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Material characterization models and test methods for historic building materials

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Abstract

Predictions of long term hygrothermal performance can be assessed by dynamic hygrothermal simulations, in which material parameters are crucial input. Material parameters for especially historic materials are often unknown; therefore, there is a need to determine important parameters, and simple ways for estimation of these. A case study of a brick wall was used to create and validate a hygrothermal simulation model; a parameter study with five different parameters was performed on this model to determine decisive parameters. Furthermore, a clustering technique has been proposed to estimate decisive parameters through simple testing of interrelated parameters that are easier to determine.

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Keywords: Historic building materials; hygrothermal simulation; moisture; material characterization; test methods

1. Introduction

In historic buildings with façades of cultural and preservation worthy values, interior insulation is the only measure to decrease heat loss through the exterior walls. The mounting of interior insulation may introduce moisture risks. Hygrothermal simulations are therefore valuable tools in the design of a suitable interior insulation system. Hygrothermal simulations take into account many specific variables for each case in question, e.g. climatic conditions, geometry and material parameters. This study has focus on material parameters and their importance in regards to said

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hygrothermal simulations. Materials used in historic buildings are extremely varied, not only in the raw materials and resources used, but also in the production method. If it can be proven that certain material properties are decisive for the hygrothermal performance and they can be determined feasibly in regards to both time and economy, it would be beneficial for future analysis of retrofit measures.

As there are numerous uncertainties in hygrothermal simulation, identification of potential discrepancies in material properties and boundary conditions were determined in a sensitivity analysis performed by Kloda [1]. The analysis concluded vital influence on output from parameters such as solar radiation absorption coefficient, thermal conductivity, suction curve, capillary conductivity and surface heat transfer coefficients. Probabilistic methods have previously been introduced by e.g. Zhao et. al. [2] and Holm et. al. [3], running 400 and 69 hygrothermal simulations respectively, for determination of the influence of material parameters and boundary conditions, and measurement uncertainties respectively. The findings of these measures were, among others, that the effect of single parameters may be seasonal, and can have both positive, negative and seasonal-dependent correlations. The studies emphasize the need for full and exact material properties for achieving valid results. By means of statistical tools however, it may be possible to attain reliability ranges for results, and simplifying the models by clustering of materials.

This paper aims to clarify the importance of the single material parameters in regards to characterization of historic building materials with limited information. It is a step towards for better prediction of hygrothermal performance by finding a linkage between clustering and simple experimental methods for material characterization.

2. Material Characterization

A major challenge in hygrothermal simulations of walls in historic buildings is to establish necessary knowledge of the material parameters. Material characterization is in the following described as a combination of the experimental and theoretical approach.

2.1. Practical determination of material properties

There are number of well-defined and standardized methods for determination of many material properties in laboratory. The methods for determination of the parameters included in this study are seen in Table 1.

Table 1: Test methods for determination of some material parameters.

Parameter	Standard method	Alternatives
Density	EN 772-13:2002 [4]	EN 1936:1999 [5]
Open porosity	EN 772-3:1998 [6]	EN 1936:1999 [5]
Thermal conductivity	EN 12664:2001 [7]	ISOMET Heat Transfer Analyzer
Water uptake coefficient	ISO 15148:2002 [8]	Plagge et. al. [9], automatic logging system Hendrickx [10], estimation by Karsten tube
Water vapour diffusion resistance factor	EN ISO 12572:2001 [11]	Bertelsen [12], considering moisture content dependency

2.2. Theoretical hygrothermal models

Moisture transport in porous media, e.g. building materials, is driven by material characteristics as well as external factors. Driving forces include gradients in partial vapour pressure, total air pressure and external total pressure, as well as gravity and pore width, defining the capillary suction [13]. Moisture transport in a material also depends on the moisture storage potential, which in turn is dependent on specific material characteristics; e.g. water retention curve relates to the porosity, effective and capillary saturation – depending on the hygroscopic range, and the function for liquid water conductivity depends on both effective saturation and water uptake coefficient. Material functions are vital as they describe properties at various conditions, therefore material functions are implemented in hygrothermal simulations together with constant material parameters. Some of the material parameters and functions are not directly measurable and therefore the process of determining the parameters also requires a calibration, either experimentally and/or numerically [14]. Simplified, the process of the material characterization can be seen in Figure 1;

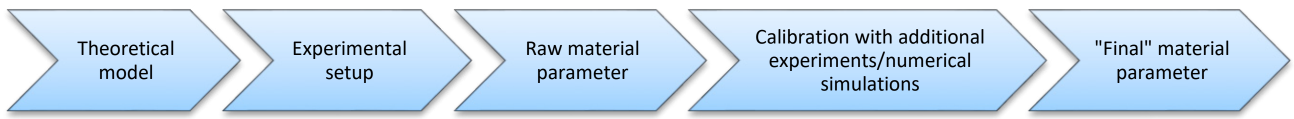

Figure 1: Flow chart of material characterization process.