Hygrothermal behaviour of hemp concrete; experimental evidences and modelling

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ABSTRACT

In a general context of global warming, an increasing interest is observed on the use of bio-based insulating materials like hemp concrete. Indeed, this kind of materials ensures good thermal characteristics while drastically reducing fossil energy consumption and greenhouse gas emissions associated with their manufacture.
In addition, thanks to their permeancy (ability to allow diffusion of water vapor within their porous network), these materials present an alternative option to isolate and rehabilitate buildings made with non-industrial materials (rammed earth, cob, adobe,...) and whose stability requires to maintain a water exchange with the outside.
However, the thermal performance of these materials is often underestimated. Indeed, in order to properly estimate the thermal comfort inside a building, we need to consider the thermal inertia of walls, as this latter can "smooth" the daily fluctuations of external temperatures compared to those inside. When we consider porous insulating systems like hemp concrete, the resulting apparent thermal inertia is in reality above what can be expected by simply considering the characteristics on thermal conductance (heat capacity, thermal conductivity, density) and the thickness of the coating. The superior performance in reality can be attributed to the latent heat associated with the liquid-to-vapor phase change of water contained within the porous network of the material.
In order to properly model this behavior, we have reformulated the problem of hygrothermal transfer through a porous medium, taking into account the liquid-vapor phase change in an appropriate form. The resulting system of partial differential equations was then solved by the FEM code COMSOL.

The model predictions are compared to experimental data of hemp concrete walls of dimensions 0.9x0.9x0.1 [m3]. These walls are instrumented with sensors to monitor water content, temperature and relative humidity. The sensors are positioned at mid-thickness and external surfaces, at mid-height of the wall. The walls are placed in a double climatic chamber that allows the regulation of temperature and relative humidity on each side of the wall, independently to each other. The material parameters used for the simulations are measured separately on decimetric samples of the same hemp concrete, which comes from the same mix and with the same apparent density. The comparison between numerical calculations and experimental data eventually allows discussing on the validity of some commonly adopted assumptions and on the key parameters needed to model properly the hygrothermal behavior of hemp concrete.

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