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Case study

Thermal performance of unfired clay bricks used in construction in the north of France: Case study

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ABSTRACT

The objective of this study is to demonstrate and to study the sustainability and the qualities of the earthen construction in real conditions. A demonstrative building was designed and built with unfired clay bricks, were industrially produced by the factory "Briqueteries du Nord" (BdN). This industrial plant is located in the north of France. This project aims to create conditions for the development of earthen construction techniques in the north of France. Moreover, it aims to prove the benefits of this material on the sanitary quality of the building.

This article is composed of three parts. Firstly, the identification of raw materials was performed in order to study the mains properties of these building materials. The second part of this work presented an experimental study conducted to investigate the dynamic thermal performance of unfired clay bricks.

To complete the tests already carried out in laboratory, an experimental investigation was carried out in situ on a demonstrative building. The hygrothermal performance of building is monitored for two consecutive years. The first analysis of the obtained data proved clearly that the earthen wall reduces the fluctuations of the outside temperature.

1. Introduction

Reducing energy consumption in the building sector is a key policy priority for the industrialized nations. As an illustration, the building sector in France consumes more than 42% of final energy. It generates nearly one-quarter of that country's greenhouse gas emissions (ADEME, French Environment and Energy Management Agency, 2010). Performance requirements to be reached over the next years appear ambitious and were expressed in France through adoption of the new RT 2012 thermal regulation. This new standard promotes the widespread construction of low-energy buildings. The objective consists on reducing the average primary energy consumption in new buildings by two-thirds. The maximum value was fixed at 50 kWh/m^2 per year on average for the five uses of heating, hot water, lighting, cooling and auxiliaries (fans, pumps).

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Creating energy savings and reducing CO_2 emissions in this sector constitute a major economic and ecological challenge, and encourage the use of sustainable construction materials. Earthen construction presents several advantages that allow it to be a current response to energy and climate issues. In fact, it is one of the main building materials used on our planet. It is estimated that almost a third of the world's population lives in some type of earthen dwelling. It is one of the oldest building materials, used in many different ways around the world for centuries. Approximately 50% of the population of developing countries, the majority of rural populations, and at least 20% of urban populations live in earth homes (Houben and Guillaud, 1994).

During the last few years, a growing interest has been considerably appeared for earth as a sustainable material. It has been then studied in the engineering laboratories around the world in the aim of the earth building products certification. Obviously, Earth is an abundant natural and recyclable resource. It is low embodied energy building material, which is in perfect adequacy with the eco-friendly construction and in the field of the sustainable development. Dethier and Eaton (2002) presented earth as the material of future with desirable sustainability attributes, which can produce interesting architecture in modern times.

Several research studies have outlined these benefits, as demonstrated by Pittet and Kotak (2009) in his comparative study between different technologies of construction (earth, concrete, brick and stone). Shukla et al. (2009) showed that construction and maintenance of an adobe house allow to save 370 GJ of energy per year, compared to conventional materials. It can also reduce CO_2 emissions by 101 tonnes per year. Lastly, Morel et al. (2001),Chel and Tiwari (2009) and Zami and Lee (2010) proved the economic benefits of earth construction, by reducing the energy required for the manufacture of these products, as well as reducing the environmental impact.

Furthermore, the thermal storage properties and humidity balancing effects of earth provide the advantages of this ecological material. It contributes to the thermal comfort and to the healthy aspects of buildings. Thus, the earth walls have hygroscopic qualities. They balance the indoor climate by absorbing and releasing moisture as the relative humidity of the air changes. In fact, a high moisture levels affect thermal performance of building and indoor air quality through the development of moulds and bacteria. The recommended relative humidity for humans comfort is between 30 and 60%, as mentioned by most of authors (Balaras et al., 2007; Wolkoff and Kjærgaard, 2007).

The earth walls have the ability to provide an excellent constant internal relative humidity, as shown in the research carried out by Minke (2000, 2006). In other hand, Padfield (1998) has tested the efficiency in buffering the indoor relative humidity of different building materials, using an experimental climate chamber. The buffer performance among the materials tested is given by wood and a specially developed mixture of bentonite with perlite. Further, Lindberg and Akander (2002) made an experiment in a full-scale room with earth walls. They concluded that the high heat and moisture buffering capacity of earth can reduce the need for energy-driven ventilation. Similarly, Morton et al. (2005) and Jaquin et al. (2009) showed the hygroscopic qualities of earth structures.

Moreover, the thermal properties of earth walls can contribute to reach the energy efficient building design requirements. The thermal mass of this material has the capacity to store daytime heat gains and to release the heat during the night. Martin et al. (2010) compared stone, adobe (traditional) and wooden (modern) houses in their investigation of the thermal behavior of existing housing in Spain. They demonstrated that the indoor environment inside the traditional houses could be comfortable with less energy consumption than new buildings. They attribute this result to the thick exterior walls of high thermal inertia.

Nevertheless, despite its qualities, the earthen construction has largely remained unrecognised; this is due to the fascination for modern materials such as concrete, brick or steel. Moreover, the lack of international standards required for the products evaluation leads to this phenomenon. Only some national reference documents and codes are used in the earth construction around the world, as mentioned by Delgado and Guerrero (2007). Orally-transmitted know-how has been lost and project owners are not aware of its advantages. However, it has many features that meet environmental concerns and is in perfect harmony with the environmentally-friendly construction approach. In this context, this study has launched with the Briqueteries du Nord company, intended to create the conditions for developing earthen construction techniques and spreading their use. The main objectives of this project are promoting this type of construction in Northern France, improving the insurability of structures, initiating an integrative approach of active involvement of regional stakeholders in the areas of eco-materials, architecture, construction and land use, and finally, demonstrating the benefits of this material in creating a healthy living environment.

The present work investigates the thermophysical properties of unfired clay bricks at laboratory scale and on situ. These bricks are industrially produced, by the Briqueteries du Nord (a factory located in the north of France), with an extrusion process. Firstly, the characterization of the raw material, used in the production of this building material, is presented. Then,

Table 1
Soil characteristics.

Constituents/properties	Values	Constituents/properties	Values
Textural composition (%wt)		Atterberg limits (%)	
Sand	15	Water content	21
Silt	80	Liquid limit	24
Clay	5	Plastic limit	21