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Experimental investigation of phase change materials for insulation of residential buildings

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ABSTRACT

In this paper, an experimental study has been conducted for using PCM as thermal insulation materials by its incorporating with layers of the walls and the ceiling. The effect of PCM and its role in improvement of thermal performance and thermal comfort is experimentally studied. Two room's models have been built, the first model is a standard room for comparison and the second model is an experimental room for testing. Wasit university in Kut city, (32.5° N) latitude, was the place of the building models and testing of PCM. The type of PCM which was used in this experiment is paraffin wax with a melting point (44 °C). Many cases were studied according to the thickness of the PCM and according to the orientation (North wall, South wall, East wall, West wall, and ceiling). Results obtained showed a reduction in indoor temperature of the zone and the reduction in cooling load and as a result saving in electricity consumption with using PCM as insulation materials.

1. Introduction

The apportionment of thermal mass inside buildings is the consequence of constitutional and architectural resolutions and can highly affect how the building interacts to internal heat gains, solar radiation or changes in outdoor conditions. Lightweight components interact readily to changes in interior gains and solar radiation. The conventional approaches employ enormous components to temperate temperature inconstancy. Thermo-physical properties of the construction materials will have a direct effect on energy consumption of the building. Within a negative solar purpose, the heat capacity of the internal wall layer is governing. This approach it applicable in sites that have an efficacious daily temperature variance, else that, heavy weight building can give rise to problems of excrescent thermal mass and cost.

The nature of Iraq's climate can be described in two basic seasons, hot dry and long summer, and cold short winter. The difference of daily range temperature is limited and causes the assemblage of heat in the building layers.

The consumption of electrical demand is increasing, especially in hot regions due to using the cooling system where the consumption of electric energy in the building sector in Iraq reach about 38% of the total energy which is produced, where in 2020 it will be built more than six million building unit and this will increase in electric demand.

The phase change materials and its using in the building material considers one of methods to improve the thermal properties of the construction material where integrate these PCM with layers of the building material play important role in shifting the cooling load especially in peak load and Contributes to reducing cooling load. In this research, we will study experimentally integrate the PCM with layers of local construction material in Kut city in Iraq.

In the field of using the PCM as insulation materials and it's incorporating with building materials there are many experimental and numerical studies were conducted.

Halford and Boehm (2007) conducted simulation of using encapsulated PCM to shift cooling load. They used encapsulated PCM in ceiling and walls and incorporated the PCM with construction materials like concrete and gypsum wallboard. They used TRANSYS program software to simulate. By comparting their results with other cases without PCM, they found 11–25% reduction in peak load compared with the case without PCM. Muruganantham (2010) conducted experimental and numerical studying about using BIOPCM in envelope building, ceiling and the walls. He used energy plus program in simulation. the layers of the wall were, from outside to inside, sliding door, insulation, BIOPCM and gypsum board as well as wood frame at two sides. BIOPCM was as small block. He made sheds contain door and window and conducted comparison between these sheds. The dimensions of the shed were (4.876 m length, 3.657 m width and 2.436 m height). He used wood frame to install BIOPCM. The melting range of the PCM was (27–31 °C). He found that maximum energy saving about 30%, and maximum cost saving was 30%. Al-Hadithi (2011) studied

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Nomenclature

Amb,T	Ambient air temperature (°C)
A	Surface area (m^2)
$CLTD_c$	Correction of cooling load temperature difference (°C)
$CLTD$	Cooling load temperature difference (°C)
$C.L.R$	Cooling load reduction (%)
$C.L_{withPCM}$	Cooling load of the room with PCM (W)
$C.L_{withoutPCM}$	Cooling load of the room without PCM (W)
DR	daily range of outdoor (°C)
F_i	Inside film resistance for envelop internal wall ($W\,m^{-2}\,K^{-1}$)
F_o	Outside film resistance for envelop internal wall ($W\,m^{-2}\,K^{-1}$)
f	Ventilation factor
K	Color correction factor
LM	Latitude and month correction factor
Q	Transfer during walls or ceiling (W)
R_T	Total Thermal Resistance ($m^2\,K\,W^{-1}$)
T_r	Indoor temperature of room (°C)
T_m	Outdoor design temperature (°C)
U	Overall heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
X	Layer thickness (m)

Greek symbols

ΔT_r	Indoor temperature difference (°C)
λ	Thermal conductivity ($W\,m^{-1}\,K^{-1}$)

Abbreviations

BIOPCM	Bio phase change material
Exp	Experimental
PCM	Phase change material

numerical method of the effect of using PCM on heat transfer in the wall. He mixed paraffin wax (25%) with concrete (75%) to create treat wall. Layers of the wall were, from external to internal, cement 5 mm, and treat wall 20 mm, brick 300 mm and gypsum 20 mm. The treated wall was west wall. He compared between treat wall and no treat wall and his results showed that treat wall reduced heat transfer by 66%. Zalewski, Joulin, Lassue, Dutil, and Rousse (2011) studied experimentally integrating phase change material in small scale composite trombe solar wall. They used the PCM in the buildings for heating purposes where the PCM works as storage material. The PCM was mixed from hydrated salats (chliarolithe ($CaCl_2{\cdot}6H_2O$) + potassium chlorides (KCl) + additives) and the melting temperature of the PCM was 27 °C. They inserted the PCM in the wall as a brick-shaped package. They replaced the PCM instant of the slab concrete in solar wall. They concluded that use the PCM was faster than the concrete slab and the interaction was 2.5 times with the knowledge that the PCM mass less than mass of concrete slab by six times. Also, they concluded that efficiency of solar wall with use the PCM was 30%. Madhumathi and Sundarraja (2012) proved experimentally of using the PCM with traditional construction materials in hot climatic zones to reduce the cooling load and air room temperature. They used organic phase change materials of Polyethylene type with melting point (25 °C and 31 °C) where it is used in hollow brick. They built models, each model was 0.020317 m^3. They concluded that the using of the PCM improved thermal comfort and reduce in entering heat into room by 33.33%. Zwanzig (2012) evaluated numerically incorporating of the PCM with building material in the field of reducing of the heating load and the cooling load. He used PCM composite wallboard in the walls and the roof. He tested using PCM as insulation material in many weathers. He used model one -dimensional transient heat equation and used the Crank-Nicolson scheme to solve this equation. He used TMY3 data for creating weather data. He found the optimizing location of the PCM in layers of building is important and depended on thermal resistance of the layers between the PCM and outside boundary. He compared his results with cases without PCM and he found reducing in the cooling load from the wall by 19.7% and from the roof by 8.1% and reducing in heating load from walls by 6% and from roof by 6.4%. Monteiro da Silva and Almeida (2013) conducted simulation for using of gypsum plasterboards with micro-encapsulated PCM and macro-encapsulated PCM in family house has area 91 m^2. They used software energy plus 7.2 for simulation. The melting range of the PCM (paraffin) was (23–26 °C) and PCM (salt hydrate) was (22 °C–28 °C). The simulation was conducted in the coolest and hottest days. They integrated the PCM with the ceiling and the walls and they used three types of construction materials: concrete wall, single hollow brick and double hollow brick. They concluded that the reduction in the heating needs by 16% in coolest day and reduction in the cooling needs about 28% in hottest day and reduced 16% in the annual energy needs. Also, they found that increasing the indoor temperature by 0.7 °C in coolest day and decreasing the indoor temperature by 1.4 °C in hottest day. Mushtaq, Ahmed, and Hasanain (2013) investigated experimentally and numerically the using of the PCM in the ceiling with cooling system to cool PCM. They used two rooms with and without PCM, dimensions of the rooms were (1.8 m*1.8 m*2.44 m). The layers of the roof, from bottom to top, without PCM were (concrete 12 cm and brick mixture + mortar 10 cm) and with PCM were (concrete 12 cm, light structure panel of aluminum with PCM 2.5 cm and brick mixture

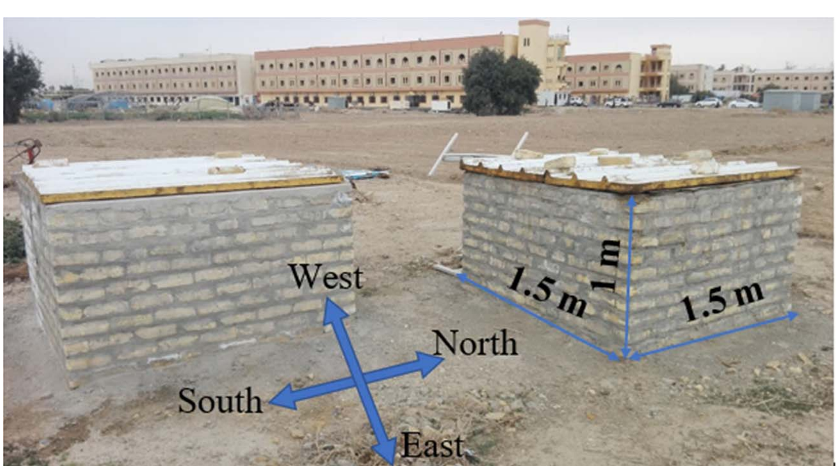

Fig. 1. Rooms Model.