Experimental Study of Thermal Blocks for Trombe Walls to Condition Buildings

SYNOPSIS

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Submitted by

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1.1 INTRODUCTION

- The Trombe Wall is a solar heating system that can be used to capture and store solar heat during the day and release it at night. The system has a thick thermal mass wall on the south-facing side of the building. The walls have two layers - a layer of glass or plastic and a layer of stone, brick or stone with an air gap in between the layers.
- Thermal blocks are optional that can be used with Trombe wall systems to improve the thermal performance. It is usually placed in the air gap between the outer layer and the inside layer thermal mass and is designed to help reduce heat from the thermal mass to the outside.
- Thermal Block is made of materials with low thermal conductivity, such as insulating foam or deep concrete. Placing this block in the air gap will help create a thermal barrier that slows the transfer of heat from the outside to inside.
- Trombe wall are usually constructed in regions where there are extreme climatic conditions like hill stations, deserts and other regions where temperature is too low or too high. The thermal block used for the construction of trombe wall are of many types few of them are hollow cement concrete blocks, stabilized mud blocks, autoclaved aerated block, polyurethane foam block etc. These thermal blocks are expensive and few of them are not locally available and are not environmentally friendly. Hence, the current research proposes a modified thermal block of cement mortar with water bottles implanted inside.

1.2 LITERATURE REVIEW

1.2.1 Working of trombe wall.

The Trombe Wall is a solar heating and cooling system used to capture and store solar energy in the buildings. It has thick walls built on the south side of the building, usually made of stone or stone-like materials.

The trombe wall is usually on the south side of the house where sunlight is intense. The building should be oriented so that a large area is available in south side.

The wall is made of two main components: a layer of glass or other transparent material and a layer of thermal block material. The two layers are separated by an air gap forming a solar collector.

Solar Absorption: Sunlight shines from the clear layer to the dark layer to improve heat absorption. The inner layer with thermal mass absorbs solar energy and converts it into heat.

Thermal Storage: A large inner thermal layer, usually made of stone or concrete, that stores the heat absorbed during the day. These materials have a large thermal capacity, which means they retain heat for a long time.

In general, Trombe walls act as thermal mass by absorbing and storing solar heat during the day, gradually releasing it into the building to heat it. It also facilitates ventilation, which aids cooling. This passive solar design reduces reliance on heating and cooling systems, making the building more energy efficient and sustainable.

1.2.2 Functions thermal block in trombe wall

Thermal blocks serve many important purposes in Trombe wall systems. The main functions of thermal blocks in Trombe walls are as follows:

1. Heat absorption: Thermal blocks are usually made of high-density materials such as stone or concrete and are responsible for absorbing and storing solar energy. The dark side of the thermal barrier improves its ability to absorb sunlight and convert it into heat.

2. Thermal Mass: A thermal block behaves like a thermal mass; This means it has the ability to store heat and release it slowly over time. During the day, when sunlight hits the thermal barrier, it absorbs and stores solar heat. As the temperature drops, especially in cold weather or at night, the thermal block gradually releases the stored heat, providing heat to the home.

3. Heat transfer: Thermal blocks help transfer heat from solar collectors (layers of Trombe walls) to the interior of the building.

It also contributes to thermal insulation and support, making Trombe walls efficient and stable solar heating.

1.2.3 Thermal performance of various bricks and blocks

In most developing countries, when designing a building, estimating the thermal insulation of materials and their thermal mass is considered difficult due to the types of buildings shown for a different purpose. In the construction of low-rise buildings, cooling and heating effects randomly affect thermal performance, especially on facades and roofs. Furthermore, in high-rise construction, the thermal mass and heat gain of a building is determined by its internal condition due to the type of wall construction and the surrounding environment. In addition, some other parameters such as household equipment, lighting, sunlight through the window and body temperature are considered as the main factors for deciding the thermal condition of the building interior. In poorly insulated buildings, almost 33% of the total heat loss was caused by external walls (Al-Tamimi et al., 2020). In every building, the wall is considered important because it controls the internal heat from a direct or alternative source and affects the human skin. The human species is usually warm-blooded; therefore, it is necessary to keep the body temperature constant even when the ambient temperature is higher (Colangelo et al., 2020). In the construction industry, energy saving problems can be found through the intelligent design of the thermal insulator. This can be achieved by careful material selection. It is necessary to select suitable insulation materials for effective control of heat flow in the building with respect to the environment, installation and ease of handling (Diego and Ramos, 2020).

The installation of the isolator can be located usually in an external exposure, cavity or internal part of the building. Both internal and external insulators are considered expensive (Benazir, 2020). Thermal insulators fixed in the outer part provide the best thermal insulation result. However, in terms of service life, it is easily affected by cyclical weather conditions, and the installation cost will be too high. In the case of interior thermal insulators, control and protection from exposure is easy. At the same time, it is very prone to fires and the release of some toxic gases (Vitiello, 2020). In recent days, the awareness of thermal standards should be seriously followed in all types of buildings by adopting thermal insulators and not increasing the wall thickness.

In the modernization of historic buildings, energy efficiency can be described by three types of labels: class C, D and F (Kubis, 2020). In a historic building, preserving its tradition and energy efficiency becomes controversial; therefore, it is mandatory to solve these problems for the future generation (Walter and Bruno, 2020). The methods likely used to assess these traditional buildings may give incorrect results with a lack of reliability. Before 1980, historic buildings were mostly built with little or no wall insulation. Maintaining energy efficiency while insulating external walls became a significant meeting (Wesam and Alaloul, 2020). Introducing energy efficiency in a historic building could improve the quality of life and condense the overall energy demand. Windows, basements, exterior walls and roofs are mostly considered to be the main potential for energy savings, especially in buildings (Liu, 2020).

In most European countries, stone walls and solid bricks were usually used for the construction of the historical period. In these types of buildings, internal insulation has been increased, leading to an increased possibility of moisture accumulation in the wall corresponding to structural deterioration. Increased moisture in the walls resulted in deformation of structural elements, salt and frost damage, corrosion and damage to wooden elements and dissolution of materials. Moisture accumulation in the wall was based on a combination of basic factors such as construction, indoor humidity, weather and building orientation. The insulation in the building was done mainly to control the vapor, permeability and drying capacity of the wall (Olacia, 2020). In 1992, the designers established the "Passive House" project according to which was implemented in Germany in order to introduce low-energy buildings with a lower thermal load of 15 kWh/m2 per year by adopting the standard. construction technology and materials (Lawanwadeekul, 2020).

According to the latest report, the total household energy consumption is 55% and home appliances contribute to it. The government of various countries have committed to improve the thermal efficiency of the building by controlling CO_2 emissions and using thermal insulation materials in their construction. The development of the tunnel kiln ceramic sector provides a wide opportunity to use waste materials in large quantities for the production of building bricks and blocks at high temperature (Li and Zhou, 2019).

In some cases, it is said that the insulating properties of bricks can be improved by introducing micropores by using some additives before firing the bricks or by creating artificial holes during casting using perforation. The thermal conductivity of bricks on walls can develop in two ways: the nature of the material present in the bricks and the geometry of the bricks. To save clay in the manufacture of bricks, a chemical called Latter was introduced. By adding this additive, it may be possible to reduce the weight of bricks and reduce thermal conductivity (Zhang, 2019). The use of insulation in external walls certainly has some negative effects, such as short life, lower safety and peeling. This can be eliminated.

1.2.4 Scope Of Present Investigation

Utilization of energy and its conservation has become prime concern due to ever increasing global warming effect. Energy can be very well be conserved if utilized properly in buildings by application of various techniques. In high rise buildings, large amount of the energy is consumed for air conditioning and heating as well as for running a number of appliances for daily use. Energy consumed for heating in buildings has the largest proportion of consumption i.e., nearly 45% which needs to be continuously evaluated so as to reduce the energy utilization and make a sustainable environment. In passive design, the location and orientation of buildings and the characteristics of building materials are taken into account that helps in providing good thermal comfort by cutting down the heating, cooling and electricity costs.

Heat from sunlight is absorbed and stored in a wall and conducted through masonry to condition interior spaces. Today small-scale energy efficient buildings are developed on an ancient technique that incorporates a thermal mass and efficient delivery system called Trombe wall which continues to serve as an effective feature of passive solar design. It is seen that the heat storage capacity in the Trombe Wall system will be increased with Thermal Blocks.

A thermal block is a unique brick constructed using water-filled plastic bottles embedded inside a plain-cement-concrete (PCC) block. The combination of concrete & water in the block enhances its overall thermal capacity while utilizing the benefit of the high thermal conductivity of concrete for efficient heat transfer in the Trombe Wall. The outer surface is black-painted to utilize black surface absorption. These modified Trombe Walls are one of the reasons for the enhanced performance of PSH buildings.

2.1 AIM - To study the temperature variations of modified thermal blocks in trombe walls for passive solar buildings.

2.2 OBJECTIVES - The following are the objectives of the research work carried out.

1. To cast normal blocks and thermal blocks implanted with plastic bottles filled with water.
2. To check the compressive strength after 28 days of water curing.
3. To check the thermal conductivity of normal blocks and thermal blocks.

4. To construct trombe wall and determine the temperature variations.

2.3 METHODOLOGY

Methodology for objective-1:

To cast normal block and modified thermal block of ratio 1:5 (cement: fine aggregate) of size 340x140x195 mm. These thermal blocks will be manufactured using water-filled plastic bottles embedded inside cement mortar blocks. The below table shows the number of cubes and blocks casted.

Table 2.1 – Cubes and Blocks Casted

Sl No	Description
1	3 Cubes of 70.5x70.5x70.5 mm for CM 1:6 and w/c – 0.45
2	3 Cubes of 70.5x70.5x70.5 mm for CM 1:5 and w/c – 0.5
3	3 Plain thermal blocks of 340x140x195 mm for CM 1:5 and w/c – 0.5
4	Modified thermal blocks of 340x140x195 mm for CM 1:5 and w/c – 0.5 with 1 bottle.
5	Modified thermal blocks of 340x140x195 mm for CM 1:5 and w/c – 0.5 with 2 bottles.
6	Modified thermal blocks of 340x140x195 mm for CM 1:5 and w/c – 0.5 with 3 bottles.

Figure 2.1 - Casting of cubes and blocks

Methodology for objective-2:

The cast blocks shall be tested for compressive strength after 28 days of curing with the help of CTM. The load will be applied gradually until the block fails. The load at the failure divided by the area of the block will give the value of the compressive strength of the block.

Compressive strength = Load (P) / Cross sectional area (bd)

Where:

P= failure load in N.

b= breadth of the block in mm.

l= length of block in mm.

Figure 2.2 - Testing for Compressive Strength in CTM

Methodology for objective-3:

Thermocouples will be implanted into the blocks at a depth of D/2 (where D is the depth of the block). These thermocouples are further connected to a K-type digital thermocouple reader. This helps to note the heat transfer through the block. This helps measure the temperature inside the thermal block near the water bottle.

Figure 2.3 - Insertion of Thermocouples in the block

Methodology for objective-4:

A room of size 1meter x 1meter x 1meter is constructed, with north and east walls of cement concrete walls and west and south walls using modified thermal blocks. The outdoor and indoor surface temperatures are measured using an infrared thermometer. Temperature inside the wall are measured using the implanted thermocouple which is connected to a K-type thermocouple reader and the temperature is noted.

Figure 2.4 - Construction of wall with thermocouples implanted inside

Figure 2.5 - Recording the temperature of thermocouple

3.1 RESULTS

- The compressive strength is obtained by testing plain thermal blocks without water bottles of size 340mm x 140mm x 195mm of 1:5 (cement: fine aggregate) and 0.5 w/c and tested for 7 days.

Table 3.1 – Compressive test results of block without water bottle

Size of block (mm)	Ratio (cement: fine aggregate) Water cement ratio = 0.5	Cross-sectional area (mm^2)	Maximum load (N)	Compressive strength after 7 days curing N/mm^2
340x140x195	1:5	47600	990000	20.79
340x140x195	1:5	47600	980000	20.58
340x140x195	1:5	47600	1010000	21.21

- The compressive strength is obtained by testing modified thermal blocks with water bottles of size 340mm x 140mm x 195mm of 1:5 (cement: fine aggregate) and 0.5 w/c at an age of 7 days in CTM. The test results are presented in table below.

Table 3.2 – Compressive test results of block with water bottles

Size of block (mm)	Ratio (cement: fine aggregate) Water cement ratio = 0.5	Cross-sectional area (mm^2)	Maximum load (N)	Compressive strength after 7 days curing N/mm^2
340x140x195 3 bottles	1:5	47600	450000	9.45
340x140x195 2 bottles	1:5	47600	565000	11.86

340x140x195 1 bottle	1:5	47600	649000	13.63

Figure 3.1 - Test specimen after failure

- After construction of the room, the outdoor surface, indoor surface as well as the inserted thermocouple temperatures were recorded for 1 week. The temperature was recorded at 9am, 11am, 1pm and 3pm. The instrument used to record temperature is infrared thermometer with K-type thermocouple reader. The average recorded temperatures are in the below table.

Table 3.3 – Average recorded temperature

Time in hrs	North wall in°C	East wall in°C	West wall in°C	South wall in°C
9:00	36.75	38.1	35.2	35.4
11:00	38.92	42.3	36.1	34.77
13:00	42.17	43.45	37.35	31.34
15:00	38.92	43.08	36.1	31.34
9:00	33.88	36.15	29.72	31.34
11:00	36.35	39.41	28.85	28.28
13:00	39.34	39.17	30.24	35.48
15:00	36.35	38.81	28.85	35.48
9:00			28.88	28.54
11:00			29.24	29.64
13:00			30.56	29.96
15:00			34.44	34.25

Legend
Outside surface
Inside suface
Thermocouple

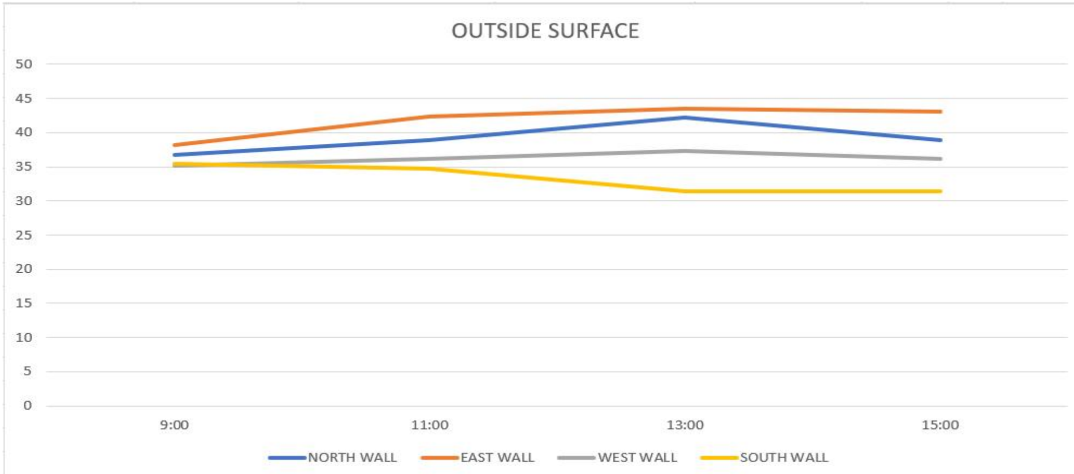

Figure 3.2 – Outside surface temperature

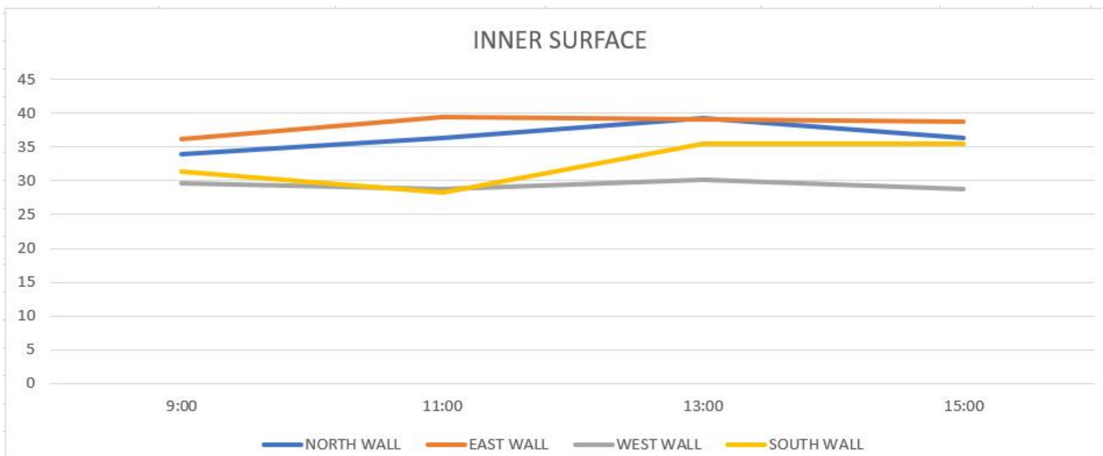

Figure 3.3 – Inside surface temperature

- Comparing the maximum and minimum temperatures of both the blocks a figure is generated which is shown below in figure 3.4 and figure 3.5.

	Outside Surface	
	Cement Concrete Block	Modified Thermal Block
Maximum temperature in °C	43.45	37.35
Minimum Temperature in °C	36.75	31.34
	Inside Surface	
	Cement Concrete Block	Modified Thermal Block
Maximum temperature in °C	39.41	35.48
Minimum Temperature in °C	33.88	28.28

Table 3.4 - Maximum & Minimum temperature recorded

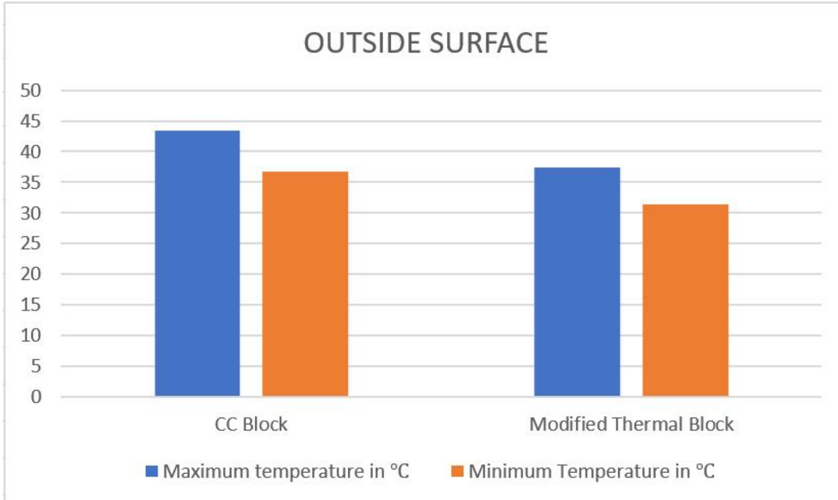

Figure 3.4 - Maximum & Minimum temperature of outside surface

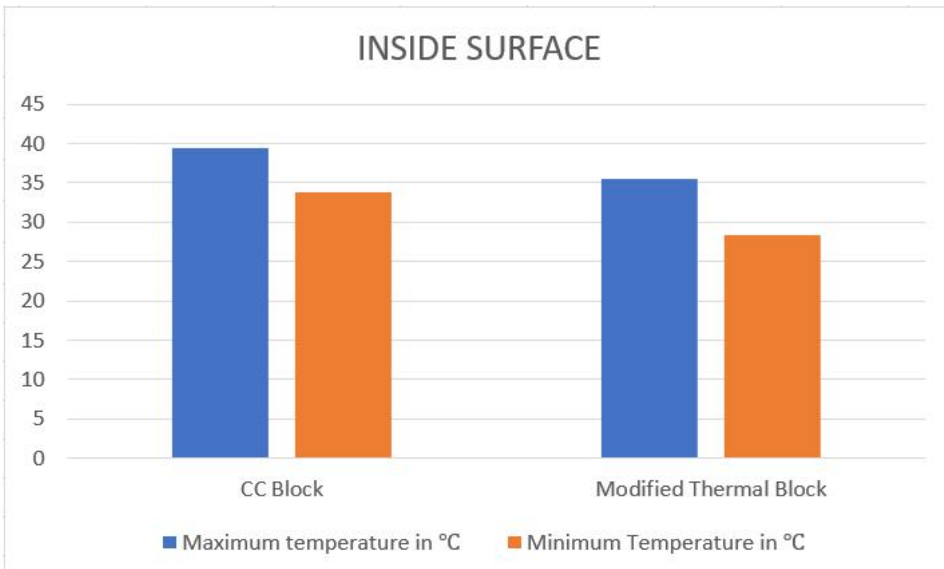

Figure 3.5 - Maximum & Minimum of inside surface

3.2 CONCLUSION

- The modified thermal blocks inside temperatures reduced from the exterior to interior surface. After testing the modified thermal block, it showed significant improvements in heat transfer reduction and energy efficiency compared to cement concrete block.
- A small room of 1mx1mx1m was constructed on the terrace of the college building. The west and south walls are built using modified thermal blocks

of 6 inches thick, north and east walls are constructed using cement concrete blocks of 4 inches thick.

At 9am

1. North wall – The maximum temperature it recorded was 38.4°C and 36.6°C on the outside surface and inside surface respectively.
2. East wall - The maximum temperature it recorded was 39.2°C and 37.3°C on the outside surface and inside surface respectively.
3. West wall - The maximum temperature it recorded was 36.4°C and 29.2°C on the outside surface and inside surface respectively.
4. South wall - The maximum temperature it recorded was 38.3°C and 32.2°C on the outside surface and inside surface respectively.

At 11am

1. North wall – The maximum temperature it recorded was 40.4°C and 37.9°C on the outside surface and inside surface respectively.
2. East wall - The maximum temperature it recorded was 43.2°C and 39.9°C on the outside surface and inside surface respectively.
3. West wall - The maximum temperature it recorded was 37.2°C and 29.2°C on the outside surface and inside surface respectively.
4. South wall - The maximum temperature it recorded was 36.4°C and 28.8°C on the outside surface and inside surface respectively.

At 1pm

1. North wall – The maximum temperature it recorded was 44.6°C and 40.1°C on the outside surface and inside surface respectively.
2. East wall - The maximum temperature it recorded was 44.8°C and 38.2°C on the outside surface and inside surface respectively.
3. West wall - The maximum temperature it recorded was 38.4°C and 31.2°C on the outside surface and inside surface respectively.
4. South wall - The maximum temperature it recorded was 38.3°C and 32.8°C on the outside surface and inside surface respectively.

At 3pm

1. North wall – The maximum temperature it recorded was 40.4°C and 37.9°C on the outside surface and inside surface respectively.
2. East wall - The maximum temperature it recorded was 44.8°C and 42°C on the outside surface and inside surface respectively.

3. West wall - The maximum temperature it recorded was 37.1℃ and 29.2℃ on the outside surface and inside surface respectively.
4. South wall - The maximum temperature it recorded was 38.3℃ and 32.3℃ on the outside surface and inside surface respectively.

- Overall, the average temperature difference between outside and inside of cement concrete block which is facing east and north is 3-4℃. Whereas in modified thermal block facing west and south walls the average temperature difference between outside and inside is 6-8℃.

4.1 SCOPE FOR FUTURE WORK

- For the adaptation of this block in cold climates which requires an additional thermal storing capacity an exterior glass wall can be fixed with an air gap in between the thermal block and glass wall.
- Over a period of time after adopting modified thermal block for wall construction, water in the bottles will get evaporated, and reduce the performance of the block.

5.1REFERENCES

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