Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 132 (2017) 297–302

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

Towards hygrothermal characterization of rammed earth with small-scale dynamic methods

Margaux Indekeu[a,*], Monika Woloszyn[a], Anne-Cécile Grillet[a], Lucile Soudani[b], Antonin Fabbri[b]

[a] *LOCIE, CNRS-UMR 5271, Université Savoie Mont Blanc, Campus Scientifique Savoie Technolac, Le Bourget-du-Lac Cedex 73376, France*
[b] *LGCB-LTDS, CNRS-UMR 5513, ENTPE, Université de Lyon, Vaulx-en-Velin Cedex 69518, France*

Abstract

Hygrothermal analysis of building envelopes requires high-quality input data and thoroughly tested models. To improve a model developed in Comsol Multiphysics for assessing the hygrothermal performance of rammed earth constructions, flexible dynamic small-scale experiments are presented. First, an experimental study shows the sample production, test setup and methodology and some preliminary test results are included. Next, a numerical study to simulate and further design the experiments is carried out.

Keywords: rammed earth; hygrothermal; dynamic inverse characterization methods; material properties; small-scale; multi-layer

1. Introduction

In the debate on energy efficient dwellings, accurate knowledge of the actual performance of the building fabric and of the pertinence of renovation actions is essential. Raw earth constructions represent a significant part of the world's existing building stock. Despite their large variability, earth building materials have a common feature: they behave hygroscopically. This characteristic is source of a great potential for natural regulation of hygric and thermal states. Meanwhile, the moisture content in raw earth materials has a strong and sometimes baleful influence on their properties. Energy efficiency and insulation potential of the material can be studied theoretically [1]. A model for assessing the hygrothermal performance of earth has been developed [2,3,4]. This model was implemented for one material layer and the experiments used for its validation were complex, long and costly. In order to improve the model calibration and validation procedure, flexible dynamic experiments on material scale are presented here. Similar works exist [5,6,7,8] only for hygric characteristics of a single material. This paper aims at exploring extension of the dynamic methods' experimental share to enable hygrothermal material characterization. The target

* Corresponding author. *E-mail address:* margaux.indekeu@univ-savoie.fr

10.1016/j.egypro.2017.09.731

hygrothermal material properties to be determined are heat conductivity, vapour permeability and sorption isotherm. Raw earth being a locally manufactured and heterogeneous material, sample preparation is first discussed in detail.

2. Experimental study

2.1. Sample production

The earth material used in this study originates from a former house in Dagneux, south-eastern France. Besides the practical relevance for studying this earth, on account of the number of dwellings to be renovated in this region, it has several advantages over other earths, such as its homogeneity and fineness [9]. The grading of Dagneux earth is shown in Fig. 1a, where d (mm) is the size of the sieve openings, and p (kg/kg) is the fraction of the total mass that passes through each sieve. The sample material is sieved at 5mm, thus preserving more than 95% of the original. So, the samples are considered to be representative of Dagneux earth.

Fig. 1b shows in grey the results of Proctor tests on Dagneux earth, giving the sample dry density (oven-dried at 105°C), ρ_{dry} (kg/m³), obtained for a given compaction pressure as a function of the manufacturing moisture content, u (kg/kg). Indeed, as in rammed earth constructions, to create the lab samples the earth is wetted. The conditions in the lab are around 25°C and 50% RH. The earth is mixed by hand with distilled water that is gradually added until a total u of 10.4% is established. For determining u before and after the mixing, material portions of 120g are oven-dried to constant mass at 105°C. Each time, this is done in triplicate and the portions are extracted from different locations in the bag containing the earth. After that, the bag is carefully sealed and the ensemble is given time to homogenise for two more days. The earth is now prepared for the sample fabrication, which also starts and ends with checking u, in the same way. All fifty produced samples come from the same bag, with values of u of the earth at the beginning and at the end of the fabrication series of 10.4% and 10.1%, respectively.

A hydraulic press is used for the production of the earth samples (Fig. 2a). This method is preferred over the construction techniques used in practice (manual or pneumatic ram), for reasons of accuracy, repeatability, homogeneity and reproducibility. The press is controlled in displacement, the speed of compaction is chosen to be 10mm/60s and the resulting compaction force together with the compaction displacement are registered for each sample. Fig. 1b shows in black the press result for an average sample. Lower pressures are required as compared to Proctor, because in the pressing process no energy is lost to heat due to impact. In order to facilitate the removal of the sample from the cylindrical mold that is used for the sample production (Fig. 2b), adhesive tape is pasted on the inner sides of the mold. With the proposed methodology, it takes one hour to fabricate one sample, the tape in the mold being the most time-consuming measure. For thirty samples an imprint of a sensor with height (H) 0.6cm and diameter (D) 1.7cm is placed at the bottom of the mold in order to create a recess in which the sensor will be placed.

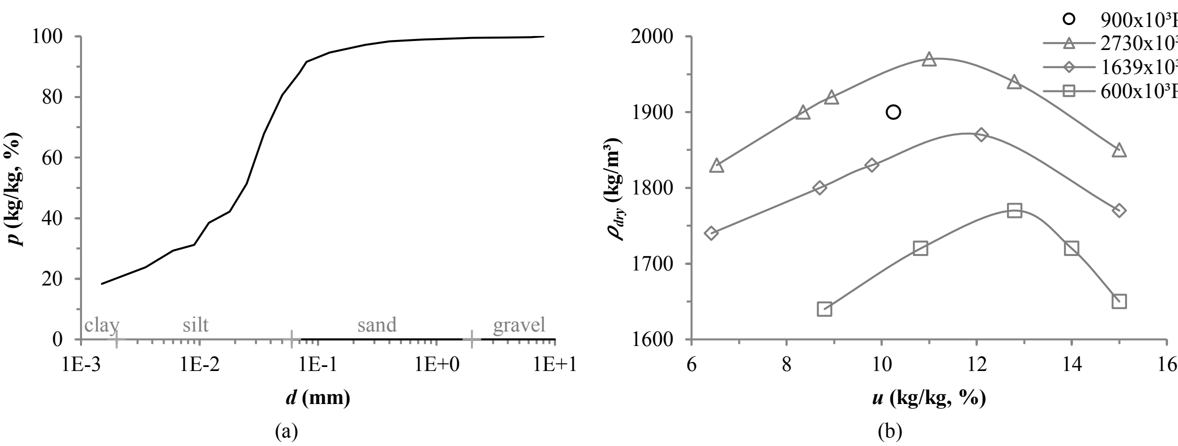

Fig. 1. (a) Particle size distribution [9]; (b) Proctor curves [9] (grey) and situation of press results (black).