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Experimental Study of Conduction Heat Transfer Using Paraffin Phase Change Material on Bricks

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Abstract. *This research examines the effect of bricks enhancement with phase change material (PCM) consisting of paraffin on their thermal considerations. The experimental methods were aimed at investigating the mechanisms of temperature transfer throughout the thermal rounds, mimicking diurnal fluctuations of temperature. Due to the high amount of latent heat contained in paraffin a portion of it was transferred into regular bricks with temperature probes tracing the heat processes. It is shown that enhancement of bricks with PCM reduced temperature range and controlled the rate of heat transmission more than the ordinary bricks did. It was significant that the PCM-embedded bricks did not drift in heat and were able to stock up excess heat during the day and release it at night which resulted in monumental energy efficiency and comfort in thermal standing. The conversation additionally seeks to bring out the function of paraffin in insulation which does not only save energy consumption but goes forward to maintain comfortable temperatures within the building. The study finally achieved its goal and assert that energy saving with the use of PCM enhanced bricks in construction makes it a preferable material in regards to energy and the fight against climate change.*

Keywords: *Bricks, Paraffin, Thermal, Energy*

1. INTRODUCTION

Renewable construction methods and materials have gained significant notoriety as the positive global energy need and the adverse impacts of climate change continue to grow. Popular studies indicate that Buildings are major energy consumers and account for a large percentage of energy use and GHGs emissions. Windows play a major role in improving thermal energy storage (TES) in buildings. TES materials are capable of absorbing, storing and releasing thermal energy thereby reducing the indoor temperature control needs and system dependence on mechanical heating and cooling equipment.

Buildings have used Phase change materials in recent developments. Their main properties are high energy storage density, and a substantial phase transition temperature process. The advantage of using these materials is their ability to absorb and release the latent heat in large quantities when changing from a solid to a liquid state. Out of a wide variety of PCMs, paraffin waxes appear to be the most efficient and commercially viable option. Their low cost, chemical stability and suitable melting temperatures make them ideal

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for construction applications. Adding Coreform S has demonstrated that paraffin PCMs permeated into bricks strongly enhance the thermal properties of the bricks significantly.

Bricks enabled with PCM can build up the excess heat during the daytime thus avoiding overheating and can also give out the stored heat during the nighttime thus lowering the heating needs. Such passive thermal regulation may result in noticeable energy cost reductions and enhanced thermal comfort in an indoor environment . This particular study centers on testing the conduction heat transfer performance of bricks, embedded with paraffin wax as the TES-PCM based material. The focus is to test the extent to which paraffin wax as a PCM improves the thermal effectiveness of bricks in relation to the amount of PCM content in the consisting composite material. This research will be applied to improving building materials with higher performance in thermal efficiency and construction materials of energy efficient buildings. The idea of employing PCM's for thermal energy storage in construction, has quite recently become popular. Many types of research were done in order to study some kinds of PCM's and their combinations with various building structures.

2. LITERATURE REVIEW

The building materials combining paraffin wax in a micrometre or nanometre range has enhanced the performance of the material due to thermal transfer efficiency. Some researchers have made an effort to mix the paraffin wax with the bricks aiming at improving the thermal performance of the building an materials. Concentrating on these aspects, Ling et al. engineered a hybrid brick embedded with microencapsulated paraffin wax and performed thermal tests and energy storage studies. Their findings indicated the effectiveness of PCM incorporated brick technologies on increasing the energy efficiency of structures. In the same manner, Li et al. investigated thermal properties of bricks coated with paraffin wax, explaining the effect of the PCM concentration on the complex thermal conductivity and the heat capacity of the composites.

We have also looked at the effect of various PCM impregnation processes on the thermal characteristics of the bricks and selected the best ones able to produce bricks with the required thermal performance and uniform distribution of the PCM material. Furthermore, computer models have been applied to simulate the heat exchange processes in PCM containing bricks and assess their effectiveness in a range of conditions. With the increasing amount of literature on PCM-enhanced building materials, the experimental studies aimed at getting a thorough understanding of the thermal characteristics of these materials and their applications in buildings appear to be wanting. This research proposes the systematic experimental examination of heat transfer of bricks with paraffin wax. The outcome of this research is likely to assist in the designing and enhancement of reliable heat insulation material for building and promote the green building concept.

3. METHODS

Materials Bricks

a. Bricks: Standard size blocks for testing.

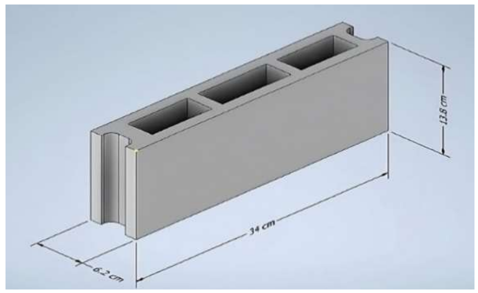

Figure 1. Sketch of Bricks

b. Phase Change Materials

Paraffin is known for its high latent heat and generally constant melting/freezing temperatures. Paraffin has excellent thermal insulation qualities, making it ideal for use as a phase transition material in this investigation. Furthermore, paraffin is easy to get and inexpensive, making supplies for experiments more accessible. This study's use of paraffin as a phase transition material is intended to deliver accurate and dependable data for future technological progress.

Figure 2. Paraffin

Experiment Set-up

Liquid cement comes to be applied first to the interior of the brick in the brick hole before such is mixed with paraffin. This prevents the holes from being open and the movement of phase change materials to the outside. Now we shall insert paraffin-ice mixture made in the recommended combinations for each sample into the brick hole. After such, we cool delicately the concrete blocks so as to enable uniform distribution of PCM within the concrete matrix. This technique is expected to improve the thermal performance and damage resistance of the concrete bricks against thermal stress.

Figure 3. Bricks

a. Paraffin-filled bricks

As a phase change material, paraffin is more efficient in absorbing and releasing heat, making it suitable for a variety of thermal applications. In addition, paraffin also has excellent stability so that it can last for a long time without degradation. This makes paraffin the ideal material for this study. Furthermore, paraffin's excellent thermal insulation properties can help optimize energy efficiency and reduce fuel consumption. As a result, we believe that using paraffin as a phase change material in this study will make a significant contribution to the development of more efficient and environmentally friendly thermal technology.

Figure 4. PCM inside bricks

b. Brick structure

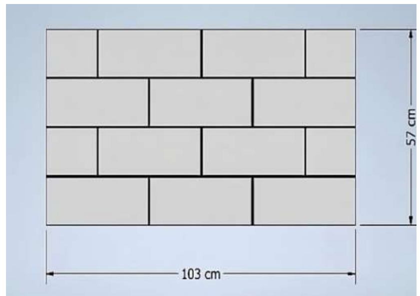

Figure 5. Brick Structure

c. Sensors temperature:

In order to assess the temperature changes, the sensors will be installed both in the interior as well on the exterior of the blocks. Thermal contraction and expansion test: the blocks will be subjected to diurnal temperature cycles within a controlled heated and cooled laboratory. The test results will assess the extent to which the PCM has managed to regulate the room temperature and control the energy consumption. We expect to get good and consistent data during the experimental setup quite meticulously. Further, controlled heating and cooling cycles will assist in evaluating the PCM effectiveness under the actual conditions of use.

Figure 6. Data Collection

d. Heating Cycle: Throughout the day, the blocks will be exposed to direct thermal cycles caused by sunlight.

Figure 1. Research location

4. RESULT

Table 1. Data Collection Temperature Difference

Time	Non PCM Temperature Difference (Kelvin)	PCM Temperature Difference (Kelvin)
6:00:00 a.m.	2,00	0,00
7:00:00 a.m.	9,00	2,00
8:00:00 a.m.	12,50	9,00
9:00:00 a.m.	12,50	12,50
10:00:00 a.m.	12,75	12,50
11:00:00 a.m.	13,00	12,75
12:00:00 p.m.	3,25	13,00
13:00:00 p.m.	3,50	3,25
14:00:00 p.m.	3,50	3,50
15:00:00 p.m.	1,25	3,50
16:00:00 p.m.	0,00	1,25
17:00:00 p.m.	0,00	0,00

Table 2. Data Collection Heat Transfer Rate

Time	Non PCM Heat Transfer Rate (Q)	PCM Heat Transfer Rate (Q)
6:00:00 a.m.	0,00	0,00
7:00:00 a.m.	0,80	2,13
8:00:00 a.m.	0,80	9,57
9:00:00 a.m.	1,06	13,30
10:00:00 a.m.	0,27	13,30
11:00:00 a.m.	0,00	13,56
12:00:00 p.m.	0,53	13,83
13:00:00 p.m.	1,06	3,46
14:00:00 p.m.	0,53	3,72
15:00:00 p.m.	0,00	3,72
16:00:00 p.m.	0,80	1,33
17:00:00 p.m.	0,80	0,00

Table 3. Data Collection Flux Radiation

Time	Non PCM Radiation Flux	PCM Radiation Flux
6:00:00 a.m.	407,04	407,04
7:00:00 a.m.	450,28	461,98
8:00:00 a.m.	456,10	511,07
9:00:00 a.m.	487,60	569,13
10:00:00 a.m.	509,48	583,07
11:00:00 a.m.	530,45	595,48
12:00:00 p.m.	548,70	641,40
13:00:00 p.m.	572,59	595,48
14:00:00 p.m.	570,86	595,48
15:00:00 p.m.	560,55	584,83
16:00:00 p.m.	547,02	555,45
17:00:00 p.m.	469,41	469,41

Table 4. Data Collection Temperature Top Surface

Time	PCM Top Surface (Kelvin)	Non PCM Top Surface (Kelvin)
6:00:00 a.m.	312,90	310,90
7:00:00 a.m.	320,90	311,90
8:00:00 a.m.	329,65	317,15
9:00:00 a.m.	331,65	319,15
10:00:00 a.m.	333,40	320,65
11:00:00 a.m.	339,65	326,65
12:00:00 p.m.	333,40	330,15
13:00:00 p.m.	333,40	329,90
14:00:00 p.m.	331,90	328,40
15:00:00 p.m.	327,65	326,40
16:00:00 p.m.	314,15	314,15
17:00:00 p.m.	273,15	273,15

5. DISCUSSION

Differences *in temperature reduction in bricks with paraffin and non-PCM*

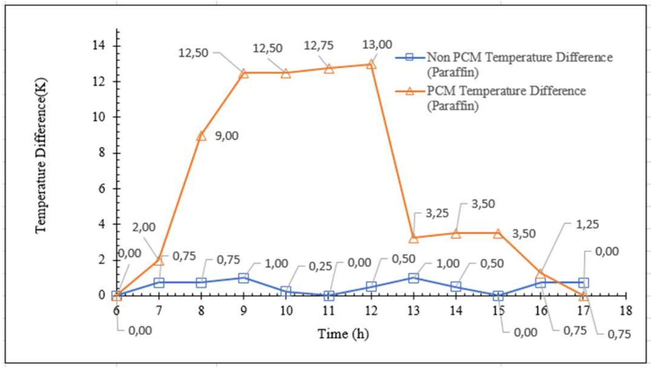

Figure 1. Temperature Difference

Temperature changes in hours for a paraffin constructed system (PCM) and a non-paraffin constructed system (Non-PCM) are shown graphically over a period of 17 hours. The use of paraffin reduces the temperature variations compared to the non-PCM system. Both systems have an initial temperature differential which rises however the non-PCM system rises more sharply reaching a maximum of 12.5 K around half past noon while the PCM system reaches a rising maximum of 12.75 K at around 11 O'Clock. This indicates that paraffin has the potential to aid in the absorption and retention of heat thus dulling the temperature escalation. From around 11 O'Clock, a change in temperature for the non-PCM system occurs while the change in humidity for the PCM system stays stagnant. This indicates that the paraffin is still at work in assisting the evaporation processes so that the temperature drop can be minimized. In conclusion, the built-in buffering effect of paraffin is beneficial in the achievement of a uniformly stable temperature in the system. This shows that in the time span that was measured, the Paraffin passed on less temperature differentials than the Non-PCM and there fore is applicable to systems that require temperature alteration.

Heat transfer rate paraffin and non-PCM

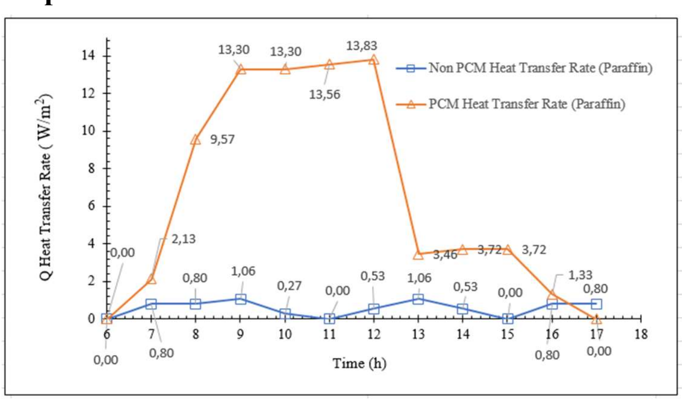

Figure 2. Heat Transfer Rate

$Q = K.A.\frac{\Delta t}{L}$

Where Q is Heat Transfer Rate, K is Thermal conductivity, A is Top Surface Area, Δt is Themperature Difference, L is Brick Wall Thicknes

This graph illustrates the Q values of the heat transfer rate in a system of paraffin (PCM) and another system of heat impulses which does not utilize the PCM over the timeframe of 18 hours. When compared to the non-PCM system, the PCM system has a more predictable and uniform profile of heat transfer. While both of the systems are seen to have some heat transfer rate at the beginning, it is the non-PCM system which sees a more steeper increase reaching a maximum of 13.83 W/m² around the time of noon. The system of paraffins which was modified however has a lesser maximum close to that of 13.55 W/m² reflecting a lower heat absorption rates. This increase, combined with the nature of paraffin's latent heat capacity enhances its ability to control the heat transfer rate as the temperature rise is not sudden but gradual. After attaining the peak, the non-PCM system then rapidly releases heat energy which leads to a rapid decrease in the heat transfer, however for the case of the PCM system, a much measured decrease is shown suggesting the existence of stored heat energy. This pattern exemplifies the behavioural features of paraffins allowing them to stabilize heat transfer by moistening the thermal environment when heat is applied, and subsequently releasing it after being sustained.

The graph demonstrates the effectiveness of paraffin as a thermal insulator, indicating its potential usage in applications requiring temperature stabilization and energy management.

Flux Radiation

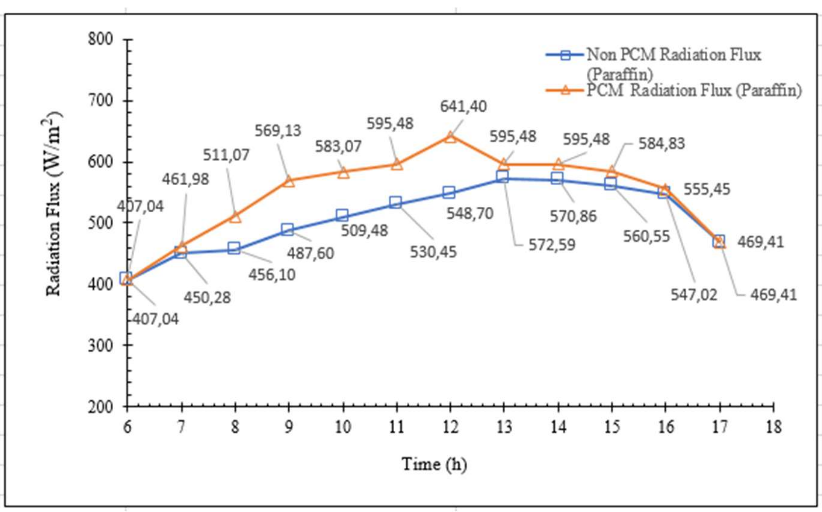

Figure 3. Fluks Radiation

$\Phi = \varepsilon.\sigma.T^4$

Where Φ is Radiation Flux, ε is Emivisibility Objects, σ is Constant Stefa-Boltzman, T^4 is Objective Themperature

The graph illustrates the radiation flux, in W/m², of a non-PCM system as well as a PCM (where paraffin was used) system over a full 18 hours. Based on the results, it appears that the level of radiation flux in the case of the PCM system was less variable than in case of the non-PCM system, which appeared to be more turbulent. Both systems initially demonstrate an overall increase in radiation flux; however, the non-PCM system displays more significant peaks and troughs. The non-PCM system achieves a maximum flux of 641.40 W/m² at 12:00, whereas the PCM system reaches a peak of 595.48 W/m² at 13:00. This indicates that the thermal properties of paraffin mitigate the influence of external radiation and therefore prevent large fluctuations. The PCM system of passive solar heating delivers relatively constant radiation throughout the day with an average of around 500 to 600 W/m². On the other hand, the non-PCM system has a wider span of values, having lower limits of around 450.28 W/m² and much higher upper limits. This suggests that the paraffin efficiently absorbs and releases thermal energy, thus mitigating the impact of incoming radiation and decreasing overall system variability. The stabilising effect of paraffin on radiation flux has important implications for applications including thermal energy storage, building temperature regulation, and solar energy systems, where consistent and predictable thermal performance is essential.

Temperature surface

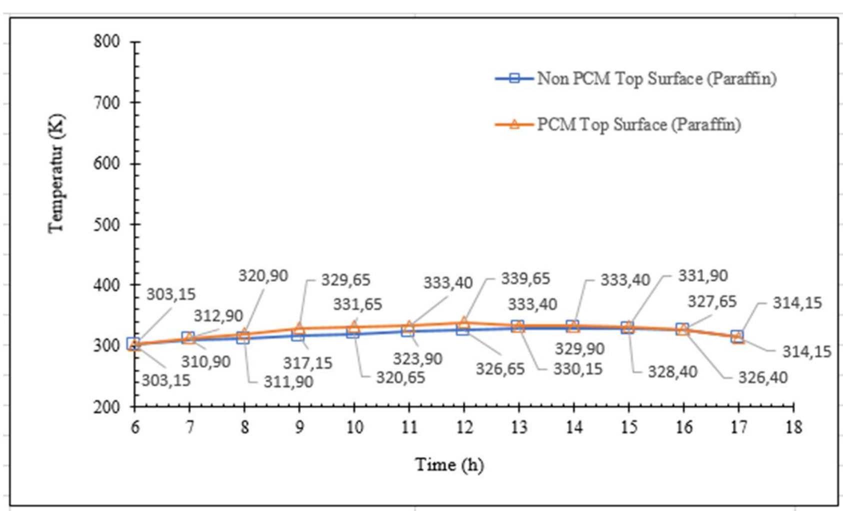

Figure 4. Temperature Top Surface

This graph measures the temperature of the upper surface of a system with phase change material - paraffin (PCM) as compared to a system with no PCM over the period of

18 hours. With a system in which PCM is used, there are fewer changes in temperature as the overall temperature remains stable as compared to a system with no PCM. The two systems exhibit an increase in temperature over the period of a day, though the non-PCMs have sudden increases. The highest temperature of the non-PCM system is registered at 333.40 K around 12:00, while a temperature of 331.90 K is peaked by the PCM around 11:00. Even though this difference seems insignificant, it highlights the ability of paraffin to take in heat and store it thus, managing the rate of temperature rise. Furthermore, the PCM system also shows greater efficiency as it is able to maintain constant temperature more often than the non PCM system. This is due to the melting and solidification phases of paraffin, in which heat is absorbed during melting and released when the substance solidifies, therefore damping thermal kinetic energy. The paraffin material is able to steady the surface temperature of a material making it useful in designs such as buildings which incorporates thermal energy storage as well a cool electronic components that require steady temperatures for high-level operating efficiency.

6. CONCLUSION

According to the test results, it is evident that the use of paraffin phase change materials (PCMs) enhances the thermal properties of bricks, suggesting their numerous applications in sustainable construction. The thermally paraffin rated bricks as developed in the present work effectively maintained thermal stability during heating and cooling cycles, with a considerable improvement in the level of temperature fluctuations as compared to unmodified traditional bricks. PCM bricks varied markedly reaching a temperature difference maximum at 12.75 K at 11:00 hrs while non-PCM bricks fluctuated around the non-PCM around 12:00 hrs attained 12.5K peak. This reduction highlights the properties of paraffin's latent heat, which in this case, has the ability to store and retain heat. Heat transfer studies also presented that at 11:00 am the highest point for PCM bricks was 13.56 W/m², whilst non PCM, the peak was at 13.83 W/m² at noon, which was seen to be more steep and higher than the former. Hence such data proves that PCM bricks are better than conventional bricks in terms of rate of heat gain and loss.

In addition, the radiation flux data indicated that the PCM bricks were less variable, showing fitting a more steady flux of approximately 500 and 600 W/m², while the non-PCM bricks were relatively unstable exhibiting high peaks of 641.40 W/m². The presence of paraffin encasement helps rather significantly in reducing external radiation, creating more stable thermal zoning. The surface temperature analysis further revealed that the surface temperature of PCM bricks was up to about 331.90 K at 11 am and did not fluctuate much, while non-brittle ZN520 reached a temperature of 333.40 K around noon. This is consistent use of PCM form bricks able to stabilize the temperature suggests passive thermal management which is ideal of these bricks. The unique feature of paraffin as a phase change material is that it can transform from solid to liquid and absorption in this process making it very effective for use in construction materials enhancing heat storage. In general, this research observes the incorporation of PCM into construction materials of paraffin origin which has a lot of potential of not only lowering energy usage but also improving thermal comfort, which is greatly needed for global sustainability pushes within the construction industry

LIMITATION

Data collection challenges can stem from many aspects like inclement weather, temperature changes and sensor malfunction. Bad weather including strong rain or wind contributes to the lack of proper measurements and hence hampers data collected. Temperature changes can be problematic as well as it will impact the functionality of equipment which are not specialized for tough conditions. Sensors are also prone to errors which could arise from the wind interference or some other outside factors which subsequently creates more problems in the course of data collection. These factors on their own demand acceptable strategies such as the weather barrier facilities and more rigorous data processing for sound results.

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