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Study on the Influence of Piloti Ratio on Thermal Comfort of Residential Blocks by Local Thermal Comfort Adaptation Survey and CFD Simulations

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Abstract

To get good outdoor ventilation and create shadow areas, piloti is commonly used in tropical and subtropical climate zones, but there are few studies reveal the comprehensive influence of piloti on wind environment in residential blocks, and furthermore, a coupled simulation method, which offers high precision prediction result, is seldom taken into consideration in piloti research field. This work firstly carried out a questionnaire survey in Guangzhou, China, to study on the local acceptance rate (TSV is lower than 1.5) during different SET* intervals. Secondly, a series of cases were simulated by coupled simulation method, which considering convection, radiation and conduction, offering high precision prediction results. At last, by adopting SET* as standard index, taking both of the questionnaire survey result and ASHRAE standard into consideration, the influence of piloti on residential block's outdoor thermal comfort was analyzed and discussed. The results showed that, due to the strict climate, for those area without shading measurement, only the whole space of 100% piloti ratio case meet the need of SET* limitation level (less than 40 °C), for other cases, part of the space is controlled with this level. For the space shaded by piloti, the area percentage that SET* is in the limitation range (less than 40 °C) of 60% piloti ratio case is about 62%, and for 80% and 100% piloti ratio cases, it is 100%. It is noticed that when piloti ratio is 40%, the thermal comfort of space shaded by piloti is very strict, which should be due to the low wind velocity. A 100 percent piloti ratio can highly improve the outdoor thermal comfort, and 100% area space meet the need of 30% acceptance rate (35°C), and about 40% area meet the need of 65% acceptance rate (34°C).

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1. Introduction

Urban heat island is now regarded as one of the most serious environmental problems, and the environmental degradation results in not only the increase of energy consumption in cities but also healthy problem of people. In Asia cities, which has hot and humid climate, many studies on urban heat island have been done in recent years, and both the National central government and local governments of major cities are very aggressive in handling the heat island problems. Many studies on urban climate have been carried out. Yoshida Shinji et al. carried out field measurement of outdoor thermal environment in summer, and spatial distributions of wind velocity, temperature, humidity and radiation are measured in courtyard canyon space around apartment complex located in Tokyo [1]. Kubota Tetsu et al. reveal the relationship between the building density and the average wind velocity at pedestrian level in residential neighborhoods [2]. Uehara Kiyoshi et al. conducted wind-tunnel experiments to study the effect of the heights and arrangements of roadside buildings on the flow and concentration fields in a street canyon [3]. Toru Kawai and Manabu Kanda et al. studied the effects of building height variation on momentum and heat transfer characteristics using Comprehensive Outdoor Scale Model (COSMO) [4]. Yoshida Shinji, Murakami Shuzo and Mochida Akashi et al. developed a new method for predicting the human comfort in outdoor thermal space with the aid of CFD (Computational Fluid Dynamics), integrated with convection, radiation and moisture transport [5]. Harayama Kazuya, Yoshida Shinji, Ooka Ryozo et al. developed a prediction method of outdoor thermal environment based on unsteady coupled simulation of convection, radiation and conduction [6]. It was pointed out that the two main parameters that influence the urban climate are the urban geometry and urban surfaces [7, 9]. The ratio of the height of buildings (H) to the distance between them (W) is one of the most important factors that influences the urban geometry, thus, affecting incoming and outgoing radiation and wind speed. At night, the heat island increases with an increase in the H/W ratio because the net outgoing long-wave radiation decreases because of the low sky view factor (SVF). In the desert city of El-Oued in Algeria, it was reported that the maximum daytime temperature tended to decrease with an increase in the H/W ratio; however, only small temperature differences between rural and urban areas were found [10]. In Dhaka, Bangladesh, the average daily maximum temperature decreased by 4.5 K when the H/W ratio increased from 0.3 to 2.8 [11]. The high thermal capability of urban surfaces contributes to daytime and night-time heat islands because of the increased reflected radiation, less daytime evaporation, and the increased heat release at night.

Fig. 1. Building piloti design in Guangzhou, China.

The outdoor thermal environment and thermal comfort have received considerable attention over the years. In outdoor conditions, the radiant exchange between the human body and solar radiation, cold sky vault, and warm and cold urban surfaces are particularly important factors related to human thermal sensation and comfort. Herrington et al. indicated that the mean radiant temperature (MRT) and wind velocity played a more important role on human response than temperature in the outdoor environment [12]. Forwood suggested that the range of acceptable MRT in the outdoor environment should be from 24 °C to 30 °C [13]. Pearlmutter et al. compared the energy exchange of the human body within and above an urban canyon with H/W = 1 in Dimona, Israel [14]. Erick Johansson investigated