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Energy Efficiency and Thermal Properties of the Composite Material Clay-straw

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Abstract

Unfired clay is a sustainable building material resisting to the hard climatic conditions. In order to improve the energy efficiency of this ecological material, this work tries to develop the thermal properties of unfired clay as an insulation material by mixing it with straw. An experimental measurement of thermal properties of unfired clay mixed with straw was done by using the flash method to determine the thermal diffusivity and the state hot plate method to estimate the thermal conductivity in order to deduce the thermal capacity. A building was simulated using the unfired clay–straw envelope with the climate data of south Morocco region, for the purpose to establish its thermal inertia and its ability to bring a good comfort by limiting summer overheating and keeping the heat in winter without heating and cooling systems.

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Keywords: Thermal simulation, thermal properties, thermal comfort

1. Introduction

In the industrialized countries, following the Second World War, the construction of unfired clay was virtually abandoned in favor of concrete construction such as the Moroccan companies of bricks which present an overtaking of 10 kJ/kg compared with the international standard of Energy consumed according to the report of Slaoui's factory [1]. As a result of climate change and increasing ecological consciousness among a growing number of people, providing naturel alternatives to concrete has become a major challenge to reduce the environmental impact of the construction sector. This reason explains the level of interest in clay because it is an ecological material with high thermal inertia, which allows to store heat and to regulate the temperature changes between day and night. It is a raw material widely available, renewable and even recyclable. The energy required for its manufacture is very low since

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no cooking is necessary. However, it can be used with an insulating vegetable fiber to constitute a more insulating mixture. Many studies have been published concerning the thermal behaviour and properties of unfired clay such as the work of Fgaier et al. [2] which present the thermal performances of unfired clay bricks used in construction in the north of France. Martín et al. [3] studied an evaluation of thermal behavior of traditional and wooden houses improving good indoor conditions inside the traditional houses in Spain. Obafemi et al. [4] conducted the environmental impacts of the use adobe in construction. A series of research studies have been done on clay mixed with natural additives such as the work of Ashour et al. [5] which examined the influence of natural reinforcement fibers on insulation values of earth plaster for straw bale buildings using the guarded hot plate. Catalan et al. [6] deals with the impact of addition of hemp fiber in adobe bricks on the mechanical strength and the thermal conductivity. The work of El Azhary et al. [7] presents a contribution to valorize the using of unfired clay resisting to the hard climatic conditions by improving its thermal proprieties. Laaroussi et al. [8,9] measured the thermal properties of clay bricks using different methods for the experimental characterization. Chaussinand et al. [10] evaluated a new construction material based on straw for a sustainable building. The work of Mokhtari et al. [11] studied the thermal comfort in the arid zones considering the relationship between architectural design and thermal comfort without using air conditioning. Therefore, Muhy Al-Din et al. [12] attemp to identify criteria to monitor thermal comfort performance building with minimum interferences of external aspects in North Cyprus. The aim of this study is to improve the thermal properties of unfired clay by combining it with straw to make it more insulating and greatly reduce energy consumption to prove its ability of resisting the hard climatic conditions and to offer thermal comfort without using the heating and cooling systems.

2. Samples preparation

Clay: The unfired clay used in this study was extracted from Ouarzazate region located in the south of Morocco.
Fiber straw: The fibers used such as clay additives were taken from wheat straw whose main chemical characteristics and composition are presented in table 1. The beams of fibers straw are characterized by the medium diameter of (1.25-2.5mm) and the density of 90 kg/m^3 [13]. The light straw particles are about 2 cm, as shown in figure 1.

Figure 1: View of composite samples with different percentages of straw

The samples presented in Figure1 were prepared by mixing clay with straw using an aggregate water ratio (W/g) of 0.23. The introduction of the fibers was carried out by the mass fraction ϕ_m of 2%, 3%, 4% and 5% relative to the initial mass of unfired clay. The samples were prepared in a mold which dimensions are 100×100×22 mm^3. After, the samples have been prepared, it were then dried in an oven at a temperature of 60°C according to the standard NF P 75-101 to remove the existing water. The daily bulk mass measurement was done until getting a constant mass, then the samples were placed in plastic bags to eliminate any kind of moisture absorption. From the knowledge of the dimensions and masses of the dry samples, we can easily determine their apparent densities which are presented in Table 2 which shows that the addition of straw fibers on the clay decreases de density of the composite material and make it lighter.

Table 1. chemical composition of straw fibers

Cellulose	Hemicellulose	Lignine	proteine	Cinder
40,8 %	31,7 %	10 %	2,4 %	5,9 %

Table 2. Density of different samples composites used

Samples	E1	E2	E3	E4	E5
Density (kg/m^3)	1985,18	1827,58	1760,85	1619,55	1544,98
ϕ_m (%)	0	2	3	4	5

3. Characterization methods

3.1. Thermal conductivity (λ)

The measurement of thermal conductivity was based on the use of the hot plate method in the steady state regime as shown in figure 1a. This method is based on the temperature measurements at the center of heating element