Building and Environment 46 (2011) 584–596

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

A design supporting simulation system for predicting and evaluating the cool microclimate creating effect of passive evaporative cooling walls

Jiang He [a,b,*]

[a] School of Civil Engineering, Guangxi University,100 Daxue Road, Nanning, Guangxi 530004, PR China
[b] Department of Environmental Science and Technology, Interdisciplinary Graduate School, Tokyo Institute of Technology, 4259-G5-2 Nagatsuta-cho, Midori-ku, Yokohama 226 8502, Japan

ARTICLE INFO

Article history:
Received 12 July 2010
Received in revised form
9 September 2010
Accepted 10 September 2010

Keywords:
Passive cooling
Evaporation
Urban environment
Microclimate
Thermal comfort
Coupled simulation

ABSTRACT

As a passive cooling strategy to control increased surface temperatures and create cooler urban environments, we have developed a passive evaporative cooling wall (PECW) constructed of pipe-shaped ceramics that possess a capillary force to absorb water up to a level higher than 130 cm. The current paper presents a simulation system to predict and evaluate microclimatic modifying effects of PECWs in urban locations where PECW installation is under consideration at the design stage. This simulation system is composed of a CFD simulation tool and a 3D-CAD-based thermal simulation tool. Simulation methodology of coupling the two simulation tools was developed and described in this paper. Numerical models for simulating surface temperatures and evaporation of PECWs were proposed based on analysis results of experimental data. Validation of the proposed numerical models was confirmed by comparing simulated results with measured data. In order to demonstrate the applicability of the proposed simulation system, a case study was then performed to predict and evaluate the microclimate in a rest station where PECWs were assumed to be installed. Spatial distributions of air temperature, airflow, moisture and surface temperature in the rest station were simulated under a sunny weather condition in the summer of Tokyo. Furthermore, thermal comfort indexes (mean radiant temperature and new standard effective temperature) were used to evaluate thermal comfort in the human activity spaces of the rest station. Simulation results show that this simulation system can provide quantitative predictions and evaluations of microclimatic modifying effects resulting from the application of PECWs.

1. Introduction

Controlling the increase of urban surface temperatures is one of most important strategies for mitigating the urban heat island effect. As one of these mitigation strategies, to cool urban surfaces by means of water evaporation, i.e., evaporative cooling approaches would be effective and of less environmental impact. From the energy-saving viewpoint, as a passive cooling approach, positive application of materials with evaporative cooling effect to the urban surface has become a great concern in the urban environmental design. In addition, cooler urban environments could be created by applying these materials to urban vertical surfaces (such as building walls or fences) that surround the human activity spaces. Thus, to provide a passive cooling strategy for reducing urban surface temperatures and creating cooler urban environments, the author's research group has developed a passive evaporative cooling wall (PECW) constructed of porous ceramics. These ceramics possess a capillary force to absorb water up to a level higher than 130 cm when their lower end is placed in water. The cooling effects and applicability of the developed PECW have been investigated through a long-term experiment conducted in an outdoor location, as documented in our previous papers [1,2].

A practical type of the PECW was proposed as a unit which was constructed of pipe-shaped ceramics (hereafter called the ceramic pipe) as illustrated in Fig. 1. A PECW unit consists of four rows of ceramic pipes with a height of 1.8 m. There are 11 ceramic pipes in each row. The PECW (ceramic pipe) surfaces can be cooled down to a temperature nearly equal to the wet-bulb temperature by facilitating the evaporation of water soaked from the water tank. This results in cooler surfaces in outdoor locations on sunny summer days, so that a radiative cooling effect could be provided to a person near the PECW. Furthermore, the PECW allows wind to pass through it, and the passing air can be cooled while passing through the PECW. As a result, cooler airflow can be provided on the leeward side

* Corresponding author. Present address: Department of Environmental Science and Technology, Interdisciplinary Graduate School, Tokyo Institute of Technology, 4259-G5-2 Nagatsuta-cho, Midori-ku, Yokohama 226 8502, Japan. Tel.: +86 7713232894; fax: +86 7713236273.
E-mail address: kanohj2010@gmail.com.

0360-1323/$ – see front matter
doi:10.1016/j.buildenv.2010.09.005