Project Work Report

Experimental Investigations on Thermal Performance of Stabilized Mud Block

Visvesvaraya Technological University

Bachelor of Engineering

Submitted by

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Certificate

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the student of eighth semester ***B.E (Civil Engineering)*** *declare that the project entitled* ***"Experimental Investigations on Thermal Performance of Stabilized Mud Block"*** *is carried out by me at* ***K.S School of Engineering and Management*** *as a partial fulfillment of academic requirement of* ***B.E in Civil Engineering*** *under* ***Visvesvaraya Technological University.*** *The content in the thesis are original and are free from plagiarism and other academic dishonesty and are not submitted to any other University either partially or wholly for the award of any other degree.*

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Nomenclature

l	cube/block length, *mm*
b	cube/block width, *mm*
d	cube/block depth, *mm*
m^3	Volume in meter.
mm^3	volume in millimeter.
Kg	Weight in kilogram
N	Newton
N/mm^2	Newton per millimeter squared
MPa	Mega Pascal
Kg/m^3	Density
m	Meter
mm	Millimetre
ml	volume of liquid in milliliter
CM	Cement Mortar
CC	Cement Concrete
W/C	Water-Cement ratio
°C	Degree Celsius
W/mk	Watts per meter-Kelvin

Abstract

The thermal performance of a building refers to the process of modelling the energy transfer between a building and its surroundings. Various heat exchange processes are possible between a building and the external environment. Heat flows by conduction through various building elements such as walls, roof, ceiling, floor, etc.

Mud blocks are one of the building techniques and have widely been used. Its abundant source benefits from direct site-to-service application to reduce the costs caused by acquisition, transportation and production. No specialized instrument and specific surroundings are required during the production. In recent years, a growing interest in overcoming the mechanical defects has been appeared and the technique of stabilization has been used in order to enhance the durability and compressive strength of earth blocks.

In this project, a stabilized mud blocks of size 229x191x102 mm is manufactured using soil, M-sand and cement. The casting of stabilized mud blocks is done using a Mardini stabilized mud block press. Infrared Thermometer is used to measure the variation in temperature between the outside and inside surfaces of the blocks, when exposed to sunlight. The thermal block is then cured for a period of 28 days. A room of size 3 x 3 x 3 ft constructed and exposed to outdoor climate conditions. Infrared thermometer is used to note the surface temperature difference between the two rooms.

This adaptation of stabilized mud blocks in the construction of a wall can reduce the indoor temperature during hot days while also adding sustainable benefits such as a reduced carbon footprint, less consumption of electricity to condition the building.

1. Introduction

1.1 Thermal Performance of the buildings

The thermal performance of a building refers to the process of modeling the energy transfer between a building and its surroundings. Various heat exchange processes are possible between a building and the external environment. Heat flows by conduction through various building elements such as walls, roof, ceiling, floor, etc. Heat transfer also takes place from different surfaces by convection and radiation. Besides, solar radiation is transmitted through transparent windows and is absorbed by the internal surfaces of the building.

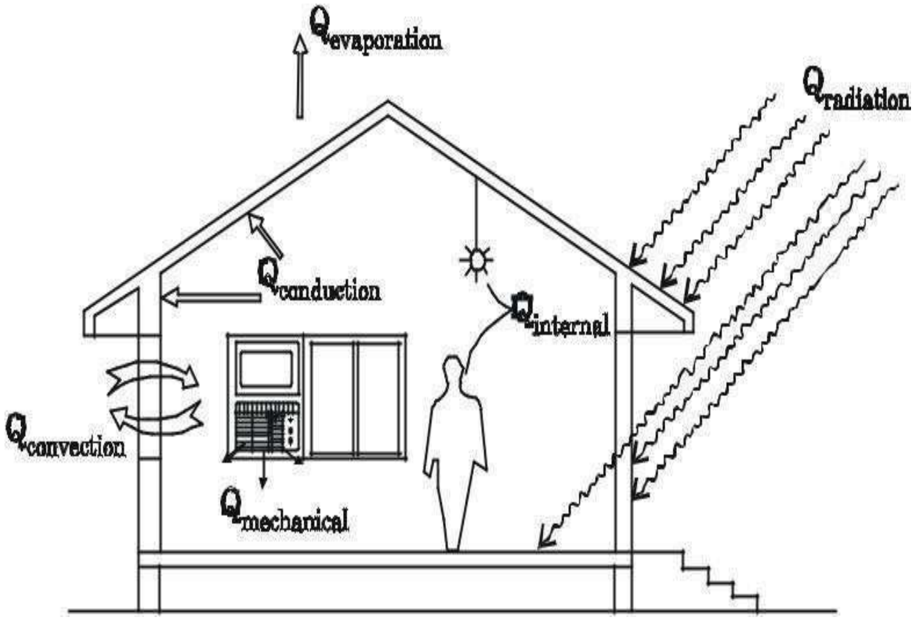

Fig 1.1: Thermal performance of a building
(Source: www.rcet.org.in)

1.2 Concrete blocks

A Concrete Block is a ‘Building Block’ composed entirely of concrete that is then mortared together to make an imposing, long-lasting construction. These construction blocks can be ‘Hollow’ or ‘Solid,’ formed of ordinary or lightweight concrete in various specified sizes, depending on the precise requirements. Concrete blocks come in various shapes and sizes, and they can be solid or hollow. 39cm x 19cm x (30cm or 20 cm or 10cm) or 2 inch, 4 inch, 6 inch, 8 inch, 10 inch, and 12-inch unit configurations are the most popular concrete block sizes. Concrete blocks are made from cement, aggregate, and water. In concrete blocks, the cement-aggregate ratio is 1:6.

1.2.1 Types of Concrete Blocks:

There are two types of concrete blocks:

1. Solid Concrete Blocks
2. Hollow Concrete Blocks

1. Solid Concrete Blocks:

Fig 1.2: Solid Concrete Blocks
(Source: homedpot.com)

The solid concrete blocks are made up of cement and sand mixture as shown in Figure 1.2. Solid Concrete blocks are used for constructing walls of homes, gardens, or commercial buildings. These are made up of high density properties. The solid concrete blocks provide strong protection from heavy rainfall or high speed blowing wind. U value ranges from

2. Hollow Concrete Blocks:

Fig 1.3: Hollow Concrete Blocks
(Source: cementconcrete.org)

In masonry construction, hollow concrete blocks are typically employed as shown in Figure 1.3. It reduces labour costs on the job site while also speeding up the construction process and saving cement and steel. These blocks reduce the natural weight of masonry structures while also improving physical wall qualities like noise and thermal insulation. Standard hollow concrete blocks come in two sizes: Full size and half size. Half-sized blocks are cubical and have one core, while full-sized blocks are rectangular and have two cores. The nominal size of concrete blocks, according to the 'Research Designs & Standards Organization of Indian Railways,' is as follows:

i) 400, 500, or 600 mm in length ii) 200 or 100 mm in height iii) 50, 75, 100, 150, 200, 250, or 300 mm in width.

Hollow concrete blocks come in various shapes, sizes, and designs, depending on the shape, needs, and design.

1.2.2 Uses of Concrete Blocks:

- Concrete Blocks are a great option for partition walls because they are quick and easy to install. The inclusion of steel reinforcement adds to the structure's strength.
- Exterior and Interior Load-bearing Walls, Partition Walls, Panel Walls, and Boundary Walls are common uses for Hollow Concrete Blocks.
- Solid Concrete Blocks are perfect for Chimney and Fireplace building, but they also work well for Non-load Bearing Walls and Garden Walls.
- Concrete blocks are also used in a variety of smaller landscaping projects. Many Outdoor Furniture & Patio ideas, for example, include Outdoor Seating, Decorative screens, Outdoor Bar, Flower Bed, and many others.

1.3 Introduction to Stabilized Mud Blocks

Along with the development of both rural villages and cities, which is the fastest growing economy in the world, the progressive increase in the demand of residential buildings requires a huge building materials to be prepared and used. Nowadays, energy shortage and pollution have become the main problems in the society, the modern building materials which have high energy costs and CO_2 emissions should be replaced by the sustainable and environmental building materials which are abundant and inexpensive. Earth construction, which is warm in winter and cool in summer, is one of the oldest and most widespread buildings in human history. It can contribute to improve living comfort and reduce environmental problems.

Fig 1.4: Soil for stabilized mud blocks
(Source: soilsensor.com)

Mud blocks are one of the building techniques and have widely been used. Its abundant source benefits from direct site-to-service application to reduce the costs caused by acquisition, transportation and production. No specialized instrument and specific surroundings are required during the production. In addition, earth buildings provide good sound and thermal insulation, and they may also help in regulating the indoor humidity. Unfortunately, earth materials have been ignored for many years in the modern construction sector; this is mainly due to the lack of strength and durability. The compressive strength represents the load-bearing performance of earth blocks; lower compressive strength means earth blocks can only be used for self-bearing members and the storey of building has been restricted. The lack of durability leads to earth buildings are vulnerable to weathering and rainfall and regular repair will cost human and financial resources. In recent years, a growing interest in overcoming the mechanical defects has been appeared and the technique of stabilization has been used in order to enhance the durability and compressive strength of earth blocks.

1.3.1 Stabilized Mud Block

Stabilized Mud Blocks (SMBs) are mud blocks for a building material primarily made from selected soil or earth. Unlike other types of mud blocks, stabilized mud bock is made by compressing a mixture of selected earth, cement, and water. The compressed blocks are then allowed to dry in the sun, without the need for firing or baking, and are used for construction purposes.

They are considered to be a sustainable and eco-friendly alternative to traditional building materials like fired bricks and concrete blocks, as they are made from locally available materials. It does not require large amounts of energy for the production of SMBs. They are also relatively low-cost and can be produced on-site as the mud is readily available. Thus, Stabilized Mud Blocks are a popular choice for construction in rural and remote areas. U-value lower than 1.1 W/mK.

1.3.2 Types of Stabilized Mud Blocks

Some of the most common types of stabilized mud blocks are:

1. Compressed Stabilized Earth Blocks (CSEBs): These are made by compressing a mixture of soil, sand, and stabilizers such as cement, lime, or fly ash, and are used for load-bearing walls and foundations as shown in Figure 1.5.

Fig 1.5: Compressed Stabilized Earth Blocks
(Source: civilpro.com)

2. Interlocking Stabilized Soil Blocks (ISSBs): These are similar to CSEBs, but they have a special interlocking design that allows them to be dry-stacked without the need for mortar. They are commonly used for walls and partitions as shown in Figure 1.6.

Fig 1.6: Interlocking Stabilized Soil Blocks
(Source: civilpro.com)

1.3.3 Material Composition of SMBs

Although it is a mud block, Stabilized mud blocks are made by mixing suitable soil, sand, cement, and water in varying proportions, depending on the soil type and its properties. The mixture is then compressed into blocks using a hydraulic or manual press. The exact proportions of the materials used may vary based on the desired strength, durability, and other properties of the blocks. However, the mix is commonly composed of 70-80% soil and 20-30% stabilizer (cement or lime).

The general composition of the materials used to make stabilized mud blocks:

1. **Soil**: The soil used for SMBs is usually clayey or silty soil, which provides good binding properties when mixed with sand and cement. The soil should be free of organic matter, rocks, and other debris that can weaken the blocks.
2. **Sand**: Sand is added to the mixture to improve the workability and reduce the shrinkage of the blocks. The sand used should be clean and well-graded, with a particle size of about 2mm.
3. **Cement**: Cement is added to the mixture to improve the strength and durability of the blocks. Usually, ordinary Portland cement or lime pozzolana mixture is used, but other types of cement can also be used.
4. **Water:** Water is added to the mixture to form a workable paste that can be compressed into blocks. The amount of water used should be carefully controlled to ensure that the blocks are not too wet or too dry.

1.3.4 Uses of Stabilized Mud Blocks:

Stabilized mud blocks (SMBs) are sustainable and cost-effective building material that has a wide range of uses and some of the uses include:

- Wall construction: Can be used for constructing load-bearing or non-load-bearing walls in buildings. The blocks have good thermal insulation properties, which help to keep the interior of the building cool in hot weather and warm in cold weather.
- Flooring: Also, it can be used for constructing floors in buildings. They have good compressive strength and can withstand heavy loads.
- Paving: These are suitable for paving walkways, driveways, and other areas. They are durable and can withstand heavy foot and vehicle traffic.
- Landscaping: SMBs can be used for constructing retaining walls, garden walls, boundary walls, and other landscaping features. They can be easily moulded into different shapes and sizes to suit the design requirements.
- Infrastructure projects: Stabilized Mud Blocks can also be used for constructing small bridges, culverts, and other infrastructure projects in rural areas. They are easy to transport and can be manufactured on-site using locally available materials.

1.4 Scope of Present Investigation

Since the stabilized mud block has good applications in civil engineering projects due to reduced carbon emission in buildings and providing low thermal conductivity, the current study investigates on the properties and thermal performance of stabilized mud block.

1.5 Summary

In the present scenario, use of eco-friendly composite blocks is gaining momentum for achieving sustainable practices in construction field hence use of stabilized mud blocks for construction reduces the thermal conductivity resulting in the reduction in use of cement blocks, there by relatively stabilized mud block is eco-friendly construction material.

2. Literature Review

2.1 Literature survey on stabilized mud block

An extensive literature survey is carried out related to development and use of stabilized mud blocks as investigated by different researchers. Aim of the present investigation, objectives of present investigation and methodology of the present. **Hassane Seini Moussa et.al** focused on the stabilization effect of the compressed earth blocks (CEB) produced from quartz-kaolinite rich earthen material stabilized with 0% - 25% calcium carbide residue (CCR). The paper evaluated various physico-thermal properties of the stabilized CEB and thermal comfort in the model building made of CEB masonry. The optical properties of CEB were evaluated from the mineral composition of the earthen material and CCR and apparent density of the CEB. A simulation was carried out on naturally ventilated model building whose masonry is made of CCR stabilized CEB comparing to the so-called conventional cementitious materials such as cement blocks and concrete. The results showed a decrease of the apparent density of the CEB from 2100 $kg \cdot m^{-3}$ for unstabilized CEB (0% CCR) to 1600 $kg \cdot m^{-3}$ for 25% CCR stabilized CEB. The thermal conductivity and depth of penetration of the heat flux on a 24 hours period of CEB respectively decreased from 1 $W \cdot m^{-1} \cdot K^{-1}$ and 12.7 cm for 0% CCR-CEB to 0.5 $W \cdot m^{-1} \cdot K^{-1}$ and 10.2 cm for 25% CCR-CEB. The emissivity, solar absorptivity and visible absorptivity of the CEB respectively decreased from 0.82, 0.82 and 0.82 for 0% CCR-CEB to 0.80, 0.64 and 0.64 for 25% CCR-CEB. The number of hours of warm and humid thermal discomfort was impacted for stabilized CEB based masonry in comparison with cement based masonry. The warm discomfort in building made of 20% CCR-CEB masonry was 400 hours lesser than that in building made of hollow cement blocks masonry. If air conditioning system is used to keep the indoor temperature below 28˚C, the economy of 310,000 CFA francs (535 USD) is made every year on energy consumption for cooling in the model building made of 20% CCR-CEB masonry, corresponding to 9.6% less, with respect to that made of hollow cement blocks masonry.

Elisabete R. Teixeira et.al conducted an experimental investigation to evaluate the mechanical, durability, and thermal performance of compressed earth blocks (CEBs) produced in Portugal. CEBs were analysed in terms of electrical resistivity, ultrasonic pulse velocity, compressive strength, total water absorption, water absorption by capillarity, accelerated erosion test, and thermal transmittance evaluated in a guarded hotbox setup apparatus. Overall, the results showed that compressed earth blocks presented good mechanical and durability properties. Still, they had some issues in terms of porosity due to the particle size distribution of soil used for their production. The compressive strength value obtained was 9 MPa, which is considerably higher than the minimum requirements for compressed earth blocks. Moreover, they presented a heat transfer coefficient of 2.66 W/(mK). This heat transfer coefficient means that this type of masonry unit cannot be used in the building envelope without an additional thermal insulation layer but shows that they are suitable to be used in partition walls. Although CEBs have promising characteristics when compared to conventional bricks, results also showed that their proprieties could even be improved if optimisation of the soil mixture is implemented.

Ayman S. Mohamed et.al conducted an experimental investigation in the field of urban development to provide a sustainable alternative to building facilities. Where the materials and construction method are chosen according to the surrounding economic conditions and these conditions are overcome by stabilized earth blocks, making use of the existing natural resources and producing building units from the compressed stabilized earth blocks. This research aims to use building units from compressed stabilized earth blocks as an alternative to traditional building materials and to achieve thermal comfort by reducing energy consumption through the use of program design builder to rationalize energy consumption to represent economic and environmental advantages. Building units manufactured from several types of earth and stabilizing materials were used by 8% cement of the total weight. The compressed stabilized earth blocks of mixtures were produced to meet the requirements of the Egyptian Code for earth Building. The study was conducted on a residential model for comparison with compressed stabilized earth blocks with local blocks units. Moreover, it is better to use cement an addition at 6% and 8% ratio to have a suitable compressive strength results, regardless of soil type without the need of using high percentages of cement which is good for environmental and economic points of view provides energy required to operate the building by 4.5% to 26% compared to local bricks, in addition to availability of earth in urban and rural areas, making it suitable in terms of construction cost for walls and types of roofs.

Khalifa Al-Jabri et.al conducted an experimental investigation in plausible reuse of wastewater and solid waste materials for compressed earth bricks (CEBs) production due to their sustainability benefits, affordability, and they are considered relatively ubiquitous raw materials. However, a study of the behaviour of CEBs produced from soil and injected wastewater from oilfields has not been well documented in the literature. This study aimed at employing an experimental testing program to assess structural and thermal properties of masonry units, mainly prism's compressive strength, masonry wall's behaviour, and thermal properties of CEBs rooms made with produced water and soil obtained from two oilfields in Oman: namely Marmoul and Nimr oilfields. It was found that prism strength decreases with increasing prism height, with Marmoul CEBs (2.4–3.9 MPa) showing slightly better performance compared to that Nimr (1.8–3.8 MPa). The masonry prism efficiency factor, which was estimated based on the ratio between the prism and block strength, was in the range of 52.3–59% for Marmoul CEBs, whereas for Nimr blocks, it ranged from 39.2% to 57.9%. The results of the masonry wall test showed that the wall reached an ultimate load of 386 kN at a deformation of 8.0 mm and the mode of failure was deformation of the wall due to overall buckling. The CEBs rooms have shown enhanced thermal performance compared to the reference room built with hollow concrete blocks. The CEBs rooms provided 1–7 h of time lags and achieved between 0.15 and 0.23 lower decrement factors than the reference room due to their high thermal mass and thermal resistance, respectively. While the CEBs under this study have shown good structural and thermal insulation potential as a sustainable building material, other factors, including indoor air quality emissions, acoustic properties, seismic resistance, and cost-benefit analysis, need to be considered in future studies.

Iynes Laouni et.al conducted an experimental investigation in develop a material that will improve indoor comfort by eliminating the effect of hot walls during the summer and lowering the amount of energy consumed by air conditioning. It also aims to promote enough thermal autonomy to maintain thermal comfort in hot arid areas, such as Biskra's climate in southeastern Algeria, as well as to provide designers with a healthy, durable, and long-lasting material, solid, and low-cost material option. The thermal properties of this material, including the proposed combination and manufacturing procedure for these compressed and stabilized earth bricks is demonstrated using different protypes. The results show that this material improves thermal wall performance and, as a result, internal thermal comfort; surface temperature is reduced by 7°C, influencing stored heat and heat flow—transferred to the interior, lowering the internal temperature to 6°C and, as a result, lowering the ambient temperature by 5°C.

Dr. Janmejoy Gupta et.al conducted an experimental investigation in inproving the Indoor thermal-comfort conditions by judicious selection of building materials. India has climatic conditions ranging from warm-humid to cold, with composite climate prevalent in considerably larger parts. Rural Indigenous mud-based architecture is a hitherto neglected aspect of architecture. Yet, 30% of the world's total population lived in earthen structures in 2011. Mud huts are an intrinsic part of the culture and life of many rural-folk through generations. This paper deals with both the thermal properties and performance of mud in composite climatic regions in India. As a typical composite climatic region, Ranchi, the capital of the eastern Indian state of Jharkhand, has been considered. The primary thermal properties of mud, which determine its applicability and effective-use, have been studied with respect to the characteristics of composite climate. To design and build dwellings in composite climate region is toughest as they have varying climatic characteristics from season to season. This paper suggests a few measures to make existing mud dwellings a more climateresponsive option throughout the year in the composite climatic zones of the country. The existing mud walls in Ranchi (450 mm thick) are best suited for the Hot-Dry and Cold Climatic parts of the year, and moderately suited for the moderate part of the year. It can be used in warm-humid part of the year, which forms a considerable period of 3-4 months, only if the existing walls are made thinner to 125 mm-150 mm (maximum). Increasing insulation-level of mud walls with insertion of bamboo frame-work and application of cow-dung layer over mud phusca. The U-Value of mud-wall can be reduced, if proper insulation is used. Also, four inch (about 10 cm or 100 mm) of rigid insulation inserted in the centre of the wall, has also been seen to bring down the U value.

Arya Narendran et.al conducted an experimental investigation in Thermal Performance of Rammed Earth in Warm-Humid Climate. Stabilized Rammed Earth (SRE) is considered as the material having the lowest environmental cost and low embodied energy. Using material that is available locally means considerably reducing the energy consumed for manufacturing and transporting, which accounts for 29% -40% of the total embodied energy of that material. Earth has excellent ability to maintain interior air humidity level and thermal mass superior to other alternatives. This research focuses on thermal performance of rammed earth wall in warm-humid region taking case of Thiruvananthapuram. Mean radiant temperature in 250 mm thickness, stabilized Rammed earth is lesser than 400mm thickness SRE, F Time lag of 250mm SRE is lesser than 400 mm thickness SRE. Lowest Mean radiant temperature is experienced in concrete wall and in brick masonry. Highest MRT is experienced in insulation type 1 and insulation type 2. Highest MRT reaches 38.6 and SRE400 39.8 and in SRE250 reaches 38.9. In morning MRT goes to 36 in brick meanwhile its 37.8 in SRE 250 and 38.4 in SRE 400.

Gabin Alex Nouemssi et.al conducted an experimental study of the characterisation of local materials used in the construction and thermal insulation of buildings. These materials are compressed earth bricks stabilised with cement and sawdust. The thermal conductivity, diffusivity, effusivity, and specific heat of earth-based materials containing cement or sawdust have been determined. The results show that the blocks with earth + sawdust are better thermal insulators than the blocks with simple earth. We observe an improvement in thermal efficiency depending on the presence of sawdust or cement stabilisers. For cement stabilisation, the thermal conductivity increases (λ: 1.04 to 1.36 $W \cdot m^{-1} \cdot K^{-1}$), the diffusivity increases (from 4.32×10^{-7} to 9.82×10^{-7} $m^2 \cdot s^{-1}$), and the effusivity decreases (1404 - 1096 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$). For sawdust stabilisation, the thermal conductivity decreases (λ: 1.04 to 0.64 $W \cdot m^{-1} \cdot K^{-1}$), the diffusivity increases (from 4.32×10^{-7} to 5.9×10^{-7} $m^2 \cdot s^{-1}$), and the effusivity decreases (1404 - 906 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$). Improving the structural and thermal efficiency of BTC via stabilisation with derived binders or cement is beneficial for the load-bearing capacity and thermal performance of buildings.

R Shiva et.al conducted an experimental study of prevailing shortage of many building materials based on natural resources has led to a considerable price escalation in recent times. This has created opportunities for developing many alternative masonry materials that can be used for wall construction. Compressed stabilised earth bricks, solid blocks and interlocking blocks are few such materials. To reduce the number of bricks used in a given area, Rat-trap bond is also gaining popularity. All these will create many challenges to the professionals involved in the building industry that have to be solved by providing data on strength and behaviour characteristics. This research compares the strength, load deformation characteristics and the applications of English and Rat-trap bond patterns in masonry construction. The findings are based on burnt clay bricks and compressed stabilized earth bricks and blocks in order to investigate comparable performance. Stabilized compressed earth blocks include; uniformed building component sizes, use of locally available materials and reduction of transportation. Uniformly, sized building components can result in less waste, faster construction and the possibility of using other pre-made components or modular manufactured building elements. Such modular elements as sheet metal roofing which can be easily integrated into a CEB structure. The use of natural, locally-available materials makes good housing available to more people, and keeps money in the local economy rather than spending it on imported materials, fuel and replacement parts. The reduction of transportation time, cost and attendant pollution can also make CEB more environmentally friendly than other materials.

Shenwei Yu et.al conducted an experimental study on Optimization of the Thermal Performance of Composite Rammed Earth Construction. Rammed earth (RE) is a low-tech recyclable building material with good heat storage and moisture absorption performance that can better maintain the stability of the indoor thermal environment and improve indoor comfort. With innovations in and the development of new technology, the field of rammed earth construction technology is gradually expanding. However, deficiencies in the thermal insulation of traditional rammed earth structures make it impossible for them to meet China's building energy codes in cold regions. This study constructs a comprehensive evaluation index of the thermal performance of rammed earth walls that is based on the heat transfer mechanism, optimizing the thickness of the boundary conditions of the building interior's design temperature, as well as the energy demand and economic efficiency. This research also offers a new design for the thermal insulation of rammed earth construction by combining the building energy savings design code with WUFI Pro software. This study demonstrates that the optimum thickness of rammed earth construction in Beijing is about 360 mm, the thickness of extruded polystyrene board (XPS) is 50 mm (for public buildings) and 70 mm (for residential buildings), and the structural form of external insulation offers the highest performance benefit. In addition, this work also evaluates the risk of condensation inside composite rammed earth construction, finding that there is a risk of condensation on the exterior side of the wall and at the interface between the insulation panels and rammed earth wall, thus requiring an additional moisture-proof layer. In this study, thermal mass and insulation are fully considered and a design strategy for rammed earth construction given quantitatively, providing a theoretical basis for the application of rammed earth materials in cold regions.

2.2 Aim of the Present Investigation

To conduct experimental investigation on thermal performance of stabilized mud blocks.

2.3 Objectives

- To determine the engineering properties of the materials.
- To design mix proportion by using cement, lime, fly ash and pozzolana as stabilizer
- To cast the stabilized mud blocks.
- To determine the compressive strengths of stabilized mud blocks and also for procured cement concrete blocks.
- To measure and compare the thermal performance of the stabilized mud block and cement concrete block structures by constructing suitable scaled buildings.

2.4 Methodology

Methodology for objective 1

Engineering properties of materials soil are determined in the laboratory as per Indian Standard specifications as shown in Figure 2.1.

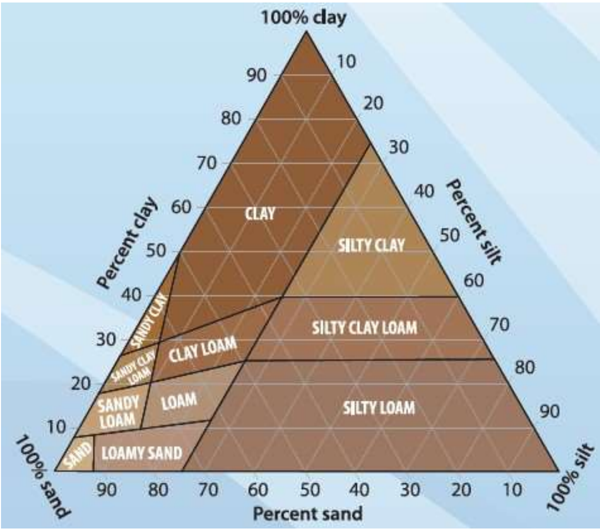

Fig 2.1: Properties of soil
(Source: Wikipedia.org)

Methodology for objective 2

The mix design is determined by trial and error method considering various mix proportions of soil, sand and cement, water cement ratio and additives for achieving a desired compressive strength) and having workability as shown in Figure 2.2.

Fig 2.2: Mixing
(KSSEM Laboratory)

Methodology for objective 3

Casting of blocks is done using Mardini press as shown in Figure 2.3.

Fig 2.3: Mardini stabilized mud block press
(KSSEM Laboratory)

Fig 2.4: Stabilized mud block
(KSSEM Laboratory)

Methodology for objective 4

The main parameters of investigation consider in this investigation is as described below. Compressive strength of the mix proportion use in the blocks is considered as more than 5.00 MPa. Testing is done using Compressive testing machine as shown in Figure 2.5.

Fig 2.5: Compression testing machine (CPM)
(KSSEM Laboratory)

Methodology for objective 5

Building scaled room of 3 x 3 x 3ft using the stabilized mud block and cement concrete blocks, measure temperature and humidity and compare the thermal performance as shown in Figure 2.6 & 2.7.

Fig 2.6: Small room constructed with stabilized mud block (KSSEM Laboratory)

Fig 2.7: Small house constructed with cement concrete block (KSSEM Laboratory)

3.Design and Experimentation

3.1 Procurement of materials

The materials used are soil, Portland Pozzolana cement and fine aggregate (M sand). Ordinary potable water was used for hydration of cement. Cement of 53 grade, M sand and concrete blocks were purchased from a local vendor. Soil which was locally available was used in the project work.

3.2 Characterization of materials

Characterization is an art of determining essential feature of the materials used. Test were conducted to determine the basic properties of the materials used in this research.

3.2.1 Cement

Cement of 53 grade OPC confirming to the IS: 12269-1987 has been used as shown in figure 3.1. The physical properties of the cement were determined and the necessities are considered as per Indian Standard: 12269-1987 and is shown in table 3.1.

Figure 3. 1 Ordinary Portland cement - 53 Grade (KSSEM Laboratory)

Table 3. 1 Physical Properties of Cement

Sl. No	Properties	Obtained Results	Requirements as per Indian Standard: 12269-1987
[1]	Setting Time • Initial • Final	 90 minutes 380 minutes	 Greater than 39 minutes Lesser than 600 minutes
[2]	Standard Consistency	32%	-----
[3]	Specific Gravity	3.09	-----
[4]	Compressive Strength (As provided by Manufacturer) 3 days 7 days 28 days	 39.5N/mm^2 51N/mm^2 70N/mm^2	 Greater than 27 N/mm^2 Greater than 37 N/mm^2 Greater than 53N/mm^2

3.2.2 Fine aggregate.

Fine aggregate (Manufacturer sand) passing through IS Sieve Designation of 4.75mm sieve has been used with water absorption of 1.5% as shown in figure 3.8. The result of sieve analysis conducted and is tabulated in Table 3.3 complying to Zone II as per the specificationsof Indian Standard: 383-1970.

Figure 3. 2 Fine Aggregate (Manufacturer Sand) (KSSEM Laboratory)

Table 3. 2 Characteristics of FA and Test results

Characteristics of Fine Aggregate (Manufacturer Sand)						
1.	Specific Gravity		2.62			
2.	Fineness Modulus		2.64			
3.	• Dry compacted bulk density		1665kg/m^3			
	• Loose bulk density		1453kg/m^3			
4.	Sieve Analysis:					
Indian Standard Sieve Designation	Cumulative		Specification as per Indian Standard: 383-1970 [Zone]			
	Retained	Passing	I	**II**	III	
4.75mm	1.65%	98.35%	90-100%	**90-100%**	90-100%	
2.36mm	8.32%	91.68%	60-95%	**75-100%**	85-100%	
1.18mm	31.66%	68.34%	30-70%	**55-90%**	75-100%	
600µm	50.23%	49.77%	15-34%	**35-90%**	60-79%	
300µm	78.89%	21.11%	5-20%	**8-30%**	12-40%	
150µm	98.96%	1.04%	0-10%	**0-10%**	0-10%	

3.2.3. Soil

Soil passing through 425micron sieve is use for determining the sand, silt and clay contain in the soil. It was found that 65% sand and 35% silt & clay contain in the soil.

3.3 Mix proportion of stabilized mud block

The stabilized mud blocks are casted by modifying the soil by adding M sand in the ratio 1 soil : 0.5 M sand by weight. 10% cement by weight of the modified soil. Water is added by 10% of the weight of the total mix. The mixing is carried out at room temperature and casted immediately. After 28days of curing testing was done using compressive testing machine. After testing its compressive strength is found out to be 17 MPa.

The Quantity of materials required for 1 stabilized mud block of size 9x7.5x4 inches (229x191x102 mm) is as shown in Table 3.2 below:

Table 3. 3 Mix Proportion for 1 block

Materials	Quantity
Volume of block	4461378 mm^3 = 0.004461 m^3
Volume of mortar	11 Kg
Volume of modified soil	10 Kg
Volume of cement	1 Kg
Volume of water	1.1 Kg = 1100 ml

3.4 Testing for blocks.

Compression test:

To determine the compressive strength, dimensions of the cubes and blocks are measured and specimen is placed in the compressive testing machine of capacity 2000 KN. The load is applied gradually as shown in figure 3.3. Application of load is continued until the specimen fails and load at failure is noted down and peak stress is calculated.

Fig 3.3: Compression testing machine (CPM) (KSSEM Laboratory)

3.5 Construction of two rooms

Two rooms were constructed. One room is constructed using stabilized mud blocks and another room is constructed using concrete blocks. Four walls facing North, East, West and South where in each side is 3feet long and 3feet high. The top is covered with thick ply board.

Figure 3. 4 Construction of Walls (KSSEM Laboratory)

Figure 3. 5 Final Structure to determine Surface Temperature (KSSEM Laboratory)

3.6 Measurement of surface temperature

The two rooms are constructed with 10 mm thick mortar joints horizontally and vertically. The outdoor and indoor surface temperature is noted down using infrared thermometer.

Figure 3.6 Recording Surface Temperature (KSSEM Laboratory)

4. Test Results and Discussions

4.1 Compressive strength of stabilized mud blocks

The compressive strength is obtained by testing the stabilized blocks of size 9 x 7.5 x 4 inches (229x191x102 mm) at an age of 28 days in CTM. The test results are presented in Table 4.1.

Table 4. 1 Compressive Strength Test Results of Stabilized Mud Blocks

Size of block (mm)	Ratio (cement: modified soil) Water 10% to the volume of mix	Cross-sectional area (mm^2)	Maximum load (N)	Compressive strength after 28 days curing N/mm^2
229x191x102 mm	1:10	43739	383200	17

Figure 4. 1 Test Specimen of Block After Failure (KSSEM Laboratory)

4.2 Thermal conductivity

After construction of the room, the temperature on the outer surface, inner surface. The 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. The average recorded surface temperatures are in table 4.2 & 4.3.

Room 1 (room constructed with concrete blocks)

Table 4. 2 Average External Surface Temperature Recorded of room 1

Time in hours	Ambient Temperature in °C	North wall in °C	East wall in °C	South wall in °C	West wall in °C
9:00	29.00	31.20	44.90	31.10	32.20
11:00	33.00	36.80	45.50	36.70	37.20
13:00	36.00	39.00	42.80	41.50	43.50
15:00	38.00	41.40	42.00	43.80	47.50

Table 4. 3 Average Internal Surface Temperature Recorded of room 1

Time in hours	Ambient Temperature in °C	North wall in °C	East wall in °C	South wall in °C	West wall in °C
9:00	29.00	27.40	29.10	27.20	27.50
11:00	33.00	32.40	37.00	31.70	32.40
13:00	36.00	35.00	39.50	35.30	35.00
15:00	38.00	37.00	39.30	37.00	39.60

The outside and inside surface temperature difference is about 8°C

At 9am -

North wall – The maximum temperature it recorded was 31.2°C and 27.40°C on the outside surface and inside surface respectively.

East wall – The maximum temperature it recorded was 44.90°C and 29.10°C on the outside surface and inside surface respectively.

South wall – The maximum temperature it recorded was 31.10℃ and 27.20℃ on the outside surface and inside surface respectively.

West wall – The maximum temperature it recorded was 32.20℃ and 27.50℃ on the outside surface and inside surface respectively.

At 11am -

North wall – The maximum temperature it recorded was 36.80℃ and 32.40℃ on the outside surface and inside surface respectively.

East wall – The maximum temperature it recorded was 45.50℃ and 37.00℃ on the outside surface and inside surface respectively.

South wall – The maximum temperature it recorded was 36.70℃ and 31.70℃ on the outside surface and inside surface respectively.

West wall – The maximum temperature it recorded was 37.20℃ and 32.40℃ on the outside surface and inside surface respectively.

At 1pm -

North wall – The maximum temperature it recorded was 39.00℃ and 35.00℃ on the outside surface and inside surface respectively.

East wall – The maximum temperature it recorded was 42.80℃ and 37.50℃ on the outside surface and inside surface respectively.

South wall – The maximum temperature it recorded was 41.50℃ and 35.30℃ on the outside surface and inside surface respectively.

West wall – The maximum temperature it recorded was 43.50℃ and 35.00℃ on the outside surface and inside surface respectively.

At 3pm -

North wall – The maximum temperature it recorded was 41.40℃ and 37.00℃ on the outside surface and inside surface respectively.

East wall – The maximum temperature it recorded was 42.00℃ and 39.30℃ on the outside surface and inside surface respectively.

South wall – The maximum temperature it recorded was 39.80℃ and 37.00℃ on the outside surface and inside surface respectively.

West wall – The maximum temperature it recorded was 47.50℃ and 39.60℃ on the outside surface and inside surface respectively.

From data recorded a graph time vs temperature is plotted as shown in figure 4.2 & 4.3.

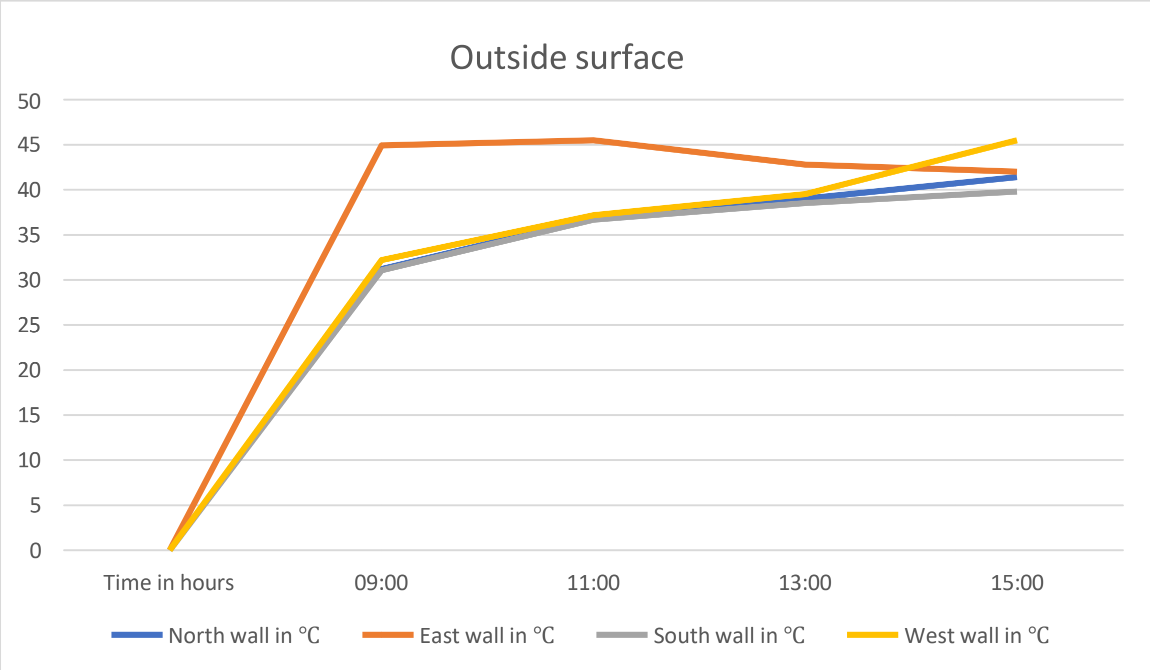

Figure 4. 2 Outside Surface Temperature of room 1

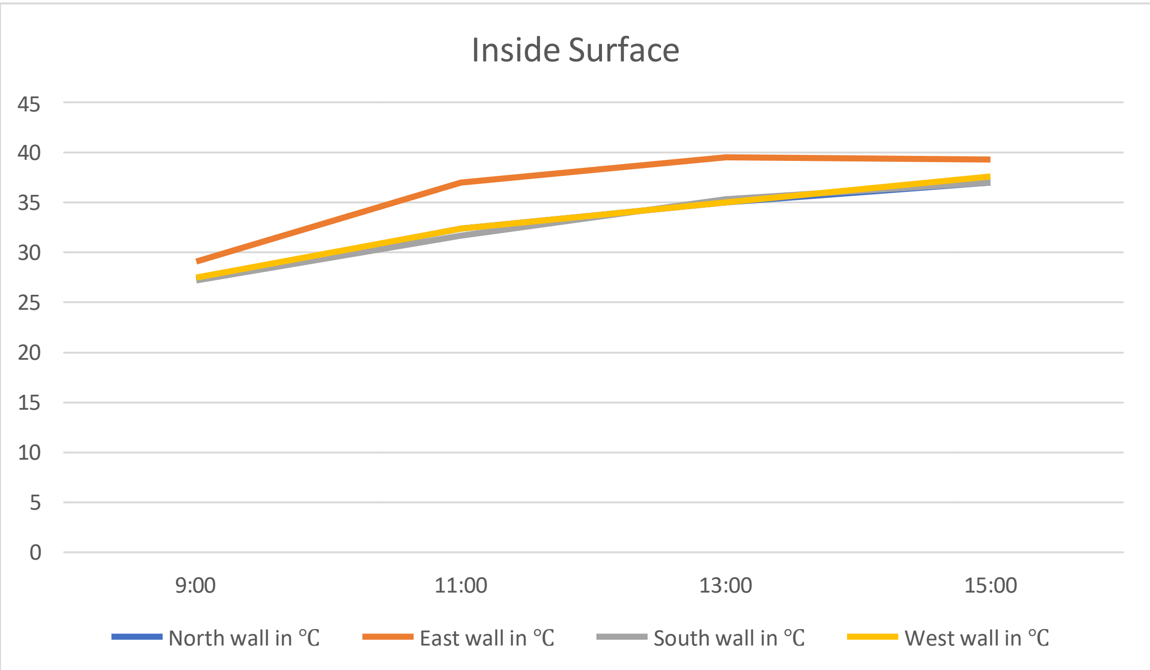

Figure 4. 3 Inside Surface Temperature of room 1

Room 2 (room constructed with mud blocks)

Table 4. 4 Average External Surface Temperature Recorded of room 2

Time in hours	Ambient Temperature in °C	North wall in °C	East wall in °C	South wall in °C	West wall in °C
9:00	29.00	32.90	44.20	31.30	35.90
11:00	33.00	39.20	45.30	36.90	37.60
13:00	36.00	40.50	41.50	40.30	43.50
15:00	38.00	41.20	40.30	42.70	47.40

Table 4. 5 Average Internal surface Temperature Recorded of room 2

Time in hours	Ambient Temperature in °C	North wall in °C	East wall in °C	South wall in °C	West wall in °C
9:00	29.00	26.50	28.60	26.80	26.80
11:00	33.00	29.10	30.90	29.30	29.10
13:00	36.00	30.70	32.40	30.30	30.90
15:00	38.00	32.20	32.40	32.70	33.00

The outside and inside surface temperature difference is about 13°C

At 9am -

North-The maximum temperature it recorded was 32.90°C and 26.50°C on the outside surface and inside surface respectively.

East-The maximum temperature it recorded was 44.20°C and 28.60°C on the outside surface and inside surface respectively.

South-The maximum temperature it recorded was 31.30°C and 26.80°C on the outside surface and inside surface respectively.

West-The maximum temperature it recorded was 35.90°C and 26.80°C on the outside surface and inside surface respectively.

At 11am -

North wall – The maximum temperature it recorded was 39.20℃ and 29.10℃ on the outside surface and inside surface respectively.

East wall – The maximum temperature it recorded was 45.30℃ and 30.90℃ on the outside surface and inside surface respectively.

South wall – The maximum temperature it recorded was 36.90℃ and 29.30℃ on the outside surface and inside surface respectively.

West wall – The maximum temperature it recorded was 37.60℃ and 29.10℃ on the outside surface and inside surface respectively.

At 1pm -

North wall – The maximum temperature it recorded was 40.50℃ and 30.70℃ on the outside surface and inside surface respectively.

East wall – The maximum temperature it recorded was 41.50℃ and 32.40℃ on the outside surface and inside surface respectively.

South wall – The maximum temperature it recorded was 40.30℃ and 30.30℃ on the outside surface and inside surface respectively.

West wall – The maximum temperature it recorded was 43.50℃ and 30.90℃ on the outside surface and inside surface respectively.

At 3pm -

North wall – The maximum temperature it recorded was 41.20℃ and 32.20℃ on the outside surface and inside surface respectively.

East wall – The maximum temperature it recorded was 40.30℃ and 32.40℃ on the outside surface and inside surface respectively.

South wall – The maximum temperature it recorded was 42.70℃ and 32.70℃ on the outside surface and inside surface respectively.

West wall – The maximum temperature it recorded was 47.40℃ and 33.00℃ on the outside surface and inside surface respectively.

From data recorded a graph time vs temperature is plotted as shown in figure 4.4 & 4.5.

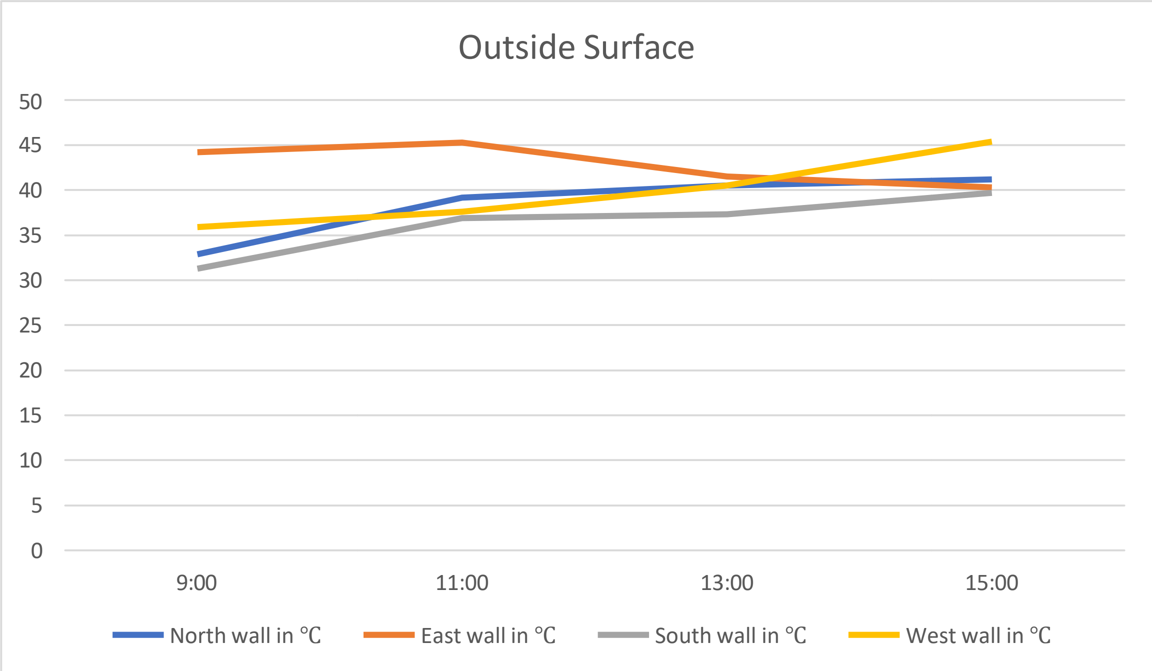

Figure 4. 4 Outside Surface Temperature of room 2

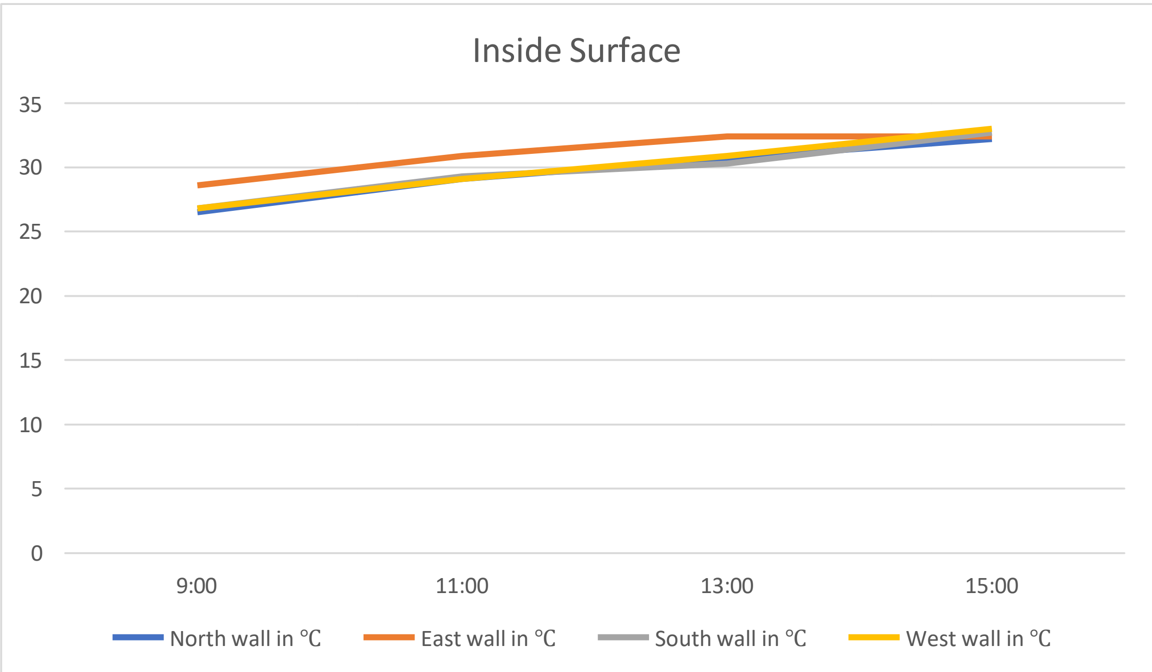

Figure 4. 5 Inside Surface Temperature of room 2

Comparing the maximum and minimum temperatures of both the blocks, the stabilized mud block and concrete blocks outside surface temperatures are similar, whereas the internal surface temperature of stabilized mud block is much lessor than the concrete block as the U-value of stabilized mud block is about 0.58 W/mk where as for concrete block is about 1.26 W/mK.

Table 4. 6 Maximum & Minimum Temperature of Outside Surface at 9am and 3pm

	Concrete block	Mud block
Maximum temperature in °C	47.50	47.40
Minimum temperature in °C	31.10	31.30

Table 4. 6 Maximum & Minimum Temperature of Inside Surface at 9am and 3pm

	Concrete block	Mud block
Maximum temperature in °C	39.50	33.00
Minimum temperature in °C	27.20	26.50

A figure is generated which is shown in figure 4.6 and figure 4.7.

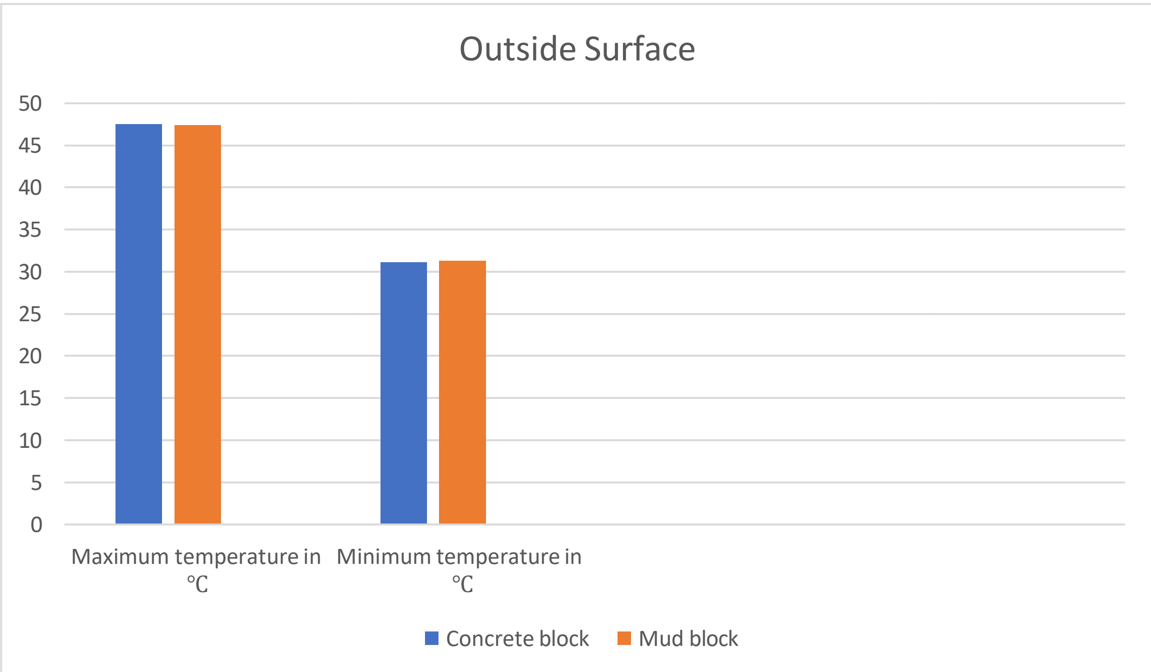

Figure 4. 6 Outside Surface Max. and Min. Temperature at 9am and 3pm

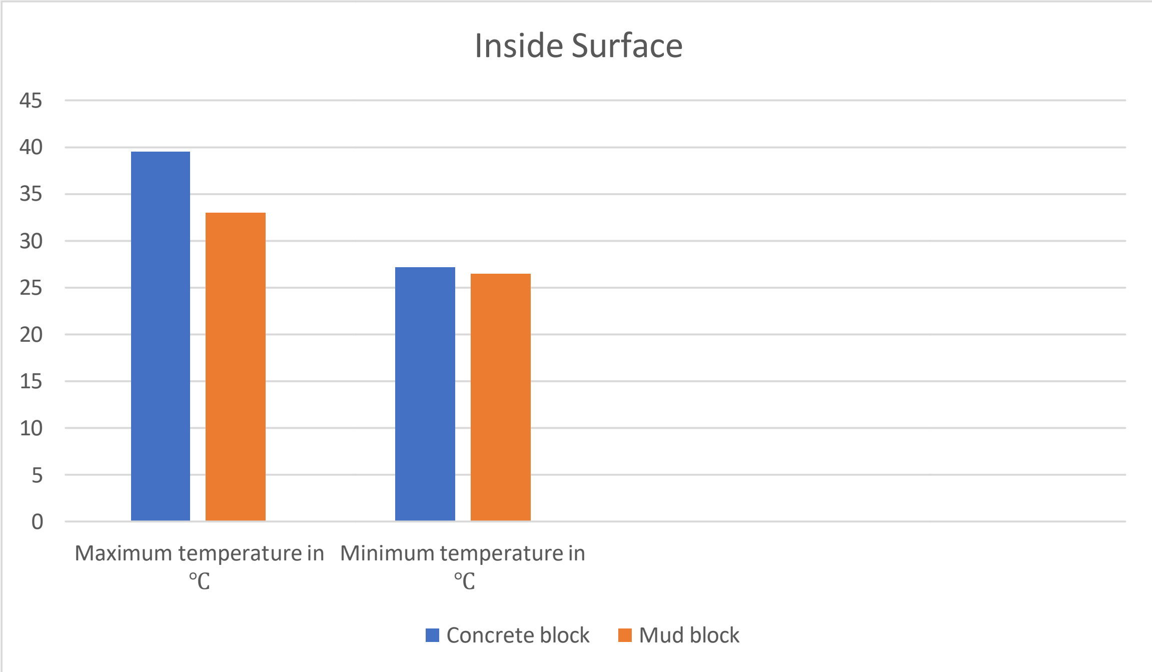

Figure 4. 7 Inside Surface Wall Max. and Min. Temperature at 9am and 3pm

5. Conclusions and Future Work

5.1 Conclusions

- The stabilized mud block inside temperatures reduced from the exterior to interior surface. After testing the stabilized mud block, it showed significant improvements in heat transfer reduction and energy efficiency compared to concrete block.
- Two small rooms of 3ft x 3ft x 3ft was constructed on the terrace of the college building. One room was built using stabilized mud block of 7.5 inches thick and another room is constructed using concrete blocks of 6 inches thick.
- External wall surface temperature:
    - ➢ The maximum wall surface temperature of room constructed with concrete blocks is recorded in west wall at 3pm about 47.50°C and minimum wall surface temperature is recorded in south wall at 9am about 31.10°C.
    - ➢ The maximum wall surface temperature of room constructed with stabilized mud blocks is recorded in west wall at 3pm about 47.50°C and minimum wall surface temperature is recorded in south wall at 9am about 31.30°C.
- Internal wall surface temperature:
    - ➢ The maximum wall surface temperature of room constructed with concrete blocks is recorded in west wall at 3pm about 39.60°C and minimum wall surface temperature is recorded in south wall at 9am about 27.20°C.
    - ➢ The maximum wall surface temperature of room constructed with stabilized mud blocks is recorded in west wall at 3pm about 33.00°C and minimum wall surface temperature is recorded in south wall at 9am about 26.50°C.
- Overall, the average temperature difference between outside and inside of concrete block is 5-6°C. Whereas in stabilized mud block the average temperature difference between outside and inside is 11-14°C.

5.2 Future Reference

1) Different stabilizers such as Areca Nut Fibre, Coconut Shell Powder, Fly Ash, etc can be used.
2) Proportions of stabilizers can be varied to prepare the mud blocks.

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