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THERMAL ENERGY ASSESSMENT OF NEW CONSTRUCTED BIO-BASED INSULATION MATERIAL APPLIED IN BUILDINGS

by

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Abstract

The building sector is moving towards energy-efficient design "low energy consumption". The development of bio-based thermal insulation materials contributes strongly to this approach. The implantation of these materials in the new designed buildings will have an excellent impact in reducing the energy consumption and subsequently in saving the non-renewable resources depletion and in decreasing the waste generation. Some commercialized bio-based thermal insulation materials, such as industrial fibers hemp, flax, and kenaf, are currently available. Recently, many research efforts have been conducted to develop thermal insulation materials from food-crop resources such as palm date, pin apple leaves, and rice husk. However, the main challenges in this research filed are to reduce the production cost and to lower the thermal resistance of these materials.

Using thermal insulation in the building envelope can substantially reduce the building's thermal load and consequently its energy consumption. Thermal insulation materials, organic or inorganic, aim to reduce the propagation of the heat by a combined heat transfer (i.e., conduction, convection, and radiation). Many new advanced insulation materials have been recently developed. However, most of these materials are not eco-friendly and their production requires substantial amount of energy and complex manufacturing processes.

UAE is one of the highest per capita consumers of rice in the world. Statistics released by Dubai states that around 772 million kilos of rice were imported in the UAE in 2013, about 40% of this amount is disposed of yearly. Rice can be reused in a more environmentally and beneficially scheme. In this research, the energy performance of a new bio-insulation material prepared from rice will be evaluated. Focusing on its physical and thermal properties such as thermal conductivity and fair reaction evaluation as a small-scale laboratory test in order to identify its potential use.

The developed insulation sample has been made by heating a fixed quantity of rice grains in a sealed chamber at high applied temperature and pressure to have the maximum expansion of the grains. The puffed rice sample properties are different than the raw grain and characterized by its ability to be formed as the shape of the mold used. It has a smooth surface, high porosity between molecules, and high interfacial areas. Different thicknesses ranging from 4 to 12 mm per layer can be fabricated by applying deferent rice sample weight, temperature, and moisture content to the raw material.

Initially, a set of screening experiments were carried out to reveal the best rice type and the direction of the optimal domain of the other parameters. One factor at a time was employed in the screening step to determine the significant factors affecting the sample thickness, sample shape, surface smoothness, and puffing ratio. In terms of puffing ability, the short grains showed a superior performance at different levels including the puffing ratio, sample thickness, sample circular shape and surface smoothness. Thus, the material optimization has been continued using the short rice grain.

The three major factors which affect the puffing ability and thermal conductivity of the insulation sample material production were sample weight, temperature, and moisture ratio. These factors were operated in the range of 15-18 g, 260-270 oC and 12-15 % respectively. Using Response surface Methodology (RSM) in Minitab 17.0 application, a total of 15 runs for optimizing the three individual parameters in the central composite design (CCD) were undertaken to estimate the minimum ratio of the required response. The best-characterized sample was 12 mm in thickness with an 8×8 cm cycle shape, 0.04971 W/(mk) thermal conductivity value, and V1 fire reaction classification.

A comparison between the developed bio-based insulation material and the common insulation material used in the UAE building sector mainly polystyrene was introduced. The new bio-based insulation material component gives a big distinction as it is cheap with huge commercialization potential, environmentally friendly, magnificent stability under fire, no toxic gas emission, and similar thermal performance of the common insulation materials. These advantages make our developed bio-based insulation material a strong competitor in the thermal insulation market.

Keywords: Building insulation, Thermal conductivity, Sustainability, Bio-based insulation, Energy consumption.