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Comparison of salt solution and air drying methods for moisture fixation in highly porous building materials

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Abstract

In recent years, research has identified some bio-based, porous building materials as good or excellent regulators of moisture in buildings. The ability of a material to absorb, release and store moisture is described by vapour sorption isotherms. It is necessary input to simulations of indoor environmental parameters in regards to human comfort, and nowadays it can be determined by a number of laboratory experiments, each of which characterized by specific specimen size, equilibration time and methodology.
The purpose of this study is to experimentally derive isotherms for three bio-based, porous building materials by a standardized testing method, using saturated salt solutions. Furthermore, results from the standard method are compared to values of moisture content for the same materials, obtained by air-drying at different relative humidity. This is done with the aim to compare the findings from the two methods with respect to time and repeatability of the results.
Derived isotherms are further used as direct input in the building simulation software BSim, which is capable of predicting indoor environment parameters by solving coupled, transient heat and moisture transport equations using finite volume method discretization. Indoor air relative humidity and moisture content distribution in the construction are compared for the experimented materials and conventional building materials. Results show better agreement between isotherms obtained by standard method and air-drying for low density materials. Simulation results suggest that bio-based, highly porous building materials are comparable to conventional building materials in respect to air relative humidity variations, compared to conventional building materials.

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Keywords: HAM Simulations, Hempcrete, Vapor sorption isotherms

1. Introduction

Every building material is capable of exchanging certain amount of moisture with its surroundings. This ability of building materials plays an important role in the indoor environment in regards to human comfort and wellbeing. It is characterized by vapor sorption isotherms, which is a curve describing moisture fixation in building materials as a function of relative humidity (RH). A single value describing the moisture buffering potential can also be used to characterize building materials in regards to moisture storage. This is the moisture buffer value, defined by the NORDTEST Project [1]. Rode and Grau [2] discovered that taking moisture buffering of building materials into account can prompt energy savings when the ventilation is controlled by RH.

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Hemp-lime building materials are highly porous building materials that have been found to have either good or excellent moisture buffer values [3,4]. Those materials also seem to be good alternatives to conventional building materials due to their carbon negative footprint [5], and moderate thermal properties [6,7].

The aim of this paper is to determine the vapor sorption isotherms for three distinct hemp-lime building materials using saturated salt solutions. Moisture content found by salt solutions is compared to moisture content of the same materials, subjected to air-drying at different RH environments. In order to analyze how porous materials compare to conventional building materials in regards to air RH, the derived isotherms are used as direct input to the building simulation software "BSim" and compared to conventional building materials by performing multiple simulations. The buffering effect of the materials is analyzed by looking at the annual variation of moisture content in the different walls, subjected to the same conditions.

2. Materials

Hemp-lime building materials are composed from the stem of the hemp plant (hemp shiv) and a lime based binder. Depending on the composition of the material, the shiv can represent a large share of the total volume of the material (up to 85% or more). Therefore, it is important to ensure that the shivs are suitable for construction purposes. This is achieved if they are free of seeds, vegetable content, dust and fiber. Shivs used for preparation of material composites in this paper are in the range from 1-9 cm with density of 102 kg/m^3 and small amount of fiber. Their moisture content, prior to mixing was determined to be 7.68% by mass, using the desktop tool Mettler Toledo Moisture Analyzer HE73.

The binder formulation used for hemp-lime composites in the majority of cases consist of hydrated (air) and hydraulic lime, pozzolanic additives, sand and cement. The composition of the binder and its proportion to shives in the mixture can be adjusted to produce hemp-lime materials with densities ranging from 200 – 800 kg/m^3 [8].

The aim for the developed materials in this paper is to create two materials representing hemp-lime composition in both low and high limit of the density range. Furthermore, it is to compare those materials to a third material, which is commercially available and lies in the middle of the typical density range. Table 1 presents an overview of the tested materials.

Table 1. Overview of tested materials and their properties.

	Low Density (**LD**) Hemp-Lime	Medium Density (**MD**) Hemp-Lime	High Density (**HD**) Hemp-Lime
Specimen image			
Dry Density [kg/m^3]	157 ±2	327 ±3	570 ±7
Composition	Hemp, Air Lime, NHL 3.5, Fly Ash	Commercial binder	Hemp, Air Lime, NHL 3.5, Fly Ash, Sand
Thermal Conductivity [W/(m.K)]	0.07	0.1	0.13
Specific heat capacity [J/(kg.K)]	400	340	400

3. Methods

3.1. Experimental methods

Standard [9] specifies two possible methods, that can be used to determine the hygroscopic sorption properties of building materials. Those are climatic chamber method and desiccator method, using saturated salt solutions. The work presented in this paper follows the desiccator method. Table 2 shows the necessary testing equipment and requirements associated with each element, as well as, conditions obtained during the experiment. As shown in Table 2, all experimental equipment satisfy the requirements set out by the standard.

The procedure for determination vapor sorption isotherms using desiccator method stated in [9] begins with oven dried specimens placed in the weighting cups. The specimens are then placed in the desiccator with lowest RH and the lid of weighting cup is removed. Specimens are weighted continuously in intervals of at least 24 hours until equilibrium is reached.

The standard specifies that equilibrium is achieved when the change in mass of the specimens is less than 0.1% of the total mass of the specimens between three consecutive weightings. The specimens are then moved to the next desiccator with higher RH and the procedure is repeated. When the specimens have reached equilibrium at the highest RH absorption curve is obtained. Then the specimens are moved to RH environments in decreasing order to obtain the desorption curve.

Four salt solutions were prepared in accordance with standard [9]. Table 3 lists the chosen salt solutions, their design and measured RH. The amount of salt and water mixed together are carefully weighted before mixture on a precision scale with accuracy of ±0.01 gram. The correct mixing temperature of the distilled water is ensured with high precision thermometer F200