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Effect of lift-up design on pedestrian level wind comfort around isolated building under different wind directions

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Abstract

The pedestrian level wind environment is seriously worsen by moderated air flow in the built-up cities like Hong Kong. The lift-up design is therefore adopted in the building constructions to improve the weak wind condition. In order to evaluate the influence of lift-up design on the pedestrian level wind comfort, the wind flow around isolated buildings with and without Lift-up design are simulated respectively via CFD approach. The turbulence model and numerical method are firstly validated by comparing the simulated wind flow data with a wind tunnel test. Then the validated model is used to simulate the wind flows around the isolated buildings. Results show that the lift-up design can improve the wind comfort at pedestrian level and its effects are highly rely on the approaching wind direction. Specifically, the wind comfort is better under the oblique wind direction than the other wind directions.

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Keywords: Lift-up design; Pedestrian level wind comfort; Computational fluid dynamics (CFD) simulation; Mean wind velocity ratio (*MVR*)

1. Introduction

The moderated air flow at pedestrian level caused by the increasing high-rise buildings in densely built-up cities results in unfavorable wind velocity and thermal comfort conditions, which in turn may eventually affect human health. The issue is more serious in the subtropical urban cities, such as the hot and humid summer in Hong Kong [1, 2]. For the purpose of improving the wind flow in a densely built-up city, Hong Kong SAR government established the air ventilation assessment (AVA) scheme [1]. However, the achievement of an acceptable wind comfort around the buildings is difficult in most urban areas.

In order to improve the weak wind condition at pedestrian level in densely built-up urban are-as, the lift-up design, in which the building block is “lifted” off the ground supported by the modern structural pillar, has been introduced into building design and urban planning [3]. The lift-up design can be regarded as one of the prominent design because it is feasible to implement and it has gained increasing attention in south-eastern Asian cities, like Hong Kong. A majority public amenity venues and transportation interchanges in Hong Kong are located in the lift-up areas underneath the high-rise buildings. However, the potential benefits of the lift-up design in improving the weak wind condition at pedestrian level have not been totally explored or understood. Previous studies have already shown that the lift-up area can create a local cooling spot for the pedestrian activities in hot and humid Hong Kong, which can in turn encourage more outdoor activities [3-6].

This study sets out to provide an insightful understanding about the effects of lift-up design on pedestrian level wind comfort around the isolated building. The lift-up design at the Hong Kong Polytechnic University (HKPolyU) campus are chosen in this study three typical wind directions are selected, including normal, oblique and parallel approaching wind directions. The turbulence model and numerical method are firstly validated by comparing the simulated wind flow data with the wind tunnel test

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results. The validated model is then utilized to simulate the wind flow around the isolated buildings with and without lift-up design. The mean wind velocity ratio (*MVR*) and mean wind velocity change ratio (Δ*MVR*) are employed to identify the wind comfort and to quantitatively evaluate the improvements due to the lift-up design.

Nomenclature

U_p	mean wind velocity at the pedestrian level, m/s
Ur	reference mean wind velocity at 200m in the in situ condition, m/s

2. Methods

2.1 Identification of pedestrian level wind parameters

In order to make the findings universal, normalized mean wind velocity known as the mean wind velocity ratio (*MVR*) is adopted in this study. The *MVR* is defined as follows:

$$MVR = U_p / U_r \quad (1)$$

In order to quantitatively assess the effects of lift-up design on the wind environment around the building, the mean wind velocity change ratio (Δ*MVR*) is proposed here, which is calculated as the following equation:

$$\Delta MVR = (MVR_{LU} - MVR_{NLU}) / MVR_{NLU} \quad (2)$$

here, the subscript *LU* means building with lift-up design, and the subscript *NLU* means building without lift-up design. MVR_{LU} is the value of *MVR* at pedestrian level with the lift-up design, while MVR_{NLU} is the value of *MVR* at same spot without lift-up design.

2.2 Identification of pedestrian level wind comfort

The annual average mean wind velocity at 200m reference height is 5m/s at the location of the HKPolyU campus and the probability of exceedance is close to 50% [7]. In order to reach the threshold value of 1.5m/s, which is the minimum noticeable wind velocity for human [8] and also meets the requirement for a person to achieve neutral thermal sensation in hot and humid summer of Hong Kong [9], an *MVR* value equal or over 0.3 is required in this study to maintain a comfortable wind environment for pedestrian activities. Therefore, when the value of *MVR* is lower than 0.3 can be deemed as uncomfortable in this study.

2.3 Turbulence model validation

The turbulence model used in this study is the Steady Reynolds Averaged Navier-Stokes (SRANS) re-normalization group (RNG) k-ε turbulence model, considering that can provide sufficient accuracy at economic numerical cost [10] and this turbulence mod-el has been widely used and reliable in wind engineering [11-13]. The wind tunnel tests conducted by Xia et al. [6] is used as the validation case, the detailed description of the tests can be found in the work by Xia et al. [6] and Du et al. [3].

For the computational domain, the upstream, downstream, lateral, and height length are 5H, 15H, 5H and 5H, respectively, which meets the requirements of the CFD practice guidelines [14, 15]. The whole computational domain is constructed with the hexahedra grids. Figure.1 shows the horizontal lines at pedestrian level plan (Z/H=0.01) at which the experiment data and the simulation results are compared. The pressure and momentum equations are coupled using the SIMPLEC algorithm, and the second-order upwind scheme is utilized in the discretization scheme. The residuals in the simulation are all set as 10^{-6}. The validation results between the wind tunnel data and the simulated results with and without lift-up design are shown in Figure.2. It can be obtained from these figures that the CFD simulations can provide sufficient accuracy for predicting the wind flow around the buildings with and without lift-up design.