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Experimental evaluation of insulation material in roofing system under tropical climate

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Abstract

The objective of this study is to determine the influence of radiant barriers on conductive and radiative heat transfers when they are integrated to a building envelope and to compare their efficiency to traditional insulation material (mineral wools, polystyrene). It is also about determining which insulation material and process can lead to a better heat flux reduction through a building roof. For this study four identical small-scale test cells were used. Their respective roof was equipped with the insulation material to be tested: One with polystyrene, the second with a radiant barrier the third one with fibber glass and the last one with no insulation material was considered as the reference cell. Different test were performed with a view to evaluate the influence of parameters such as roof absorptivity and roof air layer ventilation on the heat flux reduction through the roof. With the measured temperature, the conductive and radiative heat fluxes were calculated. With a white corrugated iron roof top the heat flux reduction provided by the radiant barrier is 37%. With a black one this material allows a reduction of 33%. It is shown that whatever the roof absorptivity value, the radiative heat flux is predominant over the conductive one. With no ventilation, the radiant barrier is comparable to polystyrene and fiber glass; when the airspace is ventilated the radiant barrier provides a better insulation.

Keywords: Insulation; Radiant barrier; Polystyrene; Heat transfer reduction; Comparison

1. Introduction

In summer minimization of solar loads through a building envelope is primordial. Sixty percent of the thermal transfer occurs in the roof. Thermal insulation of this component is of the utmost importance (Abdessalam et al., 1998; Garde, 1997).

Materials frequently used for building insulation are chosen for their low thermal conductivity and their ability to block the conductive heat flux (Hasan and Sancaktar, 1998; Ulgen, 2002). Materials having high reflectance are also used. They are made of aluminium foil combined with different layers of thin materials and are called Radiant Barriers. They cannot be characterized by a thermal resistance (Fairey, 1982). Radiant Barriers have received increased attention during the past years because of their ability to reflect the infrared radiation (Moujaes, 1996; Al Asmar et al., 1999). They are commonly used in attics to reduce

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Nomenclature

a	thermal diffusivity ($a = \frac{\lambda}{\rho C_p}$), $m^2\,s^{-1}$
B	bubble pack
C_p	specific heat at constant pressure, $J\,kg^{-1}\,K^{-1}$
NV	nonventilated
q	total heat flux through the roof, $W\,m^{-2}$
q_{ref}	total heat flux in the reference cell, $W\,m^{-2}$
q_{rad}	radiative heat flux, $W\,m^{-2}$
q_{cond}	conductive heat flux, $W\,m^{-2}$
q_{c1}	cConductive heat flux at surface 1, $W\,m^{-2}$
q_{c2}	conductive heat flux at surface 2, $W\,m^{-2}$
RB	Radiant barrier
T_1	roof top temperature, K
T_2	roof deck temperature, K
T_0	initial temperature, K
V	Ventilated

Greek symbols

λ	thermal conductivity, $W\,m^{-1}\,K^{-1}$
ε	thermal emissivity
φ	radiative heat flux density
α	surface absorptivity
σ	Stefan Boltzman constant, $5.67 \times 10^{-8}\,W\,K^{-4}\,m^{-2}$

the radiant heat transfer that occurs between the roof deck and attic floor of a residence or commercial buildings (Winiarski and O'Neal, 1996). In an attic, the radiant barriers can be located on top of ceiling insulation or underneath rafters. These products, placed in an attic, are a well documented means to reduce heat transfer through the ceiling (Hall, 1988; Medina, 2000).

In Guadeloupean building the insulation material is placed in the roof airspace, between the corrugated iron roof top and the roof deck. Polystyrene and fiber glass are mostly used. Radiant barriers have been used for a few years, in the above described configuration. However their effectiveness in reducing the heat flow through the ceiling has not been shown in such a configuration. Indeed the roof airspace is only 4.5 cm, and the dust accumulation may be important, particularly in tropical humid climate (Soubdhan et al., 2003). This study was conducted to answer two questions:

- Are the radiant barriers efficient in reducing heat flow in the way they are used in Guadeloupe?
- Out of polystyrene, fiber glass and radiant barrier, which one is the best insulation material to be used under tropical humid climate?

2. Methods

2.1. Experimental apparatus

Four identical small-scale test cells were used. They were exposed simultaneously to allow comparison between different insulation materials. Their respective roofs were equipped with the insulation material to be tested: One with polystyrene was called CP, the second with a radiant barrier was called CRB, the third one with fiber glass was called CF and the last one with no insulation material, considered as the reference cell, was called C0. (Fig. 1 shows the different roofs).

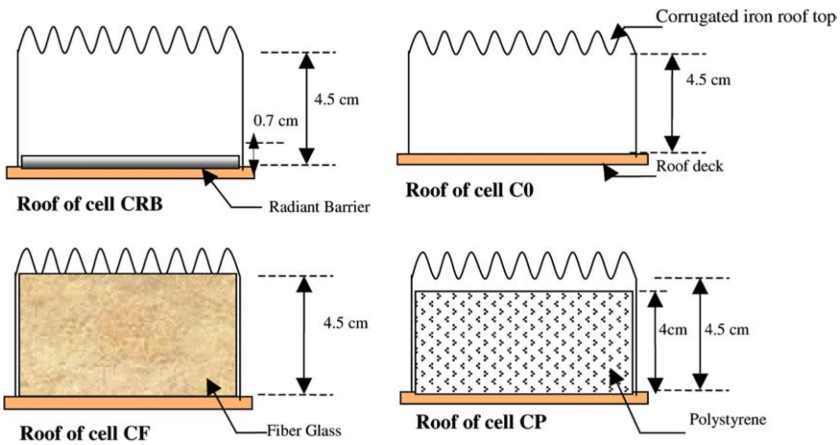

Fig. 1. Schematics of the four roof systems under test.