Thermal Insulation Clay Brick With Sludge And SCBA

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Abstract*— This project focuses on the development of thermally insulated clay bricks using waste materials, specifically water treatment sludge and sugarcane bagasse ash (SCBA), to enhance sustainability and energy efficiency in construction. The study investigates the impact of these waste materials on the thermal and mechanical properties of clay bricks, aiming to reduce environmental waste while improving building insulation. Experimental procedures included the preparation of brick samples with varying proportions of sludge and SCBA, followed by comprehensive testing for compressive strength, water absorption, hardness, and thermal conductivity. Results demonstrated that the incorporation of sludge and SCBA increased the porosity of the bricks, significantly reducing thermal conductivity and enhancing insulation properties. Although higher sludge content slightly decreased compressive strength, the addition of SCBA mitigated this effect by improving particle bonding and structural integrity. The findings highlight the potential of waste-derived materials in producing eco friendly bricks that meet industry standards for strength and durability while offering superior thermal insulation. This approach not only addresses waste management challenges but also contributes to energy-efficient construction practices by reducing heating and cooling demands in buildings. The study concludes that optimized mix designs of sludge and SCBA can yield sustainable, high-performance bricks, paving the way for further research into large-scale applications and long-term durability

Index Terms*— Clay bricks, thermal insulation, waste materials, sugarcane bagasse ash, sludge

II. INTRODUCTION

Over recent decades, rising global energy consumption—especially in industrial and developing nations—has placed significant pressure on the building sector, which accounts for 40% of total energy use and 32% of global carbon emissions due to energy-intensive processes. Clay, a commonly used construction material, offers potential for improvement in energy efficiency. Researchers are exploring the integration of waste materials like Sugarcane Bagasse Ash (SCBA) and sewage sludge into clay bricks to enhance thermal insulation. SCBA, a by-product of the sugar industry rich in silica, increases porosity, reduces brick density, and improves strength through pozzolanic reactions, while also contributing to sustainable waste management. Sewage sludge, containing both organic and inorganic compounds, creates air voids during firing, further lowering thermal conductivity and making bricks lighter and more eco-friendly. The combined use of SCBA and sludge results in energy-efficient, low-carbon, and structurally sound bricks that support sustainable construction practices.

II. MATERIAL COLLECTION AND PREPARATIONS

1. Clay – Collection and Preparation

Clay is collected from a local seller in Kattachira, Pala, Kerala, at the rate of ₹20 per kilogram. It is the primary material in brick production due to its excellent plasticity, durability, and ease of shaping. To ensure uniform quality in brick-making, the clay is first dried under direct sunlight to remove excess moisture. It is then manually crushed using a rammer and sieved through a 600 µm sieve. This sieving process ensures uniform particle size, improving the consistency and workability of the clay when mixed with other materials.

2. Sludge – Collection and Preparation

Sludge is collected from the sewage treatment plant at Amal Jyothi College of Engineering, Kanjirapally. This sludge is a byproduct of wastewater treatment and contains both organic and inorganic materials beneficial for brick insulation. To prepare it, the sludge is first sun-dried and then oven-dried to remove remaining moisture. Once completely dry, it is finely ground and sieved through a 600 µm sieve, similar to

clay, ensuring a homogenous mix. This fine, powdered sludge acts as a pore-forming agent, increasing porosity and enhancing the thermal insulation of the bricks.

3. Sugarcane Bagasse Ash – Collection and Preparation

Sugarcane bagasse is sourced from local juice vendors as a fibrous waste material. After collecting, the bagasse is burned at high temperatures to produce ash, which is rich in silica—a key component in improving the strength and thermal insulation of bricks. Once the ash is formed, it is cooled, finely ground, and sieved through a 600 µm sieve to obtain a fine, uniform powder. This refined sugarcane bagasse ash mixes well with clay, improves bonding, and contributes significantly to reducing the thermal conductivity of the bricks.

III. MIX PREPARATION

Table 1 Mix proportion

Proportion	SCBA	Sludge	Clay
M1	1	2	14
M2	1	3.5	14
M3	1	5	14

The selected proportions are blended thoroughly to create a uniform mixture. This mixing process ensures that sludge and bagasse ash particles are evenly distributed within the clay matrix, enhancing pore formation and promoting uniform thermal insulation throughout the brick. First dry ingredients were mixed thoroughly and later water was added and mixed well to get a dough consistency.

IV. BRICK PRODUCTION

The brick production process begins by casting the prepared clay, sludge, and sugarcane bagasse ash mixture into the mould to shape the bricks. The mould is filled and compacted to ensure proper form and density, crucial for achieving uniformity and strength. After casting, the bricks are sun-dried for 7 days, a step that removes moisture gradually and reduces the risk of cracking during firing. Sun drying also pre-hardens the bricks, making them more resilient in the firing stage.

Following sun drying, the bricks are fired in a furnace at a high temperature of 700°C. This firing process enhances the brick's structural integrity and solidifies the thermal insulation properties developed through the mix design. Proper firing ensures that the bricks achieve the necessary strength, durability, and thermal performance, making them suitable for insulation applications. Each batch is then cooled and prepared for quality testing.

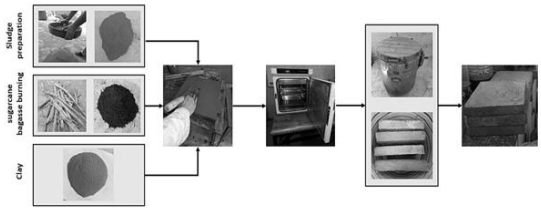

Fig 1 Brick samples preparation steps

V. TESTING AND ANALYSIS

After brick production testing and analysis are conducted to evaluate the brick's quality and suitability for thermal insulation applications. The primary tests include compressive strength, water absorption, hardness, and thermal conductivity tests.

1.Compressive Strength Test: Compressive strength test is conducted as per IS 3495 (Part 1): 1992. Compressive strength is a key parameter in evaluating the performance of clay bricks incorporating sludge in various proportions. SCBA, rich in silica, acts as a pozzolanic material, improving the bonding between particles and increasing compressive strength. When combined with sludge, SCBA helps counteract the strength reduction caused by excessive sludge content by filling voids and densifying the brick structure. As Sludge content increases it is observed that compressive strength decreases. As per IS 1077:1992, clause 4.1, the minimum acceptable compressive strength for common burnt clay building bricks is 3.5 MPa.

Table 2 Compressive strength of brick

Brick ID	Breaking load	Compressive strength(N/mm^2)
M 1	88	5.9
M 2	84	5.6
M 3	66	4.7

2.Water Absorption Test: The water absorption test is conducted as per IS 3495 (Part 1): 1992. It is a crucial factor in assessing the quality of clay bricks incorporating SCBA and sludge. As sludge content increases, water absorption increases due to its organic matter and porous nature. SCBA helps reduce water

absorption by filling pores and enhancing particle packing. SCBA's high silica content forms a denser matrix, reducing permeability

Table 3 Water absorption

Brick ID	Weight of brick(W1) kg	Weight of brick after soaking (W2) kg	Water absorption %
M 1	1.402	1..874	33.6
M 2	1.232	1.728	40.3
M 3	1.006	1.472	46.3

3.Hardness Test: The hardness of clay brick is done as per the Mohs Hardness Test. The hardness of brick is the resistance to scratching or cutting. In this test, a scratch is made on the brick surface with the help of a nail. No impressions are left on the bricks after scratching by nails. Therefore, bricks are sufficiently hard.

4.Soundness Test: The soundness test of a brick measures its resistance to impact. Two bricks are taken, one in each hand, and they are struck with each other lightly. The brick did not break and a clear ringing sound was produced. Hence the bricks are of good quality.

VI.THERMAL CONDUCTIVITY TEST

The thermal conductivity test for clay bricks assesses their ability to transfer heat. This property is essential in evaluating the insulation performance of bricks in construction. A lower thermal conductivity means better insulation, which helps reduce energy consumption for heating and cooling.

Thermal conductivity (k) is measured in watts per meter-kelvin (W/m·K). Denser bricks have higher conductivity, while porous bricks with air pockets provide better insulation. Additionally, moisture increases conductivity since water transfers heat more effectively than air.

The thermal conductivity of clay bricks depends on several factors that influence their ability to transfer heat. These factors play a crucial role in determining the insulation efficiency of bricks used in construction.

One major factor is density. Denser bricks have higher thermal conductivity because heat travels more easily through solid material than through air pockets. In contrast, porosity reduces thermal conductivity, as more air gaps act as natural insulators, slowing down heat transfer. Bricks with higher porosity are more effective at providing thermal insulation.

Another important factor is moisture content. Since water has a higher thermal conductivity than air, wet bricks conduct heat more efficiently than dry ones. As moisture levels increase, the insulating properties of the brick decrease, making them less effective in energy conservation.

The composition also affects thermal conductivity. The type of clay, the presence of additives, and the firing temperature impact the brick's structure, density, and porosity. Certain additives can enhance insulation properties by increasing air pockets within the material.

By controlling these factors, manufacturers can produce clay bricks with improved thermal performance, helping to regulate indoor temperatures, enhance energy efficiency, and reduce heating and cooling costs in buildings.

Clay bricks generally have a thermal conductivity ranging from 0.5 to 1.0 W/m·K. This makes them moderate insulators compared to materials like aerated concrete (0.1 W/m·K) but better than dense concrete (1.4 W/m·K).

Hot Disk TPS 500 S is a precise thermal conductivity meter capable of measuring the thermal conductivity and specific heat capacity of different materials quickly and accurately. It is being extensively utilized in quality control (QC) tests because it is efficient and convenient.

This instrument can process bulk sample sizes with thicknesses as low as a few millimeters. It has a thermal conductivity range of 0.03 to 200 W/m·K, so it can be used to test highly insulating and conductive materials. It also tests in a temperature range of -100°C to 300°C, enabling testing under extreme conditions.

For determining thermal conductivity 2 sample of each mix is prepared of size 3x3x2 cm

Table 4 Thermal Conductivity

M1 - (14 clay:2 sludge:1 SCBA)		
Sample ID	Temperature	Thermal Conductivity (W/mk)
Clay brick	26.7	0.1675

Clay brick	26.6	0.1665
Clay brick	26.6	0.1663
Average	26.6	0.1668

M2 - (14 clay:3.5 sludge:1 SCBA)		
Sample ID	Temperature	Thermal Conductivity(W/mk)
Clay brick	26.6	0.1591
Clay brick	26.7	0.1612
Clay brick	26.7	0.1612
Average	26.7	0.1605

M3 - (14 clay:5 sludge:1 SCBA)		
Sample ID	Temperature	Thermal Conductivity(W/mk)
Clay brick	26.6	0.1584
Clay brick	26.6	0.1562
Clay brick	26.7	0.1565
Average	26.6	0.1571

The thermal conductivity of the clay brick sample is found to be less than 0.17 W/mk confirming the material's low thermal conductivity of the samples which is typical for insulating building materials

Table 5 Thermal Conductivity of various materials

Materials	Thermal Conductivity (W/mK)	Classification
Clay Brick	< 0.17	Insulator
Fired Clay Brick	0.1–0.5	Insulator
Concrete	0.8–1.5	Moderate conductor
Wood (Oak)	0.12–0.17	Insulator
Glass	0.8–1.0	Moderate conductor
Steel	50	High conductor
Copper	385	Extremely high conductor
Polyurethane Foam	0.02–0.03	Super insulator
Air (static)	0.024	Best insulator

VII. CONCLUSION

For the purpose of to improve clay bricks' thermal insulation qualities while preserving an adequate level of mechanical strength and durability, this study investigates the addition of sewage sludge and sugarcane bagasse ash (SCBA). Because of their increased porosity, the modified bricks showed a significant reduction in thermal conductivity, with values below 0.17 W/m·K. This makes them perfect for energy-efficient construction because it reduces the need for heating and cooling.

SCBA enhanced bonding, resulting in strength values between 4.7 and 5.9 MPa that satisfy industry standards, whereas the addition of sewage sludge increased porosity and marginally decreased compressive strength. Higher porosity resulted in greater retention in water absorption tests; however, SCBA counteracted this effect by improving matrix compactness. Additionally, the bricks passed tests for soundness and hardness, demonstrating their durability.

This study establishes the potential of sludge- and SCBA-modified bricks as a sustainable, energy-efficient, and structurally viable alternative for modern construction.

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