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The effect of mineral micro particle in coating on energy consumption reduction and thermal comfort in a room with a radiation cooling panel in different climates

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ABSTRACT

Using of mineral particles in coatings and insulators to reduce thermal dissipation through the walls of buildings is one of the great importance and is of especial significance. It is recently attached to paints containing mineral micro particles as thermal insulation in order to prevent loss of energy in various industries and buildings. In the present work, in order to investigate the flow field, temperature distribution and heat transfer in a room with a radiation cooling panel, a three-dimensional enclosure is simulated under various boundary conditions. The effect of using a coating containing mineral micro particles in lieu of regular acrylic paint, on temperature distribution and heat transfer is studied in various states and under different climatic conditions and the results are compared. It was observed that coatings containing mineral micro particles act as thermal insulation and reduce energy consumption by about 20%. Besides, using of cooling panels to provide the cooling load, along with using of mineral micro particles in external walls, gives better results for hot and dry and hot and humid weather conditions.

1. Introduction

Today, energy is one of the most important economic indicators and its supply is one of the vital tools of governments. Nowadays, due to the decrease in energy supplies and increase in costs of energy consumption, the optimization of energy consumption and reduction of its losses are of crucial importance. We can insulate buildings using glass wool with a layer of paper or foil, boards or sheets of foam, rubber and paints with mineral insulating to create a radiation heat barrier, which is the latest method of insulation [1]. One of the major steps towards saving energy in buildings is to consider suitable materials such as tiles, curtains and coatings with mineral particles as a measure to reduce the cooling load [2]. Among other effective actions, we can mention use of mineral insulators in the walls of buildings. Lee has shown that with the outside and inside temperatures of the room being at 0 and 20 °C, respectively, use of these insulators reduces the energy consumption by more than 12% [3]. Hui et al. have obtained a temperature difference of about 4.7 °C between a wall with ceramic particles coatings and a wall without such coating [4]. Wang et al., by simulation of reflective mineral coatings, have reported reduction in heating and cooling loads in various climates [5]. Synnefa et al. have demonstrated that ceramic additives lower the emissivity and lead to a significant decrease in heat loss [6]. Cao et al. have studied the thermal properties of ceramic insulators. They have shown that these particles have a higher resistance to oxidation, corrosion and wear in comparison with other paint coatings [7]. In addition, Paul's studies on use of ceramic particles in paints show that they can reduce the energy consumption by up to 50% [8]. Azemati et al. have shown that coatings with mineral particles reduce the energy consumption by about 17% [9]. Niu et al. have demonstrated that ceiling radiation cooling panels have good performance in hot and humid regions. They have shown that in countries where the dew point temperature is most of the time above 22 °F and the summer is always hot and humid, use of ceiling cooling panels combined with desiccant cooling systems reduces the initial energy consumption by 44% compared to the traditional convective cooling systems [10]. Various investigations and studies by Murakami et al. including the installation of a cooling panel in a vertical plane in an office have shown that this system can serve as a desiccant system as well

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A	Area (m^2)
b	Wall thickness (m)
$F_{i\text{-}k}$	Radiation view factor for surface i seeing surface k
h	Convective heat transfer coefficient ($W/m^2\,^\circ K$)
g	Acceleration of gravity (m/s^2)
K	Thermal conductivity ($W/m\,^\circ K$)
Q	Rate of heat transfer (W)
q''	Rate of heat transfer per unit area (W/m^2)
Re	Reynolds number
C_p	Specific heat capacity ($J/kg\,^\circ K$)
RH	Relative humidity percentage
T_{air}	Inside air temperature (°C)
T_{out}	Outside air temperature (°C)
T_i	Inner wall temperature (°C)
α	Absorptance
ε	Emissivity
σ	Stefan–Boltzmann constant
ρ	Air density (kg/m^3)
μ	Dynamic viscosity (kg/m s)

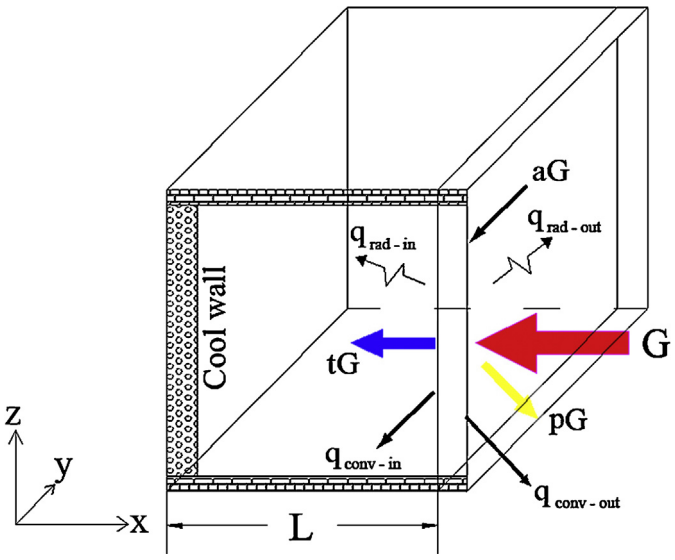

Fig. 1. Flow geometry and solution field.

as a system to reduce the energy consumption, since the surface temperature of the cooling panel can be controlled below the dew point [11]. Khorasanizadeh et al. have numerically studied the flow field and temperature distribution in a room with radiation cooling panels. They have shown that wall cooling panels give better comfort than ceiling cooling panels and reduce the energy consumption as well. They have also shown that in the cooling system with radiation panel, the contribution of radiation heat transfer is more than convective heat transfer thus, the comfort conditions in the room, from the air velocity point of view, are better than those with convection-based methods [12].

We can observe that some investigations are done in recent years by using cooling panels, most of which deal with their performance in such matters as provision of thermal comfort, cooling capacity enhancement, energy consumption reduction and heat transfer subjects. In the present study, the effects of mineral particles which coated on the walls, on the energy consumption reduction and supply of suitable thermal comfort in various climates by three-dimensional numerical simulation of a building space with radiation cooling are investigated.

2. Problem definition and governing equations

The intended model is a room of $3 \times 3 \times 3$ m (Fig. 1), assumed to be in contact with the ground from the bottom, and with the outside air from the other sides. The materials used in the walls, ceiling, and floor of the model are given in Figs. 2–4.

To model and study the thermal comfort, it is necessary to calculate first the temperature of the internal surfaces. To do this, by performing an energy balance for each surface of the model, we

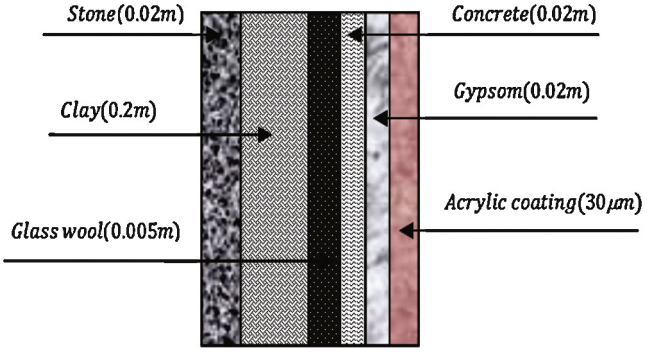

Fig. 2. Details of the wall.

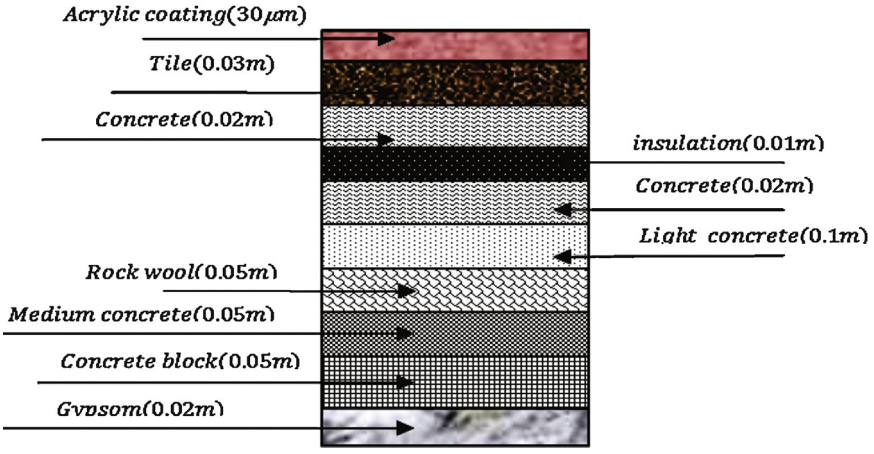

Fig. 3. Details of the ceiling.