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Investigative Study on the Properties of Hollow Concrete Blocks

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ABSTRACT- The utilization of workmanship structures is as yet broad all through the world. Hollow concrete blocks have supplanted customary bricks in late development as a result of the upsides of higher bearing limit, farmland insurance, and energy protection [1]. The hollow concrete blocks, being lightweight result in a reduced dead load of the structure [2]. They are practical and a superior option in contrast to consumed dirt blocks by their great solidness, imperviousness to fire, have good thermal protection, less dead burden, and high speed of development [3]. They are economical in comparison to the existing building materials. This project includes the preparation of samples of hollow concrete blocks with the different number of cavities and different shapes of cavities (circular and rectangular) using a concrete mix of 1:4:6 and a comparative study is executed concerning brick masonry and the blocks available in the market. The strength parameter, economy, lightweight character, and insulation property are studied and compared. The compressive qualities of the samples are thought about after permitting them to solution for 28 days in the curing tank. The thermal insulation test, block density test, and water absorption test are also carried out. The results showed a great deal of insulation from temperature. The energy consumption of buildings can be reduced to a significant amount by using these blocks [6]. The compressive parameters of these samples came to be far more than those of blocks that are being utilized in the market. Therefore these types of hollow concrete blocks can prove to revolutionize the way we design and build our structures.

KEYWORDS- Hollow Concrete Blocks (HBC), Cavity, Temperature Gradient.

I. INTRODUCTION

Buildings are one of the leading sectors in energy consumption throughout the world, especially in developed countries. They are responsible for consuming 50% of primary energy and half of the global electricity. As a result, the buildings generate a third of CO2 emissions on the planet. Further developing the energy productivity of structures has a huge advantage for energy-saving and emanation decrease on the earth. To improve the thermal performance of buildings, different thermal insulating materials have been used in the concrete mix such as expanded polystyrene, polyurethane, aerogels, extruded polystyrene, phase change materials (PCM), vacuum insulation materials (VIM), gas insulation materials (GIM), Nano insulation materials (NIM) and dynamic insulation materials (DIM) [8]. But these materials prove to be economically expensive and are not easily available. Thermal insulation in buildings contributes to reducing the size of heating and cooling systems and the annual energy consumption.

These HBC blocks are by and large generally utilized in the development of private structures, processing plants, and multi-celebrated structures [5]. Thermal insulation is accomplished because of the hollow space, which gives energy saving to all occasions [4]. The project is being carried out to meet the energy crisis by changing the geometry of concrete to increase its thermal insulation, leading to an efficient and economical way of tackling the energy issues in the building sector faced throughout the world. This project aims to study the mechanical and thermal properties of hollow concrete blocks available in the market and design hollow concrete blocks with different configurations (cavity shapes, size, and number) [6].

II. HOLLOW CONCRETE BLOCKS

A block having one or more large holes or cavities which pass through the block and having the solid material between 50 and 75 percent of the total volume of the block calculated from the overall dimensions is known as Hollow Concrete Block (HCB) [7]. They are a cost-effective and better alternative to burnt clay bricks by their good durability, fire resistance, partial resistance to sound, thermal insulation, small dead load, and high speed of construction

The ostensible dimensions of the block will be as per the following:

Length: 400, 500 or 600 mm

Height: 200 or 100 mm

Width: 50, 75, 100, 150, 200, 250 or 300 mm.

A hollow brick has two faces, the outer face, and the inner face. When solar radiations fall on the outer face of the hollow brick, the medium for transmittance of heat energy changes as there is a cavity present inside the brick and it provides thermal insulation to the building. The effect of the presence of a cavity on the thermal insulating properties of the hollow concrete blocks will be reported and proved after practical investigations have been done.

Advantages of hollow concrete blocks

- They also have high fire resistance and no efflorescence which reduces their maintenance cost.
- The hollow cores are comprised of air pockets which makes them good for thermal or heat insulation. It

provides better resistance against external weather conditions. Hollow concrete blocks can effectively be used for cold storage and industrial godowns as they are thermally effective.

- They are good for acoustics and sound insulation.
- Factor of safety of hollow concrete blocks is more than brick masonry.

III. METHODOLOGY

- Design of Hollow concrete blocks

Apart from changing the mix of the concrete, the design of hollow concrete blocks also includes modification in the shape of cavities and number of cavities, keeping the volume of the cavities the same as that of the blocks available in the market for comparison purposes.

- Mould Selection and Creation

The mould can be divided into three components. They are the external (or the outer) monolith base of the mould the internal (or the inner) mould has an inner dimension of 400mmx150mmx200mm (16inx6inx8in). For the base of the mold, marble tiles of suitable dimensions were used. The internal (or the inner) mold was made up of PVC pipes for creating the circular cavity in concrete blocks. Pipes were placed at suitable places to get the final dimension of the concrete block as mentioned. For creating the rectangular cavity, rectangular-shaped wooden logs of dimensions already specified were used.

- Proportioning

The proportioning of the concrete mix was 1: 4: 6. The water-cement ratio of 0.60 by weight basis was used for concrete hollow blocks.

- Mixing

The objective of thorough mixing of aggregates, cement, and water is to ensure that the cement-water paste completely covers the surface of the aggregates to achieve a homogeneous mix. The prepared mix is discharged from the mixer and consumed within 30 minutes.

- Placing and Compacting

Concrete mix is poured into the mould, evenly leveled, and compacted either by using vibrating machines or hands. The purpose of compacting is to fill all air pockets with concrete as a whole without the movement of free water through the concrete.

- Curing

Hollow blocks eliminated from the form are secured until they are adequately solidified to allow taking care of without harm. The blocks in this way solidified are restored in a curing tank to allow total moisturization for something like 21 days. At the point when the empty squares are relieved by drenching them in a water tank, water ought to be changed like clockwork for 4 days.

- Drying

Concrete shrinks slightly with a loss of moisture. It is essential after curing is over, the blocks should be allowed to dry out at a slow rate. Hollow blocks are laden with their cavities flat for the ease of passage of air. Generally, a period of 7 to 15 days of drying at ambient temperature will bring the blocks to the desired degree of dryness to complete their initial shrinkage.

Tests Conducted To study the various parameters of hollow block concrete, the following experiments are generally needed to be carried out:

Tests on cement:

- Fineness test
- Consistency test
- Setting time test

Tests on fine aggregates*:*

- Sieve analysis
- Specific gravity and water absorption of fine aggregates
- Silt content test

Tests on coarse aggregates:

- Sieve analysis of coarse aggregates
- Specific gravity and water absorption of fine aggregates
- Flakiness and elongation test (shape test) of coarse aggregates

Test on the fresh concrete mix:

- Slump test

Tests on hollow concrete blocks:

- Block density test
- Water absorption test
- Compressive strength test
- Thermal performance of hollow concrete blocks

The thermal gradient of hollow concrete blocks

Apparatus:

- Hollow concrete blocks, designed hollow concrete blocks, burnt clay bricks
- Mortar (1: 6)
- K-Type Thermocouples
- Temperature meter (thermocouple thermometer)
- Ceramic glass wool(800°C to 1000°C) as shown in fig.1

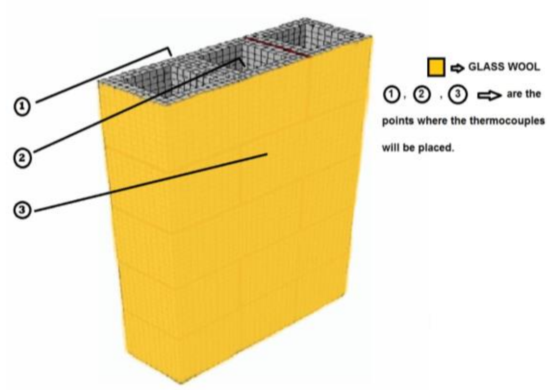

Figure 1**:** Thermal gradient test setup

IV. RESULTS AND DISCUSSIONS

Tests on Cement

Fineness test of cement
Result: Fineness of cement = 6.5%

A good cement should retain 10% weight of cement when it is sieved with the 90µ sieve. For Portland cement, the limit of percentage weight retained is 10% and it should not be more than 10% as per IS: 4031 (Part 1) – 1996.

Consistency test of cement

Result: Percentage of water for standard consistency of cement = 30 %

Setting time test

Result:

Initial setting time = 42 minutes
Final setting time = 501 minutes
The initial setting time of cement should not be less than 30 minutes and the final setting time of cement should not be more than 600 minutes i.e. 10 hours.

Tests on fine aggregates

Sieve analysis of fine aggregates

Weight of sand taken =1000 g
Fineness modulus of aggregate = 2.805

Result:

Fineness Modulus = 2.805
Type of sand = Medium sand
Zone of sand =Zone II

Silt Content test

Silt content in sand = 5.42%
The silt content in sand percentage should not be more than 8% by volume of sand.

Specific gravity and water absorption test of fine aggregates

Result:

The specific gravity of fine aggregate = 2.638
The apparent specific gravity of fine aggregate = 2.695
Water absorption of fine aggregate = 0.806%
The specific gravity of fine aggregate (sand) is about 2.65. The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average of about 2.68. Water absorption shall not be more than 0.6 percent by the weight of sand.

Tests on coarse aggregates

Sieve analysis of coarse aggregates

Total weight of coarse aggregate = 5000 g
Fineness modulus of coarse aggregates = 7.43

Specific gravity and water absorption test of coarse aggregates

Result:

The specific gravity of fine aggregate = 2.789
The apparent specific gravity of fine aggregate = 2.855
Water absorption of fine aggregate = 0.815%

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average of about 2.68.
Water absorption shall not be more than 0.6 percent by weight of coarse aggregate.

Shape test of coarse aggregates

- **Determination of flakiness index**

Total weight of sample taken (W1) = 1430 g
Total weight of aggregate passing through-thickness gauges (W2) = 274 g
Result: Flakiness index = 19.16%

- **Determination of elongation index**

Total weight of sample taken (W1) = 1430 g
Total weight of aggregate retained on length gauges (W2) = 409 g

Result:

Elongation index = 28.6%
Test on fresh concrete mix

Slump test

The vertical difference between the top of the mould and the displaced original center of the top surface of the specimen = 69.66 mm.
Result: Slump value = 69.66 mm = 70 mm (approx.)

Mechanical properties of hollow concrete blocks

Compressive strength.

Compressive strength of solid concrete blocks at 7 days = 10.76 N/mm2

Compressive strength of solid concrete blocks at 28 days = 15.38 N/mm2

Compressive strength of burnt clay bricks = 3.02 N/mm2

Compressive strength of conventional hollow concrete blocks available in the market = 3.26 N/mm2

Compressive strength of hollow concrete blocks with 2 circular cavities at 7 days = 5.03 N/mm2

Compressive strength of hollow concrete blocks with 2 circular cavities at 28 days = 7.1 N/mm2

Compressive strength of hollow concrete blocks with 3 circular cavities at 7 days = 4.76 N/mm2

Compressive strength of hollow concrete blocks with 3 circular cavities at 28 days = 6.81 N/mm2

Compressive Strength of hollow concrete blocks with 2 rectangular cavities at 7 days = 4.35 N/mm2

Compressive Strength of hollow concrete blocks with 2 rectangular cavities at 28 days = 6.07 N/mm2

Compressive Strength of hollow concrete blocks with 3 rectangular cavities at 7 days = 4.21 N/mm2

Compressive Strength of hollow concrete blocks with 3 rectangular cavities at 28 days = 5.90 N/mm2

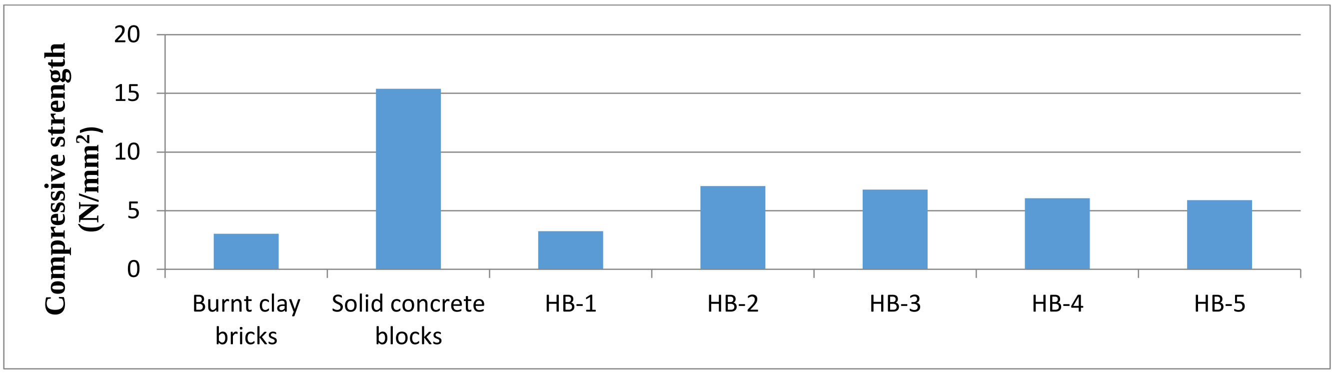

Figure 2: Comparison of compressive strength at 28 days

It is observed from fig.2 that the compressive strength of samples of HB-2, HB-3, HB-4, and HB-5 increased by 117.8%, 108.9%, 86.2%, and 81% respectively as compared to samples to HB-1.

Water absorption

Water absorption percent of solid concrete blocks = 3.90%
Water absorption percent of burnt clay bricks = 18.3%
Water absorption percent of conventional hollow blocks available in the market = 6.245%

Water absorption of hollow concrete blocks with 2 circular cavities =3.96%
Water absorption of hollow concrete blocks with 3 circular cavities =3.87%
Water absorption of hollow concrete blocks with 2 rectangular cavities = 4.93%
Water absorption of hollow concrete blocks with 3 rectangular cavities = 4.62%

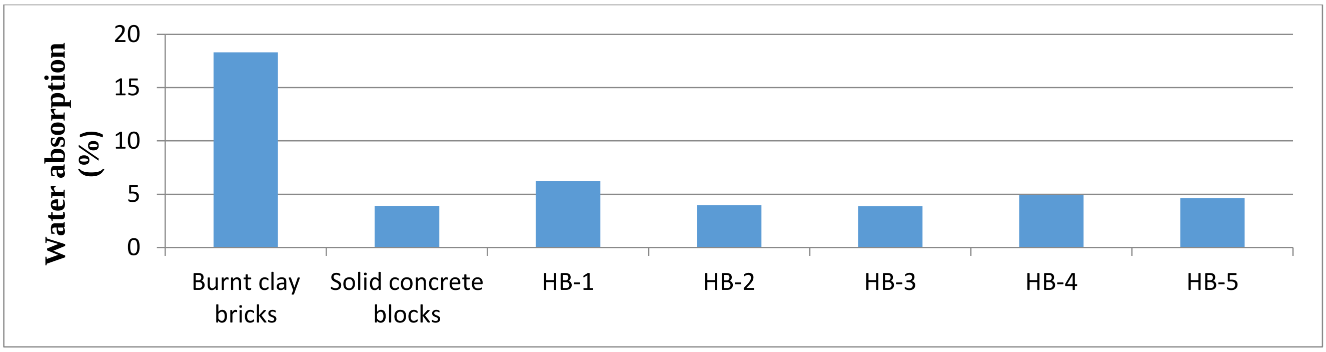

Figure 3: Comparison of water absorption percent

The results from fig.3 show that the water absorption of HB-2, HB-3, HB-4, and HB-5 decreased by 57.7 %, 61.37%, 26.7%, and 35.17% respectively as compared to HB-1.

Block Density

Block density of solid concrete blocks = 2604.45 kg/m3
Block density of solid concrete blocks = 2201.3 kg/m3
Block density of conventional hollow concrete blocks available in the market = 1595.5 kg/m3

Block density of hollow concrete blocks with 2 circular cavities = 1856.87 kg/m3
Block density of hollow concrete blocks with 3 circular cavities = 1930.42 kg/m3
Block density of hollow concrete blocks with 2 rectangular cavities = 1887.29 kg/m3
Block density of hollow concrete blocks with 3 rectangular cavities =1829.36 kg/m3

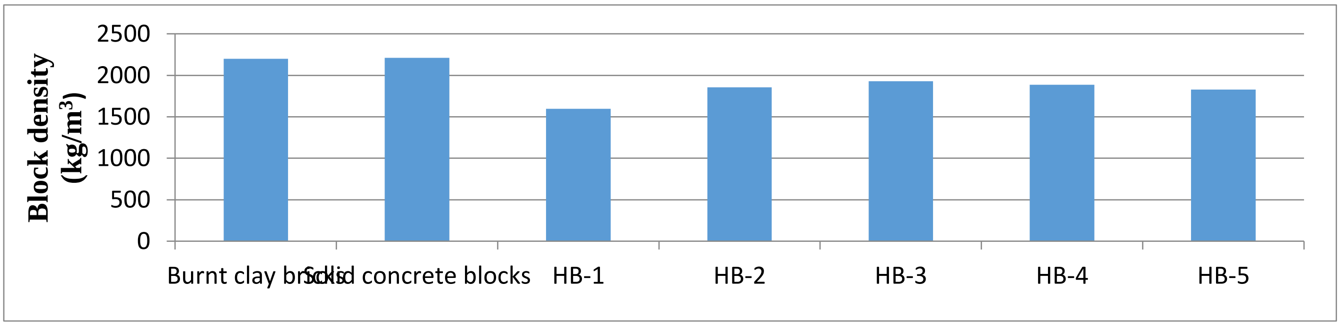

Figure 4: Comparison of block density

It can be seen in fig.4 that the block density of all the modified hollow concrete blocks are in the same range and confirm the requirements given in IS 2185 (part -1): 2005.

Thermal Properties of hollow concrete blocks

Thermal gradient

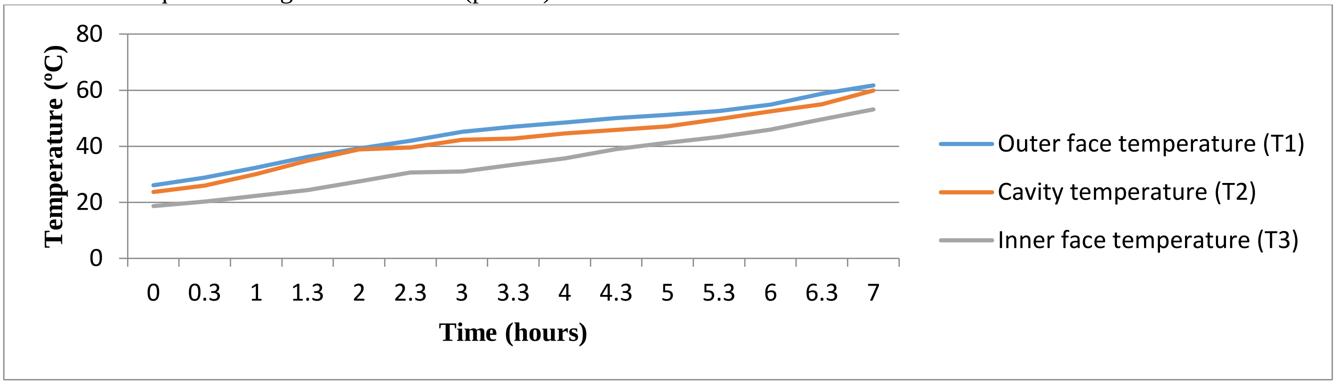

Figure 5: Temperature variation concerning time in HB-2 wall

The temperature gradient of the HB-2 wall From fig.5 average temperature difference = 11.85 ◦ C

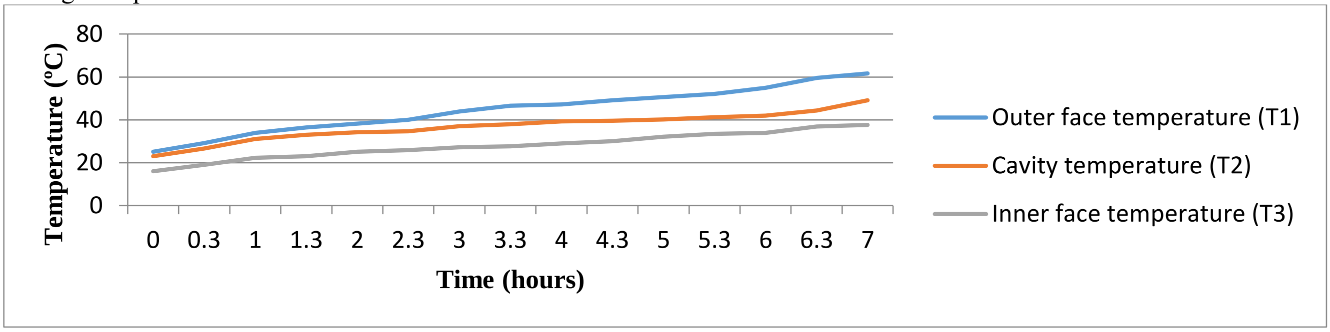

Figure 6: Temperature variation concerning time in HB-3 wall

The temperature gradient of the HB-3 wall From fig.6 average temperature difference = 16.76 ◦ C

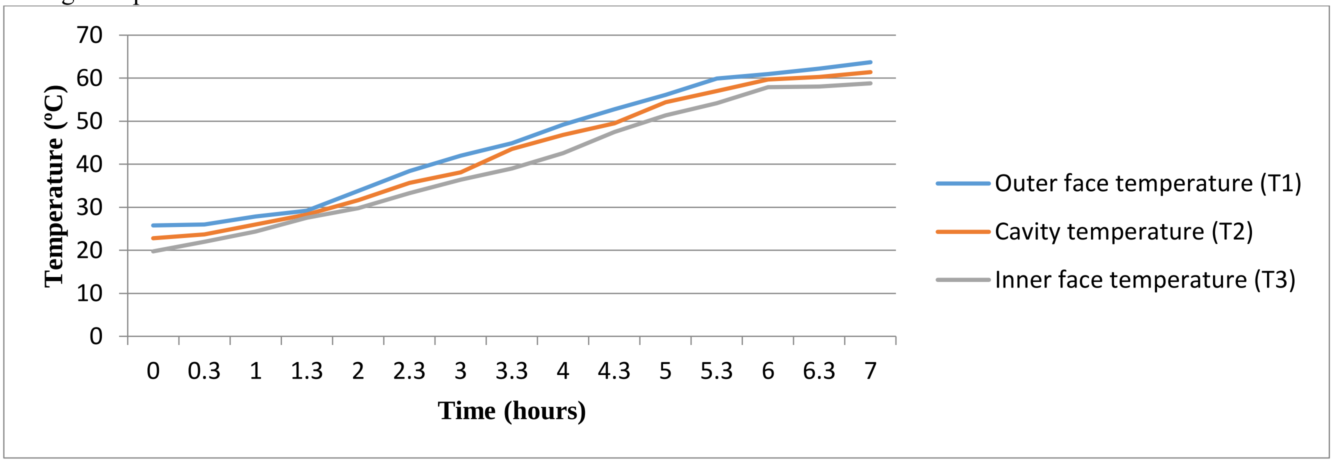

Figure 7: Temperature variation concerning time in HB-4 wall

The temperature gradient of the HB-4 wall From fig.7 average temperature difference = 7.7 ◦ C

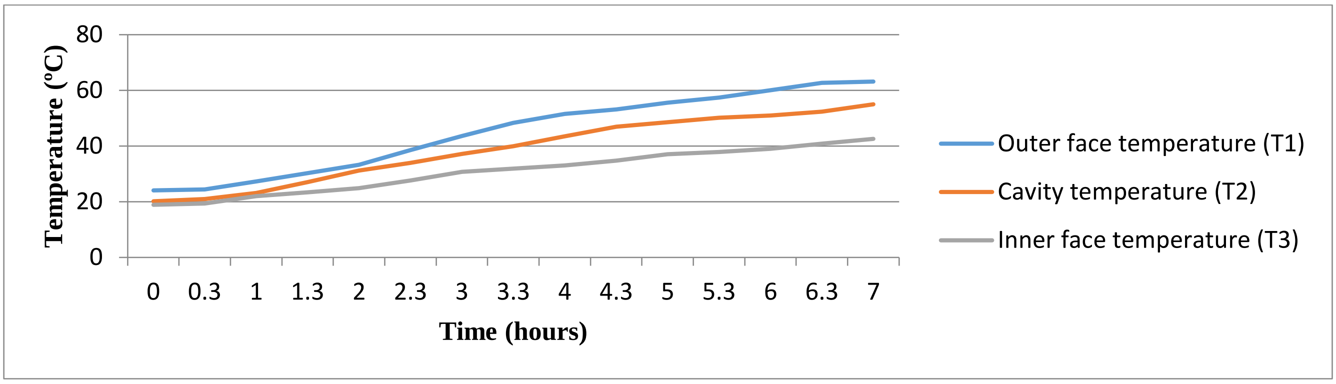

Figure 8: Temperature variation concerning time in HB-5 wall.

The temperature gradient of the HB-5 wall From fig.8 average temperature difference = 14.04 ◦ C

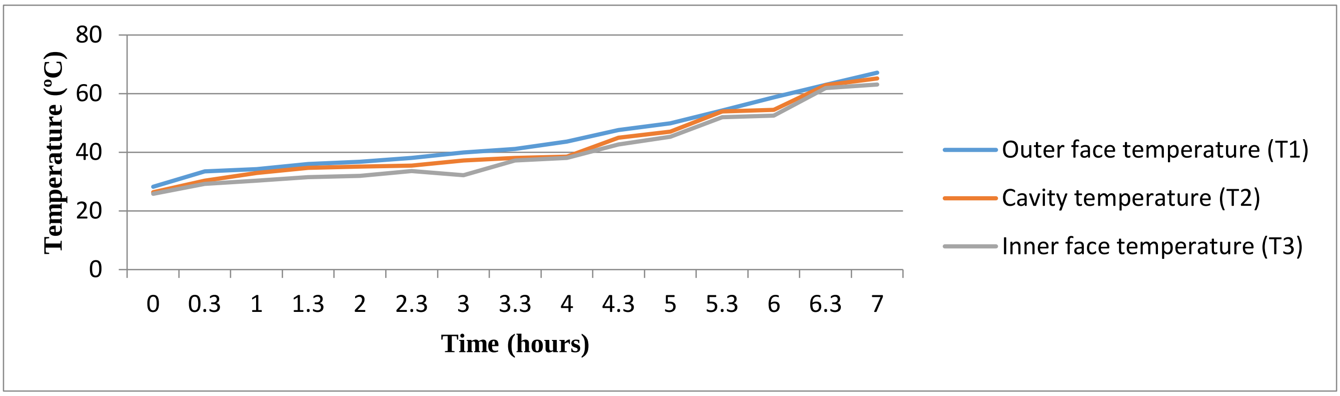

Figure 9: Temperature variation concerning time in HB-1 wall.

The temperature gradient of the HB-1 wall From fig. 9 average temperature difference = 4.3 ◦ C

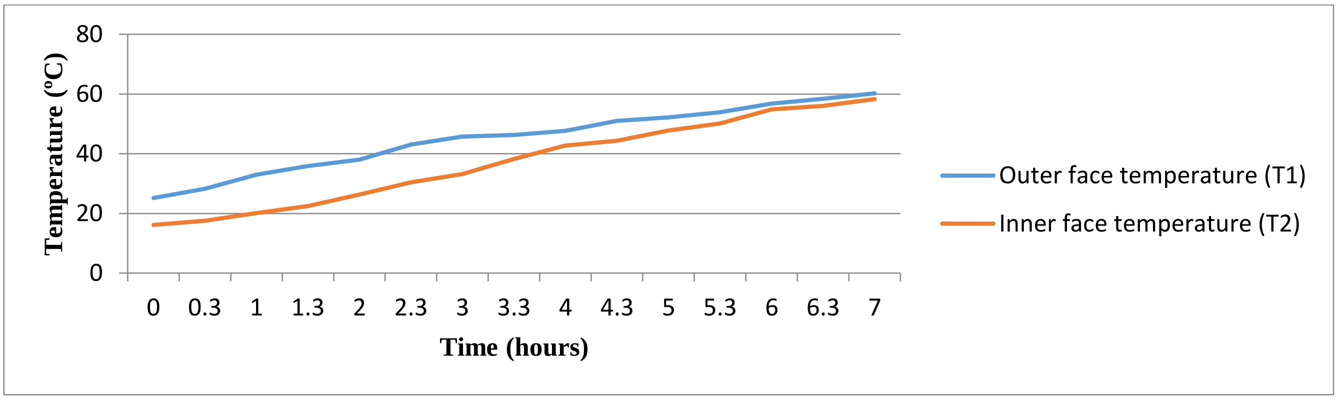

Figure 10: Temperature variation concerning time in Brick wall

The temperature gradient of the Brick wall From fig.10 average temperature difference = 6.96 ◦ C

- **Temperature gradient Comparison**

The following bar charts show the temperature gradient of different blocks at 0, 1, 2, 3, 4, 5, 6, and 7 hrs respectively:

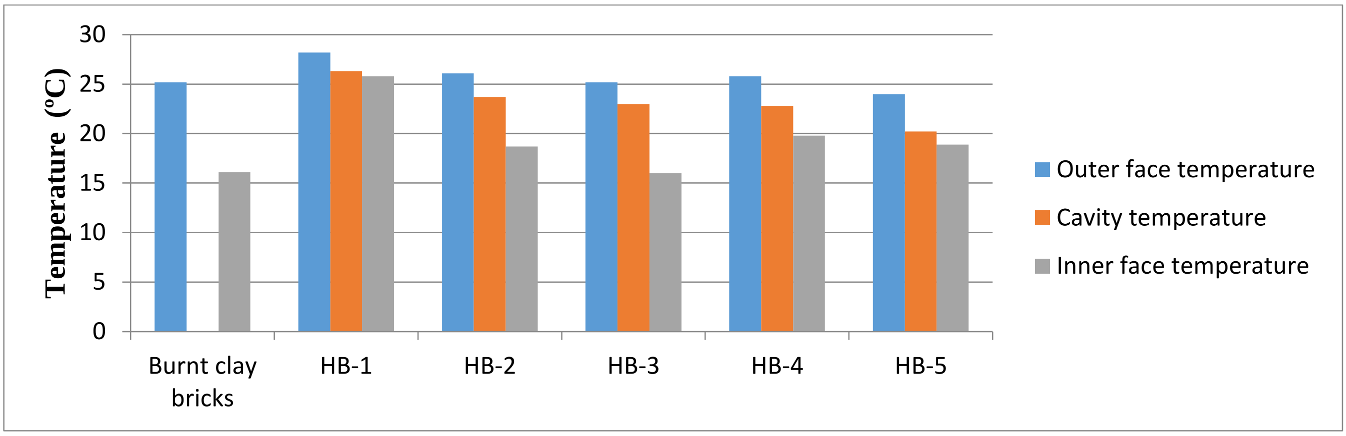

Figure 11: Temperature gradient comparison at 0 hrs

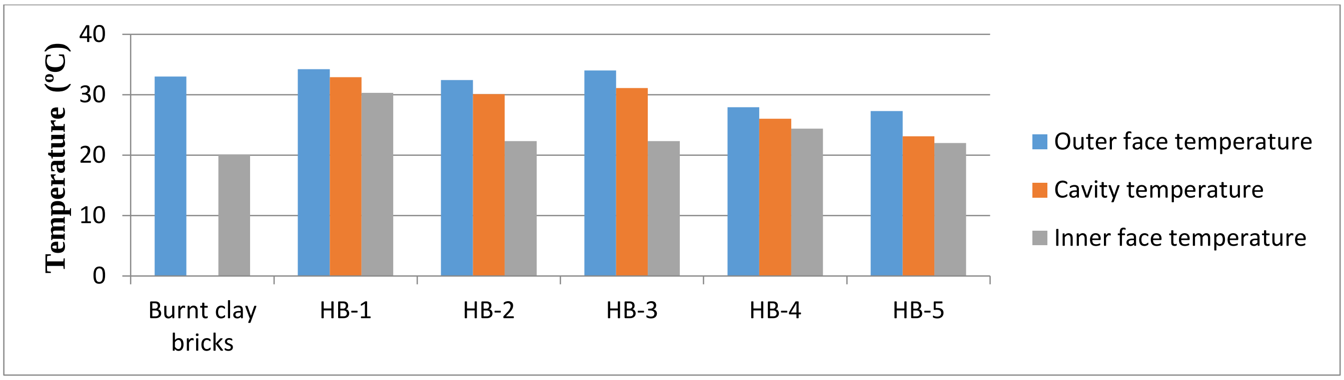

Figure 12: Temperature gradient comparison at 1 hrs

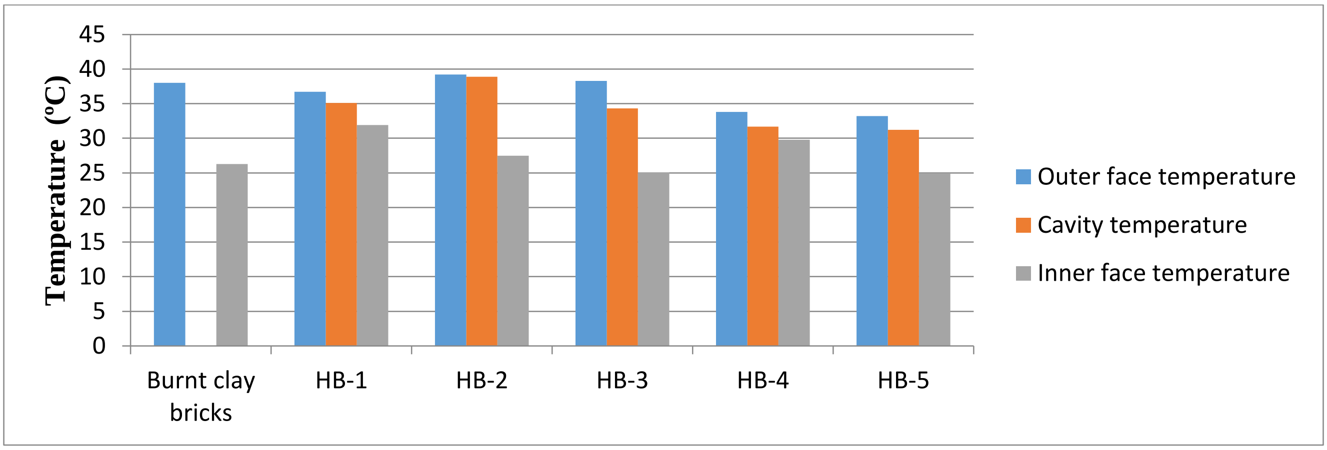

Figure 13: Temperature gradient comparison at 2 hrs

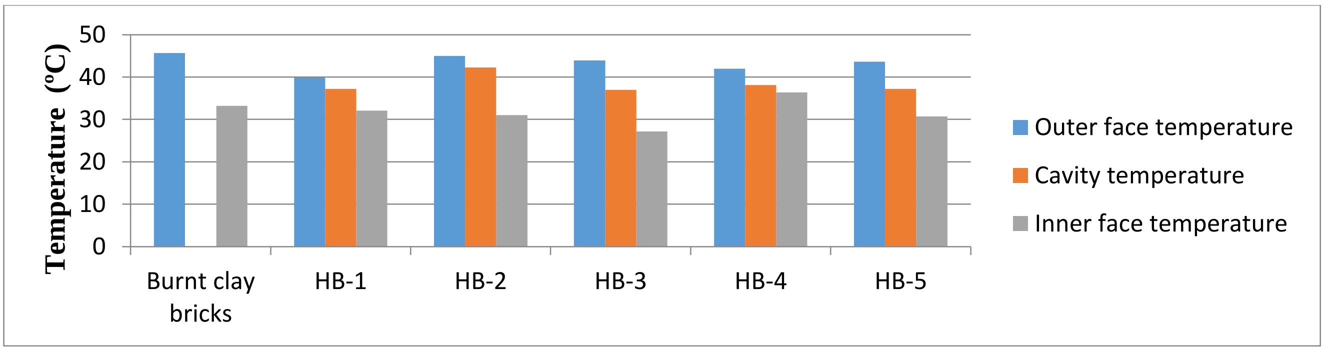

Figure 14: Temperature gradient comparison at 3 hrs

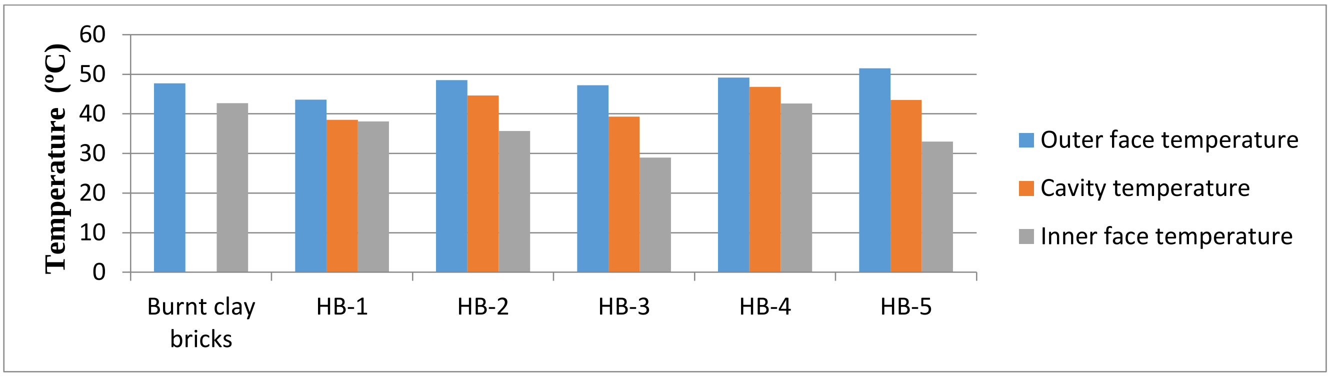

Figure 15: Temperature gradient comparison at 4 hrs

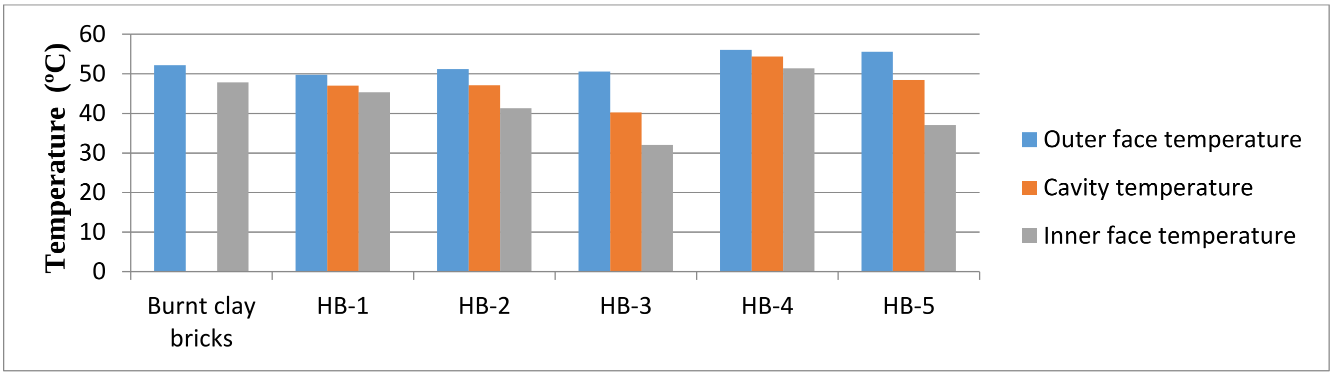

Figure 16: Temperature gradient comparison at 5 hrs

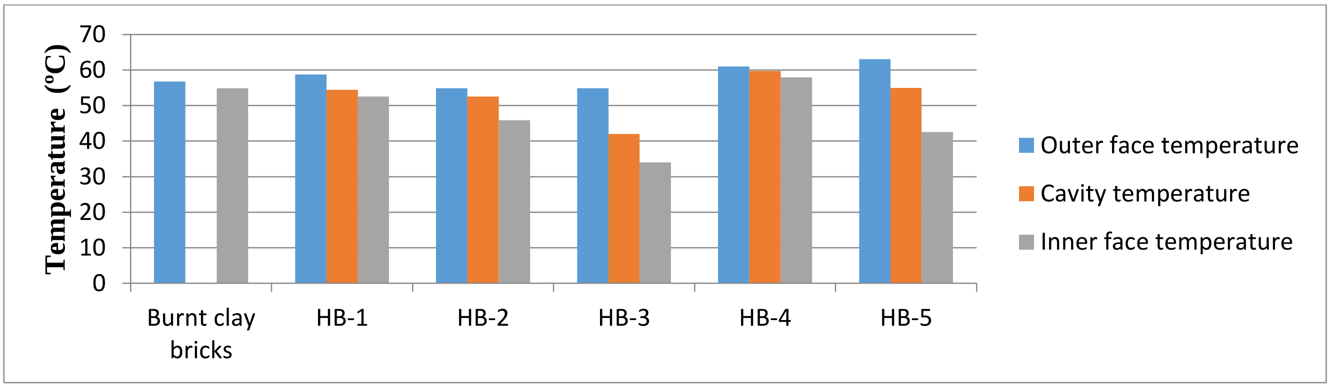

Figure 17: Temperature gradient comparison at 6 hrs

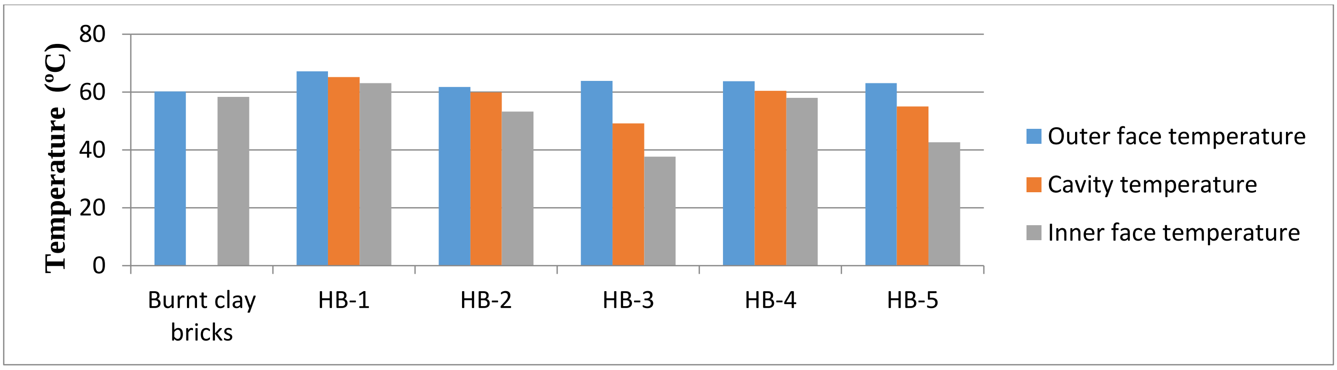

Figure 18: Temperature gradient comparison at 7 hrs

From the above figures; fig.11, fig.12, fig.13, fig.14, fig.15, fig.16, fig.17 and fig.18, it is observed that the average temperature difference of samples of HB-2, HB-3, HB-4, and HB-5 increased by 175.6%, 289.77%, 79.06%, and 226.51% respectively as compared to samples of HB-1. The average temperature difference of samples of HB-

2, HB-3, HB-4, and HB-5 increased by 70.26%, 140.8%, 10.63%, and 101.72% respectively as compared to conventional burnt clay bricks.

The average temperature difference of samples of HB-3 increased by 41.43% as compared to samples of HB-2. The average temperature difference of samples of HB-5 increased by 82.33% as compared to samples of HB-4. The average temperature difference of samples of HB-2 increased by 53.89% as compared to samples of HB-4. Also, the average temperature difference of samples of HB-3 increased by 19.37% as compared to samples of HB-5.

V. COST COMPARISON

The cost of one modified hollow concrete block of size 16 in x 6 in x 8 in and net volume 580.49 in3 is Rs. 31.52 /-. If we consider the profit on one hollow concrete block to be Rs. 6 /-, the selling price of the hollow concrete block would be Rs. 38 /- approximately, whereas the selling price of the hollow concrete block available in the market is Rs. 40 /- per block. For the same price range, we are getting modified hollow concrete blocks with high strength and good quality. Furthermore, if we consider a wall of volume 2304 in3 (16in x 6in x 24in), the cost of modified hollow concrete blocks required to build this wall is Rs. 114 /-, the cost of conventional burnt clay bricks required to build this wall is Rs. 152 /- and the cost of hollow concrete blocks available in the market is Rs. 120 /-. The cost of hollow concrete blocks for walls of volume 2304 in3 comes out to be 33.33% less than that of walls made of bricks and 5.26% less than that of hollow concrete blocks available in the market. Hence the construction of a hollow concrete block wall is more economical and speedy.

The cost comparison can be easily understood with the help of fig.19.

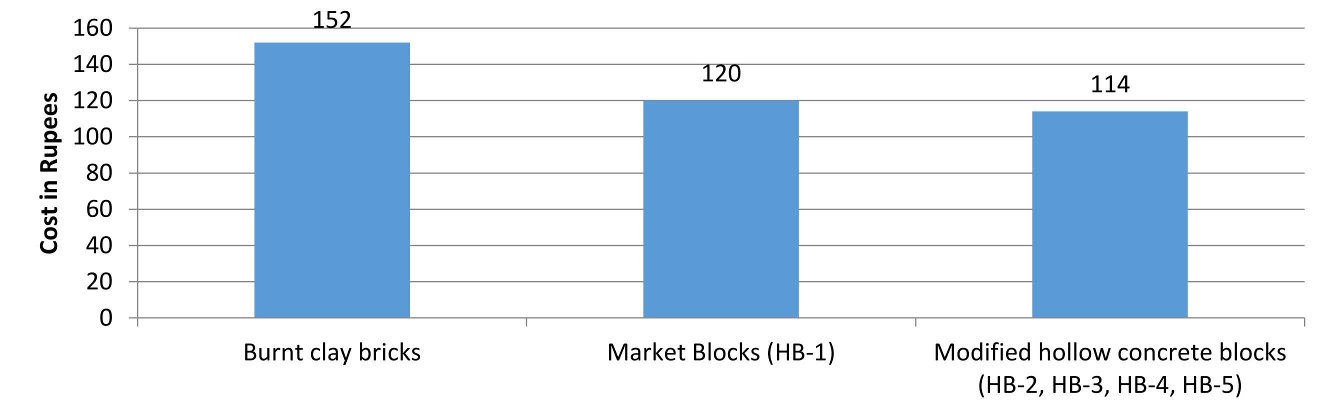

Figure 19: Cost comparison

VI. CONCLUSION

This project was carried out to explore the possibility of enhancing the thermal performance of hollow concrete blocks and increasing their strength by changing the mix of concrete and shape optimization of cavities. Based on the results obtained, the following conclusions can be drawn:

- The compressive strength of modified hollow concrete blocks with 2 circular cavities (HB-2), 3 circular cavities (HB-3), 2 rectangular cavities (HB-4), and 3 rectangular cavities (HB-5) increased by 117%, 108%, 86.2%, and 81% respectively in comparison to the contemporary hollow blocks (HB-1).
- The water absorption of modified hollow concrete blocks with 2 circular cavities (HB-2), 3 circular cavities (HB-3), 2 rectangular cavities (HB-4), and 3 rectangular cavities (HB-5) decreased by 57.7%, 61.37%, 26.7%, and 35.17% respectively as compared to the hollow concrete blocks available in the market (HB-1).
- The average temperature difference of samples of HB-2, HB-3, HB-4, and HB-5 increased by 175.6%, 289.77%, 79.06%, and 226.51% respectively as compared to samples of HB-1. The average temperature difference of samples of HB-2, HB-3, HB-4, and HB-5 increased by 70.26%, 140.8%, 10.63%, and 101.72% respectively as compared to conventional burnt clay bricks. This shows that the modified hollow concrete blocks provide better thermal insulation than hollow concrete blocks available in the market and conventional burnt clay bricks.
- The average temperature difference of samples of HB-3 increased by 41.43% as compared to samples of HB-2. The average temperature difference of samples of HB-5 increased by 82.33% as compared to samples of HB-4. The temperature difference or the thermal gradient between the outer and inner face of walls made of circular cavity blocks (HB-2 & HB-3) is higher than those of walls made of rectangular type hollow concrete blocks (HB-4 & HB-5). This shows that circular cavity blocks provide better insulation than rectangular cavity blocks.
- The average temperature difference of samples of HB-2 increased by 53.89% as compared to samples of HB-4. Also, the average temperature difference of samples of HB-3 increased by 19.37% as compared to samples of HB-5. This shows that the 3 cavity hollow concrete blocks exhibit better thermal performance than the 2 cavity hollow concrete blocks.
- The cost of hollow concrete blocks for a wall of volume 2304 in3 comes out to be 33.33% less than that of a wall made of bricks and 5.26% less than that of hollow

concrete blocks available in the market. So, modified hollow concrete blocks prove to be economical.

VII. FUTURE SCOPE

- The circular type hollow concrete blocks proved to be a better alternative as compared to contemporary blocks for thermal insulation of a building but their compressive strength is less as compared to solid concrete blocks. The addition of reinforcing materials such as polypropylene fibres can improve the compressive strength and also decrease the rate of water absorption.
- The use of fly ash as a partial replacement of cement in the hollow concrete blocks can prove to be advantageous as it increases the thermal insulation property of blocks. Also, the use of fly ash along with cement will help to make it an eco-friendly material.
- Incorporation of high strength SFR-MS mortar (steel-fibre reinforced mortar admixed with micro silica) in the head and bed joint can bring about a 17% enhancement in lateral load capacity of the walls. The SFR-MS mortar is compatible with wall masonry components and can be used both as a retrofit plaster and also as a head and bed joint mortar. The SFR-MS mortar enhances not only the shear capacity but also increases the ductility of the masonry structure.

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