NUMERICAL SIMULATION OF STATIC INTERFERENCE EFFECTS FOR SINGLE BUILDINGS GROUP

Xing-qian Peng\textsuperscript{1}, Chun-hui Zhang\textsuperscript{2} and Chang-gui Qiao\textsuperscript{2}

\textsuperscript{1}Professor, College of Civil Engineering, Huaqiao University, Quanzhou, Fujian, China, 362021, pxq@hqu.edu.cn

\textsuperscript{2}Graduate student, College of Civil Engineering, Huaqiao University, Quanzhou, Fujian, China, 362021, zchijw@163.com

\textsuperscript{2}Graduate student, College of Civil Engineering, Huaqiao University, Quanzhou, Fujian, China, 362021, qcg-0902@163.com

ABSTRACT

In wind field of category C ground feature, numerical simulation of static wind load and wind field were performed for single buildings group composed of three buildings by CFD. Through careful analysis, following the change of spacing at any wind angle, distribution laws and characteristics of wind pressure coefficient interference factor on this kind of building surface have been obtained. Results indicate that: When wind angle is 0°, distribution laws of wind pressure coefficient interference factors for three buildings vary from one another. The major affected building is located in the middle of building groups, the building located in the end takes the second place, and the front building is less affected. In most building surfaces, they are all affected by favorable interference. When wind angle is 45°, distribution laws of wind pressure coefficient interference factors for two buildings in the back are very similar. When wind angle is 90°, distribution laws of wind pressure coefficient interference factors for these three buildings are very similar. In this condition, they are all affected by unfavorable interference. The result of numerical simulation could provide basis for building groups distribution optimization and wind-resistant design of structures.

KEYWORDS: SINGLE BUILDINGS GROUP, NUMERICAL SIMULATION, INTERFERENCE FACTOR, WIND PRESSURE COEFFICIENT

Introduction

With the improvement of the modern urbanization level of our country, a large number of buildings of high-density appear in each city. Flowing field interference and the wind load on building in the actual environment and that measured in single building are quite different. Existing research shows: In some cases the interference effect of the building groups will make the structural wind load and respond increase. In recent years, the research of the structural wind engineering mainly concentrates on single building and the mutual interference between two buildings; it is less considered mutual interference among three buildings and more [Xie et al. (2003)]. To the building groups of more than 3 buildings, it is difficult to obtain some quantitative even qualitative conclusions since there are a lot of working conditions and more focused on specific projects at present [Huang et al. (1999)]. The research object of this text is to explore the wind pressure distribution characteristics of the surface of every building of a single buildings group composed of three buildings.
1 Computing model

In order to facilitate the analysis, the models chose the same geometric size as \( b \times l \times h = 40m \times 15m \times 25m \), the layout of models and wind directions are shown in Fig.1, Sx is the spacing of along-wind direction among the buildings.

In order to study each surface of the buildings, building division are expanded in the horizontal plane as shown in Fig.2, the arrow point shows as 0 degrees of wind directions, the windward side of the building is A, leeward one is C, and two sides are B, D respectively, the building roof is E.

2 Numerical simulation

2.1 Basic equation and turbulence model

In this paper, the closed turbulence model equation was adopted. Because of the existence of mutual interference in building groups, there is a strong wind flow anisotropy, which use k-\( \varepsilon \) RND turbulence model [Yang et al. (2004) and Murakami et al. (1988)]. The general form of control of air flow equation is

\[
\frac{\partial (\rho \varphi)}{\partial t} + \text{div}(\rho u \varphi) = \text{div}(\Gamma \text{grad} \varphi) - S
\]

In the above equation, the four parts respectively mean transient term, convection term, diffusive term and source term, \( \varphi \) is the generic variable, \( \Gamma \) is spread coefficient for broad sense, \( S \) is source one of broad sense.

2.2 Parameters and domain setting

While carrying the numerical simulation of the wind pressure of building surface, considering the flow characteristic and convergence of iterative calculation, regional interface should be made far away from building as far as possible, and also guarantee there is enough length in tail shedding area in order to enable the flow to fully develop, at the same time, giving consideration to computational efficiency, the size of the area should be moderately made. The computational domain \( 550m \times 250m \times 200m \) is finally decided [Qiao et al. (2008)], and the building models were placed along one-third of the flow of wind.

In order to meet the need of the shape of the building groups, tetrahedron discrete grid with good adaptability have been adopted. In order to obtain better simulate wind flow characteristics in the domain, the grids near the building models are smaller and the distribution is denser, while the grids away from the building models are bigger and the
distribution is sparse. The total grid numbers is about 1,200,000.

2.3 Boundary conditions setting
(1) Entry: The initial wind profile is described by power law \( u(z) = u_0 (Z / Z_0)^a \) [Zhou (2005)], where \( U_0 \) is the wind speed at 1m above the ground, \( a=0.22 \) under the terrain C.
(2) Export: Fully developed turbulence and developed flow boundary condition used.
(3) Adopt symmetrical boundary conditions on top and both sides of flow field, which is equivalent to the free sliding wall; while no-slip wall conditions is adopt at the building models surface and the ground [Zhang et al. (2003) and Sakamoto et al. (1988)].

3 Numerical simulation results

The interference factor \( IF \) generally describes the interference effect quantitatively, this text employed \( IF \) to describe interference effect of building groups [Xie et al. (2004) and Xie et al. (2006)]:

\[
IF = \frac{C_p I}{C_p A} \tag{2}
\]

\( C_p I \) - mean wind pressure coefficient when interfered with, \( C_p A \) - mean wind pressure coefficient of single building without interference in type (2).

The along-wind spacing \( S_x \) is considerable to be \( [b, 3.5b] \) in this article. The result of the simulation of wind pressure of every building surface in different wind directions are shown in the following graphs.

![Graphs showing variation of interference factor for different buildings](image)

**Fig.3.** Variation of interference factor of the mean wind pressure coefficient under 0 degrees of wind direction

3.1 Angle of 0 degree of wind direction

When the angle of wind direction is 0 degree, the interference factor curve of each
surface is shown in Fig.3, Wind-velocity vector field for some along-wind spacing and height of 2h/3 is as shown in Fig.4, from these figures, we can find out:

(1) Building 1: Mean wind pressure coefficient of the windward side A1 compared with when being single, diminish slightly, it is not big influenced by the spacing. The interference factors of two sides B1 and D1, leeward surface C1 and top surface E1 roughly present linear decreasing change with the spacing, the reason is with the increasing of the spacing, the swirl that forms at the back area is more fully developed, air flow paces of side and top surface slow down at a certain extent, therefore the wind pressure of the surfaces reduce at some extent. When the spacing is b, the wind pressure coefficients of C1 and E1 increase a little compared with when being single.

(2) Building 2: Sheltered by building 1, great changes have taken place in the wind pressure coefficient of every surface in building 2. The windward side A2 with negative pressure roughly presents linear increasing with the spacing, when the spacing is b, the minimum interference factor is - 0.8. The interference factor of side B2 and D2, leeward surface C2 and top surface E2 following in 0.6, that is favorable to resist the wind to the structure.

(3) Building 3: The wind pressure of the windward side A3 presents negative when the spacing is less than 2b, the interference factors are minus, when the spacing is greater than 2b, the wind pressure turns to positive pressure, and the interference factors are greater than 0. When the spacing is 2b, the interference factor of surface B3 and D3 is about 0.32. The interference factors of leeward surface C3 present linear increase with spacing with a maximum of 0.735. The interference factors of top surface E3 also present linear increase, the minimum is 0.25 at the spacing of b. The reason is the shelter effects formed by the first two buildings.

Fig.4. Wind-velocity vector field for height of 2h/3 under 0 degrees wind direction

In this wind direction, when the spacing increase, the windward side of building 1 is interfered with smaller impact, the interference factors of other surface roughly present linear decrease. The building 2 is interfered severely, the minus interference factor of the windward side presents linear increase, while the positive interference factors of other surfaces are
small. The wind pressure of the windward side of building 3 is negative and rises gradually, the critical spacing is about 2b from negative value to positive value.

3.2 Angle of 45 degrees of wind direction

When the angle of wind direction is 45 degrees, the interference factors curve of each surface is shown in Fig.5, Wind-velocity vector field for some along-wind spacing and height of 2h/3 is shown in Fig.6, from these figures, we can find out:

(1) Building 1: Interference factors of A1 are greater than 1.0, but its changes is not big, the reason is that the existence of building 2 and building 3 make the air current flowing into the building A1 accelerate (with the single to compare), so the static wind loads acting on surface are strengthened. Interference factor of B1, C1 and E1 is about 0.9, and it does not change obviously. D1 is severely interfered, when the spacing is b, the interference factor is 1.7, when the spacing is 3.5b, it is still 1.5, this should bring designer's attention, the reason is the same as analyzed with A1, the air current that just flows into D1 accelerates obviously.

(2) Building 2: When the spacing is smaller than 2b, interference factor of A2 is minus, when the spacing is 2b, it is 0.087, when the spacing is greater than 2b, it is greater than 0, the critical spacing is about 2b. The wind pressure coefficients of the B2、the C2 and D2 are little interfered, at most spacing interference factor is close to 1.0. D1 is severely interfered, interference factor is generally about 1.75, and the variation is not obvious with spacing.

(3) Building 3: Interference factor of every surface is similar to building 2.

Fig.5. Variation of interference factor of the mean wind pressure coefficient under 45 degrees in wind direction

In this wind direction, D1, D2 and D3 are greatly affected, the interference factor is up to 1.6, it is the position that should pay attention to in the structure resists the wind. The interference factor of A1 is about 1.15, when the spacing is about 2b, the wind pressure in surface A2 and surface A3 is transferred from negative value to positive value.
3.3 Angle of 90 degrees of wind direction

When the wind direction is 90 degrees, the interference factor curve of each surface is shown in Fig.7. Wind-velocity vector field for some along-wind spacing and height of 2h/3 is shown in Fig.8, from these figures, we can find out:

Fig.7. Variation of interference factor of mean wind pressure coefficient under 90 degrees in wind direction
Fig. 8. Wind-velocity vector field for height of 2h/3 under 90 degrees in wind direction

(1) Building 1: With the increase of the spacing, interference factors of A1, B1, C1 and E1 present roughly linearly decrease but greater than 1.0. The canyon effect makes interference factor of surface B1 greater, for example, when the spacing is 2b, it is up to 1.6, and so it should be taken into account in the structural design or wall design. The interference factors of surface D1 are around 1.05 with little change with spacing.

(2) The change law of the interference factors of each surface of Building 2 and Building 3 is very similar to building 1.

4 Conclusions

In this paper, the numerical simulation of the wind pressure of surfaces of Single buildings group had been carried on, and the change laws of the average wind pressure coefficient interference factor of every surface with the angle of wind direction and building spacing change have been obtained, at the same time, the feasibility of the numerical simulation has been validated. Some conclusions are as follows:

(1) Angle of 0 degrees of wind directions is left, mutual interference of buildings mainly show as "sheltering effect". On most building surfaces, they are all affected by favorable interference. The ones that need to arouse attention are as follows, when the spacing is b, the mean wind pressure coefficient of leeward surface C1 of building 1 increase 10%, and top surface of building 1 increase about 20%.

(2) Angle of 45 degrees of wind directions is left, with the increasing of the spacing, the mean wind pressure coefficient of every surface decrease in various degrees. D1 of building 1, D2 of building 2 and D3 of building 3 are interfered severely. The mean wind pressure coefficients increase 50% at most cases which needs the designer's attention.

(3) Angle of 90 degrees of wind directions is left, the "slit effect" among the buildings make the mean wind pressure coefficient of the majority surfaces of the buildings have increase in various degree.

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