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Performance assessment of sustainable composite roofing assemblies using experimentation

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Abstract

Over the hot climatic zones where the exposed building roofs impart significant heat gain in the buildings can be protected using reflecting and insulating materials as a retrofitting solution. The present paper elaborates application of sustainable reflecting-cum-insulating (R-I) materials over the flat concrete roof surface for reducing the impact of heat gain inside the buildings. The composite R-I assemblies used for thermal performance assessment include aluminum sheet, broken glazed tiles, expanded polystyrene (construction waste), sawdust (industrial waste), mineral fiber board (recycled content 38%) and false ceiling panels (recycled content 90%). These materials were placed in two different combinations as a composite heat barrier assembly for exposed concrete roof of the two model rooms in an educational building over the considered geographic location. In comparison to the untreated concrete slab, the applied composite R-I assemblies resulted in an overall increase in thermal resistance of the first and second assembly by 1.9 and 3.9 times respectively. Over a period of a year under experimentation, the first and second retrofitted assembly resulted in 6% and 19% reduction in surface temperature respectively. The considered R-I materials for the experimentation have proved to be thermally efficient, lighter and cost effective solution for energy conservation inside the buildings. The R-I product can further be applied on larger roof areas by the designers to reduce the cooling load of the built environment as well as to increase the occupants comfort over the local climatic zone.

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Keywords: Sustainable reflecting-cum-insulating (R-I) assembly; concrete roof; temperature; thermal resistance

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1. Introduction

Thermal insulation plays significant role in reducing cooling requirement inside a building in hot climate. In a typical commercial establishment, the space conditioning accounts for 50-70% of the total energy used [1]. The construction practices adopted mainly involve concrete as the roofing element which is noted for its high thermal conductivity. The exposed roof surfaces absorb solar heat that will input continuous heat inside the building and will add to the cooling load. Thermal barrier for building roof is generally installed either as over or under deck insulation. Al-Homoud (2005) presented an overview of the basic principles of thermal insulation along with detailed investigations on the most commonly used building insulation materials and their performance characteristics [2]. Alvarado et al. (2009) investigated the thermal effects of newly designed passive cooling systems on concrete roofs in existing buildings. Commercially available materials such as aluminum-1100 and galvanized steel were used as radiation reflectors; and polyurethane, polystyrene, polyethylene, and an air gap was used as insulation [3]. Double envelope roof constructions were investigated either as a preheating system of the external air [4] or as a double shell system in tilted roofs. In this case, ambient air passes through the air gap that incorporates a wet surface into its lower part, becomes cooler through evaporation and thus, lowers the surface temperature of the internal part of the roof [5]. Heat-insulating materials provided an effective means of reducing the apparent density and improving the refractory properties of manufactured components. Materials of natural occurrence viz., vermiculite, diatomite, infusorial earth, perlite, as well as synthetic materials - hollow microspheres obtained by sputtering of high-melting oxides such as Al_2O_3, mullite, and spinel were used as porous fillers [6-9]. However, the hollow spheres are costly products and are normally used to fabricate special high-temperature heat insulators [10]. Al-Malah *et al.* (2007) focused on the formulation of polyester–clay composite as an insulating material that gives the best thermal and mechanical properties [11]. Korjenic *et al.* (2011) developed, optimized, and observed the behavior of thermally insulating materials composed of renewable raw material resources originating from agricultural sources [12]. Hasegawa and Konna (2001) carried out an analysis on the thermal effect of the rooftop spraying system on slant roof [13]. Tanabe *et al.* (2000) had done a field study on a rooftop spraying system. The effect of roof spraying contributed to room temperature reduction in the summer season [14]. Ishihara *et al.* (1996) carried out an experimental study on thermal characteristics and water performance of rooftop lawn [15]. Hoyano *et al*. (2000) clarified the indoor thermal control effect of rooftop lawn planting with thin soil layer on a wooden building [16]. Al-Sanea (2002) evaluated and compared the thermal performance of building roof elements subject to steady periodic changes in ambient temperature, solar radiation and nonlinear radiation exchange. An implicit, control volume finite-difference method was developed and applied for six variants of a typical roof structure used in the construction of buildings in Saudi Arabia [17]. Tsang & Jim (2011) developed a theoretical basis of green roof thermal performance and applied theoretical calculations to estimate the effectiveness of green roof thermal performance and associated energy saving [18]. From the reviewed literature, it is significant that the substantial amount of energy is consumed for the space conditioning. It was also observed that the appropriate design of thermal barrier over the roof surfaces plays a significant role to improve the thermal performance inside the buildings. Application of appropriate, reflecting-cum-insulating material either over or under the roof slab is an effective solution to conserve the energy and the cost of operation (cooling load) as well. A very little research had revealed the application of sustainable materials for the reduction of overheating of the buildings. The present paper focuses on analyzing the behavior of roof surface temperature due to application of sustainable composite roofing assemblies for reducing cooling load of the built environment by experimentation. The techno-economic feasibility of considered composite roofing assemblies is also carried out**.**

2. Methodology

In order to assess the performance of considered sustainable composite roofing assemblies the following stepwise methodology was adopted.

- The ambient temperature data over the specific geographic location was collected for the study of temperature variations.
- The volume of the built room under the study was estimated.
- Locally available low cost, sustainable materials were identified.