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Thermo-physical analysis of low-cost ecological composites for building construction

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Abstract

The building sector is one of the highest energy consumers in the world, driving the scientific community to find different alternatives for solving the problem. The choice of suitable materials represents a considerable challenge for enhancing thermal comfort in buildings. In the present study, new composite samples based on locally available materials are manufactured and experimentally evaluated in order to obtain low-cost ecological materials with better thermo-physical properties. The composites are intended to be used in building walls. They are mainly cement-stabilized red clays (CSRC) with incorporation of different kind of natural and industrial insulators. Red clay is presented as material with high thermal performance. Natural wastes are of great importance owing to their low-cost and environment-friendly nature. Thermal conductivity and thermal diffusivity measurements are carried out using Hot Disk thermal analyzer. Combined with the density data, thermal capacity is calculated. The results of the investigation show that the thermal performance of a building material can be improved by using red clay as basic material instead of sand, and incorporating thermal insulators. The thermal conductivity of cement-stabilized sand (0.934 W/m.K) is greater than cement-stabilized clay (0.591 W/m.K), which becomes lower when incorporating polystyrene (0.591 W/m.K). The CSRC incorporating sawdust, petiole, straw, Argan shell, and palm fibers offer interesting thermal performance in comparison to ordinary concretes, with an average thermal capacity and conductivity of respectively 1120 kJ/m^3.K and 0.43 W/m.K. Additionally, it is revealed that the thermal conductivity is mostly affected by cement content, humidity and temperature. By varying the cement content of stabilized clay (from 5 to 20%), the thermal conductivity increases by about 39%. For an average water content ranging between 1.2 and 12.9%, it increases by 74%. An increase of about 10% in conductivity is recorded between room temperature and 50 °C. Finally, comparing the results, the CSRC incorporating Argan shell is considered as the best building material in this study.

Keywords : Thermal performance; Locally available materials; Composite samples; Thermo-physical properties; Cement-stabilized red clay (CSRC).

1. Introduction

The increase of energy consumption in many countries of the world propelled researchers to solve the problem of heat exchange between dwellings and environment. One third of the total energy consumption is attributed to the building sector [1,2], which is responsible for 30% of Carbone dioxide emissions. In Morocco, many regions experience larger temperature fluctuations of the outdoor space, which requires buildings heating during cold seasons and air conditioning during warm seasons in order to achieve an ambient and comfortable climate. For this purpose, the temperature must vary between 18 and 28 °C and the relative humidity between 20 and 80% [3]. In that case, a decrease of about 20% in annual energy consumption can be attained [4]. However, mechanical air-conditioning systems are simultaneously energy-intensive and eco-destructive [5].