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Heat and moisture transport in wooden multi-composite panels. Dynamic study of the air layer impact on the building envelope energetic behavior

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ABSTRACT

Heat and moisture transfers in the building envelope play a significant role in the energetic performances of a construction. In the present study, the dynamic behavior of a multi-composite wooden panel, including an air layer, is considered through heat and mass transport calculations. To address this problem, a vertical channel filled with humid air between hygroscopic walls was considered. Balance equations for mass, momentum, energy and vapor are solved taking into account conduction, convection, radiation, diffusion and condensation mechanisms. The transient evolutions of temperature, heat fluxes and humidity were observed versus several climatic parameters through a set of different boundary conditions. Realistic hygroscopic material and humid air properties varying with temperature and vapor mass fraction were also taken into account.

1. Introduction

Nowadays, energy efficient buildings frequently use multi-layered components and innovative technical solutions. Several studies have pointed out the advantages of using wooden constructions and renewable materials in the context of energy saving issues and sustainable development. However in these organic materials both thermal and hygroscopic transport must be considered to accurately predict the energetic behavior and the overall comfort of the construction. Before considering the behavior of the whole building envelope, one of its basic parts, "the wall", needs to be accurately modeled. In most recent insulation technologies the wall itself is made of several different material layers. They are chosen according to their own performances and the construction design. For efficient insulation, air layers are often used between the different wall materials. Passive and active behavior may be expected according to the air motion in the layer yet both heat and mass transport in these layers strongly depend on the nature of the building material. In the case of organic materials, vapor flows through the wall and thus a fully coupled modeling of heat and mass transport in both domains (solid and fluid) is required to assess the performance of the building envelope. Also, according to climatic conditions, temperature and humidity fluctuations within the humid air layer might give rise to condensation occurring on the coldest parts of the walls. The resulting surface wetting is responsible for the deterioration of building panels and could be a cause of discomfort for the occupants. In order to appraise the magnitude of this phenomenon, phase change must be considered in the balance equations. All these phenomena describing the thermal and hydric mechanisms which drive the heat and mass exchanges through a wall have been partly addressed in previous studies.

The problem of mixed convection in enclosures and convection in a channel has been frequently investigated. Studies dedicated to vertical enclosures are numerous and often deal with very different subjects and engineering applications. For example, in Fedorov et al.'s work [1] the influence of a wetted wall on the air/water vapor mixture flow was investigated in laminar and turbulent conditions. In more recent works the evaporation and condensation phenomena in vertical ducts were studied in the case of a cavity with isothermal walls [2,3]. For other applications, models that include radiative heat exchange coupled to convection through differentially heated cavities or channels have been developed [4–7]. It has been shown that the radiative heat flux can profoundly affect velocity and temperature fields of the gas mixture. However, evaporation and condensation phenomena have been the subject of little study, especially at the boundaries of the layer. The convection and condensation of humid air in cavities with impermeable

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