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Thermal transport in: Building materials

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ABSTRACT

Building materials, have recently been demonstrated to have great potential for improving the heat transfer properties of solids. Building materials play different roles in construction industry and they should have suitable characteristic behaviors. Several characteristic behaviors of building materials have been identified, including thermal conductivity, heat flux and emissivity constant effects. This paper reviews the new approaches of building materials (such as Aluminum, Brick, Ceramic, Cement, Concrete, Glass, Marble, Plaster, and Granite) for thermal transport and other properties associated with them and in the following it discusses and classifies the nonthermal and thermal properties of building materials. At the end, this review points out several important clues in future issues.

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1. Introduction

One important element in the concept of sustainable building is the use of materials. The higher the use of sustainable materials in building, the more sustained the building is. Rational selection of building materials for their optimal performance and minimal environmental impact is complex, as materials are multi-functional [1,2]. Development of new and innovative materials to meet the ever increasing demand of construction industry without compromising sustainability has always been a challenge for civil or construction engineers [3]. In the following, we discuss the building material studies and their synthesis in regard to thermal transport, saving energy, strength and stability. Then we speak about interfacial thermal resistance and heat transfer. In Section 2, we review the new experimental studies of building materials (such as Aluminum, Brick, Ceramic, Cement, Concrete, Glass, Marble, Plaster, and Granite) and the importance of another properties on building materials. In Section 3, thermal properties in building materials have been reviewed. In Section 4, we conclude thermal transport along with other mechanisms in mentioned building materials by identifying outstanding and key studies that still need to be done, and in Section 5 we present an outlook and our perspective on the future directions of materials of the buildings research.

1.1. Building material studies in construction industry

Multiple problems arise from poorly insulated properties, and the twin foci regards the performance of residential external wall insulation [4]. Most of the building codes for energy saving are focused on strengthening the insulation and air tightness of the building envelope. Insulation and air tightness of the building envelope reduces heat loss during the heating season, but can lead to overheating in the cooling season according to the building types owing to the internal heat gain levels. Less total energy was required for heating and cooling by enforcing the insulation level in buildings with low internal heat gain levels, while more energy was required in large office buildings with high internal heat gain levels. According to the studies, annual cooling energy consumption has increased as the thermal insulation has improved regardless of the indoor thermal density. As expected, the annual heating energy consumption has decreased with increasing strength of the thermal insulation in all cases. Thus, the current policy of strengthening the thermal insulation of the envelope effectively improves the energy consumption during heating in building. The annual energy consumption for cooling and heating has decreased proportionally when the U-value (one of the envelope thermal insulation properties) of the building envelope is small and the internal heat gain is less than 38.2 W/m^2 [5].

Numerous theoretical and experimental studies have shown that composite materials are good thermal insulators with thermal conductivity less than 0.5 W/m.K, which depends on the straw amount. Even less than 0.5 wt% straw reflects on the insulating properties by decreasing the thermal conductivity coefficient with nearly 50% [6]. Experiments of heat transfer on brick consist of time that is needed for heat transfer and thermal conductivity test as well. Experiments were conducted on a wall coated by Phase Change Material (PCM) which was exposed on a day and night cycle to analyze the heat storage and heat release. PCM used in these experiments was coconut oil. The use of encapsulation on an empty brick can increase the time of thermal heat transfer. Thermal conductivity values of a brick containing encapsulated PCM was lower than hollow bricks, where each value was 1.3 W/m.K and 1.6 W/m.K [7]. Physical processes occurring during time-dependent phase change heat transfer in PCMs and PCM-incorporated element that has been numerically modeled using COMSOL Multiphysics. The numerical analysis showed that all three PCM-enhanced building elements, incorporating 5% by weight PCM, 10% by weight PCM, and 20% by weight PCM, reduced the impact of the diurnal temperature variation in the interior spaces of the building elements in comparison to the reference plaster building element [8].

A building envelope is made-up of several individual elements such as brick, mortar, surface finishes, external coatings, etc. It acts as an interface separating the external environment from the indoors environment. That is responsible for regulating indoor thermal comfort in response to external climatic conditions. The heat transfer through the material is a combination of conductive, convective and radiative heat transfer components. A schematic representation of the heat transfer mechanism through the porous building-material microstructure is shown in Fig. 1. Conduction involves heat transfer through excitation of atoms, while convection involves heat transfer through molecule movement induced by differential temperature variation; radiative heat transfer involves heat-transfer through electromagnetic energy [9].

Heat transfer through porous material mainly depends on the material forming constituents (type of particle, shape, size and particle structuring) and their microstructure (pore structure). Building material configurations to form the building envelope can be altered by appropriately arranging the materials to obtain the required performance. Building materials properties that are easily alterable (packing density, composition and mix-proportions) are distinct from those that are unalterable (micro-pore size and geometry, inherent mineral property) [9]. Also heat transfer depends on the geometry of the material specimen and the fatigue tester as well as on material boundary conditions such as concrete [10].

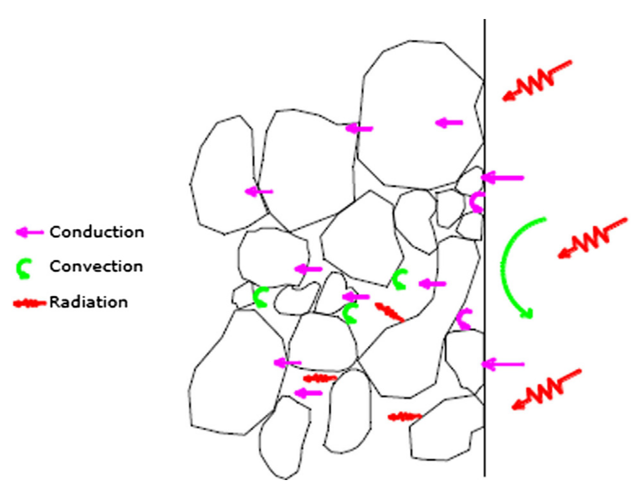

Fig. 1. Heat transfer mechanisms through the porous building material [9].

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