STUDY ON URBAN MICROCLIMATE IN HOT-HUMID REGION OF CHINA – A LITERATURE REVIEW

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Abstract

The present paper makes a literature review on the study of urban microclimate in hot-humid region of China, especially Guangzhou, including the theoretical and simulation studies, and experimental and testing studies.

Key words: urban microclimate, hot-humid region, urban heat Island

1. INTRODUCTION

Hot-humid region in China, including the Yangtse River and its south, has 2.6 million square kilometers in land area, 21 provinces, 0.7 billion people, two most developed economical regions and produces 65.4% GDP of China. With the rising of urbanization, problems with urban heat island and building energy consumption in this region becomes more and more serious. Lack of reasonable scientific instruction on urban plan and building design is aggravating the problems. It's very necessary to understand basically the mechanism, develop the effective control technologies and establish a evaluation system for the microclimate in hot-humid region of China. Guangzhou, lies in longitude 113°17' and latitude 23°8', is a typical city in hot-humid region of China. The present paper makes a literature review on the study of urban microclimate in hot-humid region of China, especially Guangzhou, including the theoretical and simulation studies, and experimental and testing studies.

2. THEORY AND SIMULATION

2.1. Air temperature model in urban near-ground layer

Meng et al considered the effect of turbulence in vertical directions and airflow in horizontal directions on air temperature, and proposed a mathematical model for air temperature in near-ground layer of urban based on the heat balance equations for different layers of air and surfaces of ground and wall. The model was testified through site experiment in a small size zone and a large size zone in summer in Guangzhou, and the results show that the difference between simulation and measurement is less than 3.62% and the model could be used for prediction of air temperature in near-ground layer of urban in hot-humid region of China. The linkage between the model and the commercial CFD software is on going.

2.2. Lumped parameter model of urban air temperature

Meng et al improved CTTC model, which is originally proposed by Swaid and Hoffman, according to the in-situ investigation of urban microclimate of Guangzhou in the following aspects: surface temperature calculation, temperature change due to long-wave radiation, effect of the trees on long-wave radiation and the green heat transfer coefficient factor. The improved model was verified by evidential testing in a residential community in Guangzhou, and the results show that the model can predict urban air temperature more accurately than the original model. The improved CTTC model advances the prediction accuracy while maintaining the advantage of easy model and short time reaction, which can be well used by architects in the beginning stage of urban plan or zone design. More detailed studies should be performed on the CTTC constant determination of various materials and structures, the effect of evaporation and the heat transfer due to air turbulence in vertical directions and so on to improve the model prediction accuracy.

2.3 Urban air velocity simulation

Li et al investigated the relationship between building density, floor area ratio and outdoor mean air velocity by simulation of typical building groups in closed type and queued type in hot-humid region with the model validated by wind-tunnel experiments. The studied building density changed from 10% to 50% and the floor area ratio changed from 0.5 to 5. The simulation results show that the effect of building density is more significant than floor area ration. 10% increase of building density could reduce 0.1 in mean outdoor air velocity ratio in all directions at 1.5m plane. Floor area ration does not affect outdoor air velocity significantly while it is greater than 3. The mean outdoor air velocity was greater in queued type zone than the one in closed type zone while the building density and floor area ratio were maintained the same. The recommendation on plan and design was also proposed for

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the typical cities in hot-humid region in China, including Guangzhou, Fuzhou, Shanghai, Wuhan, Chongqing and Kunming based on the simulation results. A simple model of urban air velocity is planned to be established based on the existing systematic simulation results, which can predict mean outdoor air velocity easily and quickly by inputting local meteorological data, building density, floor area ration and the type of building distribution.

3. EXPERIMENT AND TESTING

3.1 Hot-humid dynamic wind tunnel

The hot-humid region in China has long summer, strong solar radiation and abundant rainfall. Porous material, which can be matted on pavement, could hold rainfall and evaporate the water when solar radiation is strong, resulting in reduce of surface and air temperatures. Zhang et al developed a hot-humid dynamic wind tunnel for testing evaporative heat transfer performance of porous materials, in which air temperature, humidity, velocity and solar radiation can be controlled continuously to accurately simulate the periodical change of outdoor climate and evaporation and evaporative heat flow can be measured continuously as well. The wind tunnel testing results were compared with the real outdoor measurements and the comparison indicates that the wind tunnel can well reproduce outdoor climate in artificial way. Zhang et al also analyzed the effect of material properties, initial time and local climate on evaporation. The well established hot-humid dynamic wind tunnel can supply the basic heat and mass transfer parameters of various materials or structures applied in urban surface, which would be the foundation of all predictive models.

Fig.1 Hot-humid wind dynamic tunnel

3.2 Remote sensing of urban microclimate

Meng et al made an analysis on surface temperature distribution of Guangzhou Higher Education Mega Center by using the infrared remote sensing images from satellite in 2006 (Fig. 2). The analysis shows that the construction idea of combination of development and protection is very helpful to reduce urban heat island intensity, and the outdoor shading, water and green land cool down the surface temperature significantly and improve the outdoor thermal environment. Feng et al summarized the remote sensing accuracy, time, height, area and the calculation equations of air temperature for the existed airborne remote sensing and proposed a set of airborne remote sensing method for hot-humid region in China with a new remote sensing system consisted of an infrared thermal sensor and a remote-controlled airship (Fig. 3).

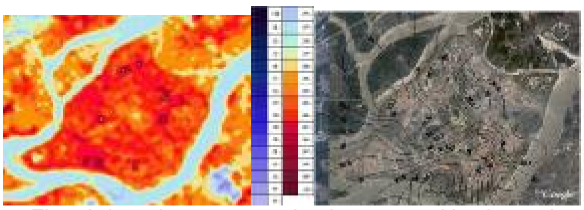

Fig.2 Infrared remote sensing images and isothermal graph of Guangzhou Higher Education Mega Center

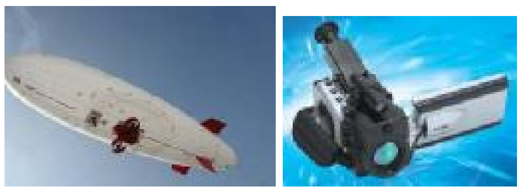

Fig.3 A new remote sensing system

3.3 Site testing of urban microclimate

Li et al performed a continuous 33 hours site testing in a typical public and residential building group in South China University of Technology in Guangzhou (Fig. 4-5). The 29 testing points measured local climate, air temperature, humidity, velocity, airflow direction, black-bulb temperature, WBGT at 1.5m plane and surface temperature. The testing results show that in the place under umbrage the air velocity is smaller and the air temperature is lower than the place under sunshine and the biggest temperatur e difference is 2.5℃; dooryard and overhead reduce air temperature and WBGT significantly; the ground surface temperature under umbrage maintains constant all day at 28℃ and the one for concrete under sunshine reaches 50.2℃.

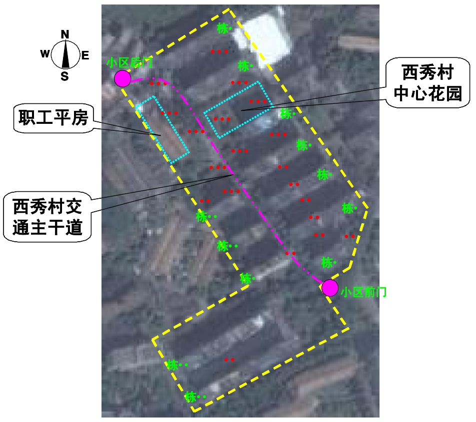

Fig.4 Measurement positions in public building area

Fig.5 Measurement positions in residential building area

Chen et al investigated the effect of lake, tree and surface material on outdoor thermal environment by site testing of air temperature, humidity, black-bulb temperature and air velocity. The testing results show that without shading of tree, concrete surface and lack of natural ventilation are the main reason for poor outdoor thermal environment in summer, and the cooling impact is around 1.6-1.8℃ for water and 0.7-3.5℃ for shading of tree.

Zhao et al performed site testing on grass, concrete road, shale brick square and umbrage and obtained the air temperature gradient change within 1.5m and the relationship between surface temperature and near-ground air temperature. It was found that the boundary layer was less than 0.5m for the surface and the air temperature changed from high to low in the following order: shale brick square, concrete road, grass and umbrage.

3.4 Urban outdoor thermal comfort investigation

Jin et al investigated the effect of outdoor thermal environment on thermal sensation and comfort by collecting 868 questionnaires in a courtyard in Guangzhou from Sep to Nov in 2004 (Fig. 5-6). The integrated effects of wind speed, air temperature, relative humidity and solar radiation on the human perception, preference and overall comfort were analyzed and outdoor comfort zone for shading and non-shading was proposed. Zhai et al made detailed analysis based on the survey conducted by Jin et al and found that the neutral temperature and the upper acceptable temperature were 25.4°C (SET*) and 31.6 °C (SET*). Several thermal indices were calculated based on the survey data and compared with human thermal sensation vote. It was found that the widely accepted thermal indices such as PMV, SET*, ET*, PET and WBGT may not be appropriate for assessing outdoor thermal comfort without any modification in Guangzhou. Zhai et al also made a literature review on outdoor thermal environment assessment, in which included the studies on outdoor thermal comfort, safety and death. The review mentioned that some safety indices were used for comfort assessment and vice versa, which was needed for validation and till now no outdoor thermal environment assessment index was universal.


Fig.6 Investigation sites without shading


Fig.7 Investigation sites with shading

4. CONCLUSIONS

Many progresses have been achieved in the studies on theory and simulation, experiment and testing in hot-humid region in China, which constructs a concrete base for well understanding, plan and design of urban microclimate.

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