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A simplified mathematical model for urban microclimate simulation

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ABSTRACT

Techniques for modelling urban microclimates and urban block surfaces temperatures are desired by urban planners and architects for strategic urban designs at the early design stages. This paper introduces a simplified mathematical model for urban simulations (UMsim) including urban surfaces temperatures and microclimates. The nodal network model has been developed by integrating coupled thermal and airflow model. Direct solar radiation, diffuse radiation, reflected radiation, long-wave radiation, heat convection in air and heat transfer in the exterior walls and ground within the complex have been taken into account. The relevant equations have been solved using the finite difference method under the Matlab platform. Comparisons have been conducted between the data produced from the simulation and that from an urban experimental study carried out in a real architectural complex on the campus of Chongqing University, China in July 2005 and January 2006. The results show a satisfactory agreement between the two sets of data. The UMsim can be used to simulate the microclimates, in particular the surface temperatures of urban blocks, therefore it can be used to assess the impact of urban surfaces properties on urban microclimates. The UMsim will be able to produce robust data and images of urban environments for sustainable urban design.

1. Introduction

The microclimates in urban areas have important impacts on building performance in terms of energy, the indoor thermal environment and the potential of passive cooling measures. On the other hand, building and urban design will affect the urban microclimates, for example, the urban heat-island (UHI) effect results in increased local atmospheric and surface temperatures in urban areas compared to the surrounding rural areas. [1]. In current building energy design practices, an individual building is assumed isolated within its surroundings; its energy demand is predicted against the local meteorological data. The study of computer simulation of the energy demand of a typical office building in Adelaide, Australia, demonstrated that accounting correctly for urban modifications to the microclimate could lead to estimates of the annual heating consumption that were 25% lower and cooling 15% higher than estimates that do not incorporate these effects [2]. The UHI will increase the overheating risk and the peak cooling load of buildings in summer but reduce heating load in winter. Therefore the studies of urban microclimates; the effect of outdoor thermal climatic parameters on the accuracy of dynamic building thermal simulation; the effect of urban form and texture on energy-efficient urban design; outdoor thermal comfort and the feasibility of the deployment of Renewable Energy in buildings have been widely conducted in recent years.

The approaches to the study of the urban microclimates include numerical, experimental and CFD (Computer Fluid Dynamics) simulation methods [3–9]. The experimental methods, e.g. site monitoring and wind tunnel experiments, are expensive and only limited cases can be studied. The CFD simulation tools are widely used to analyse thermal phenomena in the urban context in different cities or neighbourhoods, which is relatively economic. The CFD models are very powerful and require heavy calculations but provide detailed results that can show clearly the defects of a proposed design. However, this process is time-consuming. Furthermore, due to the lack of accurate data of the boundary conditions and the ignorance of the buoyancy effect of solar radiation, dynamic simulations are difficult to achieve with classic CFD codes [9]. Due to the heavy involvement of calculations, it appears unsuitable for application in the early stage of a strategic urban design.

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