagonal and circular building. Due to the high-velocity channel, a low-pressure zone emerges between the high-rise and low-rise buildings. These results confirmed the analysis of velocity contour since these are the areas where the wind is at a stationary state. Pressure differences may be produced on a building's leeward side by separation flows. Increased wind pressures could occur from this, which could harm the building's exterior or lead to structural instability. Additionally, the increased air infiltration and draughts might make residents uncomfortable. Separation flows may interfere with a building's normal ventilation patterns, which could reduce the building's energy efficiency. Buildings depend on optimum airflow for cooling and ventilation, and the natural ventilation process may be hampered when separation flows take place. This could result in a greater reliance on mechanical ventilation and cooling systems, which would raise energy use and operational expenses.

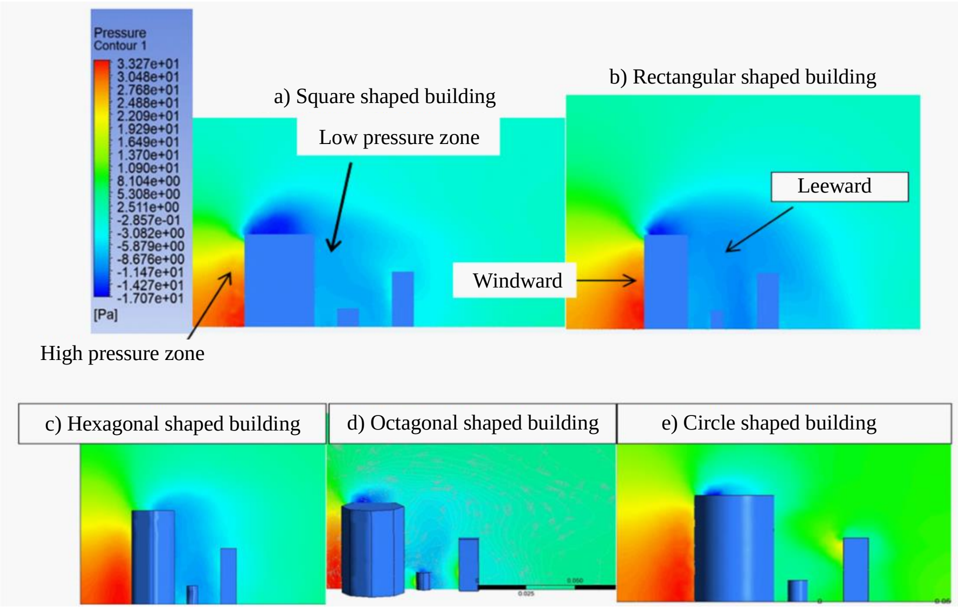


Fig. 8. The downwash impacts on the high-rise and low-rise buildings are described by pressure contours (Side view of (a, b, c, d, and e buildings).

4.4 Effect of Channel C5 – C6 = 12 m on Different Shaped Buildings

The inlet velocity remains constant before pedestrian wind starts (0 – 40 m) and from C5 pedestrian wind level starts as shown in Fig. 9. The pedestrian wind level flows are continuing from points C5 to A and at the point A and B (72 m – 110 m), the pedestrian wind level breaks for a small distance. Form C5 to point A (40 m – 72 m), Winds tend to be stronger and move more quickly for pedestrians than they would in more open spaces Walking can be more difficult in stronger winds, especially when they're combined with additional elements like wind direction and turbulence as shown in Fig. 9.

In Fig. 10, the pedestrian wind level of Rectangular-shaped building conditions is similar as square shaped building. High wind speeds can also make it feel rougher, which can be uncomfortable and pose health risks which has been seen in Fig (9 and 10). At the pedestrian level, narrow street canyons or spaces between buildings can operate as wind channels, increasing wind speeds. Walking may become more challenging and uncomfortable as a result of these faster winds, which may also produce larger gusts.

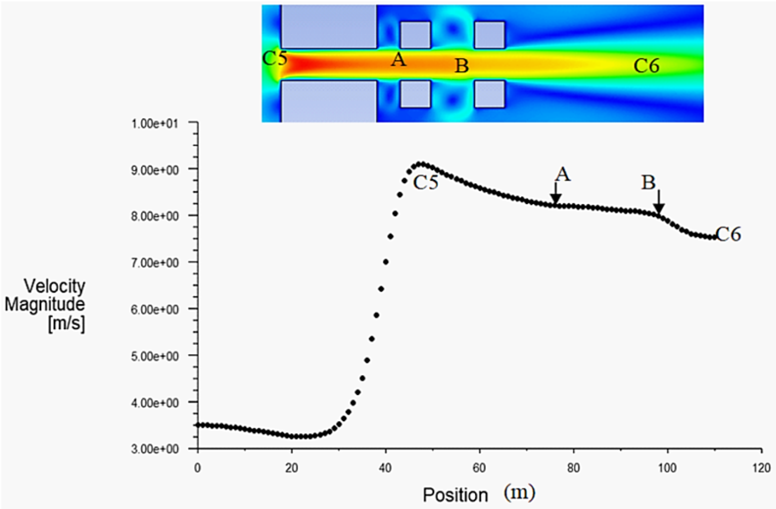


Fig. 9. Velocity variations of wind around the square shaped buildings.

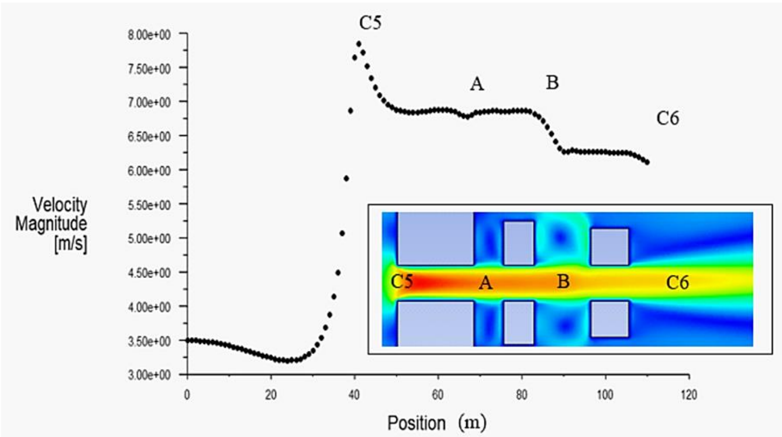


Fig. 10. Velocity variations of wind around the Rectangular shaped buildings.

In Fig. 11, there are two separations at small edge of hexagonal buildings. The pedestrian wind level breaks at points A (55 m) and B (72m). The velocity of wind explores in all directions of channels because of this pedestrian level lies in comfort zone as compared to Square and Rectangular shaped buildings. In Fig. 11, found ventilation comfort zone after 50 m of channel C1 – C2 and C3 – C4. Separation flows may result in an accumulation of dust and debris carried by the wind in the vicinity of a structure. For pedestrians, loose objects like leaves, rubbish, or construction debris can be dangerously lifted and transported by turbulent airflow. If dust and pollutants are stirred up and blown by the wind, it can also result in poor air quality, which can cause respiratory discomfort and health problems.

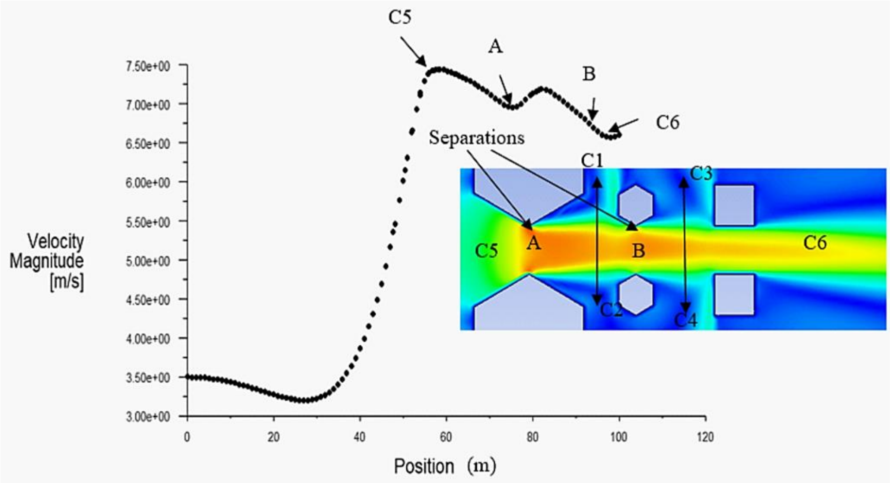


Fig. 11. Velocity variations of wind around the Hexagonal shaped buildings.

Fig. 12, there are two narrow regions at point A and point B where the figure found maximum velocity which disturb the pedestrian wind level and channel flow for Octagonal shaped building. The pedestrian level is comfort more than the conditions of Hexagonal shaped building. Wind can become more turbulent and erratic as it is forced into constricted areas, which can cause abrupt changes in wind direction and velocity. Winds that are gusty and unexpected can make it easy for pedestrians to stay stable and comfortable as compared to square, rectangular, and hexagonal shaped building.

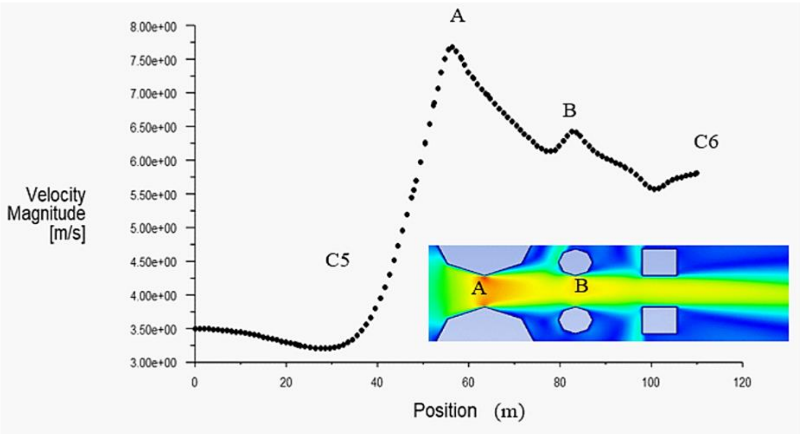


Fig. 12. Velocity variations of wind around the Octagonal shaped buildings.

Fig. 13, shows the comfort of pedestrians as a whole is ultimately influenced by the impacts of channel flow on pedestrian-level wind fluctuations for circular shaped building. For Octagonal and Circular shaped building, Walking will be comfortable in strong winds, turbulence, and sudden gusts, especially if you're an old person, a youngster, or someone who has trouble moving around in channel C5 – C6 = 12 mm.

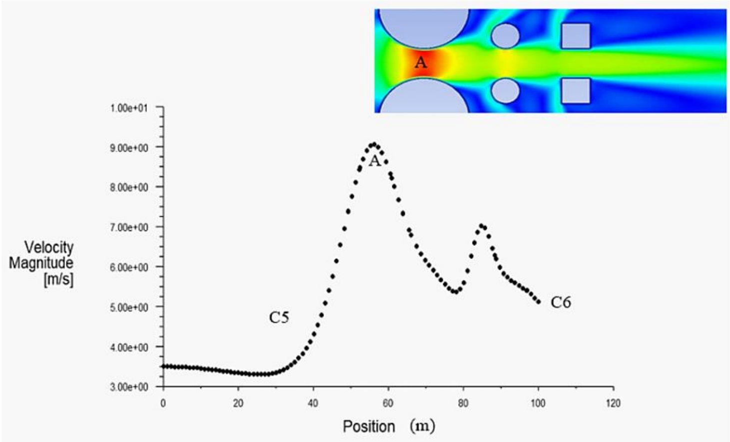


Fig. 13. Velocity variations of wind around the Circular shaped buildings.

5. Conclusion

This study has taken into account the architectural geometry that is promoted by a real-world field setting. Two further instances involving a change in the building's shape (from a square to circular shape building) and the height to width ratio were explored after a standard geometry. In all five instances, higher velocities were seen in the pedestrian channel due to the venturi effect. The octagon and circular - shaped building performed better aerodynamically in comparison. Increasing building sides reduces pressure force and downwash impact. The research investigates the relationship between building shapes and pedestrian wind comfort. It uncovers that the venturi effect, which results in pedestrians traversing high-rise buildings at a quicker rate, has a substantial influence on urban security and safety in the zone C5-C6 between high-rise buildings, is a significant factor in these effects.

- In case -1 (C5 – C6 = 12 m), the velocity contour justifies the pressure contour for square shaped buildings. The velocity of pedestrian wind is nearly the same due to the same breadth of square and rectangular shape buildings. The change in pedestrian wind velocity is visible when the breadth of high-rise buildings varies.
- In case -1 (C5 – C6 = 12 m), wind speeds are often minimum in high space locations. In high-channel areas, winds may be lighter and more comfortable for pedestrians due to the venturi effect.
- The Octagonal shaped building provides a comfortable pedestrian level compared to square, rectangular, and hexagonal shaped buildings. The octagonal building, with its small channel space and low separation zone, provides a comfortable pedestrian level compared to other buildings.
- The pressure effect on pedestrians near buildings is influenced by various factors such as wind patterns, building designs, and urban area layout. Buildings may experience zones with higher and lower air pressure due to wind blowing over and around them. This can lead to increased wind force and turbulence, which could compromise the comfort and stability of pedestrians.
- The downwash effect, or downwash phenomena, is especially important near tall buildings, as wind flowing over the structure causes air to flow downward on the leeward side. The downward effect is maximum in square and rectangular buildings, while minimum in octagonal and circular buildings.
- The pedestrian wind level in different shapes of buildings is affected by various factors, including wind direction, turbulence, and channel flow.
- Square and rectangular buildings have similar pedestrian wind levels, but high wind speeds can make walking rougher and pose health risks.
- Hexagonal buildings have a comfort zone, while circular buildings have more comfortable walking conditions. The comfort of pedestrians is ultimately influenced by the impacts of channel flow on pedestrian-level wind fluctuations.
- Circular shaped building observed good conditions for comforts of pedestrian wind level.
- The square and rectangular shaped buildings have high separation of wind.

In conclusion, increase pedestrian comfort and safety, the study emphasizes the need for enhanced infrastructure, community engagement, education, and enforcement in building design. Alterations in channel geometry have an adverse effect on leeward-facing minor structures.

6. Future Scope

The study investigates different facets of wind-related matters, encompassing dynamic wind impacts, localized microclimate modelling, the improvement of building shape, wind-induced natural ventilation, metrics for pedestrian wind comfort, virtual wind tunnel testing, interactive design tools, simulation of urban wind flow, and building skins that respond to wind.

The objective is to comprehend the impact of wind conditions on pedestrian comfort and safety, create predictive models for localized microclimates, enhance building designs, and advocate for energy-efficient ventilation techniques. The project also aims to establish more precise measures for evaluating wind comfort, include sophisticated turbulence models, and construct interactive tools for real-time exploration of various building designs. The research also examines the possibilities of adaptable building skins or façade features to enhance airflow patterns while preserving architectural beauty and energy efficiency. The research closes by conducting thorough validation and benchmarking procedures to assure the precision and dependability of computational models.

Nomenclature

L	Length of building (m)
H	Height of building (m)
W	Width of building (m)
D	Diameter of Circular Building
CFD	Computational fluid dynamics
C1	Channel one face of road
C2	Channel second face of road
C3	Channel third face of road
C4	Channel fourth face of road
C5	Channel five face of road
C6	Channel sixth face of road
Vw	Velocity of wind (m/s)
T_a	Temperature of air (K)
T	Tall building
S	Small building

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