Experimental Investigation of Thermal Energy Storage Performance of Aluminium-Encapsulated PCM Integrated Porotherm Wall for Energy-Efficient Buildings

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***Abstract*—Buildings consume a large portion of global energy, mainly due to heating and cooling requirements needed to maintain indoor thermal comfort. Improving the thermal performance of building envelope materials is therefore an important strategy for achieving energy-efficient and sustainable buildings. This study presents an experimental investigation of a Porotherm wall integrated with aluminium-encapsulated phase change materials (PCMs) to enhance thermal energy storage and passive thermal regulation. The PCM was encapsulated in aluminium pipes and embedded within the cavities of the Porotherm block wall to improve heat transfer performance. Expanded polystyrene (EPS) insulation was incorporated in the experimental setup to minimize heat losses and ensure efficient thermal storage within the system. Temperature measurements were carried out at different locations across the wall using thermocouples to evaluate the heat transfer characteristics and thermal response during heating and cooling cycles. The results indicate that the integration of PCM within the Porotherm wall significantly enhances the thermal energy storage capacity and delays heat transfer through the wall. The PCM absorbs excess heat during peak temperature periods and releases it during cooler periods, thereby reducing temperature fluctuations across the building envelope. The proposed system demonstrates improved passive thermal regulation and shows potential for enhancing energy efficiency in building applications.**

***Index Terms*— Phase Change Material, Thermal Energy Storage, Porotherm Wall, Aluminium Encapsulation, Energy Efficiency, Heat Transfer, Thermal Performance.**

I. INTRODUCTION

The building sector is a major contributor to global energy consumption and greenhouse gas emissions, largely due to the demand for indoor thermal comfort through heating, ventilation, and air-conditioning (HVAC) systems. In warm and tropical climates, excessive heat gain through building envelopes—such as walls, roofs, and windows—results in elevated indoor temperatures and increased reliance on mechanical cooling. This leads to higher electricity consumption and environmental impacts, including carbon emissions and global warming. Therefore, improving the thermal performance of building envelope materials is essential for achieving energy-efficient and sustainable building designs. Among building envelope components, walls play a significant role in regulating heat transfer between outdoor and indoor environments. Conventional wall materials, such as bricks and concrete blocks, have limited thermal storage capacity, allowing heat to rapidly penetrate into indoor spaces during peak temperature periods. This results in increased indoor temperatures and higher cooling loads. To address this limitation, the integration of thermal energy storage (TES) systems within building materials has emerged as an effective solution.

Phase Change Materials (PCMs) are widely recognized as efficient TES materials due to their high latent heat storage capacity and ability to maintain nearly constant temperature during phase transition. PCMs absorb excess heat during melting and release it during solidification, thereby reducing temperature fluctuations and enhancing indoor thermal comfort. When incorporated into building envelopes, PCMs act as thermal buffers, delaying heat transfer and reducing dependence on active cooling systems.

Various techniques have been developed for integrating PCMs into building materials, including direct incorporation, micro-encapsulation, macro-encapsulation, and form-stabilized composites. Among these, macro-encapsulation is commonly preferred for building applications as it prevents leakage, enhances durability, and ensures practical implementation. The selection of encapsulation material plays a crucial role in determining heat transfer efficiency, with high thermal conductivity materials being desirable.

Porotherm hollow clay blocks have gained considerable attention in modern construction due to their lightweight structure and improved thermal insulation properties. The presence of internal cavities in these blocks reduces density and enhances insulation by trapping air. These cavities also provide an opportunity for integrating PCMs, thereby increasing the thermal storage capacity of the wall system. During daytime, the PCM absorbs heat from the external environment, and during cooler periods, the stored heat is released gradually, reducing temperature fluctuations and improving indoor comfort.

Encapsulation is a key factor in PCM-based systems, influencing both thermal performance and structural stability. Aluminium is widely used as an encapsulation material due to its high thermal conductivity, corrosion resistance, and mechanical strength, which enable efficient heat transfer and improved thermal response. Additionally, insulation materials such as Expanded Polystyrene (EPS) are used to minimize heat losses and ensure controlled experimental conditions.

Despite significant research on PCM-integrated building materials, experimental studies on PCM-integrated Porotherm wall systems with aluminium encapsulation are limited. Therefore, this study aims to experimentally investigate the thermal performance of a PCM-integrated Porotherm wall system. In this work, PCMs are encapsulated in aluminium pipes and inserted into the cavities of Porotherm blocks. EPS insulation is incorporated to reduce heat losses, and temperature measurements are conducted to evaluate the thermal response under heating and cooling conditions. The findings of this study are expected to contribute to the development of energy-efficient building envelope systems with enhanced thermal performance.

II. METHODOLOGY

The present study focuses on the experimental investigation of a PCM-integrated Porotherm wall system to evaluate its thermal energy storage performance. The methodology involves material selection, fabrication of the wall model, integration of PCM using aluminium encapsulation, and thermal performance analysis under controlled heating conditions.

2.1. Selection of Wall Material

Porotherm Clay Block

Porotherm clay blocks are widely used in modern construction due to their excellent thermal insulation properties and ease of installation. These blocks are manufactured from natural materials such as clay, coal ash, rice husk, and granite slurry, making them suitable for sustainable building applications. A typical Porotherm block has dimensions of approximately 400 × 200 × 200 mm.

The presence of multiple perforations (cavities) within the block improves thermal insulation by trapping air, which reduces heat transfer through the wall. As a result, buildings remain cooler during hot conditions and warmer during cold conditions, enhancing indoor thermal comfort.

In this study, Porotherm blocks are selected mainly due to their 12 internal cavities (4 × 3 arrangement), which provide sufficient space for integrating the PCM encapsulation system. Aluminium pipes filled with PCM can be easily inserted into these cavities without affecting the structural strength of the block.

Additionally, Porotherm blocks offer several advantages, including:

- Lightweight structure
- Good mechanical strength
- High durability
- Fire resistance
- Reduced mortar usage and faster construction

These properties make Porotherm blocks a suitable and efficient choice for experimental investigation of thermal energy storage systems in building walls.

Fig:1. Porotherm Block

2.2. Selection of Phase Change Materials (PCMs)

Phase change material is the material which have property of thermal energy storage, high heat of fusion, melt and solidify at a specific temperature, and are capable of storing and realizing thermal energy. Heat energy is absorbed or released when the material changes from the solid state to liquid state or vice versa.

The heat energy is absorbed during the melting process of phase change material when compared with normal material and a greater amount of energy is absorbed when PCMs melts. The melting points of PCMs are depending on latent heat of storage of the unique materials. The materials will absorb the heat till it changes its phase.

There is a continuation in absorption of heat without a significant rise with temperature until all PCMs materials are transformed to the liquefied phase. Whenever temperature of the material falls, then the PCMs released the stored latent heat. This transformative capability holds immense promise in diverse industries, ranging from construction and energy systems to electronics and textiles. This report delves into the principles, applications, and advancements in Phase Change Materials, unraveling their pivotal role in enhancing energy efficiency and sustainability across various sectors. The selection is based on their melting temperature range (18°C–32°C), which matches the comfort zone for tropical climates.

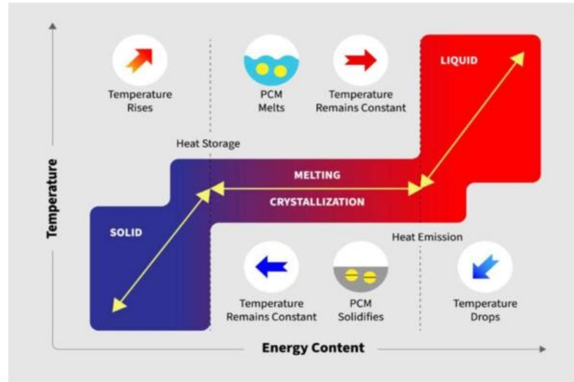

Fig: 2. PCM Melting Point

PCM 1 - Paraffin wax

Paraffin wax is an organic phase change material (PCM) commonly used for thermal energy storage. It is a mixture of hydrocarbons obtained from petroleum refining. Paraffin wax is widely used because it has high latent heat storage capacity, good thermal stability, and is non-toxic. When the temperature increases, paraffin wax absorbs heat and melts, storing thermal energy. When the temperature decreases, it solidifies and releases the stored heat. This property helps maintain stable temperatures in building systems. In this project, paraffin wax is used as a PCM inside an aluminium cover placed within an aluminium pipe, which is inserted into the cavities of the Porotherm wall to improve thermal energy storage and energy efficiency in buildings.

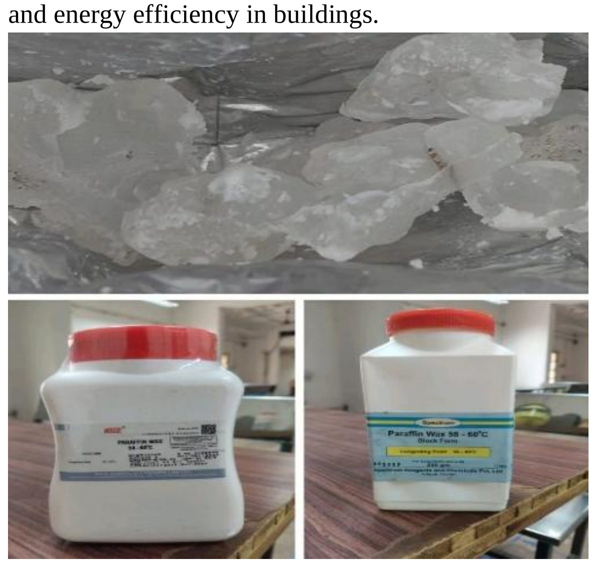

Fig: 3. Paraffin wax

PCM 2 - Capric–Palmitic eutectic mixture

The Capric–Palmitic Eutectic PCM is a fatty acid-based organic phase change material formed by mixing Capric acid ($C_{10}H_{20}O_2$) and Palmitic acid ($C_{16}H_{32}O_2$) in an optimized weight ratio, typically 70:30. This combination provides a stable eutectic mixture with a melting temperature around 26–28°C, making it suitable for thermal management in buildings. It offers a good balance between latent heat, thermal stability, and environmental safety. This also used as a PCM inside an aluminium cover placed within an aluminium pipe, which is inserted into the cavities of the Porotherm wall to improve thermal energy storage and energy efficiency in buildings.

Fig :4. Capric–Palmitic Eutectic Mixture

2.3. Selection of Insulation Material

To further enhance thermal resistance, Expanded Polystyrene (EPS) is selected as the inner insulation layer. It acts as a barrier to conductive and convective heat transfer, complementing the effect of the PCMs.

Expanded Polystyrene (EPS)

- Expanded Polystyrene (EPS) is a lightweight, closed-cell foam insulation material made from polystyrene beads expanded using steam and pentane gas. It is widely used in building envelopes, wall cavities, and roof insulation for its excellent thermal insulation, moisture resistance, and cost-effectiveness.
- In your project, EPS acts as a supporting thermal barrier, minimizing heat losses from the PCM-integrated Porotherm wall and improving overall energy efficiency.

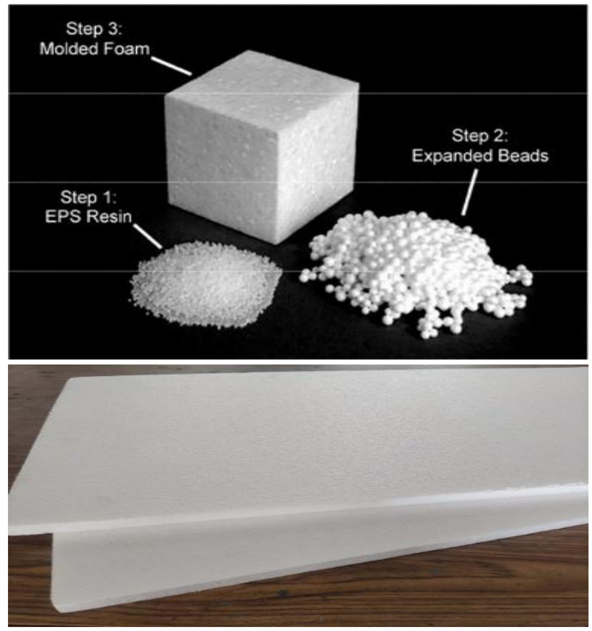

Fig: 5. Expanded Polystyrene (EPS)

2.4. Selection of Aluminium Pipe for Encapsulation

Aluminium pipe is selected as the encapsulation material in this study due to its high thermal conductivity, lightweight nature, and corrosion resistance. The high thermal conductivity of aluminium enables efficient heat transfer between the Porotherm wall and the Phase Change Material (PCM), which improves the charging and discharging rate of thermal energy storage. In addition, aluminium is easy to fabricate and readily available, making it suitable for experimental applications. A rectangular aluminium pipe of size 1 × 2 inch is used in this project. The rectangular shape fits effectively inside the cavities of the Porotherm block and provides good contact with the surrounding wall surface, which enhances heat transfer. The aluminium pipe also provides structural strength and acts as a protective outer container for the PCM system. Therefore, aluminium pipe is considered an effective encapsulation material for integrating PCM within building wall structures.

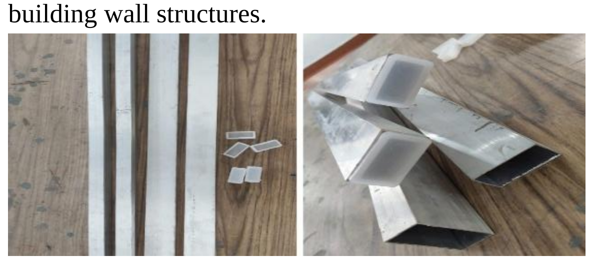

Fig: 6. Aluminium Pipe

2.5. Selection of Aluminium Cover for PCM Encapsulation

An aluminium cover is used as the inner container to hold the PCM inside the aluminium pipe. The primary purpose of the aluminium cover is to prevent leakage of PCM during the melting process, since most PCMs change from solid to liquid during heat absorption. The aluminium cover ensures safe containment of the PCM and maintains the stability of the thermal energy storage system. Aluminium is selected for the cover material because it has good thermal conductivity, durability, and chemical compatibility with most PCMs. These properties allow efficient heat transfer between the PCM and the surrounding aluminium pipe. The aluminium cover also helps maintain the shape and distribution of PCM during repeated heating and cooling cycles. Thus, the combination of aluminium cover and aluminium pipe provides a reliable macro-encapsulation system, ensuring leakage prevention, improved heat transfer, and long-term durability of the PCM integrated Porotherm wall system.

Fig: 7. Aluminium Cover

III. THERMAL ENERGY STORAGE TECHNOLOGIES

Thermal Energy Storage (TES) is an important method used to improve energy efficiency by storing excess heat and releasing it when required. In building applications, TES helps reduce cooling load, maintain indoor thermal comfort, and improve overall energy performance.

TES systems are mainly classified into three types:

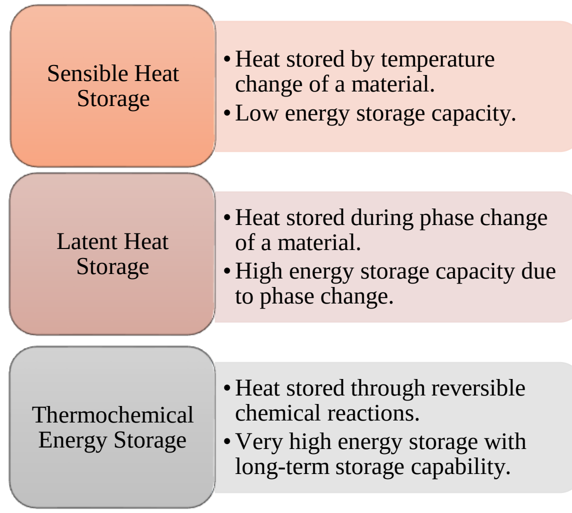

Table :1 Criteria for various energy storage methods.

Criteria	Sensible heat	Latent heat	Thermo-chemical
Energy density	Moderate	High	High
Volume requirement	High	Low	Low
Temperature control	Limited	Complex	Precise
Efficiency	Good	Good	Good
Implementation complexity	Low	Moderate	High

3.1. Latent heat storage and PCMs

Among the above-mentioned thermal energy storage methods, latent heat storage is promising technology, because its capacity to offer a high energy storage density and its characteristics to store heat at a nearly constant temperature, aligning with the phase transition temperature of the phase change material. PCMs are substances that absorb or release significant amounts of latent heat during a transition in their physical state. PCMs provide a significant heat capacity over a limited temperature range and could act as near-isothermal heat storage. These materials can undergo various transformations including solid-solid, liquid-gas, and solid-liquid transition.

PCMs are classified into three main groups: organic, inorganic, and eutectic materials. These classifications are further subdivided based on the chemical constituents that make up the PCM. Fig.8 illustrates a comprehensive schematic representation of these classified PCMs. Organic PCMs, consisting primarily of carbon-hydrogen chains, are divided into paraffinic and non-paraffinic materials, the latter including subgroups such as fatty acids, esters, glycols, and alcohols. These organic PCMs find extensive use in heat storage applications, especially in lower to medium temperature ranges. Their advantages include high storage density, stable chemical and physical properties, and a suitable phase change temperature range of 0-150 °C. In contrast, inorganic PCMs do not contain carbon and hydrogen atoms and are made of materials such as salts and metals. They offer melting temperatures ranging from 100 °C to 1000 °C, almost ten times higher than that of organic PCMs, making them favorable for solar applications. Eutectic PCMs, a mixture of at least two PCM types, allow each component to melt and solidify congruently, forming a crystalline mixture during crystallization. Eutectics can include various combinations, including organic-inorganic, inorganic-inorganic, or organic-organic compositions. By mixing materials latent heat, melting temperatures, and thermal conductivity can be tailored to desired specifications. Despite limited data available on eutectic PCM properties, notable advantages include sharply defined melting temperatures and satisfactory volumetric thermal storage density. Each type of PCM (organic, inorganic, or eutectic) must have different advantages and disadvantages, highlighting the critical importance of thoroughly evaluating these properties to achieve the greatest thermal efficiency in building applications.

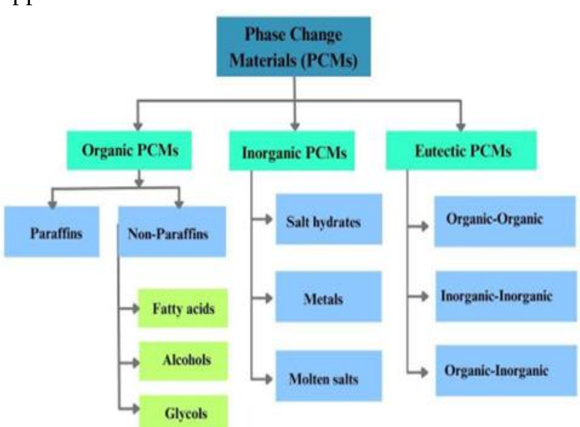

Fig. 8. Classification of PCMs.

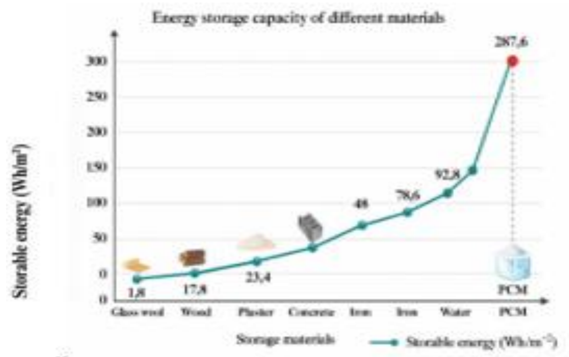

Fig: 9. Energy Storage Capacity of different materils

The use of the PCMs is based on a sampling principle: As the temperature increases and the melting point is reached, PCM absorbs heat in an endothermic process (at a constant temperature) and changes from a solid to a liquid. However, when the temperature decreases below the melting temperature, the PCM undergoes an exothermic process, releasing heat, and reverts to its solid phase. PCMs can save between 5 and 14 times more thermal energy within a given unit volume compared to their traditional counterparts. A comparison of storable energy covering different materials including glass wool, wood, plaster, concrete, iron, water, and PCM in Fig.9 In this comparison, PCM has a storable energy of 287.6 Wh/m^2, while water has 92.8 Wh/m^2.

IV. INCORPORATION OF PCMS INTO BRICK STRUCTURES

The integration of Phase Change Materials (PCMs) into brick structures is an effective method to improve the thermal energy storage capacity of building walls. PCMs absorb excess heat during high temperature conditions and release it during cooler periods, thereby reducing temperature fluctuations and improving indoor thermal comfort. PCMs store energy in the form of latent heat during phase change. When temperature increases, PCM melts and absorbs heat; when temperature decreases, it solidifies and releases the stored heat. This process helps in stabilizing wall temperature and reducing cooling load. Various methods are used to incorporate PCM into bricks, such as direct mixing, micro-encapsulation, macro-encapsulation, and cavity filling. Among these, macro-encapsulation is widely used due to its simplicity and leakage prevention.

In this study, PCM is encapsulated using aluminium cover and pipe, and placed inside the cavities of Porotherm blocks. Aluminium improves heat transfer and ensures safe containment of PCM. This integration enhances the thermal performance and energy efficiency of the wall system.

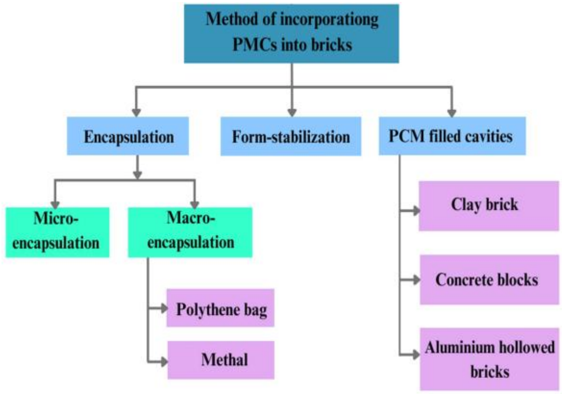

Fig: 10. Method of Incorporating PCMs into bricks

Fig: 11. Incorporating PCMs into bricks

V. EXPERIMENTAL SETUP

5.1. Porotherm Wall Structure

Fig:12. Porotherm Wall

5.2. Insulation Material

Fig: 13. Expanded Polystyrene with Porotherm wall

5.3. Phase Change Material

Fig: 14. Paraffin wax

Fig:15. Palmitic Acid

Fig: 16. Capric Acid

5.4. Porotherm Block with Aluminium Pipe PCM System

The Porotherm hollow clay block used in this study contains 12 cavities arranged in a 4 × 3 configuration. These cavities reduce the weight of the block and also provide space for integrating thermal energy storage components. In the experimental setup, a rectangular aluminium pipe of size 1 × 2 (inch) is inserted inside one of the cavities of the Porotherm block. The aluminium pipe acts as the primary encapsulation structure because aluminium has high thermal conductivity, which helps in efficient heat transfer between the wall and the PCM. Inside the rectangular aluminium pipe, an aluminium cover container is used to hold the phase change material securely and to prevent leakage during the melting process. During operation, heat from the external environment passes through the Porotherm wall and reaches the aluminium pipe. The PCM stored inside the aluminium cover absorbs heat and undergoes phase change, storing thermal energy in the form of latent heat. When the surrounding temperature decreases, the PCM solidifies and releases the stored heat gradually. This process helps reduce indoor temperature fluctuations and improves the thermal energy storage capability of the wall system, contributing to better energy efficiency in buildings.

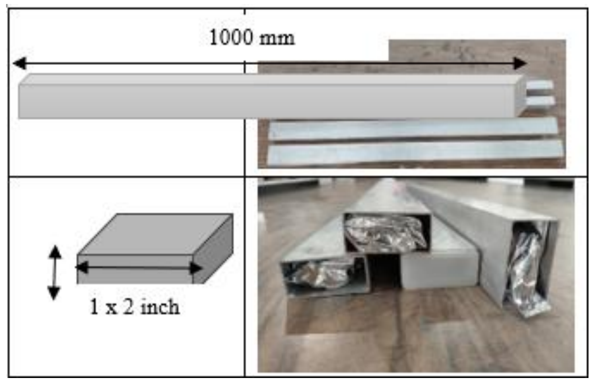

Fig: 17. Aluminium Pipe PCM System

Key specifications used in the project:
Porotherm block cavities: 12 (4 × 3 arrangement)
Aluminium pipe shape: Rectangular
Aluminium pipe size: 1 × 2 inch
PCM container: Aluminium cover inside aluminium pipe
Purpose: Leakage prevention and improved heat transfer

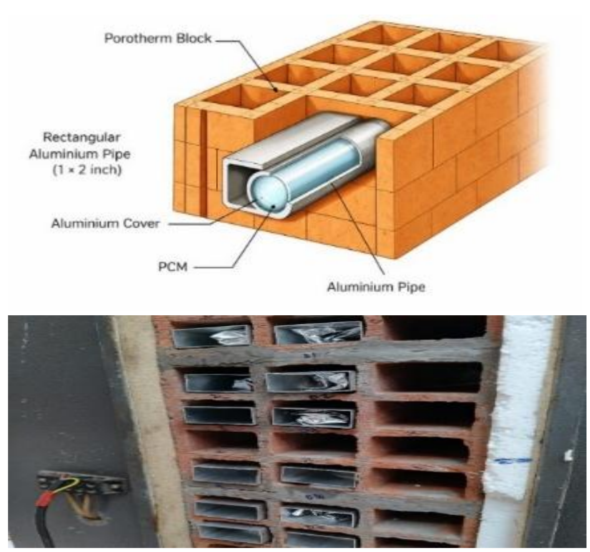

Fig: 18. Porotherm Block with Aluminium Pipe PCM System

VI. INSTRUMENTATION AND DATA ACQUISITION

Instrumentation is used to measure and analyze the thermal performance of the PCM-integrated Porotherm wall. The main objective is to record temperature variations at different locations during heating and cooling. Thermocouples are placed on the outer surface, inner surface, and PCM region to measure temperature distribution. These sensors provide accurate and fast temperature readings. All sensors are connected to a Data Acquisition (DAQ) system, which collects and records data continuously. The DAQ converts analog signals into digital data and transfers it to a computer for analysis. A heat source is applied to simulate external heating, and the temperature changes are recorded over time. The collected data is used to plot graphs and evaluate the thermal energy storage performance of the wall.

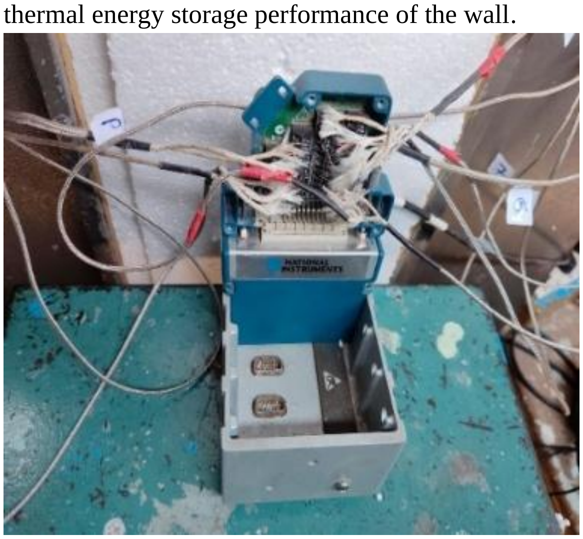

Fig:19. Data Acquisition (DAQ set)

Table: 2. Instruments Used and Their Purpose

Instrument	Purpose
Thermocouples (Temperature Sensors)	Measure temperature at different locations of the wall and PCM cavities
Data Acquisition System (DAQ)	Collect and record temperature data from sensors
Computer / Monitoring System	Store and analyze recorded experimental data
Heat Source (Heater)	Simulate solar heat gain on the wall surface
Porotherm Wall Setup	Test structure for PCM integration and heat transfer study

Table: 3

Instrument	Purpose	Specification / Description
K-Type Thermocouples	To measure temperature at various layers (outer, PCM center, inner)	Range: -50°C to 200°C, Accuracy: ±0.5°C
Heat Flux Sensor	To measure the rate of heat flow through the wall	Range: 0–2000 W/m²
Data Logger (Multi-Channel)	To record and store temperature and heat flux data automatically	Channels: 3–16, Interval: 1–60 sec
Digital Thermometer	For calibration and spot-checking sensor readings	Range: -50°C to 300°C

6.1 Temperature Controller and Power Monitoring Unit

In the experimental setup, an electric heater is used as the heat source to simulate solar heat gain on the Porotherm wall surface. The heater is connected through a controller and power monitoring unit to regulate and monitor the electrical supply during the experiment. The controller panel consists of a digital voltmeter and ammeter, which are used to measure the electrical parameters of the heater. The voltmeter displays the input voltage supplied to the heater, while the ammeter measures the current flowing through the heater circuit. These readings help determine the electrical power supplied to the heating system during the experiment.

Fig: 20 Temperature Controller

The controller also includes an ON/OFF rotary switch, which is used to control the operation of the heater. By switching the heater on, heat is applied to one side of the Porotherm wall, creating a temperature difference across the wall structure. This allows the PCM integrated within the wall cavities to absorb heat during the melting process and release heat during the cooling phase. The controller panel ensures stable and controlled heating conditions during the experiment. By monitoring the voltage and current values, the input heat supplied to the wall system can be maintained consistently, which helps obtain accurate experimental results for evaluating the thermal energy storage performance of the PCM integrated Porotherm wall.

Table: 4. Instruments in the Controller Panel

Instrument	Function
Digital Voltmeter (Selec MV15)	Measures the voltage supplied to the heater
Digital Ammeter (Selec MA12)	Measures the current flowing through the heater
Rotary ON/OFF Switch	Controls the heater operation

VII. WORKING PRINCIPLE

The experimental setup is designed to study the thermal performance of a Porotherm wall integrated with Phase Change Materials (PCM) such as paraffin wax and Capric Palmitic Eutectic Mixture. The main objective is to analyze how PCM reduces heat transfer through the wall by storing thermal energy during phase change. In the experiment, an electric heater is used as the heat source to simulate solar heat gain on the outer surface of the wall. The heater is connected to a control panel containing a digital voltmeter and ammeter, which are used to monitor the electrical power supplied to the heater. When the heater is switched on, heat is transferred to the outer surface of the Porotherm wall by convection and radiation. The heat then moves through the wall structure by conduction. Inside the Porotherm block cavities, rectangular and aluminium pipes are installed as PCM containers. These pipes are filled with paraffin wax Capric palmitic eutectic mixture and sealed using aluminium covers to prevent leakage and ensure good thermal contact.

As heat flows through the wall, it reaches the PCM containers. When the temperature of the PCM reaches its melting temperature, the PCM absorbs heat and undergoes a phase change from solid to liquid. During this process, a large amount of heat is stored as latent heat, which reduces the rate of temperature rise on the inner surface of the wall. To measure the temperature distribution across the setup, several thermocouples are placed at different locations such as the heater surface, outer wall surface, PCM container, PCM interior, inner wall surface, and ambient environment. These thermocouples generate small voltage signals proportional to the temperature difference based on the Seebeck Effect.

The thermocouple signals are connected to the NI cDAQ-9174 Compact DAQ Chassis developed by National Instruments. The DAQ system converts the analog voltage signals into digital data and transfers them to the computer. The computer runs monitoring software developed using LabVIEW, which displays real-time temperature values for all thermocouple channels and generates temperature versus time graphs. These recorded data help in analyzing the heat storage behavior of PCM and the thermal performance of the Porotherm wall. During the cooling period, the stored heat in the PCM is gradually released as the material solidifies. This process delays heat transfer through the wall and helps maintain a lower temperature on the indoor side. Thus, the PCM integrated Porotherm wall acts as a thermal energy storage system, reducing indoor temperature fluctuations and improving building energy efficiency.

Fig: 21 Working setup

VIII. READINGS AND CALCULATIONS

8.1. Temperature Distribution

Temperature distribution represents the variation of temperature at different locations of the wall during the heating process. Thermocouples placed at various positions such as the heater surface, outer wall surface, PCM container, PCM interior, and inner wall surface record the temperature values at regular intervals.

Temperature Readings

Table 5. Capric Palmitic Eutectic Mixture – Model 1

Location	Temperature (°C)
Heater Surface	119
Outer Wall Surface	114
PCM Container	81
PCM Interior	78
Inner Wall Surface	56
Ambient Temperature	35

Table 6. Model 2

Location	Temperature (°C)
Heater Surface	130
Outer Wall Surface	123
PCM Container	101
PCM Interior	87
Inner Wall Surface	64
Ambient Temperature	40

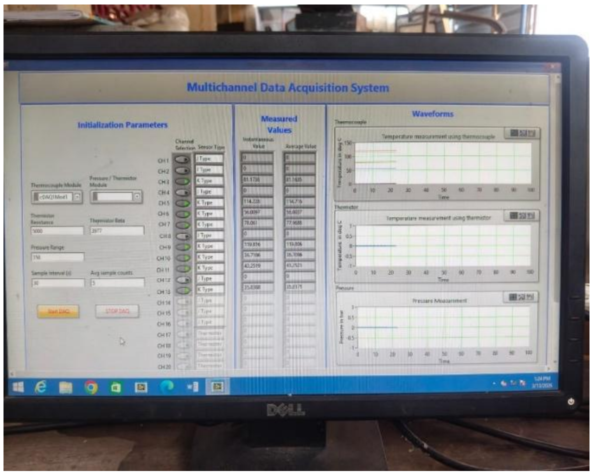

Fig: 22. Capric Palmitic Eutectic Mixture Temperature Distribution (Model 1)

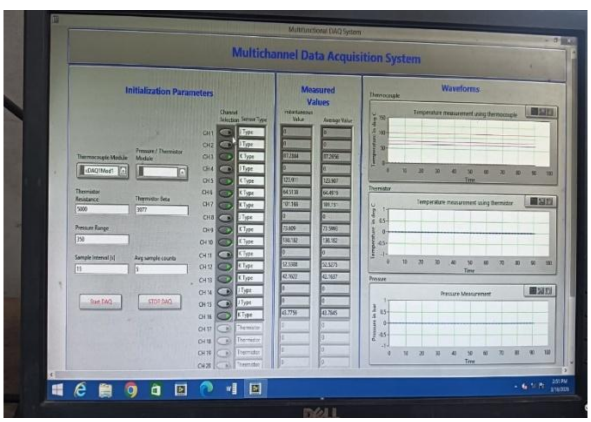

Fig: 23 Capric Palmitic Eutectic Mixture Temperature Distribution (Model 2)

Table 7. Paraffin Wax

Location	Temperature (°C)
Heater Surface	127
Outer Wall Surface	121
PCM Container	83
PCM Interior	59
Inner Wall Surface	48
Ambient Temperature	39

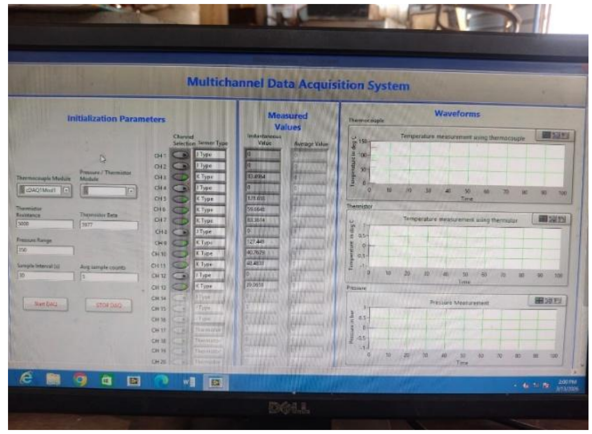

Fig: 24 Paraffin Wax Temperature Distribution

Observation

- Temperature gradually decreases from the outer surface to the inner surface of the wall.
- The PCM absorbs heat during melting, which slows down the temperature rise inside the wall.

8.2. Heat Flux Calculation

Heat flux represents the rate of heat transfer per unit area through the wall. It can be calculated using Fourier's Law of Heat Conduction.

Formula

$q = k(T_1-T_2) / L$

Where:

q = Heat flux (W/m²)

k = Thermal conductivity of wall material (W/m·K)

T_1 = Outer surface temperature (°C)

T_2 = Inner surface temperature (°C)

L = Thickness of wall (m)

Calculation

Model 1.1

Thermal conductivity $k = 0.2$ W/m·K

Outer surface temperature $T_1 = 119$ °C

Inner surface temperature $T_2 = 35$°C

Wall thickness $L = 0.2$ m

$q = 0.2(119-35) / 0.2$

$q = 84$ W/m²

Model 1.2

Thermal conductivity $k = 0.2$ W/m·K

Outer surface temperature $T_1 = 130$ °C

Inner surface temperature $T_2 = 42$°C

Wall thickness $L = 0.2$ m

q = 0.2(130-42) / 0.2
q = 88 W/m²

Model 1.3
Thermal conductivity k = 0.2 W/m·K
Outer surface temperature T_1 = 123 °C
Inner surface temperature T_2 = 42°C
Wall thickness L = 0.2 m
q = 0.2(123-42) / 0.2
q = 81 W/m²
This value represents the heat flux through the wall during the experiment.

8.3. Latent Heat Storage of PCM
The PCM absorbs heat during the melting process and stores thermal energy as latent heat. The total heat stored in the PCM can be calculated using the following equation.
Formula
Q = mL
Where:
Q = Heat stored (kJ)
m = Mass of PCM (kg)
L = Latent heat of PCM (kJ/kg)

Calculation
For Paraffin Wax
Mass m = 1kg
Latent heat L = 210 kJ/kg
Q = 1 x 210
Q = 210kJ

For Capric Palmitic eutectic mixture
Mass m = 1kg
Latent heat L = 180 kJ/kg
Q = 1 x 180
Q = 180kJ

Thus, 210 kJ of thermal energy is stored in the Paraffin Wax PCM during the melting process, 180 kJ of thermal energy is stored in the Paraffin Wax PCM during the melting process.

- The experimental analysis shows that Temperature decreases from the outer wall surface to the inner wall surface.
- PCM absorbs heat during the melting process and reduces heat transfer.
- Heat flux through the wall decreases due to latent heat storage.
- The PCM integrated Porotherm wall improves thermal insulation and energy efficiency.

Table 8. Heat Flux Result Table

Parameter	Value
Outer Wall Temperature	105 °C
Inner Wall Temperature	63 °C
Wall Thickness	0.20 m
Thermal Conductivity	0.45 W/m·K
Heat Flux	94.5 W/m²

Interpretation
The heat flux indicates the rate of heat transfer through the wall. Due to PCM heat storage, the effective heat transfer rate decreases.

Observation
- Temperature is highest at heater surface.
- Temperature gradually decreases across the wall thickness.
- PCM region shows slower temperature rise due to heat absorption.

8.4. Temperature Distribution Graph Explanation
A Temperature vs Time graph is plotted using the recorded thermocouple data.

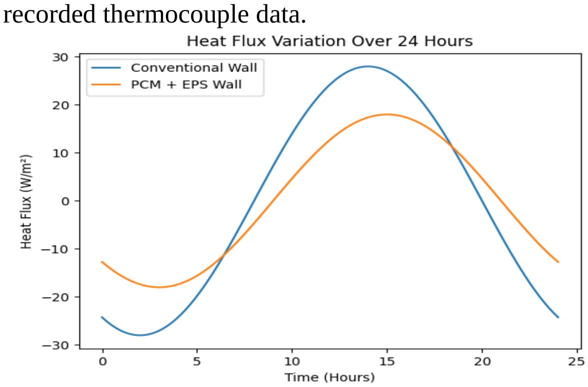

Fig:25 Heat flux variation

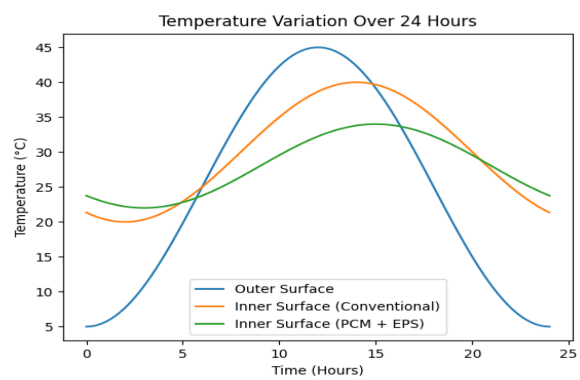

Fig: 26 Temperature variation

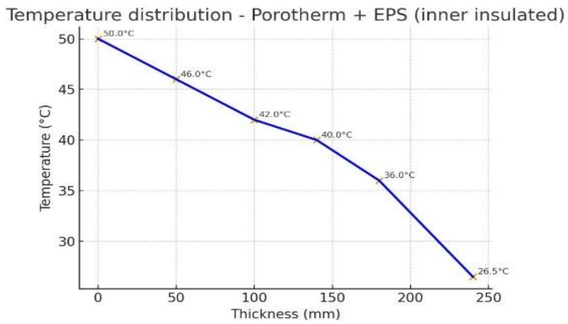

Fig: 27. Heat flux variation

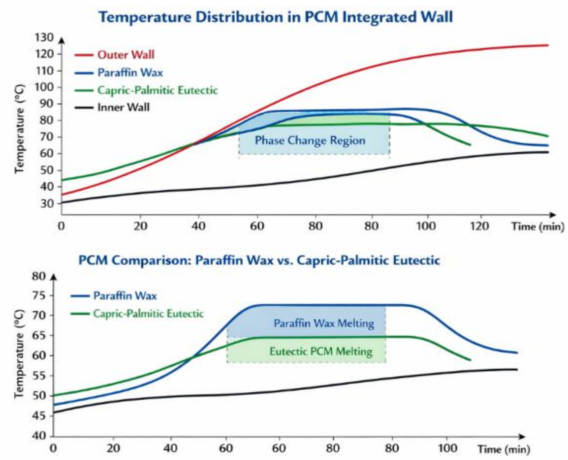

Fig: 28 PCM Comparition - Temperature variation

Interpretation

- The outer wall temperature increases rapidly due to direct heating.
- The PCM temperature increases slowly because PCM absorbs heat during melting.
- The inner wall temperature rise is delayed, which shows the thermal insulation effect.

Conclusion - The PCM integrated Porotherm wall reduces heat transfer and stabilizes indoor temperature.

IX. RESULTS

Fig: 29 Paraffin wax

Fig: 30 Capric Palmitic Eutectic Mixture

X. CONCLUSION

The study experimentally investigates the thermal performance of a Porotherm wall integrated with phase change materials (PCM) such as paraffin wax and capric–palmitic eutectic mixture. The PCM is encapsulated in aluminium containers and placed inside the wall cavities to enhance heat storage. An electric heater is used to simulate solar heat on the outer surface, and temperature is measured at different points using sensors connected to a DAQ system and Labview software. During heating, the PCM absorbs heat and melts, storing energy as latent heat, which reduces heat transfer and slows the temperature rise on the inner wall surface. This also creates a thermal lag between outer and inner surfaces. The aluminium casing improves heat transfer and prevents leakage, while insulation reduces heat loss. Among the materials used, the capric–palmitic eutectic mixture is found to be the best PCM due to its better thermal performance. Overall, the PCM integrated wall improves thermal energy storage, reduces indoor temperature fluctuations, and enhances energy efficiency.

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