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Building bricks with PCM inserts for Passive cooling applications

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Abstract The vital predicament that mankind will face in near future is the deficiency of energy. Heavy dependency of fossil fuels for driving the systems make the problem too complex by adding the Green House Gas (GHG) emission also. Across the sphere, consumption pattern confirms the major role of building sector, mostly for space conditioning application. Passive cooling by Latent Heat Thermal Energy Storage is well-established method. In this work commercially available Phase Change Material (PCM) is used for latent heat storage. The PCM is inserted in the brick cavity. The performance of two types of PCM insert is compared, ie, macro encapsulation at the middle of the brick and microencapsulation near the outer wall of the brick. The results show that, the centrally encapsulated brick performs better in heating cycle, but during night time the heat entry into the living space is more. The micro encapsulation at offset to the wall side justifies for the night use.

1. Introduction

Referring to the report of International Energy Agency (IEA), buildings are accountable for 30% of the energy consumption in the world where major share is used for space heating and space cooling applications [1]. Moreover, buildings are responsible for nearly one-third of the Greenhouse gas emissions (GHG) around the world. Even though the energy efficiency practices made a substantial effect (with nearly 12% reduction) on the energy usage during the year 2000 and 2017 in the building subdivision, the energy necessity of buildings has increased 20% during the same retro [1]. If we can save a portion of this energy by implementing active or passive cooling/heating system, the end result will be promising for future energy. The figure 1 describes the projected share of energy consumption by building sector for the next three decades [2].

Various methods are experimented to decrease the building energy consumption by implementing techniques like solar energy and thermal energy storage systems [3,4]. Due to high thermal energy storing capacity, Phase Change Materials (PCMs) are very popular for building applications. Various researchers and scientists used PCM for different applications in buildings like solar thermal wall [5,6], dry wall panels [7], HVAC components [8,9], construction materials [10,11], floor panels [12,13], roof [14,15,16] and wall [17,18]. Several studies are conducted on building blocks or bricks with PCM insert. A majority of results attempted with macro encapsulation of PCM, where the PCM is contained in metal or PVC containment [19,20,21,22,23].



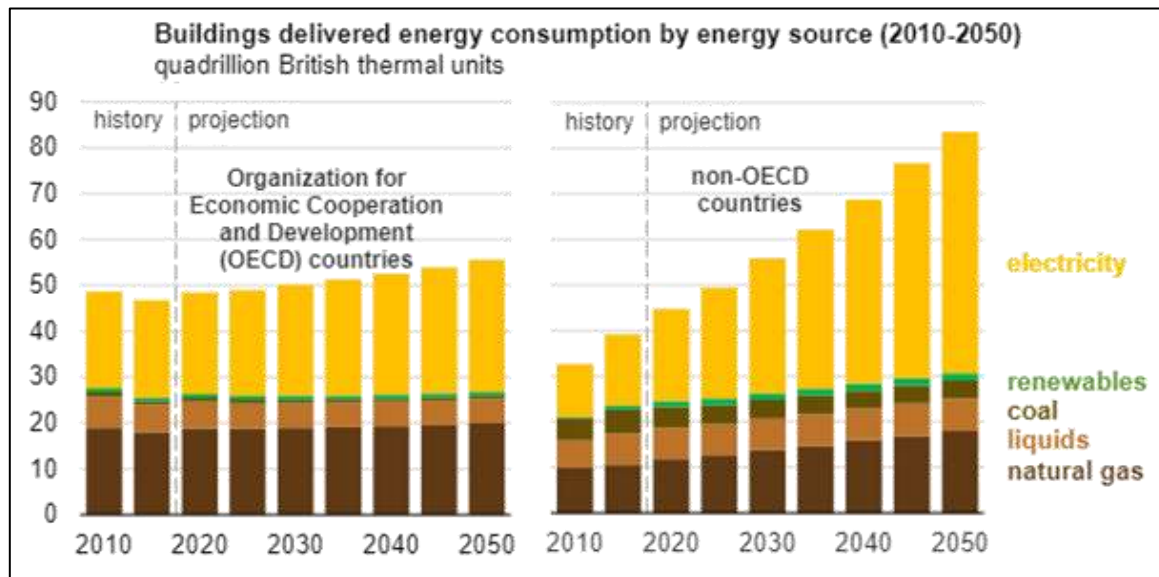


Figure 1. Energy consumption and future trends for building sector [2]

1.1 Encapsulation of PCM

Thermal energy storage application of PCM in building cause leakage problems during the melting cycle. This is a major concern for the commercial use. To prevent the leakage problem, the material is encapsulated in a container or capsule. The encapsulation also increases the heat transfer rate by increasing the surface area [24]. It also helps to improve the thermal conductivity of material and prevents the contamination of PCM and hence improves the stability [24]. The encapsulation is done in such a manner that the PCM is the core and the container or capsule is the shell. Depending upon the size of the container, encapsulation is divided into two – macro encapsulation and micro encapsulation.

If the size of the container is more than 5 mm, the encapsulation is called macro. Containers of various shapes like spherical, cylinder, cube, tubes, pouches etc. can be used for encapsulating PCM. For building application, the geometry of the container mainly depends the size of the building component in which the PCM is encapsulating. A right container material for encapsulation will improve the performance of PCM in building applications [25]. The desired properties are high thermal conductivity, strength and flexibility, non-toxic, non-corrosive and fire resistive. The container material will be chemically and physically stable with building material.

In micro encapsulation, the size of the particle will be less than 100 micro meter. The synthesis of micro PCM include physical processes like spray drying and solvent evaporation, chemical processes like interfacial, in-situ, suspension and emulsion polymerization and physical and chemical combination like coacervation and sol-gel methods [26]. The properties of PCM micro capsules are strongly affected by the material and method of synthesis. The micro PCMs are widely used in powder and slurry form for the building and textile industry. The major problem regarding the use of micro PCM is that of super cooling.

The present paper describes the comparison of thermal performance of PCM encapsulated building bricks with micro and macro encapsulation for heating and cooling cycles. Commercially available PCMs HS29 (for macro encapsulation) and ME29P (for micro encapsulation) are used for the experiment.

2. Experimental setup

The thermal performance of the building bricks with macro and micro encapsulation are tested inside psychrometric chamber. Figure 2 give the schematic of experimental setup and brick models tested.

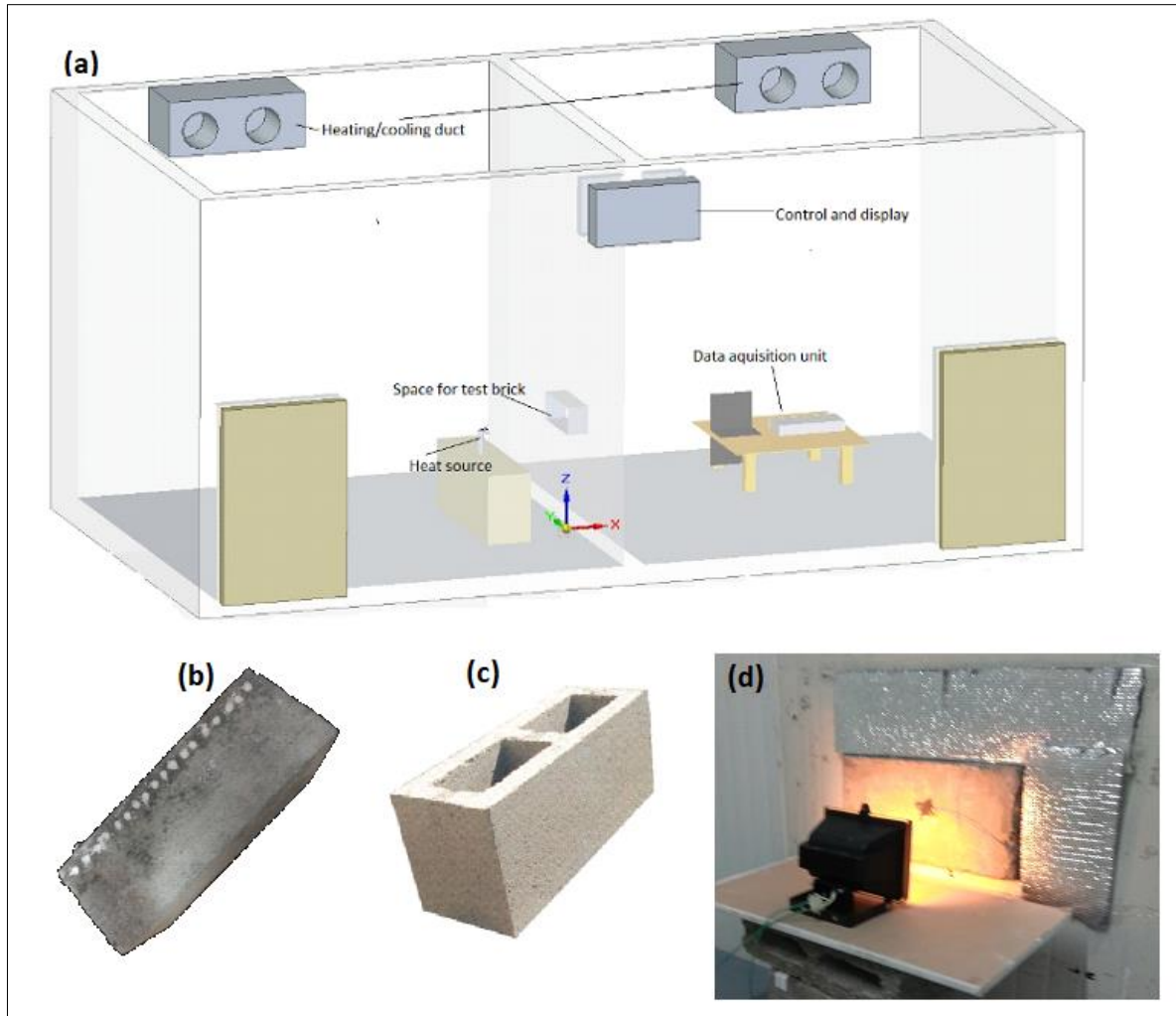


Figure 2. (a) Schematic of Psychrometric chamber for the experiment (b) Brick with micro encapsulated PCM (c) Brick for macro encapsulation (d) Brick fixed in the chamber with heat source.

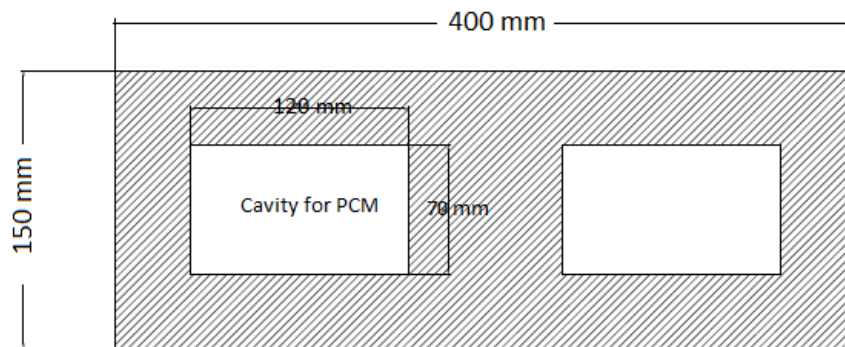
The psychrometric chamber is a fully insulated room of size 20 ft x 10 ft x 10 ft in length, breadth and height. The room divided into two by a central wall with a slot for the test brick. Both the bricks are tested for the same climatic conditions, which is simulated in one chamber and other chamber kept at room condition throughout the experiment. A variable intensity light source, which can vary radiation intensity according to hourly variation is used as heat source.

Two different brick geometries are used for the experiment. The brick schematic is given in the figure 3. For macro encapsulation the brick with two central cavities are used. The PCM is filled in the aluminum container and the sealed container inserted in the cavities. The micro PCM in the powder form is directly filled in the cylindrical cavities near the brick outer wall.

The brick geometry, materials used and the details of brick encapsulation is given in the Table 1. Both micro and macro encapsulated PCM had comparable thermal properties and same melting point is used for the experiment.

(a)

Figure 3. (a) Brick with



two central cavities for macro encapsulation of PCM HS29 (b) Brick with 18 cylindrical cavities near the outer wall side for direct filling of micro encapsulated PCM ME29P in powder form.

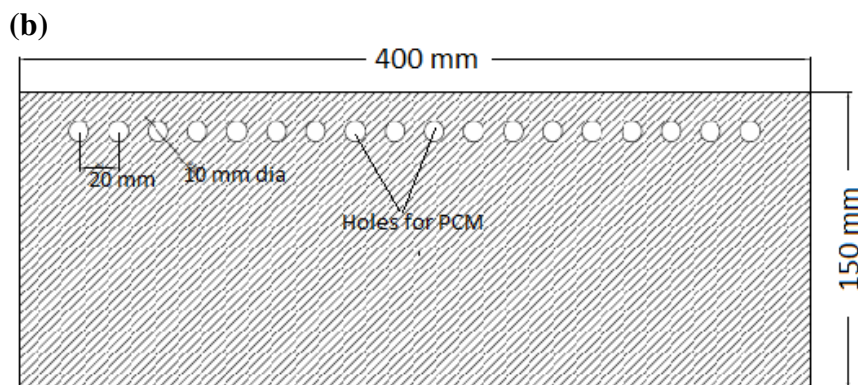


Table 1: Properties of materials used

Description	Macro encapsulation	Micro encapsulation
Brick size	400 mm X 200 mm X 150 mm. with two central cavities	400 mm X 200 mm X 150 mm. (Solid 605 type) with 18 cavities
Material	Concrete	Concrete
Encapsulation material	Aluminium container	No container (Direct in holes)
PCM	SavE HS 29	CrodaTherm ME29P
Melting temp	> 29 °C	> 29 °C
Density	1681 kg/m ³	337 kg/m ³
Latent heat	190 kJ/kg (at solid state)	183 kJ/kg (at solid state)

The bricks were heated with the radiation source according to the hourly solar intensity variation and the temperature variation at inner wall and outer wall of the brick are noted. For measuring the temperature, T type thermocouples are connected at various points on the bricks.

3. Results and discussions

The experiment is conducted throughout the day and the readings are noted for one-hour duration. The inner wall temperatures, outer wall temperatures and corresponding radiation intensity are noted and shown in figure 4. The inner wall temperature for both the bricks shows that, during the heating cycle, the macro encapsulated brick performs better than that of micro encapsulated brick. For the same outside conditions, nearly two-hour shift for maximum temperature is attained by using macro

encapsulation. But for the cooling cycle during night, the heat enters to the interior space and hence the wall temperature is higher than that of micro encapsulated brick.

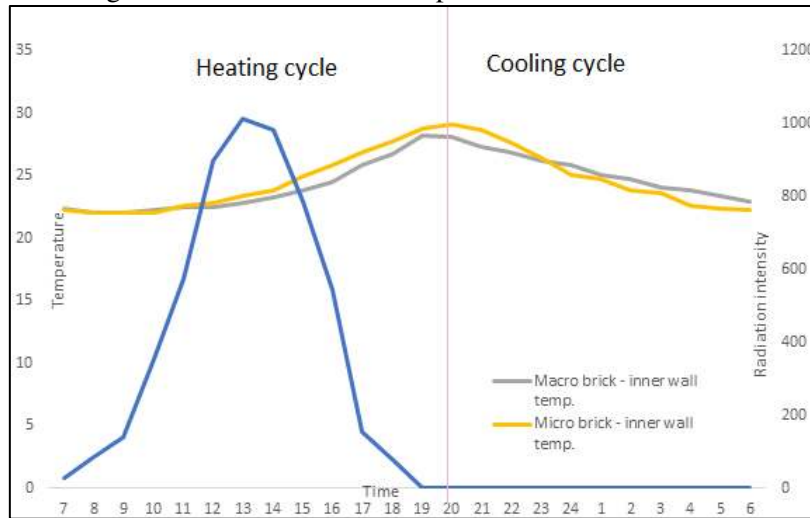


Figure 4. Inner wall temperature variations for macro and micro encapsulated bricks

In case of macro encapsulated PCM, more heat energy is stored during the melting process because of high density compared to micro PCM. This heat energy needs to release during the solidification. Since the PCM located at the middle of the brick, a major portion of the heat moves to the living space and hence the inner wall temperature is higher during the cooling cycle as shown in figure 4.

Also, the inner wall temperature variation for the micro encapsulated brick is in well accordance with the numerical results of the work by the authors [27] as shown in figure 5.

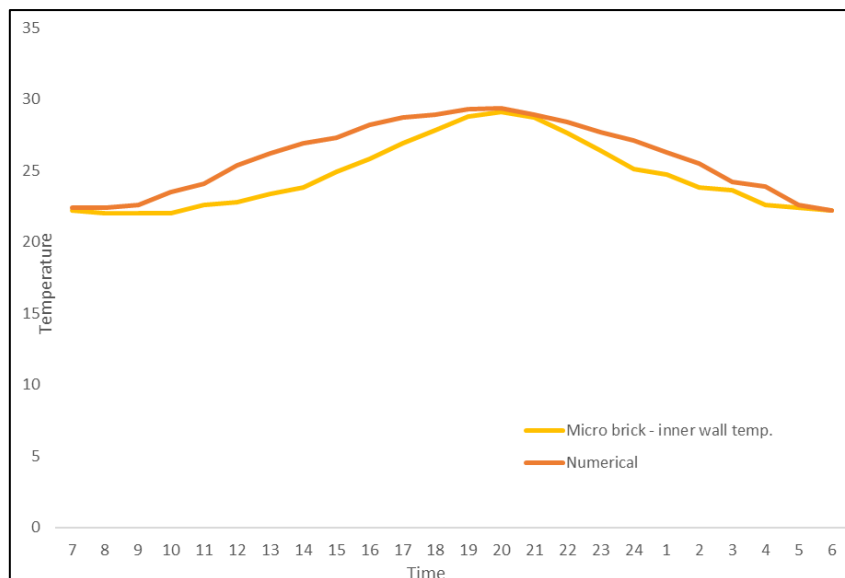


Figure 5. Comparison of experimental result with Numerical value [27]

4. Conclusions

This experimental work compared the performance of two geometrically identical brick, one with PCM encapsulated in the central cavities in the Aluminium container and another with micro

encapsulation directly in the holes near the wall. The results clearly justify the use of both type of encapsulation for thermal management. But, for macro encapsulation a metal container is required. This creates cracks in the brick as a result of uneven expansion and contraction during heating and cooling cycles. Addition of the container makes the construction complex and also more quantity of PCM required for macro encapsulation brick. These difficulties are reduced in case of micro encapsulated bricks.

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