Building and Environment 87 (2015) 234–243

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Experimental evaluation of hydric performances of masonry walls made of earth bricks, geopolymer and wooden frame

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ARTICLE INFO

Article history:
Received 5 November 2014
Received in revised form
9 January 2015
Accepted 10 January 2015
Available online 11 February 2015

Keywords:
Masonry wall
Earth bricks
Geopolymer binder
Wood
Hydric performances

ABSTRACT

This paper focuses on the characterization of the hydric properties of a new construction system in masonry structures composed of extruded earth bricks, geopolymer binder and wooden frame. The study was based on experimental tests such as the sorption desorption isotherms, the water vapor permeability tests on the different materials and the hydric test on a real size wall. The obtained results show the good properties of several materials, particularly in the storage of humidity. The different solicitations applied on the wall allowed to appreciate the ability of a earth brick wall to regulate humidity inside a house.

1. Introduction

Similar to the development of renewable energy to compensate for the decrease of fossil fuels, building energy consumption has become increasingly studied and mediated. The building construction field uses more energy and contributes to more discharges of cement produce, which represents 5% of the total CO_2 output. This field also consumes approximately 1.6% of the energy requirements worldwide [1]. Therefore, it is very necessary to adopt a global approach in this industry for the material and building life cycles and create this approach as a sustainable development perspective. Reflections must be made on several scales and considering architectural aspects, such as raw materials, materials, structure elements (wall), and building. Thus, our study is focused on developing new composite materials called eco-materials that are composed of earth bricks, wooden frame and geopolymer binder. The earth is the oldest mineral and granular construction material and has been used for thousands of years [2,3]. For example, the 16th-century old city of Shibam (Yemen), sometimes called the "Chicago of the desert" or the "Manhattan of the desert", which presents one of the earliest and most perfect examples of rigorous planning based on the principle of vertical construction. The tallest house is eight stories in height (29.15 m). The Great Mosque of Djenné (Mali), dating from 1907, is also considered by many architects to be one of the greatest achievements of the Sudano-Sahelian architecture and is characterized by the intensive use of earth, specifically in its architecture. This and natural material is interesting because the manufacturing of unfired earth bricks primarily requires local resources and low energy. Earth bricks are inexpensive to produce, recyclable and widely available. In addition, the hydric regulation characteristics and high thermal inertia of the earthen walls help increase indoor comfort [4–6]. However, according to the people living in earthen buildings, the evaporation of the water contained within the earthen walls has a cooling effect in hot weather; therefore, earth walls become natural air conditioners.

Previous studies were focused on the traditional earth building, primarily rammed earth buildings and compressed earth blocks [5,7,8]. Fewer researchers were interested in extruded bricks because there is no standard to determine their mechanical and hygrothermal

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http://dx.doi.org/10.1016/j.buildenv.2015.01.036
0360-1323/

Table 1
Earth bricks parameters.

Type	Granular characteristics	Chemical composition/ % mass	Mineralogy	Dry density, kg/m^3	Total porosity, %
Br_1	29% clay 63% silt 8% sand	73.2 SiO_2 8.6 Al_2O_3 3.2 Fe_2O_3 4.7 CaO	Quartz, muscovite, illite, albite, calcite	1700	35
Br_2	54% clay 32% silt 14% sand	64.5 SiO_2 18.4 Al_2O_3 5.4 Fe_2O_3 2.0 K_2O	Quartz, muscovite, illite, kaolinite	2100	22

properties. However, this manufacturing technique has some significant advantages; for example, the extrusion process is very fast and permits large quantities of homogenous bricks (density, form and size) to be produced [6,9]. Geopolymers, developed in 1978 by Joseph Davidovits, are solid inorganic materials that are synthesized at ambient temperature and atmospheric pressure [10]. They belong to the aluminosilicate family and result from the reaction of an aluminosilicate oxide with an alkaline solution.

The composite assembly of wood and earth bricks is appropriate for construction systems and is used in many existing structures [11]. The mechanical properties of wood provide good strength and a light weight; the earth bricks provide thermal inertia and a stored moisture [6,7,12]. However, cracks can appear at the interface when differences in dimensional variations are observed. This situation is related to temperature and moisture evolution. These cracks lead to sealing defects, insulation and esthetics that are incompatible with the user's requirements. Such problems can be avoided by using a binder that is able to adhere on wood and earth bricks, in contrast to the natural earth mortar used currently. An inorganic mineral mortar, such as geopolymer binders, can also be considered because of its ecological properties with respect to this type of structure. Indeed, a preliminary study on a porous geopolymer binder developed in the laboratory showed the ability of the binder to adhere to the wood and earth [13].

From the perspective of industrial development, such a solution allows the realization of a masonry wall that is composed of earth bricks and a wooden frame and bound by geopolymer mortar. However, a characterization of the mechanical [14], thermal and moisture behavior of the materials and their assembly is important for developing a reliable and stable construction system.

This study aims to evaluate the hydric performance of a new composite construction system made of extruded earth bricks, a wooden frame and a geopolymer binder. In this paper, the sorption–desorption and water vapor permeability tests on the materials (brick, wood and geopolymer) are presented, allowing the study of the hygroscopic characterization at the local scale. A wall with a real size (2.4 × 2.5 m^2) was tested in a double climatic room with different conditions. The results showed the performances of this new construction system and confirmed a good interaction among the earth bricks, geopolymer and wood.

2. Materials and methods

Two types of industrial earth bricks, manufactured by extrusion in French brickworks, were used in this study [14]. They differed in mineral composition and were thus denoted Br_1 and Br_2, and their

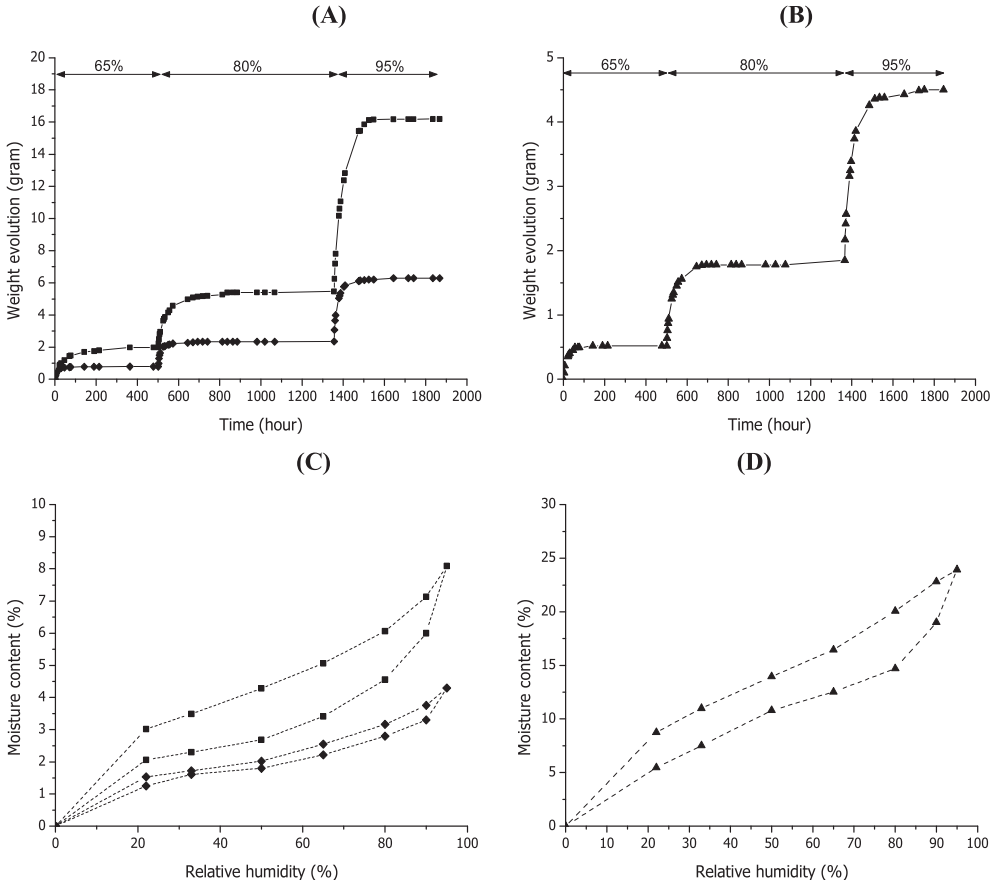

Fig. 1. Mass evolution vs time at different relative humidity levels 65, 80 and 95% for (A) ◆ Br_1 and ■ Br_2 bricks, (B) ▲ wood, and sorption–desorption isotherms (0–100% RH) at 23 °C for (C) Br_1 and Br_2 bricks (D) wood.