Project Report on Research Paper

Dynamic Thermal Performance of Multilayer Hollow Clay Walls Filled with Insulation Materials :

Toward Energy Saving in Hot Climates

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Project Team Details

Ganesh B (CH22B002)
Sai Shiva Charan (CH22B005)
Aayush Bhakna (CH22B008)
Shivansh Gupta (CH22B011)
Deepanjhan Das (CH22B020)

1 Application of the Project

Hollow concrete and clay block components are frequently used in Moroccan architecture. In general, the parameters used to assess the thermal efficiency of buildings vary depending on the climate. Morocco is generally known for its continental climate, which is very hot in summer and cold in winter. Therefore, steady-state and dynamic thermal analyses must be established to measure the possibility of enhancing the thermal efficiency of buildings with hollow clay walls subjected to the climatic conditions of Morocco.

Saafi et al. demonstrated that the application of phase change materials on the exterior face of brick walls allows for a significant increase in the thermal inertia. Ait-Taleb et al. studied numerically the heat transfer by conduction, convection, and radiation across a case of hollow clay submitted to thermal excitations in the transient state. Fraine et al. were able to undertake a computational investigation of coupled heat and moisture transmission through hollow brick walls. The findings showed that utilizing a phase change material in cavities can significantly improve the thermal efficiency of walls.

As we report in later sections, this study has led to significant improvement in architectural efficiency by completely revolutionizing the usual energy model of buildings, replacing it with a base of this new construct.

2 Motivation of the Project

In Morocco, Because of the national policies aiming at increasing energy efficiency, reducing energy requirements through thermal optimization of the envelope gained importance. Building Industry consumes a substantial amount of 33% of overall energy consumption. In addition to this, annual energy consumption for cooling and heating buildings has increased considerably. Thus, the main goal of this analytical study is to assess the feasibility of conserving energy through incorporating passive techniques into the alveolar structures of the building envelope.

3 Important Questions to be Addressed

3.1 Scientific relevance of this project :

In cold climates, thermal resistance is the principal measure that can be used to evaluate the feasibility of saving energy. The aim is to evaluate the energy performances of the hollow components to reduce the significant energy consumption in buildings.

A study on heat transfer across hollow brick walls shows that using low emissivity materials in builds can reduce use of energy significantly. Protuberances inside brick cavities can improve the thermal performance of hollow blocks, short protuberances result in the lowest overall heat transmission rate. A study using finite element analysis to determine the best design for hollow masonry concrete blocks in terms of thermal efficiency revealed that optimum masonry concrete blocks have the lowest heat conductivity compared to standard blocks.

It is possible to improve the thermal efficiency of hollow clay brick walls by changing their geometrical distributions. Compared to the cold season, the warm season has higher solar radiation intensity, resulting in an external thermal wave with a higher amplitude received by the building envelope. In this case, the building envelope components must be carefully selected with adequate dynamic thermal characteristics to improve thermal efficiency. The Primary goal of this project is to demonstrate the effectiveness of insulating materials used in filling sintered hollow bricks in terms of their energy performance.

3.2 Engineering relevance to this project :

Marrakesh(a city in morocco) has a continental climate which is characterized by hot summers and cold winters. Therefore, steady-state and dynamic thermal analyses must be established to measure the possibility of enhancing the thermal efficiency of buildings with hollow clay walls subjected to the climatic conditions of Marrakesh.

In this context, in this project, the thermal transmittance and the thermal inertia characteristics of hollow clay walls integrated with two passive techniques were studied and the effect of using insulation materials in cavities and covering the internal surfaces of the brick holes with low emissivity paint on the thermal transmittance and the dynamic thermal characteristics were evaluated.

4 Relevance of CMTP

4.1 Why CMTP is needed

Normally when we deal with making bricks, we assume there is no hollow space/-cavity in them while filling the moulds, so we generally need not have to deal with CMTP, instead usual solid mechanics equations help us understanding the interactions.

However in this case, the clay bricks have hollow space in them which either get filled with air, which is fluid. So we need CMTP for dealing with them to understand the near perfect interactions.

4.2 Parts of CMTP relevant to this paper

The parts of CMTP which are being used here in this paper are as follows :

- Navier-Stokes equation - Linear Mass Balance and Momentum Balance.
- Differential energy balance equation for temperature.
- Properties of material (including strain and stress elements).

5 Key Terms used in this paper

5.1 Building Envelope

A building envelope, also known as the building enclosure or building shell, is the physical separator between the interior and exterior environments of a building. It includes all the elements of the building's structure that enclose the internal space and play a role in the energy efficiency and environmental performance of the building. The building envelope is crucial for regulating temperature, managing moisture, providing insulation, and controlling air quality within the structure.

5.2 Thermal Optimization of The Envelope

The thermal optimization of the envelope refers to the process of improving the thermal performance of a building's envelope. The building envelope is the outer shell of a building, consisting of the walls, roof, windows, and floors, which separates the interior and exterior environments. Thermal optimization aims to enhance the envelope's ability to regulate heat transfer, minimize energy consumption for heating or cooling, and create a more comfortable and energy-efficient indoor environment.

Key considerations for thermal optimization of the envelope include Insulation, Windows and Doors, Ventilation, Thermal mass, Solar Control, Air Tightness and Roof Design.

5.3 Emissivity

Emissivity is a measure of how efficiently a surface emits thermal radiation. Thermal radiation is the transfer of heat in the form of electromagnetic waves, and all objects with a temperature above absolute zero emit thermal radiation. Emissivity is a dimensionless value ranging from 0 to 1, where:

- A surface with an emissivity of 0 is a perfect reflector that does not emit any thermal radiation.
- A surface with an emissivity of 1 is a perfect emitter that radiates all incident thermal radiation.

Real-world surfaces typically have emissivity values between 0 and 1. Shiny and reflective surfaces, like polished metals, tend to have lower emissivity values, while dull and dark surfaces have higher emissivity values.

5.4 Finite Element Method

The finite element method (FEM) is a numerical technique used to approximate solutions to engineering and physical problems.

5.5 Time lag and decrement factor

The time period required for the heat wave to propagate from the outer surface of the wall to its inner surface is called **time lag**. The ratio of the heat wave amplitudes at the two surfaces of the wall is referred to as the **decrement factor**. The heat flow from the inner surface is less than the heat flow into the outer surface due to the thermal capacity of the wall and this is taken into account by the decrement factor. The time lag and decrement factor are important parameters in evaluating the thermal performance of walls because they determine its heat storage abilities.

5.6 Thermal Transmittance and Thermal Inertia

Thermal transmittance, often represented by the symbol U or U-value, is a measure of how well a material conducts heat. It is an important parameter in the field of building construction and insulation. The U-value quantifies the rate at which heat is transferred through a structure, such as a wall, roof, window, or door. In simple terms, a lower U-value indicates better thermal insulation, as it means that the material is less conductive to heat flow. Conversely, a higher U-value suggests that the material allows more heat to pass through and has poorer insulation properties.

Thermal inertia, also known as thermal mass, refers to the ability of a material or a system to resist changes in its temperature. Materials with high thermal inertia can absorb and store a significant amount of heat energy, which can then be released gradually over time. This property is particularly relevant in the context of building design and energy efficiency.

Buildings with high thermal inertia can help regulate indoor temperatures by absorbing heat during periods of warmth and releasing it during cooler periods. In contrast, materials with low thermal inertia heat up or cool down quickly in response to changes in temperature. Lightweight materials like wood and some types of insulation have lower thermal inertia.

5.7 Classical Radiosity Modeling

Radiative exchanges between the interior surfaces of the brick hole are taken into account using classical radiosity modeling. The following radiation heat flux density is received by each of the brick hole's four surfaces -

$$\mathbf{q_{r,i}}(r_i) = \mathbf{B_i}(r_i) - \sum_{j=1}^{4} \mathbf{B_j}(r_j) \cdot \mathbf{K}(r_i, r_j) dS_j \tag{1}$$

The $\mathbf{q_{r,i}}$ is the net radiative heat flux along surface '**i**', $\mathbf{B_i}(r_i)$ is the radiosity and $\mathbf{K}(r_i, r_j)$ is the Kernel function.

5.8 Sol-Air Temperature

The sol-air temperature $T_{s-a}(t)$ is used to characterize the external thermal excitations, and it is represented by the following equation -

$$T_{s-a}(t) = \frac{|T_{max} - T_{min}|}{2} \sin\left(\frac{2\pi t}{P} - \frac{\pi}{2}\right) + \frac{|T_{max} - T_{min}|}{2} + T_{min} \tag{2}$$

The data for T_{max}, T_{min} and P was taken from the temperature variations on 26^{th} August 2020 in Marrakesh City, Morocco.

6 Emphasis of the Project

Before going into the math, we re-emphasise and summarize the points so far:

- The study focuses on Marrakesh's climate and aims to assess the feasibility of enhancing the thermal efficiency of buildings using passive techniques.
- The building industry in Morocco consumes about 33% of overall energy consumption. Hollow concrete and clay block components are commonly used in Moroccan architecture.
- Dynamic thermal analyses have been used to investigate the thermal performance of building envelopes.
- It has been found that the application of phase change materials on brick walls can increase thermal inertia and improve thermal efficiency.

7 Balanced Equations

7.1 Mass Balance Equation :

$$\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} = 0 \tag{3}$$

7.2 Momentum Balance :

$$\rho \left(\frac{\partial v_x}{\partial t} + v_x \frac{\partial v_x}{\partial x} + v_y \frac{\partial v_x}{\partial y} \right) = -\frac{\partial P}{\partial x} + \mu \left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} \right) \tag{4}$$

$$\rho \left(\frac{\partial v_y}{\partial t} + v_x \frac{\partial v_y}{\partial x} + v_y \frac{\partial v_y}{\partial y} \right) = -\rho g \beta_T (T - T_o) - \frac{\partial P}{\partial x} + \mu \left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} \right) \tag{5}$$

β_T refers to the thermal coefficient of volumetric expansion (K^{-1}).
The term $\beta_T(T - T_o)$ accounts for the changes in the body forces due to thermal expansion of material.

7.3 Energy Balance :

$$\rho c_P \left(\frac{\partial T}{\partial t} + v_x \frac{\partial T}{\partial x} + v_y \frac{\partial T}{\partial y} \right) = - \left(\frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} \right) - \left(\frac{\partial \ln \rho}{\partial \ln T} \right)_P \frac{DP}{Dt} \tag{6}$$

OR

$$\rho \left(\frac{\partial T}{\partial t} + v_x \frac{\partial T}{\partial x} + v_y \frac{\partial T}{\partial y} \right) = \frac{\lambda_{eq}}{c_P} \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) \tag{7}$$

The term c_P denotes the specific heat of material in $(J \cdot K^{-1} kg^{-1})$.
λ_{eq} refers to the thermal conductivity in units $(W m^{-1} K^{-1})$.

8 Constitutive Relations

8.1 In case of solid material :

The fired-clay bricks used in this study have been assumed to have no deformations or movements. As such, the displacement field is taken to be *zero*, meaning that strain and stress have been ignored.

$$\text{Displacement gradient} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \tag{8}$$

$$\epsilon_{xx} = \frac{\partial u_x}{\partial x} = 0 \qquad \epsilon_{yy} = \frac{\partial u_y}{\partial x} = 0 \tag{9}$$

$$\gamma_{xy} = \frac{\partial u_y}{\partial x} + \frac{\partial u_x}{\partial y} = 0 \qquad \omega_{xy} = \frac{1}{2}\left(\frac{\partial u_y}{\partial x} - \frac{\partial u_x}{\partial y}\right) = 0 \tag{10}$$

8.2 In case of fluids :

The paper has assumed that the fluid in question, air, is homogenous and isotropic in nature. It is also considered that air is linearly viscous. This allows the use of Newton's law of Viscosity to approximate the values of strain and stress tensor, given as follows -

$$\dot{\epsilon}_{xx} = \frac{\partial v_x}{\partial x} \qquad \dot{\epsilon}_{xy} = \frac{\dot{\gamma}_{xy}}{2} \tag{11}$$

$$\dot{\gamma}_{xy} = \frac{\partial v_y}{\partial x} + \frac{\partial v_x}{\partial y} \qquad \dot{\omega}_{xy} = \frac{1}{2}\left(\frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y}\right) \tag{12}$$

$$\text{Total Stress Tensor} = \begin{bmatrix} -P + 2\mu\frac{\partial v_x}{\partial x} & \mu\left(\frac{\partial v_y}{\partial x} + \frac{\partial v_x}{\partial y}\right) \\ \mu\left(\frac{\partial v_y}{\partial x} + \frac{\partial v_x}{\partial y}\right) & -P + 2\mu\frac{\partial v_y}{\partial y} \end{bmatrix} \tag{13}$$

9 Important Considerations

9.1 Main Assumptions :

- This model assumes that the air in the various holes is incompressible and Newtonian, with constant thermophysical properties.
- The Boussinesq formulation is adopted in the currentwork. This approximation helps us model the air density in the buoyancy term.
- It is assumed that the fluid is completely transparent and does not participate in radiation.
- In the energy equation, viscous heat dissipation is ignored, and only two-dimensional coupled heat transfer is analyzed.
- It should also be noted that the numerical simulations are applied to a single brick cell surrounded by mortar, with an adiabatic condition below and above the brick cell.

9.2 Boundary Conditions :

1. No slip velocity conditions are considered at internal surfaces of holes.

$$v_x = v_y = 0$$

2. The boundary condition on both sides of the wall, $x = 0$ denoting the inside and $x = L$ denoting the outside, is given by [1]-

$$\lambda_{\mathbf{s}} \frac{\partial T(x,t)}{\partial x}\bigg|_{x=0} = h_1 T(0,t) - h_1 T_i \quad \forall\ y \tag{14}$$

$$\lambda_{\mathbf{s}} \frac{\partial T(x,t)}{\partial x}\bigg|_{x=L} = -h_2 T(L,t) + h_2 T_{s-a}(t) \quad \forall\ y \tag{15}$$

3. The boundary condition applied on the horizontal faces of the bricks[2] are given by -

$$\lambda_{\mathbf{s}} \left.\frac{\partial T}{\partial y}\right|_{y=0} = 0 \quad \forall\ x \tag{16}$$

$$\lambda_{\mathbf{s}} \left.\frac{\partial T}{\partial y}\right|_{y=L} = 0 \quad \forall\ x \tag{17}$$

4. The conditions at solid-fluid interface[3] are given by -

$$T_s(x,y) = T_f(x,y) \tag{18}$$

$$-\lambda_{\mathbf{s}} \left.\frac{\partial T}{\partial x}\right|_{solid} = -\lambda_{\mathbf{f}} \left.\frac{\partial T}{\partial x}\right|_{fluid} + \mathbf{q_{r,i}} \tag{19}$$

$$-\lambda_{\mathbf{s}} \left.\frac{\partial T}{\partial y}\right|_{solid} = -\lambda_{\mathbf{f}} \left.\frac{\partial T}{\partial y}\right|_{fluid} + \mathbf{q_{r,i}} \tag{20}$$

[1] λ_s is the thermal conductivity of the solid (fired clay), while λ_f is the thermal conductivity of the fluid (air).

[2] L is the thickness of the clay brick in meters.

[3] h_1 is the combined convection and radiation heat transfer coefficient in the inside and, h_2 is the combined convection and radiation heat transfer coefficient in the outside.

10 Results

10.1 Effect of Emissivity on Thermal Efficiency

10.1.1 Thermal Transmittance (U) and Emissivity

Graph (Fig. 1a): The study looked at how changing the emissivity (a measure of how well a surface emits thermal radiation) affects thermal transmittance (U) in hollow clay brick walls.

Observation: When the emissivity of internal surfaces increases (from 0.1 to 0.5 and 0.9), the thermal transmittance U increases by 14.5% and 17.27%, respectively.

Explanation: Lower emissivity means less heat transfer through radiation, leading to lower total heat flux. This significantly increases the thermal resistance of the building walls, making them better at preventing heat from escaping or entering.

10.1.2 Time Lag and Emissivity

Observation: Increasing emissivity from 0.1 to 0.9 results in a 21.8% decrease in time lag. Time lag is the delay in the propagation of the thermal load wave within the building.

Explanation: Lower emissivity slows down the movement of thermal energy within the building's interior.

10.1.3 Decrement Factor and Emissivity

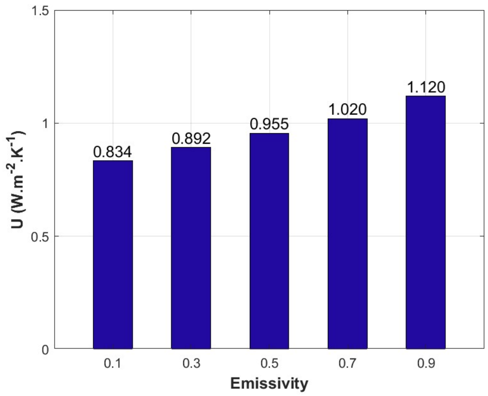
Graph (Fig. 1b): Decreasing emissivity leads to an increase in the decrement factor.

Explanation: Lower emissivity reduces heat transfer coefficient by radiation in cavities, significantly decreasing heat flow and improving the heat resistance of hollow clay walls. Painting the inner surfaces with low-emissivity paint enhances this effect.

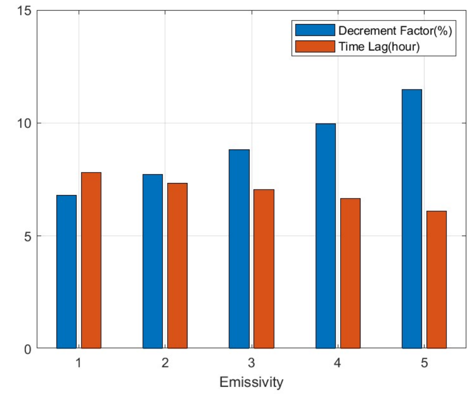
10.1.4 Internal Temperature Fluctuation and Emissivity

Observation: Reducing emissivity from 0.9 to 0.1 significantly reduces the internal temperature fluctuation peak, with a potential 40.7% reduction in the decrement factor.

Explanation: Lower emissivity helps maintain more stable internal temperatures.



(a) Variation of the thermal transmittance with the different values of emissivity



(b) Variation of the Time lag and Decrement factor with the different values of emissivity

10.1.5 Heat Flux at Inner Surface and Emissivity

Observation: Increasing emissivity from 0.1 to 0.9 results in a 34.2% increase in heat flux at the inner surface.

Explanation: Higher emissivity levels contribute more to radiation in overall heat transmission through the walls. Lowering thermal emissivity decreases heat flux, reducing electricity network load and energy consumption.

Material name	$\rho(\mathbf{kg/m^3})$	$\mathbf{C_P(J/kg.K)}$	$\lambda(\mathbf{W/m.K})$	$\mu_\mathbf{f}(\mathbf{kg/m.s})$	$\beta(\mathbf{K^{-1}})$
Air	1.161	1007	0.0263	1.846x10^{-5}	0.00353
Clay	1810	775	0.54	–	–
Mortar	1650	1701	0.613	–	–
EPS	22	1280	0.041	–	–

Table 1: Thermophysical properties of materials

10.2 Additional Information

Tables 1 and 2: Provide thermophysical properties of materials and quantitative comparisons for different EPS filling ratios.

Tables 2 and 3: Offer quantitative comparisons for different EPS filling ratios and emissivity values between the analytical approach and full CFD simulations.

Time lag (hour) : EPS filling rate	0%	20%	40%	60%	80%	100%
Full CFD simulation	6.1	6.6	7	7.35	7.88	8.34
Analytical approach	6.74	7.27	7.69	8	8.5	9.12
Deviation (%)	**9.49**	**9.21**	**8.97**	**8.12**	**7.3**	**8.55**
Decrement factor (%) : EPS filling rate	0%	20%	40%	60%	80%	100%
Full CFD simulation	11.48	9.67	8.74	8.22	7.25	6.64
Analytical approach	11.3	9.98	9.2	8.4	7.72	6.87
Deviation (%)	**1.59**	**3.1**	**5**	**2.14**	**6.08**	**3.34**

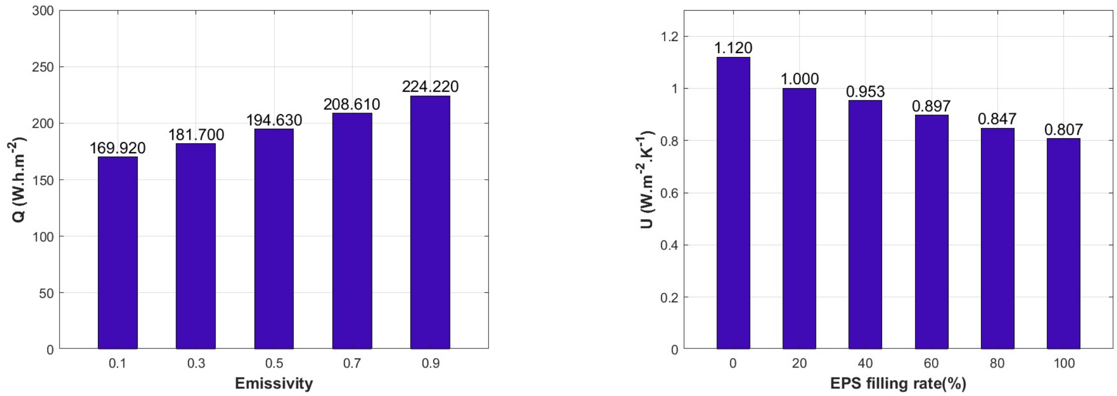
Table 2: Quantitative comparison of the decrement factor and time lag between the present analytical approach and the complete method(full CFD simulations) for different EPS filling ratios

Time lag (hour) : Emissivity	$\epsilon = 0.1$	$\epsilon = 0.3$	$\epsilon = 0.5$	$\epsilon = 0.7$	$\epsilon = 0.9$
Full CFD simulation	7.8	7.34	7.05	6.65	6.1
Analytical approach	8.56	8.07	7.61	7.18	6.74
Deviation (%)	**8.87**	**9.04**	**7.35**	**7.39**	**9.49**
Decrement factor (%) : Emissivity	$\epsilon = 0.1$	$\epsilon = 0.3$	$\epsilon = 0.5$	$\epsilon = 0.7$	$\epsilon = 0.9$
Full CFD simulation	6.81	7.72	8.81	9.96	11.48
Analytical approach	7.56	8.34	9.22	10.19	11.3
Deviation (%)	**9.91**	**7.43**	**4.44**	**2.25**	**1.59**

Table 3: Quantitative comparison of the decrement factor and time lag between the present analytical approach and the complete method(full CFD simulations) for different values of emissivity

Graphs (Fig. 1a and Fig. 1b): Illustrate variations in thermal transmittance, time lag, and decrement factor with different emissivity values.

Conclusion: The research emphasizes how manipulating emissivity influences the thermal behavior of hollow clay brick walls, impacting factors like thermal transmittance, time lag, decrement factor, internal temperature fluctuations, and heat flux at the inner surface. These insights are crucial for optimizing the energy efficiency of buildings.



(a) Variation of the Heat Flux Q

(b) Variation of the U

10.2.1 The Effect of EPS Filling on Thermal Efficiency

Thermal Transmittance and EPS Filling Graph (Fig. 2b): The study explores how increasing the EPS (expanded polystyrene) filling ratio impacts thermal transmittance (U) in hollow clay brick walls.

Observation: Thermal transmittance (U) decreases significantly with an increase in the EPS filling ratio. A 100% EPS filling ratio results in a 30% reduction in thermal transmittance for hollow brick walls.

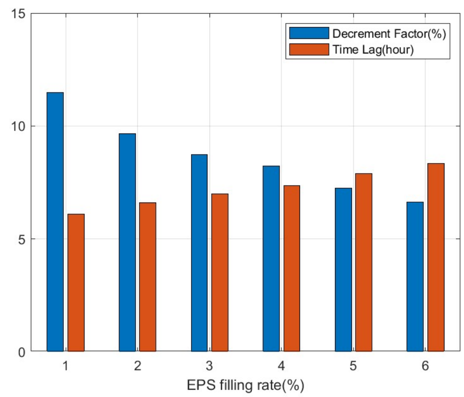
Explanation: Filling cavities with EPS insulation inhibits both radiation and convection, leading to a substantial decrease in overall heat flow across the brick. This improves the thermal resistance of the wall.

10.2.2 Dynamic Thermal Properties and EPS Filling

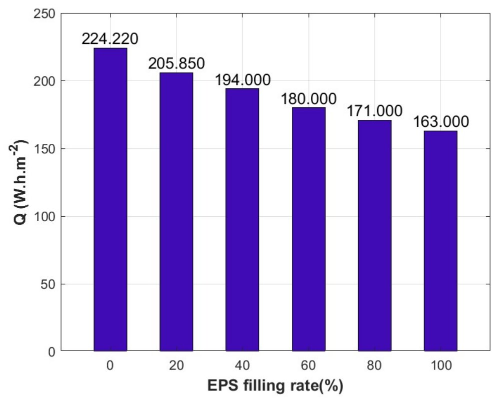
Graphs (Fig. 3a): The dynamic thermal properties, including time lag and decrement factor, are investigated for varying EPS filling ratios (ranging from 0 to 100

Observation (Time Lag): Increasing the EPS filling ratio from 0 to 100% results in a significant 36.72% increase in time lag. Filling cavities with insulating material delays the passage of the outer thermal load wave into the interior environment, enhancing interior comfort.

Observation (Decrement Factor): As the EPS filling ratio increases, the decrement factor of inner surface temperature decreases significantly, reaching a reduction of approximately 42.16%. Lower decrement factor levels allow for smoother indoor temperature distribution, suppressing exterior temperature changes.



(a) Variation of the time lag and decrement factor with the different EPS filling ratios



(b) Variation of the heat flux Q at the inner surface with the different EPS filling ratios

Graph (Fig. 3b): Examining the impact of decreasing emissivity on total heat load (Q) over 24 hours at the inner surface.

Observation: Lowering emissivity results in a considerable reduction in total heat load (Q) over 24 hours at the inner surface. Applying low emissivity paint to the inside surfaces of brick cavities significantly reduces heat transfer flux, helping to decrease electricity network demand and enhance thermal comfort in buildings.

Additional Graph (Fig. 2a): Examining the variation of heat flux (Q) during 24 hours at the inner surface with different values of emissivity.

Observation: Lower emissivity values lead to a significant reduction in heat transfer flux across walls over 24 hours. This reduction is attributed to the low contribution of radiation to heat transfer at low emissivity values.

Conclusion: The research indicates that increasing the EPS filling ratio in hollow clay brick walls substantially improves thermal efficiency. This is achieved by reducing thermal transmittance, increasing time lag, decreasing the decrement factor, and minimizing heat transfer flux, contributing to enhanced energy efficiency and thermal comfort in buildings.

11 Conclusion

In this research, the impact of insulation materials in cavities and covering the internal surfaces of the brick holes with low emissivity paint on thermal transmittance and dynamic thermal characteristics was evaluated.

- Focus was on Marrakesh city in Morocco with real thermal conditions.

11.1 Key Findings on Thermal Transmittance :

- EPS filling rate significantly affects thermal transmittance of hollow brick walls.
- 100% EPS filling results in a notable 30% reduction in thermal transmittance.
- Emissivity plays a significant role; a change from 0.1 to 0.9 increases thermal transmittance by 31.8%, so it is concluded that U increases with the increase of emissivity, also in this emissivity change it significantly increases the total heat load over 24 h.

11.2 Effect of low emissivity coating :

- Coating internal surfaces of brick holes reduces radiation heat transfer in cavities.
- A 35% reduction in total thermal load over 24 hours is achieved with a surface emissivity of 0.1.

11.3 Impact of cavity insulation :

- 100% cavity insulation delays temperature peak by about 2.3 hours.
- Decrement factor is lowered by approximately 43%, reaching a value smaller than 0.07.

11.4 Effect of wall configurations :

- Improved configurations (100% insulation filling) reduce total thermal load by about 28% compared to traditional configurations (100% air filling).

12 Significant Takeaway

12.1 Objective of the Study :

The research aims to enhance the dynamic thermal performance of multilayer hollow clay brick walls through the incorporation of passive techniques.

12.2 Role of Continuum Mechanics :

Continuum mechanics principles, embedded in the finite element approach, provided a robust framework for understanding the behavior of the materials and fluid dynamics within the walls.

12.3 Effect of Emissivity :

Significant findings include an increase in the total heat load over 24 hours when emissivity is raised from 0.1 to 0.9.

12.4 Impact of Insulation Materials :

Filling 100% of cavities with insulation materials demonstrated benefits such as a delayed temperature peak by about 2.3 hours and a reduction in the decrement factor by roughly 43% (with a value smaller than 0.07).

12.5 Improvement in Thermal Efficiency :

Improved wall configurations, with 100% insulation filling cavities, showcased approximately 28% reduction in total thermal load compared to traditional wall configurations with 100% air filling cavities, contributing to improved building energy efficiency.

12.6 Evaluation of EPS Filling and Emissivity on Thermal Transmittance :

- Examining the thermal transmittance of hollow brick walls revealed that a 100% filling ratio of expanded polystyrene (EPS) in cavities led to a substantial 30% decrease.
- Thermal transmittance (U) was found to increase with higher emissivity, with a 31.8% increase observed when emissivity changed from 0.1 to 0.9.

12.7 Significance of Transport Phenomena :

The study underscores the importance of transport phenomena, as evidenced by the dynamic thermal response analysis, in understanding how heat and mass are transferred within the wall systems.

12.8 Future Perspectives :

The proposed numerical solution approach, rooted in continuum mechanics, will be extended to study the thermal inertia of walls in different climates of Morocco. Future research will also explore the effect of moisture content on the thermal efficiency of hollow clay bricks.

In summary, the research emphasizes the critical role of continuum mechanics and transport phenomena in comprehending the dynamic thermal behavior of multilayer hollow clay brick walls, offering insights for optimizing building energy efficiency in diverse climates.

13 Citations

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