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Sensitivity Analysis applied to Hygrothermal Simulation of a Brick Building in Hot and Humid Climate

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Abstract

Based on the Fourier law, Fick law and Darcy law, a coupled heat and moisture transfer model for porous media was established. Relative humidity and temperature were chosen as the driving potentials. The effects of sorption capacity, water vapor permeability, liquid water conductivity, specific heat, and thermal conductivity on the coupled heat and moisture transfer in porous media were investigated under hot-humid climate. The results show that liquid water permeability and thermal conductivity have greater effects on the coupled heat and moisture transfer, and the average errors are 2% and 2.2%. The effects of other parameters are negligible, and the average errors are less than 0.1%.

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Keywords: porous wall; coupled heat and moisture transfer; relative humidity; temperature; Sensitivity analysis.

1. INTRODUCTION

In hot and humid climate regions, temperature changes frequently which intensifies the moisture migration. Walls are normally subjected to both thermal and moisture gradients. The heat and moisture transfer through the walls has an important effect on the building energy consumption, thermal performance of walls. In addition, too high levels of indoor relative humidity can cause mould growth on the inside surfaces of the

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walls which lead to indoor air quality problems[1]. Therefore, it is necessary to study on the heat and moisture transfer behaviors in the walls.

It is time-consuming and complex to simulate the heat and moisture transfer phenomenon in porous media, since the mass transfer and heat transfer is simultaneous and the dependent variables are highly coupled. Many studies have been carried out to investigated the heat and moisture transfer behavior in porous media[2-3].

Most of the models are based on the work by Philip and Luikov[4] and De Vries[5] who developed transient models that used moisture content as the driving potential for moisture transport. However, parameters of models are functions of temperature and moisture content which leads to highly nonlinear of the governing equations. Abahri et al.[6] developed a model based on the theory of Luikov which take all parameters as constants and they used the transfer function method to solve the partial differential equations. According to the Fourier law, Fick law and Darcy law, Qin et al.[7] developed a two-dimensional hygrothermal model with variable physical properties. Wang et al.[8] proposed a dynamic mathematical model with which they studied effect of moisture migration on the heat conduction through walls. . It is obvious that the way to deal with the parameters of the walls will affect the solution of the governing equations directly. Therefore, the purpose of this paper is to investigate the effects of the parameters on the coupled heat and moisture transfer within the walls.

Nomenclature

ξ	sorption capacity
Dv	water vapor permeability (s)
Ps	saturation vapor pressure (Pa)
Dl	liquid water permeability (s)
Pw	density of liquid water (kg/m3)
R	general gas constant (8.314J/(mol • k))
M	molar weight of water vapor (0.018kg/mol)
Cm	specific heat capacity of the material (J/(kg • k))
Pm	density of the dry material (kg/m3)
λ	thermal conductivity (W/(m • k))
Cpl	specific heat capacity of the water liquid (J/(kg • k))
Cpv	specific heat capacity of the vapor (J/(kg • k))
L	vaporization latent heat (J/kg)

2. Mathematical model

Most building materials are porous and composed of solid matrices and pores. A hygrothermal model for the porous materials has been developed according to the mass and energy conservation laws. Assumptions are as follows:1) water vapor is an ideal gas; 2) The material is homogenous. 3) The effect of temperature on equilibrium moisture content is negligible.

Neglecting the effect of airflow[9-10], energy and mass transfer equations can be expressed as:

$$\xi \frac{\partial \varphi}{\partial t} = \frac{\partial}{\partial x}\left[\left(D_v \varphi \frac{\partial P_s}{\partial T} + D_l \frac{\rho_w R}{M} \ln \varphi\right)\frac{\partial T}{\partial x} + \left(D_v P_s + D_l \frac{\rho_w R}{M}\frac{T}{\varphi}\right)\frac{\partial \varphi}{\partial x}\right] \quad (1)$$