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A Comparative Study of the Effect of Paraffin Phase Change Material Mixture and Ice Bag on Temperature Control in Bricks

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Abstract. The study aims to enhance thermal performance and energy efficiency in building materials by incorporating phase change materials (PCMs) into bricks. This research specifically evaluates a paraffin-ice bag PCM mixture to regulate temperature fluctuations and improve the thermal inertia of bricks. Paraffin offers high latent heat and chemical stability, while ice bags provide efficient low-temperature thermal regulation. The combination leverages their complementary properties to address challenges such as low thermal conductivity and phase transition leakage in paraffin. A 50:50 ratio of paraffin and ice bag PCM was integrated into standard bricks. The experimental setup involved coating brick surfaces with liquid cement to prevent PCM leakage, filling brick cavities with the PCM mixture, and subjecting the bricks to controlled heating and cooling cycles. Temperature sensors recorded data to assess thermal performance. Results demonstrated that PCM-enhanced bricks significantly reduced temperature fluctuations compared to non-PCM bricks, maintaining thermal stability during peak heating and cooling periods. The PCM bricks also exhibited higher heat transfer rates during phase changes, enabling efficient energy absorption and gradual release. This study highlights the potential of PCM-enhanced bricks as a cost-effective and sustainable solution for reducing energy consumption in buildings, contributing to advancements in thermal energy storage and climate-responsive construction practices.

Keywords : PCM, Bricks, Temperature, Paraffin, Ice bag

1. INTRODUCTION

Construction has become one of the most important industries in our age as it provides necessary structures and housing. However, this industry has also a severe problem on its hand in the form of energy use and environmental concerns. Structures account for a large percentage of the world's energy consumption, for the most part, during the heating and cooling processes. This demand for energy results in greenhouse gasses emissions which enhances climate change. As a result, green building practices that reduce energy use and increase thermal animals' comfort are in great demand.

Integrating phase changing materials within the building materials is one potential way to achieve this goal. Phase change materials which are also known as PCMs are materials that can store heat energy or thermal energy during the process of the material changing its state for instance during melting or freezing. When the temperature of a surface or heating alters, intermediate PCMs incorporated in a building regulate the in its areas temperature and pressure without additional systems. As the temperature increases, PCMs become more liquid

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and absorb excess heat and thus help to prevent the indoor temperature from rising too dramatically. If the surrounding temperature decreases, stored heat comes from the PCMs which are in the solid state; the indoor environment remains pleasant when the comfortable temperature range is desired.

Chinese brick manufacturing productivity and global competitiveness are analysed in this paper providing a productivity assessment in a multi-time scale. The subject of performance is Chinese brick manufacturing in the context of world market orientation. More detailed, brick and tiles, mortars, mixtures for concrete and masonry, heat insulation materials and ceramics are viewed as market oriented products in countries where they are available. Furthermore, Strong economy, the sustained rate of expansion of industries, as well as the level of global competitiveness are forecasted in current and future scenarios in this section of the paper. Also this section provides dynamics of productivity and competitiveness of the corporations in developing countries, enabling to establish a cause-and-effect connection between the stage of expansion of industries, the maturity of the Corporation itself and the global competitiveness level. China as country with most intensively growing productive industry competitiveness is focus of this paper. The relevance of the topics undertaken, and the possible outcomes are addressed in sections. It should also be mentioned that, at this stage, the potential of the Chinese brick manufacturing should be evaluated. The focus on the advantages and strategies of global bricks and tile mortars will create sufficient economic viability for brick manufacturing. Therefore trends in the development of production will be correlated with competitive ideas and the most effective solutions for the country under study. This conclusion validates the significance of the identifying purpose of targeting countries aimed ultimately at globalization.

2. LITERATURE REVIEW

Many researchers have examined the integration of PCM's within building envelopes which include walls, roofs, and floors. For example, Li et al. (2018) created a so-called wall panel called the wallboard which included PCM or microencapsulated paraffin wax in the construction. Their findings proved that the PCM-wallboard made it possible to reduce variations in domestic temperature and to achieve a higher level of thermal comfort. PCM-filled concrete panels were also studied by Huang et al. (2020) where they examined the viability of the PCMs and noticed that both maximum indoor temperature and energy consumption levels were considerably reduced. The other direction of PCMs application related studies is connected with the use of these materials in the composition of bricks. Rao et al. (2019) used clay bricks in the construction of paraffin wax containing bricks and carried out research on thermal properties on the paraffin wax containing bricks. It was noted that the PCM-bricks possessed high thermal inertia and less heat transfer than ordinary bricks. Likewise, Sharma et al. (2021) also investigated concrete bricks reinforced with shape-stabilized PCM materials and recorded a significant improvement in thermal performance of the concrete bricks with energy savings reported too.

The implementation of ice bags as a PCM has also been studied in different applications. For instance, Wang et al. (2022) created a new thermal energy storage system based on ice for air conditioning. Their system incorporated ice bags to capture chilling energy during the non-peak hours and discharge it at peak hours which helped them cut costs dramatically. This paper extends the former works by integrating paraffin wax with ice bags that are used as PCMs in bricks. The objective of doing so is to culminate an affordable and an efficient means of thermal energy storage and control within buildings. The thermal characteristics of the PCM-enhanced bricks will be evaluated via experimental tests and numerical modeling of the elements. The results will help develop eco-friendly building materials and technologies to improve energy efficiency, as well as thermal comfort to the buildings.

3. METHODS

Materials

1. Bricks: Standard sized blocks for testing

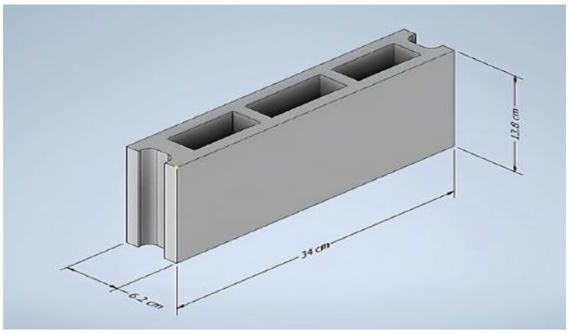


Figure 1. Sketch Bricks

2. **Phase Change Materials:**

   The characteristics of paraffin are that it has high latent heat and a relatively stable melting/freezing point.

Figure 2. PCM Paraffin

3. **Ice Bag (PCM based on gel)**

   The characteristics of ice bag have a lower melting point, providing efficient thermal regulation at lower temperatures

   .

Figure 3.Ice Bag

Experiment Set Up

Liquid cement coats the inner surface of the brick inside the brick hole before mixing it with paraffin to cover its pores and prevent PCM from absorbing into the outer surface. Next, we will pour a mixture of paraffin and ice into the brick hole, following the specified ratio for each sample. Next, we will slowly cool the concrete blocks to evenly distribute the PCM throughout the concrete structure. We expect this method to enhance the thermal efficiency and resilience of concrete bricks against extreme temperature fluctuations.

Figure 4.Bricks

1. Material mixing process

The mixture with the ratio of paraffin and ice pack is (50:50)

Figure 5. Mixture PCM dan Ice Bag

A 50:50 ratio to test the effectiveness of the PCM mixture. After preparing all the mixtures, we will test them in a specially designed environment that simulates extreme temperature conditions. We will collect and analyze data to identify the most effective mixture for optimal thermal regulation.

2. Bricks structure

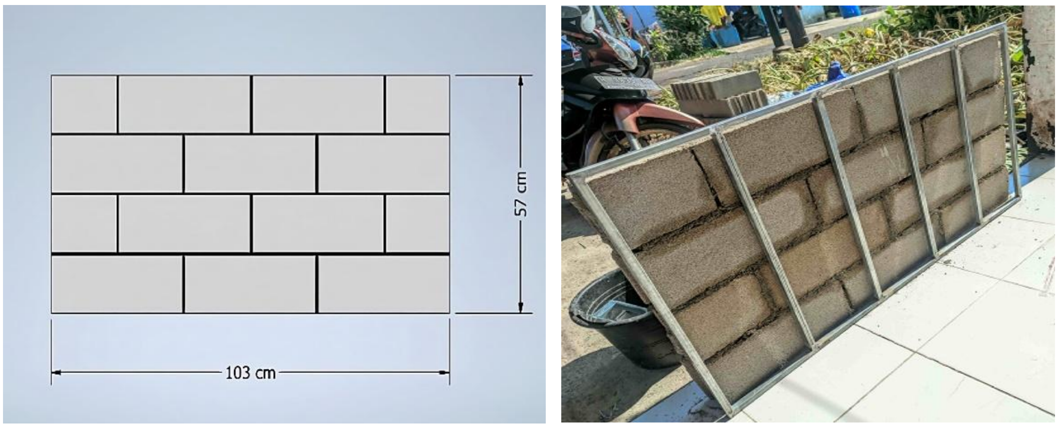


Figure 6. Brick Structure

3. Temperature Sensor

Position sensors inside and on the surface of the block to measure temperature changes.

Figure 7. Data collection

4. Heating Cycle

Throughout the day, direct thermal cycles with sunlight will expose the blocks.

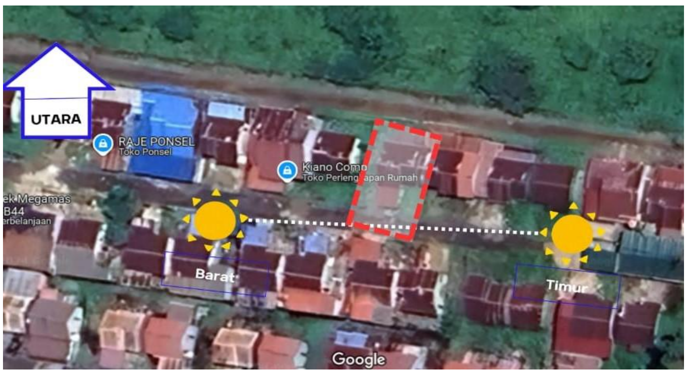


Figure 8. Research location in Pontianak

4. RESULTS

Table 1. Data Collection Temperature Difference Non PCM and Mixture

Time	Temperature Difference Non PCM	Temperature Difference Mixture
06.00.10 a.m	0,00	0,00
07.02.00 a.m	3,25	6,00
08.03.51 a.m	7,00	8,25
09.05.42 a.m	5,25	14,25
10.07.33 a.m	11,00	16,25
11.09.24 a.m	10,25	16,50
12.11.16 p.m	9,75	16,50
01.13.08 p.m	3,75	10,50
02.14.59 p.m	1,75	8,50
03.16.51 p.m	1,00	6,25
04.18.43 p.m	0,50	0,75
05.20.34 p.m	0,25	0,50

Table 2. Data Collection Heat Transfer Rate Non PCM and Mixture

Time	Heat Transfer Rate Non PCM	Heat Transfer Rate Mixture
06.00.10 a.m	0,00	0,00
07.02.00 a.m	0,40	0,74
08.03.51 a.m	0,87	1,02
09.05.42 a.m	0,65	1,76
10.07.33 a.m	1,36	2,01
11.09.24 a.m	1,27	2,04
12.11.16 p.m	1,21	2,04
01.13.08 p.m	0,46	1,30
02.14.59 p.m	0,22	1,05
03.16.51 p.m	0,12	0,77
04.18.43 p.m	0,06	0,09
05.20.34 p.m	0,03	0,06

Table 3. Data Collection Radiation Flux Non PCM and Mixture

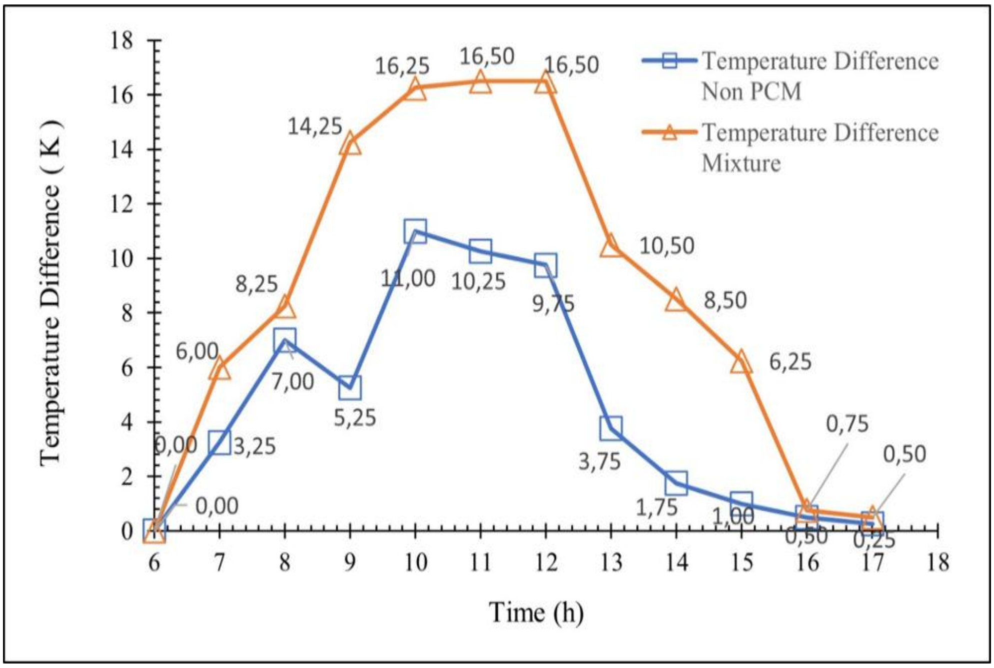
Time	Radiation Flux Non PCM	Radiation Flux Mixture
06.00.10 a.m	407,04	407,04
07.02.00 a.m	479,95	484,53
08.03.51 a.m	500,01	492,23
09.05.42 a.m	543,68	572,59
10.07.33 a.m	608,08	609,89
11.09.24 a.m	630,14	633,88
12.11.16 p.m	652,81	650,89
01.13.08 p.m	620,88	619,04
02.14.59 p.m	608,08	617,20
03.16.51 p.m	600,85	599,06
04.18.43 p.m	586,60	560,55
05.20.34 p.m	579,56	547,02

Table 4. Data Collection Top Surface Non PCM and Mixture

Time	Top Surface Non PCM	Top Surface Mixture
06.00.10 a.m	303,15	303,15
07.02.00 a.m	315,90	316,65
08.03.51 a.m	319,15	317,90
09.05.42 a.m	325,90	330,15
10.07.33 a.m	335,15	335,40
11.09.24 a.m	338,15	338,65
12.11.16 p.m	341,15	340,90
01.13.08 p.m	336,90	336,65
02.14.59 p.m	335,15	336,40
03.16.51 p.m	334,15	333,90
04.18.43 p.m	332,15	328,40
05.20.34 p.m	331,15	326,40

5. DISCUSSION

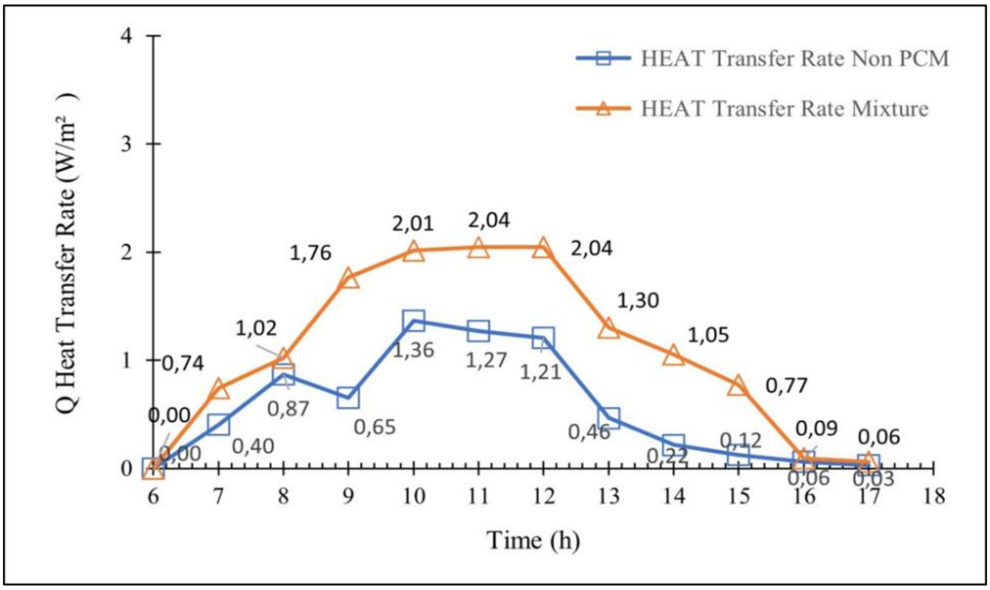
Differences in temperature reduction in bricks with mixed PCM and non-PCM



Graphic 1. Temperature Difference

The graph above illustrates how the temperature changes with time in PCM (phase change material) and Non-PCM materials. Blue lines illustrate the materials which were not incorporated with PCM while orange lines form the materials that utilized PCM as a mixture. This implies that the study material which was PCM incorporated recorded a better heat storage capability than the PCM Free material. Depending on graphical data (6.00-9.00) during the first hours, the temperature of both materials slightly rises, the material with PCM at 10:00 reached a maximum temperature difference of (16.50 K) from the last time measurement, non PCM reached only (10.25 K). At this moment onward PCM Free material recorded a higher drop rate of temperature than the PCM containing material. This shows that a PCM material is better for applications where gradual heating and cooling is necessary. Previously noted hours 15.00 – 17.00 show that the temperature differences of PCM material is lesser than the non PCM. Therefore it can be concluded that PCM materials are better for limiting temperature fluctuations and that PCM can be used in many thermal control applications enabling better thermal characteristics in the end product.

Heat transfer rate mixed PCM and non-PCM



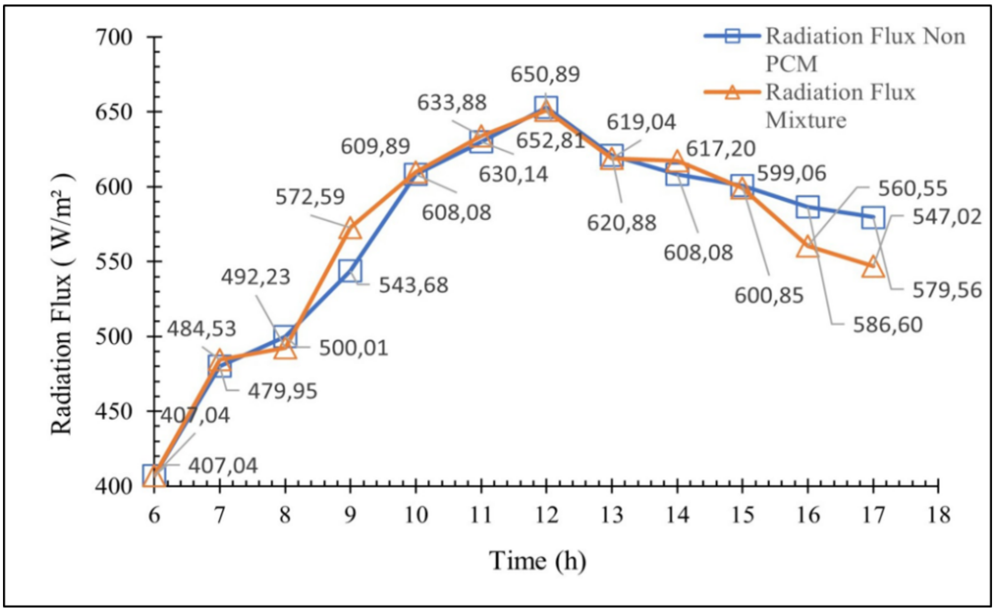
Graphic 2. Heat Transfer Rate

$$Q = K.A.\frac{\Delta t}{L} \quad (1)$$

Wherei Q is Heat Transfer Rate,K is Thermal Conductivity,A is Top Surface Area, ΔT is Themperature Difference, L is Brick Wall Thicknes

The graph below provides a comparison between the heat transfer rates, Q Non PCM Heat Transfer Rate, of the system without PCM and Q Mixed Heat Transfer Rate of the PCM mixture system with paraffin and ice bags. Both systems showed a heat transfer rate of 0 W/m² at 6:00 a.m. which was expected due to thermal equilibrium in both systems at this point. With the increase in time and solar radiation, Q Mixed Heat Transfer Rate for the system with PCM mixture rose higher and faster than Q Non PCM Heat Transfer Rate for the system without PCM. By 8:00 am, while the system without PCM was able to reach 0.87 W/m², the system with PCM mixture reached 1.02 W/m² instead. One reason for the increased growth of the PCM system is because the material which underwent phase changes can retain heat without causing an increase in temperature. Between 10 am and 12 noon, the system with the PCM mixture achieved a maximum heat transfer rate of 2.04 W/m². Because the PCM material could store latent heat during a phase transition, this figure lasted for a while. The turning point in the system without PCM occurred around 10 am with 1.36 W/m² which is much lower than the value attained in the system with PCM. The statement demonstrates the cooling power of the PCM system when it was required to provide a higher heat transfer surface area for longer periods and hence effectively manages the thermal loads by timely getting rid of the excess heat that is absorbed. After lunch when the environment was very hot forcing system 2 this time also experienced the highest heat transfer rates; though heat transfer rates of both systems started to decline. The PCM-mixed system's rate of decline was slower than the growth rate of the PCM return phase's effects on stored heat transfer; it declined from 2.04 W/m2 and 3.00pm to about 0.077 W/m2. On the contrary, the one without PCM was in sharp decline to almost zero around the same time. This behavior shows thermal lag effect of the PCM system which makes it possible to have better thermal stability and regulation of heat release.

Solar radiation waves in Watt/m^2 units.



Graphic 3. Fluks Radiation

$$\Phi = \varepsilon.\sigma.T^4 \qquad (2)$$

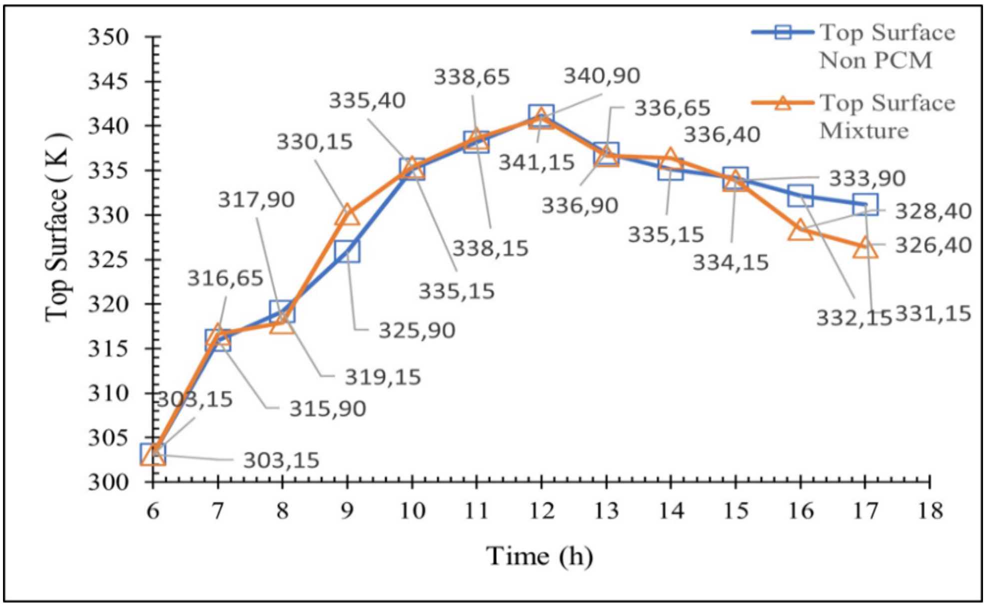
Where Φ is Radiation Flux,ε is Emivisibility of Objects,σ is Constant Stefa-boltzman,T^4 is Objective Temperature

The graph depicts the time monotonic evolution of the radiation flux differential between the non-PCM system and the PCM mixture of paraffin and an ice bag. The graph indicates the flux in Kelvin (K). The two systems had the same initial values at around 407.04 K about 3 hours after 6:00 AM. Between 6:00 AM and 12:00 PM both systems were increasing the solar radiation received and energy stored, with the PCM system attaining slightly upper values as it was. Owing to the latent heat effect in the paraffin and ice bag mixture, the PCM has an improved energy absorption capability. The PCM system peaked at about 650.89 K at

1:00PM while the non-PCM system attained about 652.81 K at around the same time. The gradual and prolonged peak of the PCM system shows that it is the better system for the management of temperature changes through energy storage or absorption. After hitting the peak, radiation flux in both systems started falling. The rate of fall in the PCM system was more gradual and stable than that of the non-PCM one supporting its claim for dominance in thermal regulation.

The thermal management unit of the PCM has the advantages of gradually releasing the thermal energy stored within the device due to the phase-change aspect of the material. On the other hand, the non-phase-change unit showed a rapid decrease of temperature indicating a low potential heat storage. During the duration between 16:00 to 18:00, the radiation flux of the PCM unit was observed higher and more stable than that of the non PCM unit, illustrating its effectiveness in heat management.

Top Temperature Surface



Graphic 4. Temperature Surface

The graph displays the time evolution of the surface temperature of the top of the brick for materials without PCM (non-PCM) and that which has PCM in it (paraffin and Ice bags included) as decorative elements in window frames. As for the bricked wall surface which was coated on the top with decorative materials, the blue line indicates the course of the top surface temperature of a non-PCM brick while the orange line depicts the course of the value with a mixture of PCM.

In the afternoon, in the morning, (6:00 – 8:00), the temperature of both types of brick increased gradually to each other and the temperature range is almost similar in both the type of bricks. Between 9:00 and 12:00 noon, the temperature of both materials was observed to be at its maximum level. Non-PCM brick attained a maximum heat value of 340.90 W at 12:00 noon while that mixed with PCM attained a peak temperature of 336.56 W at the same time, but this value was slightly lower than that for the non-PCM brick. This was noted to be 340.90 W, thus showing that the PCM mixture is able to reduce the temperature rise to the peak temperature. As a result, in the hottest hour of the day, the surface of the brick has PCM which is cooler than the surface of the brick without PCM.

The peak temperature is followed by a steady decrease in the surface temperature of both materials. However, the temperature drop rate for the PCM-mixed brick is lower than that of the non-PCM brick. Bricks made of PCM-concrete had a more constant surface temperature during the afternoon to evening hours (15:00 to 18:00) than did those made of non-PCM materials. For example, at 18:00 the non-PCM bricks had an upper surface temperature of 326.40 W, while the PCM-concrete bricks were able to keep the upper surface temperature at around 333.90 W.

6. CONCLUSION

This experiment investigated the heat load bearing capacity of bricks enhanced with a mixture of paraffin and ice bags used as phase change materials (PCM). The findings emphasize the ability of PCM bricks to maintain uniform temperature fluctuations thereby making heat transfer much more efficient than bricks without the use of PCM. The improved bricks with PCMs showed lower maximum temperatures reached and lower maximum rates of temperature decrease, signifying that these materials phase-shift and absorb heat more efficiently. The PCM-controlled structure has illustrated the thermal load management that utilizes a peak heat transfer rate of 2.04 W/m² with thermal energy storage and release occurring during phase shift. The stable radiation flux also indicates that changes in the temperature can be countered by the PCM systems which are capable of absorbing and emitting energy with great efficiency. The surface temperature of bricks containing paraffin during peak hours was lower and the time taken to get to its highest melt point was longer making them assist in keeping the indoor temperature much more in comfortable range. The results clarify that PCM brick is a safe and intelligent approach to minimizing energy consumption in buildings with improved thermal comfort. Future studies may evaluate long-term application and durability of the technology possessing economic benefits.

LIMITATION

The data collection process in the field often faces various challenges, such as unpredictable weather, temperature instability, sensor errors, and the influence of wind. Extreme weather can compromise measurement accuracy, while sudden changes in temperature often affect equipment performance and data quality. In addition, sensor errors, caused by technical glitches or suboptimal calibration, are a significant obstacle. Strong winds can also affect the stability of the measuring device, resulting in inconsistent data.

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