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Transient Thermal Optimization of Hollow Block for Roof Slab using PCM Integration and other Efficient Infill Materials Under Real Climatic Conditions

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Abstract: This study focuses on the thermal optimization of hollow concrete blocks by incorporating different infill materials to enhance their thermal performance. A numerical model was developed to analyse transient heat transfer through hollow blocks under varying thermal conditions. The study considers different infill materials, including Phase Change Material (PCM), Expanded Polystyrene (EPS), and foamcrete. The geometry of the hollow block was modelled based on standard dimensions, and material properties were adopted from established literature. The temperature boundary conditions were established utilizing hourly climatic data for Dammam during peak summer conditions, sourced from Time and Date and employed in the transient thermal analysis. The validation of the slab panel model was conducted by comparing the numerical results with available published data to ensure accuracy and reliability. Thermal performance was evaluated using parameters such as temperature variation and heat flux.
Keywords: Thermal optimization, hollow block infill materials,PCM, Transient thermal,EPS, foamcrete

I. INTRODUCTION

People often use hollow block slabs to build homes because they are lighter and cheaper than other types of slabs. However, in hot climates, they don't always work well to keep heat out, which means more cooling is needed. To fix this, infill materials like Expanded Polystyrene (EPS), foamcrete, and Phase Change Materials (PCMs) are put inside the cavities to improve insulation and temperature control. EPS is great at stopping heat from moving, foamcrete is a light and compatible insulating option, and PCMs make thermal stability better by storing and releasing latent heat. This study conducts a comparative analysis of hollow block slabs devoid of infill, EPS, foamcrete, and PCM to evaluate temperature distribution and heat flux, with the objective of identifying an optimal and practical solution for energy-efficient construction

II. OBJECTIVE

Tostudy the thermal performance of hollow blocks without and with infill materials such as PCM, EPS and foamcrete at peak temperature of the summer day of Saudi Arabia

To study the effect of the number of cavities filled with the optimal infill material on the thermal performance of hollow blocks during nighttime conditions.

III. METHODOLOGY

The primary aim of this study is to assess and improve the thermal performance of structural components utilizing hollow blocks with various infill materials. To achieve this, models featuring diverse infill configurations, including none, EPS, foamcrete, and phase change materials (PCM), are created and their performance is evaluated. The study primarily employs ANSYS Workbench software to analyse temperature distribution and heat flux characteristics, emphasizing the enhancement of thermal efficiency and the examination of the impact of various infill materials on heat transfer behaviour.

A. Modelling of hollow block

Using ANSYS DesignModeler, a hollow masonry brick measuring 400 mm × 200 mm × 250 mm was created. It had six rectangular cavities that were evenly spaced apart, with each cavity measuring 100 mm × 55 mm and spaced 25 mm apart in the length and 30 mm apart in the width.

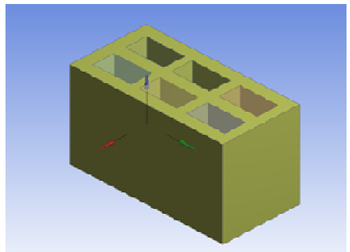

Fig. 1Modelling of hollow bricks

B. Material properties

The following material properties are adopted for this study.

Materials	Thermal properties			
	Density(kg/m³)	Thermal conductivity (W/m·K)	Specific Heat capacity(J/kg·K)	Melting Temperature(K)
concrete	1342	2.43	1040	
EPS	30	0.039	1380	
Foamcrete	400	0.076	762.5	
PCM	722	0.264	2330	304

Table. 1Material properties

C. Boundary conditions

Climatic data for Dammam (Eastern Province, Saudi Arabia) representing peak summer conditions were obtained from the Time and Date database, with hourly temperatures for 17 July 2025 used as boundary conditions for the transient thermal analysis

Time	Temperature
0.00	34°C
01.00	33°C
02:00	33°C
03:00	30°C
04:00	30°C
05:00	31°C
06:00	32°C
07:00	34°C
08:00	36°C
09:00	40°C
10:00	41°C
11:00	44°C
12:00	45°C
13:00	47°C
14:00	45°C
15:00	40°C
16:00	41°C
17:00	40°C
18:00	40°C
19:00	39°C
20:00	38°C

21:00	36°C
22:00	36°C
23:00	34°C

Table. 1Temperature Data

IV. RESULTS AND DISCUSSION

The model is subjected to transient thermal analysis. Figures 2–9 illustrate the temperature variations and heat flux distribution at the peak temperature observed at 1 PM.

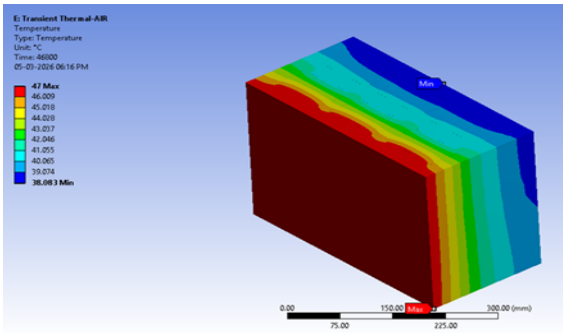

Fig. 2Temperature Variation (Without infill)

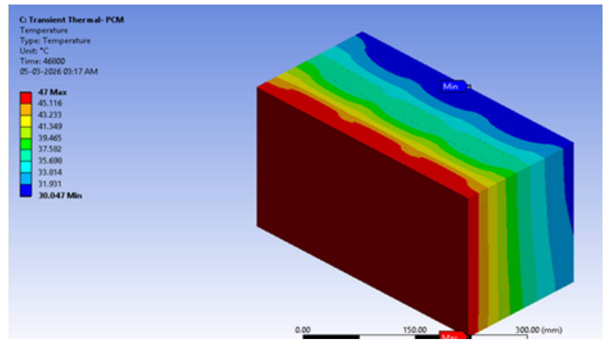

Fig. 3Temperature Variation (PCM)

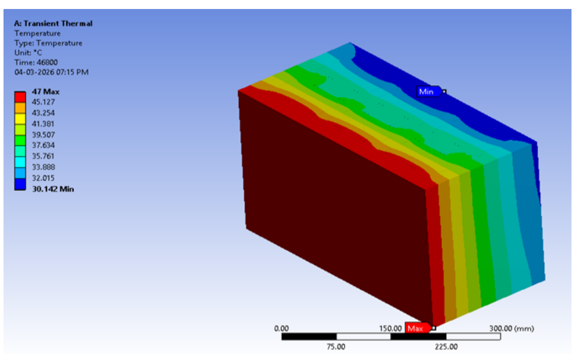

Fig. 4 Temperature Variation (EPS)

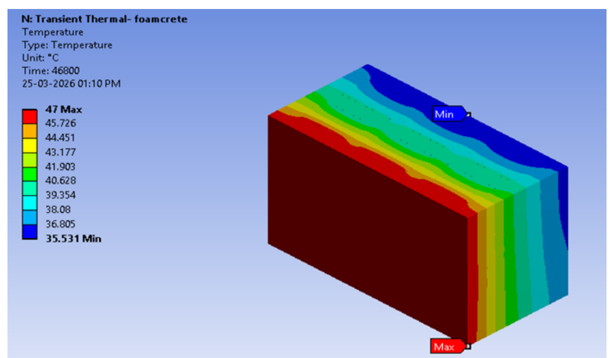

Fig. 5 Temperature Variation (Foamcrete)

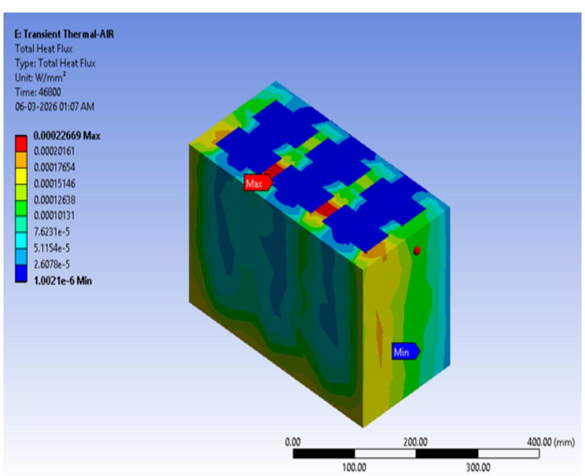

Fig. 6Heat flux distribution (Without infill)

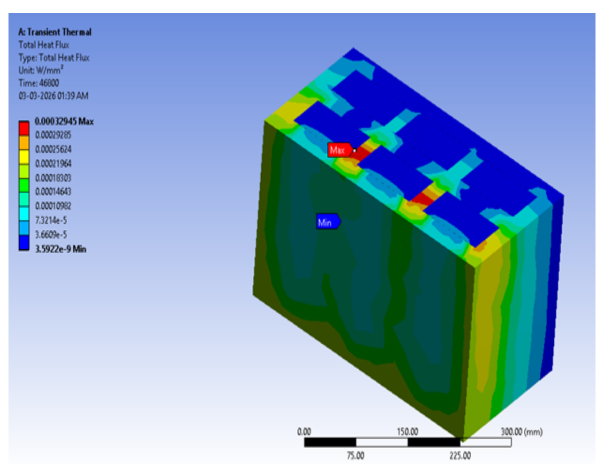

Fig. 7Heat flux distribution (PCM)

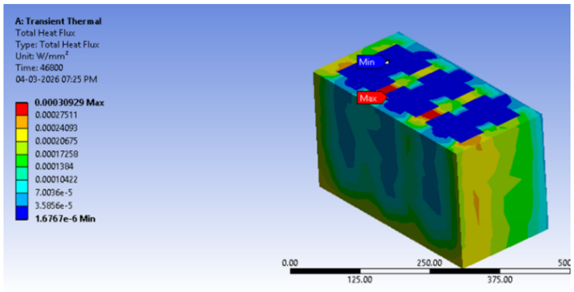

Fig. 8 Heat flux distribution (EPS)

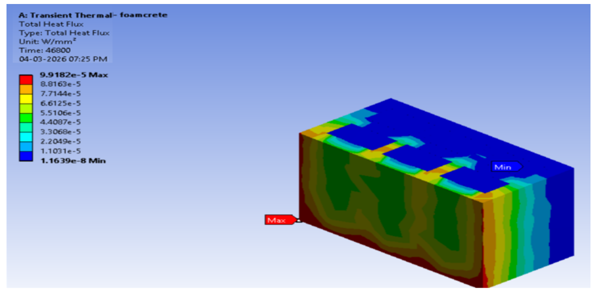

Fig. 9 Heat flux distribution (Foamcrete

Material	Temperature Variation (°C)	Heat flux distribution(W/m^2)
Without infill	38.083	1.0021
With PCM as infill	30.04	0.003592
With EPS as infill	30.142	1.6767
With Foamcrete as infill	35.531	0.01639

Table. 3Overall results

V. CONCLUSIONS

The research shows that infill materials make hollow masonry bricks work much better in terms of heat transfer when the temperature is at its highest. PCM infill lowered the peak temperature by about 21.13% and the heat flux by 99.64% compared to the unfilled brick. This is because it can store latent heat, which makes it the most efficient. EPS infill also lowered the temperature by about 20.85%, but it raised the heat flux by about 67.30%. Foamcrete infill lowered the temperature by about 6.70% and the heat flux by 98.36%.The results also show that the type of infill material and how well it stores heat have a big effect on how the brick reacts to heat. PCM effectively slows down the transfer of heat by taking in and releasing latent heat. This makes the temperature inside more stable and less likely to change. The decrement factor analysis shows that PCM does a better job of blocking heat waves than other materials. These results show how important it is to choose the right infill materials for energy-efficient building design, especially in hot weather. In general, PCM is the best material for filling in gaps in hollow masonry systems because it improves thermal comfort and reduces heat gain.

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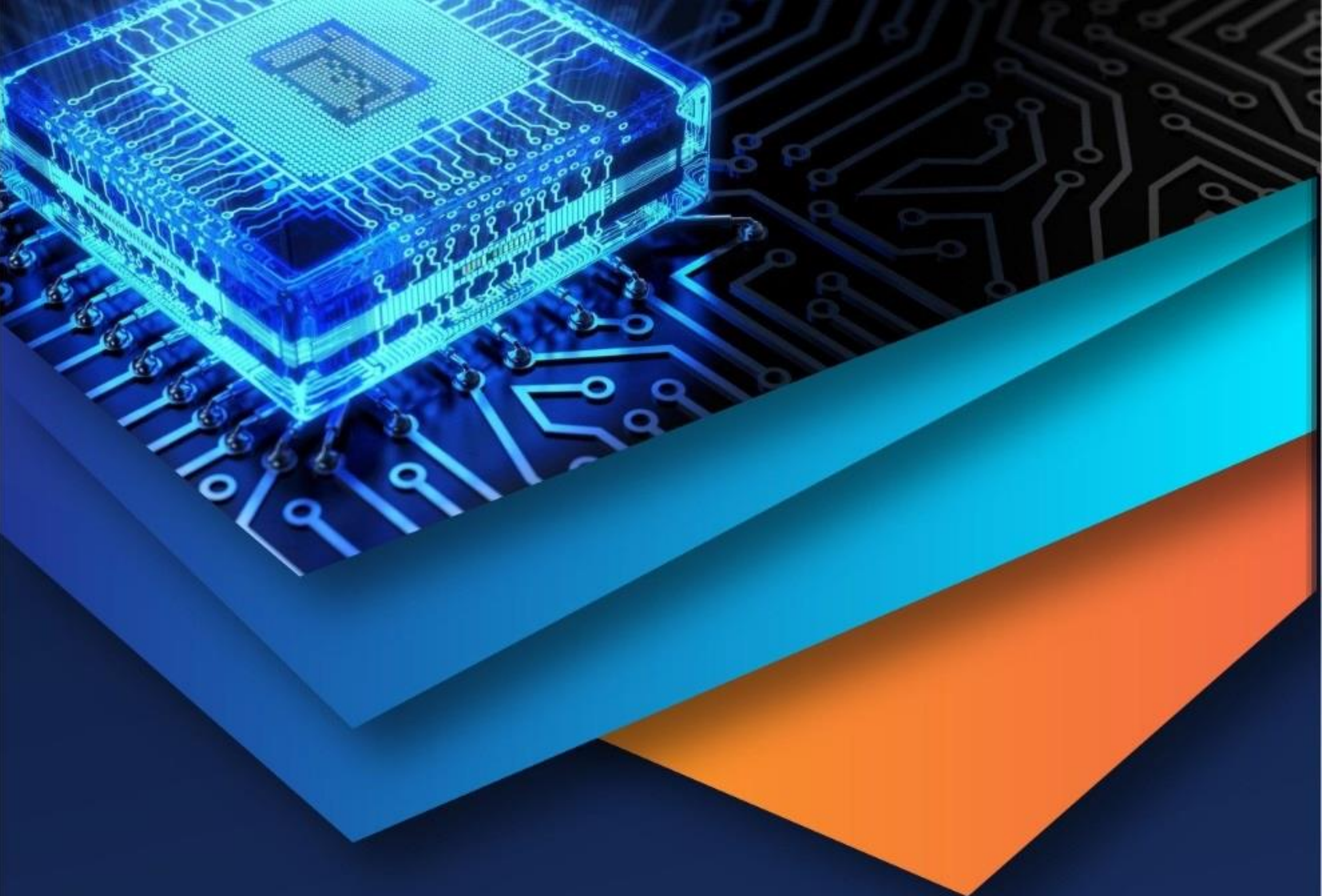

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