Wind Tunnelling Effect on Different High-Density Building Environments: A Computational Fluid Dynamics Approach

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High-density building environments have become a significant characteristic of modern urban landscapes in response to the requirement of supporting an increasing urban population. The clustering of building structures in these situations presents distinct issues for pedestrian comfort and safety due to the wind interactions with structures such as tunnelling, shielding, and downwash effects. Most past studies on wind effects have focused on a selected arrangement of two or three buildings, without examining wind variations in different building arrangement types. Therefore, through this study, the wind tunnelling effect acting in three main categories of high-density building environments was explored using a block of 25 building units. Computational Fluid Dynamics (CFD) was employed here, utilising the Reynolds-Averaged Navier-Stokes (RANS) method with the Shear Stress Transport turbulence model (2k-ω SST). The mesh size around the building edges was set to 0.9 m, with the element size growth rate as 1.05 in model development. Categories I and II feature a central high-rise building (120 m height), while Category III has a central low-rise building (6 m height). In Category-I, the surrounding buildings have uniform height, with the relative height (λ) being the key parameter. In Categories II and III, the parameter measures the arrangement angle of building heights (θ) to the horizontal plane in negative and positive directions, respectively. The power law wind profile was used with a 5 ms^{-1} reference wind velocity at a height of 10 m above the ground. The parametric study was conducted by observing wind velocity variations at a height of 2 m above the ground (pedestrian level), and it was observed that Categories I and II demonstrated a gradual reduction of the tunnelling effect, which was followed by a subsequent increase with the increment of their respective parameters λ and θ. This gradual reduction in the tunnelling effect is due to the vortex shedding effect being significant, which dampens the tunnelling effect within the specific parameter range under consideration. Category III illustrated a consistent development in the tunnelling effect with the increment of the relevant parameter θ. This research clarifies how pedestrian comfort levels vary with different building arrangements, aiding city designers in optimizing building layouts to enhance pedestrian comfort.

Keywords: CFD Simulation, Pedestrian Comfort, Tunnelling Effect, Turbulence Models, Wind Response