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ScienceDirect

Energy Procedia 139 (2017) 92–97

Energy Procedia

www.elsevier.com/locate/procedia

International Conference On Materials And Energy 2015, ICOME 15, 19-22 May 2015, Tetouan, Morocco, and the International Conference On Materials And Energy 2016, ICOME 16, 17-20 May 2016, La Rochelle, France

Thermal behavior in dynamic regime of a multilayer roof provided with two phase change materials in the case of a local conditioned

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Abstract

Phase change materials (PCMs) inserted into walls and roofs of the premises; is one of the solutions to reduce the effect of external climatic conditions and energy consumption. This work is intended to compare the thermal behavior of two roofs types of local conditioned located in the cities of Casablanca and Ouarzazate. The first roof taken as a reference is constituted by the conventional building materials. In the second, two phase change materials are inserted in several combinations. The comparative study is performed using a numerical code developed and successfully validated. Comparison criterion between the reference roof and that provided with phase change materials is the annual heat flux density transmitted to the local conditioned. The simulation results show that insertion of phase change materials within the reference roof is favorable. The reduction of energy consumption in the room conditioned depends on the choice of the PCMs inserted and the temperature of the conditioned room.

Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016.

Keywords: Thermal comfort; Energy consumption; Multi-layer's roof; Phase Change Materials.

1. Introduction

Use of phase change materials (PCMs) within the walls and roofs of the premises is one of the solutions to reduce the effect of external climatic conditions and the energy consumption of buildings. This is due to the storage of heat energy by sensible and latent heat. The high energy storage density involved, makes phase change materials very used in several applications [1-3]. The evaluation of the thermal performance of roofs including PCM is performed

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1876-6102
Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016
10.1016/j.egypro.2017.11.179

for periodic external climatic conditions, according to the choice of building materials and the level of internal thermal comfort [4, 5].

As roof with a single Phase change material does not ensure good climate conditions inside room for the whole year [5], it is necessary to introduce a second PCM for thermal comfort for each month of the year. Several cases of roof are resulting by the insertion of two phase change materials within the reference roof. Based on the study [6], the best configuration of roof provided with two phase change materials is retained in this paper. The purpose is to determine the effect of phase change material insertion within building roofs by a comparative study between two kinds of roofs. The first roof, taken as reference is constituted by usual building materials. Inside the second, two different phase change materials are inserted according combinations of several PCMs within referential roof layers. The roofs have the same thickness and are treated under the same internal and external thermal conditions relating to cities of Casablanca and Ouarzazate.

The criterion of this comparative study is the required energy to maintain the constant indoor air temperature. Numerical simulation of annual energy consumption should allow determining the best combination of phase change materials for the two cities.

Nomenclature

I_s Solar radiation (W/m²)
T Temperature (K)
x Position within layer (m)
c Specific heat ($J.kg^{-1}K^{-1}$)
k Thermal Conductivity (W/m K)
h Convective heat transfer coefficient ($W.K^{-1}m^{-2}$).
L Roof thickness (m)
f Liquid fraction of phase change material
α Thermal diffusivity (m²/s)
λ_f Latent heat of fusion (J/Kg)
ω Pulsation (Rad/s)
ε Solar absorptivity
τ Dimensionless time
Indices
o/i Outside /Inside
m Melting

2. Analysis and mathematical model

The first roof taken as reference is composed by a multilayer structure: cement rendering, concrete and plaster with thickness respectively: $e_{cr} = 5cm$, $e_c = 20cm$ and $e_p = 5cm$. The second roof provided with phase change materials has the same thickness $L = 30cm$. The insertion of PCMs having the same thickness (3cm) is performed of either side of the concrete whose thickness is maintained the same. The external surface of the two roofs is exposed to solar radiation (I_s) in addition to heat transfer by convection (h_o), and a radiation exchange (R_{ES}). The interior surface of the roofs is in contact with a supposed local conditioned. The study relates to the cities of Casablanca (33˚32'N latitude, longitude 7˚41'W) and Ouarzazate (30˚93'N latitude, longitude 6˚9'O).

To determine the numerical model, it is necessary to take some assumptions in order to develop the study of the problem. The heat transfer within roof is considered unsteady and one dimensional according to x direction. The indoor environment is considered always kept at a constant temperature. The effect of natural convection in PCM liquid phase is neglected due to the small form factor [7, 8]. The volume expansion is disregarded in the phase