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Interference effect of tall building in various arrangements using Lattice-Boltzmann-Method based CFD simulation

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SUMMARY:
In this study, we perform Large Eddy Simulation (LES) to investigate the interference effect of tall square buildings in parallel, tandem, and oblique positions using Lattice-Boltzmann-Method (LBM) based Computational Fluid Dynamics (CFD) simulations. The buildings have a distance spacing of 1.5 times their width and are identical in dimension. The simulation results are compared with experimental data and show good agreement. The interference effect is quantified by interfering factor of mean pressure coefficient ($\mathrm{IF}_{\text{Cp-mean}}$) on each face of the primary building. It is found that the side-by-side arrangement resulted in the highest $\mathrm{IF}_{\text{Cp-mean}}$ on the left side and the tandem arrangement shows a high magnitude of negative $\mathrm{IF}_{\text{Cp-mean}}$ on the front surface, indicating the shedding effect of the interfering building. This study demonstrates the effectiveness LBM-based CFD simulations in investigating the interference effect of tall buildings and highlights the importance of considering such effects in building design and wind environment assessment.

Interference effect, LBM, tall building

1. MOTIVATIONS

The design of tall buildings must take aerodynamics into consideration as wind loads can significantly affect the building's stability and safety. Tall, slender buildings are susceptible to wind-induced vibrations and loads that can cause discomfort for occupants, structural deflection, and even failure (Tanaka et al., 2012). The number of tall buildings has increased in recent decades, particularly in Asia and the Middle East, due to strong economic growth and urbanization. Shenzhen, China is a leader in tall building construction, with 18 projects completed in 2019. (Qu et al., 2021). Modern tall buildings are typically located in dense urban areas and creating a complex wind field, distinct from that of isolated high-rise buildings. The increased demand for research on this interference effect has led to the use of computational fluid dynamics (CFD) and Large-Eddy-Simulation (LES). Apart typically used together with finite volume method (FVM) it could also be integrated into Lattice Boltzmann Method (LBM), a particle-based solver which offers lower computational time and cost (Kareem, 2020). This emerging technique has gain recent interest from the wind engineering community such as the studies done by Han et al. (2020) and Buffa et al. (2021) to simulate wind flow over an isolated building. In this study, we perform LBM-LES CFD simulations to investigate the interference effect between two tall square buildings.

2. METHODS

The models in this study are based on the wind tunnel experiments conducted at the Tokyo Polytechnic University, which were described by Kim et al. (2011). The study focuses on the effect of two identical square buildings with a width of 70mm and a height of 280mm, where one building is fixed and the other is located at three different points to induce the interfering effect. The computational domain as described in Fig. 1 was defined with a coarsest voxel size of 35mm and three sub-domains with three refinement levels (RL). Another three RL was defined close to the buildings surfaces which means that the finest refinement was at level 6 (RL6) with a voxel size of 0.55mm, resulting in a total of around 152 million voxels. The wind exposure was defined with a velocity profile and a synthetic turbulent generator, with a reference velocity of 8.2 m/s and an incident angle of 0°.

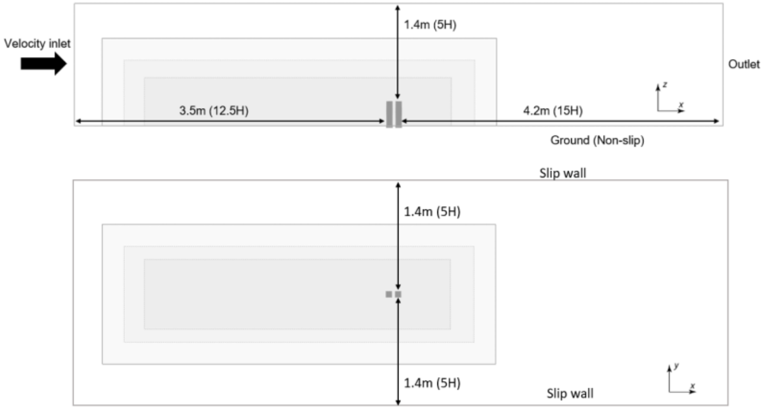

Figure 1. The computational domain.

As previously mentioned, three interference cases are investigated: the tandem (Pos.1), oblique (Pos.2), and side-by-side (Pos.3) arrangements. The coordinates of these arrangements are illustrated in Fig. 2. To quantify the interference effect, a simulation of flow over an isolated building was conducted. All other simulation parameters, including the domain size, are kept constant for each case. The physical simulation time is fixed for 7.5s. A total of around 12 hours computational time was required for one case.

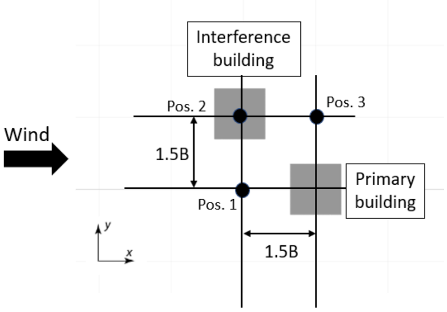

Figure 2. Different locations of interfering building.

3. RESULTS

The results of mean pressure coefficient, Cp-mean at about two-thirds of the building height were extracted and shown in Fig.3 for all cases. All simulation results are compared with their respective experimental data, except for the isolated case, which only has a simulation result because its result is not available in the database. For all the three positions of the interfering building, the simulation model is capable of reproducing most of the results, especially for the front and rear side of the principal building. Some slight differences can also be seen on the front side edges in tandem (Pos.1) arrangement. This could be due to the lower accuracy of turbulence estimates caused by the presence of the interfering building. A denser mesh might improve these results.

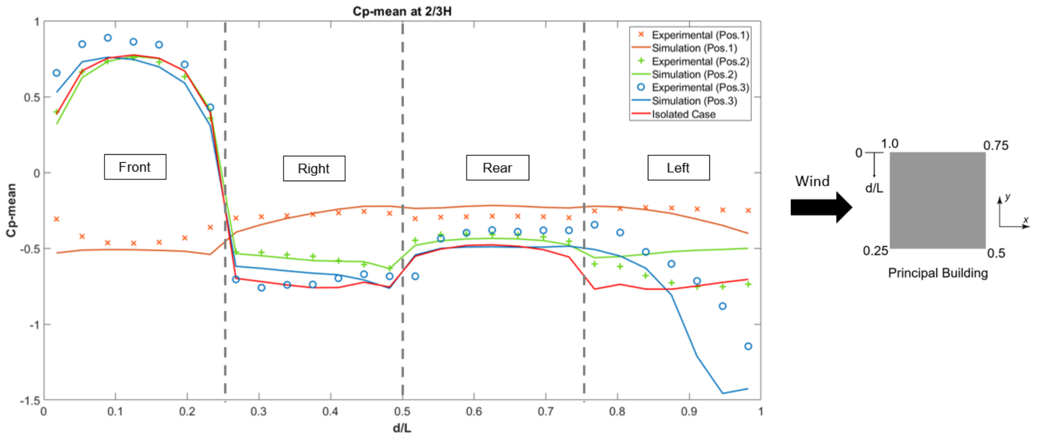

Figure 3. Distribution of Cp-mean along the perimeter of principal building at z=2/3 H

The interference factor of the mean pressure coefficient, $IF_{Cp\text{-}mean}$ for each case can be determined from the following equation:

$$IF_{Cp-mean} = \frac{C_{p-mean}\ with\ interfering\ building}{C_{p-mean}\ without\ interfering\ building} \qquad (1)$$

A distribution of $IF_{Cp\text{-}mean}$ for the three cases is represented in Fig.4.

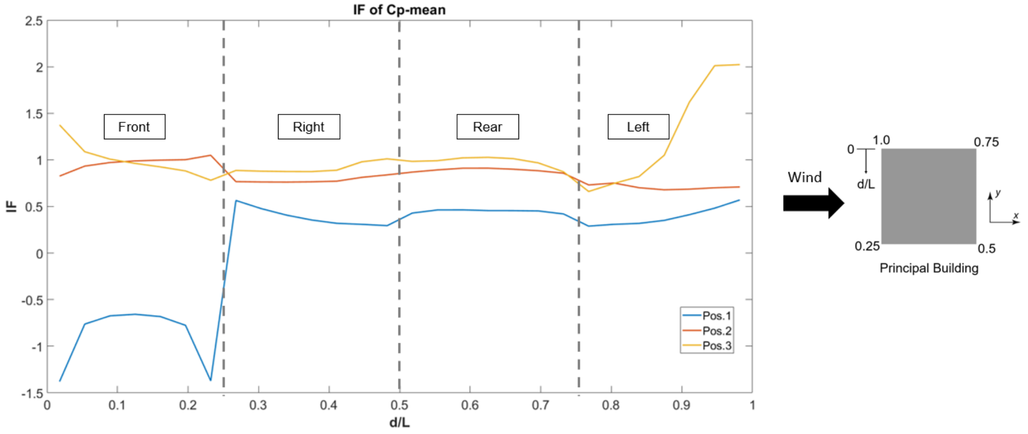

Figure 3. Distribution of Cp-mean along the perimeter of principal building at z=2/3 H.

It is observed that the $IF_{Cp\text{-}mean}$ for oblique and side-by-side arrangements are almost the same for the right and rear faces. showed the highest $IF_{Cp\text{-}mean}$ on the left side of the primary building, which is due to the channeling effect created by the interfering building. The tandem arrangement produced a high magnitude $IF_{Cp\text{-}mean}$ with the opposite sign on the front surface, clearly showing the shedding effect caused by the interfering building.

4. CONCLUSIONS

In conclusion, the study presented investigated the effect of three different building arrangements on wind pressure distribution on a square building using LBM-based Computational Fluid Dynamics (CFD) models. The simulation results were compared to wind tunnel experiments and showed good agreement, especially for the front and rear sides of the primary building. The interference effect of different arrangements was also quantified and thus providing valuable insights for predicting wind pressure distribution in urban areas with multiple buildings and can assist the design of wind-resistant structures.

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