VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI-590 018

A
PROJECT REPORT

ON

"TRANSFORMING SEWAGE SLUDGE INTO SUSTAINABLE BUILDING BLOCKS - EXPLORING ECO-FRIENDLY BRICK PRODUCTION"

Submitted in partial fulfillment for the award of degree of

BACHELOR OF ENGINEERING
in
CIVIL ENGINEERING

Submitted by

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DEPARTMENT OF CIVIL ENGINEERING
SRI VENKATESHWARA COLLEGE OF ENGINEERING
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CERTIFICATE

This is Certified that the Project work entitled **"TRANSFORMING SEWAGE SLUDGE INTO SUSTAINABLE BUILDING BLOCKS - EXPLORING ECO-FRIENDLY BRICK PRODUCTION"** carried out by **GIRISH P (1VE21CV003), RAKSHITH TALLAM V (1VE21CV007), SUNIL YADAV N (1VE21CV009)** a bonafide students of **SRI VENKATESHWARA COLLEGE OF ENGINEERING, Bengaluru** in partial fulfillment for the award of degree of **BACHELOR OF ENGINEERING** in **CIVIL ENGINEERING** of the **Visvesvaraya Technological University, Belagavi** during the year 2024-25. The project report has been approved as it satisfies the academic requirement in respect of dissertation work prescribed for the said Degree.

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DECLARATION

We hereby certify that the dissertation work which is being presented in the report titled **"TRANSFORMING SEWAGE SLUDGE INTO SUSTAINABLE BUILDING BLOCKS - EXPLORING ECO-FRIENDLY BRICK PRODUCTION"** in partial fulfillment for the award of degree of **BACHELOR OF ENGINEERING** in **CIVIL ENGINEERING** of the **Visvesvaraya Technological University, Belagavi** is an authentic record of my own work carried out during 2024-25.

The matter embodied in this dissertation work has not been submitted by me for the award of any other degree.

Place: Bengaluru
Date:

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ABSTRACT

In recent days, researchers are increasingly exploring waste utilization to supplement conventional building materials, mitigating environmental impacts. There have been various efforts to repurpose waste, addressing decomposition challenges. Sewage sludge, a byproduct of wastewater treatment, poses environmental and health risks due to pathogens and harmful chemicals. Leveraging this material can alleviate these concerns. This study explores utilizing sewage sludge to create eco-friendly bricks. The sewage sludge was utilized at 10%, 15%, 20%, 25%, and 30% replacement of clay for the manufacture of the bricks. Fly ash was also utilized at a constant dosage of 15% to improve the bonding between soil particles of the brick. In addition, manufactured sand (M-Sand) was incorporated into the brick composition as a sustainable alternative to river sand, enhancing the particle packing and bonding characteristics. From the experimental observations, it was found that 20% replacement of clay by sludge, 15% fly ash, and the inclusion of M-Sand showed feasible results in terms of compressive strength, resistance to water absorption, hardness, and soundness properties.

Keywords: Sewage sludge, Fly ash, M sand, Soil.

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CHAPTER-1

INTRODUCTION

1.1 General

Sewage sludge, the semi-solid byproduct generated during wastewater treatment, poses significant environmental challenges if not managed properly. In recent days the researchers are increasingly exploring waste utilization to supplement conventional building materials, mitigating environmental impacts. There have been various efforts to repurpose waste, addressing decomposition challenges. Sludge poses environmental and health risks due to pathogens and harmful chemicals. Leveraging this material can alleviate these concerns. Sewage sludge often contains heavy metals (e.g., lead, cadmium, mercury) that can contaminate soil and water sources when improperly disposed of. Untreated or poorly treated sludge can harbor pathogens like bacteria, viruses, and parasites, posing health risks to humans and animals when spread on land or released into the environment. Decomposition of organic matter in sludge can release methane (CH_4) and nitrous oxide (N_2O), potent greenhouse gases contributing to climate change. Disposing of sludge in landfills consumes valuable space and may lead to leachate production. Advanced sludge treatment methods like anaerobic digestion or composting are expensive and may not be accessible in all regions due to high costs.

Sewage sludge bricks are a sustainable construction material that incorporates treated sewage sludge into traditional clay or cement bricks. This method reduces the environmental impact of sludge disposal and conserves natural resources in brick production. The process involves dewatering and stabilizing the sludge to reduce pathogens and pollutants. The sludge is then mixed with clay or cement, shaped into bricks, and sundried to neutralize remaining pathogens and stabilize hazardous elements. Depending on the sludge composition and manufacturing process, sewage sludge bricks can have comparable strength, thermal insulation, and durability to traditional bricks. However, careful management is necessary to control heavy metals or contaminants in the sludge.

Sewage sludge is the semi-solid by product of wastewater treatment plants, containing organic matter, nutrients, and pollutants. It undergoes stabilization processes like anaerobic digestion, composting, or dewatering to reduce pathogens, odors, and water content. Properly treated sewage sludge can be repurposed as soil amendment, fertilizer, or energy source, but its application must be managed carefully due to potential harmful contaminants.

India faces significant environmental and logistical challenges in disposing of sewage sludge due to rapid urbanization, limited treatment infrastructure, and high sludge production rates. Many treatment plants lack advanced processing facilities, leading to the risk of harmful contaminants entering water bodies, soil, and the atmosphere. Challenges include limited treatment infrastructure, contamination risks, land scarcity, lack of regulations and standards, and public health concerns. Untreated sludge can pose health and environmental risks, contaminating soil, crops, and water sources. Land scarcity is particularly challenging near urban areas due to population density and pollution risks. India lacks comprehensive guidelines on safe sludge disposal, leading to inconsistent practices across states and regions. Solutions to overcome the challenge is sludge-to-energy conversion, safe land application, and reuse in construction materials are emerging, but require significant investments and regulatory support to be effective at scale. Reduces the volume of sludge sent to landfills or incinerators, minimizing environmental pollution. Lowers the use of clay and promotes circular economy principles. Availability of sludge as a low-cost material can reduce overall production expenses.

Fly ash is a sustainable alternative to traditional clay in brick manufacturing, mixed with lime, gypsum, and sand. This process creates durable, lightweight bricks that consume less energy and offer advantages like higher compressive strength, reduced water absorption, and improved thermal insulation. Fly ash bricks are also environmentally friendly, reducing the need for clay and preventing land degradation from clay extraction. They also help manage fly ash waste from power plants.

Manufactured sand (M-sand) is a fine aggregate produced by crushing hard stones, typically granite, into sand-sized particles. It serves as an eco-friendly and sustainable alternative to natural river sand, which is increasingly scarce due to excessive mining and environmental concerns. The production process involves crushing, screening, and washing to ensure uniform particle size, clean texture, and minimal impurities. M-sand offers several advantages, including better strength and durability in concrete, consistent quality, cost efficiency, and reduced transportation needs when locally sourced. Widely used in construction applications like concrete production, plastering, and mortar, it helps meet the growing demand for sand while preserving natural ecosystems.

The soil used in the manufacturing of stabilized mud blocks plays a crucial role in determining the quality and strength of the blocks. Ideally, the soil should have a high clay content of 20-40%. To determine the soil's suitability, various tests and analysis are conducted. These include soil classification tests, such as compressive strength tests, and water absorption tests.

1.2 Significance of the project

- Utilizing sewage sludge in bricks reduces the volume of waste_that would otherwise require disposal, contributing to more sustainable waste management practices.
- Incorporating organic waste into brick production can reduce the need for traditional raw materials like clay or sand, thereby conserving natural resources.
- Using waste materials like sewage sludge can lower the overall carbon footprint of brick production, contributing to climate change mitigation.

1.3 Objectives of the project

- To prepare the mud bricks incorporated with sewage sludge & Fly ash.
- To investigate the variations in the compressive strength properties of the bricks incorporated with sewage sludge & Fly ash.
- To investigate the resistance towards the water absorption of the bricks incorporated with sewage sludge & Fly ash.
- To identify optimum mix proportions of the brick for enhanced properties

CHAPTER 2

LITERATURE REVIEW

2.1 General

Tuani Zat, et al., [1] “Potential re-use of sewage sludge as a raw material in the production of eco-friendly bricks”. Despite being classified as non-hazardous class II-A (not inert) waste, sewage treatment facilities generate a significant amount of sludge, which is often disposed of in sanitary landfills. It follows that the environmental movement has to assess how much value it can contribute. In order to produce red ceramic bricks by extrusion, sewage sludge is used as a raw material in this study. The study focuses on the technological changes that occur when sludge is present during the plastic forming process, specifically regarding the mixture's plasticity and subsequent extrudability. Green (wet) prismatic samples produced with different moisture and sludge concentrations were used in shear strain amplitude torsional studies to quantitatively establish the optimal moisture conditions for the extrusion of high-quality products. Regarding sewage31–33 weight percent was found to be the ideal moisture content for sewage sludge contents up to 10 weight percent. Higher water consumption was found for 15 weight percent of sludge; 35 weight percent of moisture was needed to provide the best extrusion performance. Both the water absorption and the overall linear shrinkage during drying and firing were within the parameters needed for ceramic bricks for all sludge contents. The findings regarding the burned bricks' compressive strength further show that it is quite possible to produce extruded ceramic bricks by adding up to 15 weight percent sewage sludge to the clay mixture.

Joo-Hwa Tay, et al.,[2] “Bricks Manufactured from Sludge” Disposal issues arise with sludge from wastewater treatment plants. Dewatered sludges are usually disposed of either spreading them over the ground or by landfilling them. However, because of land limits, landfilling sludge may not be the best option for heavily developed places. An other course of action might be combustion. But following the burning process, a significant amount of ash will be created, which needs to be disposed of in another way. The outcomes of using sludge ash and dried sludge as building materials for bricks are presented in this research. The highest proportions of sludge ash and dried sludge that may be used with clay to make bricks are 40% and 50%, respectively. For 0% sewage, the bricks' compressive strength is 87.2N/mm2, and for 40%

sludge, it drops to 37.9N/mm2.

Nara Cangussu et al.,[3] “Environmental benefits of using sewage sludge in the production of ceramic bricks” The growing population and government initiatives to enhance sanitation are contributing to a rise in the amount of sludge produced by sewage treatment plants. Sanitation firms face a significant problem in treating and disposing of this sludge, as it poses a risk to human health and the environment. The circular economy idea holds the key to the solution: This sludge has qualities that make it a good raw material for the ceramics industry. This study aims to measure the environmental effects of replacing 10% of the clay in brick manufacture with sewage sludge, both in terms of resource use and air emissions. Tools for life cycle assessments were employed to create a comparison between the typical brick production scenario and using a situation where 10% sewage sludge is added and exclusively employing ceramic mass made of clay. According to the findings, there are several advantages to incorporating sewage sludge, with the lowest environmental impacts in all categories examined: 15% in energy savings, 15% in terrestrial acidification and fine particle formation, 10% in mineral resource scarcity, and 8–10% in photochemical ozone formation.

Lesław Świerczek et al.,[4] “The potential of raw sewage sludge in construction industry” Excess sewage sludge in wastewater treatment plants is a significant issue due to improved treatment technologies, expansion of sewage systems, and new industrial plants. The use of sewage sludge in construction eliminates expensive and energy-intensive stages, resulting in stable and safe products. Research on strength properties, water resistance, frost resistance, and heavy metal leaching confirms this, especially when the amount of sewage sludge is low. The article presents the latest methods of using sewage sludge in building and construction materials, as well as methods for producing low-strength materials for landfilling. Stabilizing sewage sludge with binding additives improves durability, but sintering sewage sludge into ceramic products and lightweight aggregates requires more energy expenditure. The authors suggest that one of the best methods of managing sludge in building materials is sintering sewage sludge into lightweight aggregates.

Maria P. Durante et al.,[5] “Use of Sewage Sludge as Raw Material in the Manufacture of Soft-Mud Bricks” The article investigates the use of sewage sludge in the ceramic industry, specifically in soft-mud brick manufacturing, to determine the maximum sludge incorporation for technically sound and environmentally friendly bricks. Results show that sludge does not alter the bricks' odor, but high concentrations negatively affect properties like mechanical strength and absorption. Compressive strength is significantly diminished with sludge addition, with bricks with 5% sludge losing an average of 45% of the strength compared to the control brick. The study concludes that 20% is the maximum proportion of sludge that can be incorporated into a ceramic mass without compromising technical and environmental requirements.

Ahmed M, et al.,[6] “Thermal performance analysis of clay brick mixed with sludge and agriculture waste” The decarbonization of buildings is a critical challenge in the construction industry, and agricultural and human residues are becoming popular choices due to their cost-effectiveness and environmental friendliness. This research investigates the thermal properties of proposed brick samples made from clay, sludge, and sugarcane bagasse ash, and their feasibility in reducing energy consumption. Four clay brick samples were tested experimentally and a comparative simulation analysis was conducted using Energy Plus. The results showed a significant improvement in thermal conductivity and an average 64% reduction in heat flow compared to conventional wall systems. Annual energy consumption was reduced by 16.5% in the building with the proposed brick walls compared to traditional clay bricks. Average thermal comfort conditions increased by 6.3%. These findings can guide further research on waste utilization in the development of replicable and energy-efficient buildings.

Gaurav Goel, et al.,[7] “Potential pathway for recycling of the paper mill sludge compost for brick making” The study aimed to explore the recycling of paper mill sludge compost (PMSC) in brick making. By reducing moisture content and making shredding easier, the addition of PMSC increases porosities in bricks and makes them lighter. This reduces construction costs by reducing labor and transportation costs. The study investigated brick properties in alluvial and laterite soils in India and fired oven-dried bricks at different temperatures. Results showed that adding PMSC to soil by up to 10% yielded mechanical properties compliant with Indian and ASTM codes. Toxicity characteristic leaching procedure (TCLP) tests confirmed that PMSC-incorporated bricks are safe for use in regular applications. This study aligns with the European Green Deal's focus on circular economy and the UN sustainable development goals.

Maria Del Pilar Durante Ingunza, et al.,[8] “Use of Septic Tank Sludge as Raw Material in the Manufacture of Bricks” The paper explores the use of septic tank sludge treated in an anaerobic pond as a raw material in the ceramic industry. An experiment was conducted at a Brazilian ceramic plant, manufacturing 500 bricks using 6.5% sludge. The bricks were evaluated for compressive strength, water absorption, and lixiviation, adhering to Brazilian and international standards. The results show the technical feasibility of using sludge as raw material in the red ceramic industry, with firing temperature being a determinant. The sludge-clay mixture's moisture content was a limiting factor in the manufacturing process, with a moisture value of 22% considered acceptable.

Denise Alves Fungaro, et al.,[9] “Utilization of Water Treatment Plant Sludge and Coal Fly Ash in Brick Manufacturing” The study aimed to evaluate the technical possibilities of incorporating cyclone fly ash (CFA) and sludge from a waste water treatment plant (SWTP) in the production of ecological bricks. The wastes were analyzed for physico-chemical, mineralogical, and morphological properties. Various mixtures were prepared by incorporating these industrial wastes in brick production. The effects of waste incorporation on physical properties such as compressive strength and water absorption were determined. The best result was reached by the series of bricks produced with 60% soil, 12% cement, 8% coal fly ash, and 20% SWTP by weight. The results showed that SWTP and CFA presented potential as waste additives in the production of soil-cement bricks.

Badr El-Din E, et al.,[10] “Brick Manufacturing from Water Treatment Sludge and Rice Husk Ash” Bricks have been made from clay for thousands of years, and water treatment plant sludge, which is similar to brick clay, could be a potential substitute. However, the sludge generated in most treatment systems is discharged into water, leading to accumulative aluminum concentrations in water and human bodies, which has been linked to Alzheimer's disease. The use of sludge in producing constructional elements is considered the most economic and environmentally sound option. A study investigated the complete substitution of brick clay by water treatment sludge incorporated with rice husk ash (RHA). Three different sludge-RHA proportions were studied, and the physical and mechanical properties of the produced bricks were determined and evaluated according to Egyptian Standard Specifications. The results showed that 75% was the optimum sludge addition to produce brick from sludge

RHA mixture, with superior properties compared to clay control-bricks and those available in the Egyptian market.

Andelina Bubalo, et al.,[11] “Use of Sewage Sludge Ash in the Production of Innovative Bricks - An Example of a Circular Economy” In this paper the properties of clay bricks with 5 wt%, 10In comparison to the control bricks (50.4 N/mm2), the compressive strengths of bricks with 5 weight percent SSA (54.0–54.5 N/mm2) and 10 weight percent Sewage Sludge Ash (50.2–51.0 N/mm2) were greater, whereas the compressive strengths of bricks with 20 wt% sewage sludge ash (37.0–43.9 N/mm2) were notably lower. In comparison to control bricks, bricks containing Sewage Sludge Ash had a reduced coefficient of saturation. When the sewage sludge ash fraction was 20 weight percent, the early absorption values were more noticeable wt%, and 20 wt% sewage sludge ash were studied and compared with the properties of control bricks made of 100% clay. Sewage sludge was collected at two wastewater treatment plants in Croatia - wastewater treatment plants Zagreb and wastewater treatment plants Karlovac - and incinerated at a temperature of 900°C The bricks were produced on a laboratory scale. A total of seven types of bricks were produced - control bricks and six types of bricks as combinations of different wt% of sewage sludge ash generated from sewage sludge that was collected at two different wastewater treatment plants. The physical and mechanical properties of produced bricks were tested.

Anđelina Bubalo, et al.,[12] “Influence of combustion temperature on the performance of sewage sludge ash as a supplementary material in manufacturing bricks” The study examined the impact of combustion temperature on the properties of sewage sludge ash (SSA) as a substitute material for fired clay bricks. Experiments were conducted using sewage sludge from wastewater treatment plants in Zagreb and Karlovac. The resulting SSA was compared with clay and SS, and bricks with 5 wt% SSA as a clay substitute were prepared. SSA bricks produced at higher temperatures showed higher strengths and lower water absorption, which are desirable properties. Compressive strength tests showed that SSA obtained at a firing temperature of 900 °C was the most suitable for brick use. The study also examined the influence of SSA on the content of soluble salts in bricks. The results showed increased values of soluble salts in SSA bricks compared to control bricks. However, bricks with higher temperatures had lower soluble salt content. The total amount of Na+, K+, and Mg2+ in all bricks made with SSA was below the limits for category S2 according to EN 771-1.

Gabrie Popescu, et al.,[13] "Innovative solutions for the production of bricks from wastewater treatment sludge" The use of sludge in brick manufacturing is proposed to recover waste from wastewater treatment plants. Bricks are made from various materials, including burnt clay, cement, sand, and unconventional materials. To use sludge for brick fabrication, it must be inert and have a moisture content below 80%. The physio-chemical and ecological parameters must be suitable for sludge utilization and within legal limits. The sludge is centrifuged to reduce moisture content to 80%, treated, characterized, and finally recovered by inert cement. This approach aims to reduce waste and improve construction materials.

Masoud Ahmadi et al.,[14] "Potential Use of Water Treatment Sludge as Partial Replacement for Clay in Eco-Friendly Fired Clay Bricks" The traditional production of clay bricks is a significant source of greenhouse gas emissions and environmental degradation. This research explores the use of water treatment sludge (WTS) as a sustainable alternative to traditional clay in fired clay brick production. Five mixtures were created, with WTS replacing clay at different ratios. The mechanical properties and durability of the bricks were analysed, showing that as WTS content increased, Atterberg limits and apparent porosity increased. However, bulk density, compressive strength, and bending capacity decreased as the WTS replacement ratio increased. Moderate efflorescence was observed in samples with higher sludge ratios. This study aims to explore the potential of WTS in reducing environmental pollution in the construction industry.

Kailash Chandra Badgujar et al.,[15] "An Experimental Study on the Reuse of Waste Water Treatment Plant Sludge in the Manufacturing of Bricks" The study investigates the suitability of different soil types (Kanota soil, Sabodh soil, and Black cotton soil) in combination with wet and dry forms of sludge from Dehlawas (unit-1), ASP (Activated Sludge Process) based Sewage treatment plant Jaipur for constructing environmentally friendly construction materials. The research evaluates six scenarios to determine the most viable clay sludge combination. Challenges encountered include cracking during the drying process and anaerobic decomposition. The second scenario with dry sludge caused significant issues, with all 70 bricks exhibiting cracks and breeding problems. The third scenario with fresh wet sludge with

Kanota soil yielded favorable outcomes. The fourth scenario with burnt sludge with Black cotton soil caused shrinkage, reducing brick length by approximately 1 inch. The sixth scenario with fresh wet sludge with Samodh soil showed no cracks, while minor cracks were observed with a 30% wet sludge replacement. The compressive strength of the bricks decreased as the sludge content percentage increased.

Amir Detho, et al.,[16] "Utilization of wastewater treatment sludge in the production of fired clay bricks: An approach towards sustainable development" The research looks on the incorporation of wastewater treatment sludge into burned clay bricks. Samples were taken from Senggarang and Perwira IWK. X-Ray Fluorescence was used to determine the amounts of heavy metals in the sludge. For both forms of sludge, bricks with a 5% sludge content had the best mechanical and physical qualities. Senggarang sludge, however, produced superior outcomes. The leachability of heavy metals was also examined; bricks from Senggarang that included up to 20% sludge had the lowest leachability. Based on characteristics and leachability, the study finds that 5% of both sludges is the ideal amount for burnt clay bricks. In order to achieve the Sustainable Development Goals, this study emphasizes how crucial it is to use cleaner production methods while producing bricks.

Budi Prasetyo Samadikun, et al.,[17] "Potential Utilization of Sewage Sludge from Water Treatment Plant as Brick Material" The water treatment process produces sludge, which is typically collected and delivered to a landfill. However, this process incurs additional costs due to handling sludge waste. To minimize the impact of the Water Treatment Plant, a waste recycling process can be developed using sludge from the process, which can be used in brick making. This study investigates the potential of sludge from water treatment plants for brick making by investigating its physical and characteristics. The research findings indicate that sludge waste can be used as a brick raw material, depending on its nature and clay microstructure.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

In this chapter properties of material will be assessed for the present experimental exploration. We have taken crushed stone sand, soil, flyash as per accurate codes of practice characterization, and sewage sludge were used in this experimental exploration mix proportion will be accompanied as indicated terms in typical guidelines.

3.2 Characterization of materials

For current experimental exploration thorough examination of materials have been carried out & noted below

3.2.1 Physical properties of the soil

Soil is a fundamental raw material that significantly impacts the quality of the final product. The soil used in brick-making primarily consists of clay, along with silt and sand. Clay provides the necessary plasticity to shape the bricks, while sand helps reduce shrinkage during drying and firing. The soil is carefully selected and processed to remove impurities, ensuring the production of durable, strong bricks.

Figure 1 Soil Sample

Table 1 Typical soil physical properties

Sl.no	Properties	Results
1	Bulk density, kg/m3	1317
2	Specific gravity	2.62
3	Fineness	3.12
4	Water absorption	1.2

3.2.2 Physical properties of the dry sludge

Dry sewage sludge is the solid material that remains after the treatment of wastewater in sewage treatment plants. It is the result of the removal of water from the wet sewage sludge, which contains a mix of organic matter, microorganisms, and inorganic substances, such as metals and chemicals. Dry sewage sludge can be used as a fertilizer in agriculture, as it contains organic matter and nutrients like nitrogen, phosphorus, and potassium, which are beneficial for soil.

Figure 2 Dry sludge Sample

Table 2 Typical dry sludge physical properties

Sl.no	Properties	Results
1	Bulk density, kg/m3	987
2	Specific gravity	1.95
	Fineness	3.54
3	Water absorption	2.4
4	Moisture content	4.12

3.2.3 Physical properties of the fly ash

Figure 3 Fly Ash Sample

Fly ash is a fine, powdery byproduct produced during the combustion of coal in thermal power plants. It is captured by electrostatic precipitators or filters before it can be released into the atmosphere. Fly ash is rich in minerals and compounds such as silica, alumina, and calcium, making it a valuable material for use in various industrial applications, particularly in construction. Fly ash is typically classified into two types: Class F and Class C, based on its chemical composition and properties. Class F fly ash is produced from burning anthracite or bituminous coal and is used primarily for enhancing the durability and strength of concrete. Class C fly ash is produced from burning lignite or sub-bituminous coal and contains higher calcium content, which gives it self-cementing properties, making it more suitable for use in concrete as a binder.

Table 3 Fly ash physical properties

Sl.no	Properties	Results
1	density, kg/m3	1128
2	Specific gravity	2.32

3.2.4 Physical properties of the M-Sand

M-Sand, or Manufactured Sand, has distinct physical properties that make it a suitable alternative to river sand for construction purposes. One of its notable properties is its cubical shape. It serves as a substitute for natural river sand in construction, particularly for making concrete Additionally, M-Sand has a consistent particle size distribution, typically ranging from 150 microns to 4.75 mm. M-Sand is manufactured under controlled conditions, ensuring consistent quality and size distribution. The main advantage of M-Sand is its sustainability, as it reduces the environmental impact of sand mining from rivers, which can lead to habitat destruction and soil erosion. The quality of M-Sand must be carefully monitored, as excessive fine particles can affect the strength and workability of the bricks. Despite this, when produced properly, M-Sand is a reliable and sustainable option for manufacturing brick. Despite this, when produced properly, M-Sand is a reliable and sustainable option for manufacturing bricks, contributing to more eco-friendly and cost-efficient construction practices. It offers several advantages, including sustainability, as it reduces the environmental impact of sand mining from rivers, which can lead to soil erosion and ecosystem damage.

Figure 4 M-Sand Sample

Table 4 M-Sand physical properties

Sl.no	Properties	Results
1	specific gravity	2.6
2	bulk density	15.69kN/m^3
3	fineness	2.8
4	silt content	Less than 1%

3.2.5 Water

Water which is clean and uncontaminated available in laboratory gratifying the requisite as per IS 456-2000 is utilized in this work.

CHAPTER 4

TESTS ON MATERIALS

4.1 Tests on soil

4.1.1 Determination of the grain size distribution of the soil

The grain size distribution of a soil sample, which involves preparing the sample by air-drying and breaking down clods, then shaking it through a series of standard sieves with different mesh sizes, ranging from coarsest to finest, to separate and weigh the soil particles retained on each sieve. The results are calculated by determining the percentage of soil particles retained on each sieve and the percentage passing. It provides the soil's texture and composition, and allowing for classification according to its grain size distribution.

Figure 5 Sieve analysis of soil

Table 5 Sieve analysis of soil

Sieve size	Weight passing (kg)	Weight retained (kg)	Percentage passing (%)	Percentage retained (%)	Cumulative percentage of retained soil (%)
4.75mm	1	0	100	0	0
2.36mm	0.95	0.05	95	5	5
1.18mm	0.77	0.18	77	18	23
600µm	0.62	0.15	62	15	38
300 µm	0.34	0.28	34	28	66
150 µm	0.18	0.16	18	16	82
75 µm	0.09	0.09	9	9	91
Pan	0	0.09	0	9	100

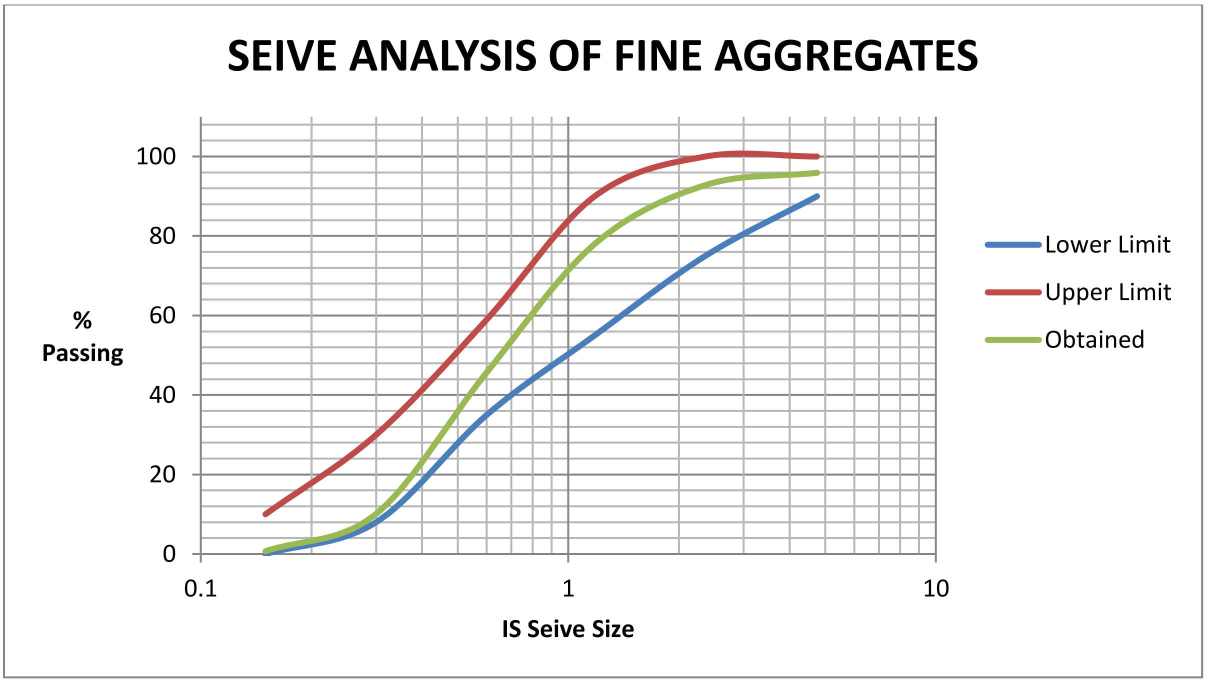

Figure 6 Sieve analysis of fine aggregates

4.1.2 Determination of the specific gravity of the soil

The determination specific gravity of soil, start by collecting a representative air-dried soil sample, then weigh an empty pycnometer (W1) and fill it with water, and weigh it again (W2). Next, add the soil sample to the pycnometer and water and weigh it once more (W3). Next, add the water to the pycnometer and weigh it once more (W4). Finally, calculate the specific gravity of the soil using the formula: Specific Gravity = (W3 - W2) / (W2 - W1).

Figure 7 Specific gravity of soil

Table 6 Specific gravity of soil

Sl.no	Particulars	Trial 1 (g)	Trial 2 (g)
1	Empty weight of pycnometer (w_1)	620	620
2	Weight of pycnometer + soil (w_2)	720	720
3	Weight of pycnometer + soil + water (w_3)	1575	1578
4	Weight of pycnometer + water (w_4)	1515	1519
5	Specific gravity	2.5	2.43

4.1.3 Determination of the density of the soil using the modified proctor test

To determine the density of soil using the modified Proctor test procedure, a representative soil sample is compacted into a mold with a known volume in five layers, each layer being compacted with 56 blows of a 4.5 kg rammer dropped from a height of 457 mm, resulting in a higher compactive effort than the standard Proctor test. The compacted soil is then weighed and its density calculated by dividing the weight by the mold volume, allowing for the determination of the soil's maximum dry density and OMC.

Table 7 Density of soil by modified proctor test

Sl.no	Particulars	Trial 1	Trial 2	Trial 3	Trial 4
1	Water content (%)	10	18	20	22
2	Mass of mould + compacted soil (g) (M_1)	6664	6725	6795	6837
3	Mass of mould (g)(M_2)	4944	4944	4944	4944
4	Mass of compacted soil (g)(M_1-M_2)	1720	1179	1851	1893
5	Bulk unit weight of compacted soil (g/cm^3) (M/V) [where V=944.88]	1.82	1.88	1.96	2.00
6	Water content (%)	16.3	18.8	19.4	22.8
7	Dry unit weight $\gamma_d \frac{\gamma_t}{1+W}$	1.57	1.58	1.64	1.62

Figure 8 Density of soil

4.2 Tests on dry sewage sludge

4.2.1 Determination of the grain size distribution of the dry sludge

To determine the grain size distribution of dry sludge, a representative sample is sieved through a series of standard sieves with decreasing mesh sizes, typically ranging from 4.75 mm to 0.075 mm, and the weight of the material retained on each sieve is measured. The sieving process is usually performed using a mechanical sieve shaker or by hand, and the material passing through the finest sieve is collected and measured separately. The grain size distribution is then calculated by determining the percentage of material retained on each sieve and plotting the results on a cumulative percentage passing curve, which provides a graphical representation of the grain size distribution of the dry sludge.

Figure 9 Sieve analysis of dry sludge

Table 8 Sieve analysis of the dry sludge

Sieve size	Mass of sludge retained (kg)	Percentage mass of sludge retained (%)	Cumulative percentage of sludge retained (%)
4.75 mm	0	0	0
2.36 mm	0.21	21	21
1.18 mm	0.54	54	75
600 µm	0.16	16	91
300 µm	0.06	6	97
150 µm	0.03	3	100
75 µm	0	0	-
pan	0	0	-

4.2.2 Determination of density of dry sludge using modified proctor test

To determine the density of dry sludge using the modified Proctor test procedure, a representative sludge sample is compacted into a mold with a known volume in five layers, each layer being compacted with 56 blows of a 4.5 kg rammer dropped from a height of 457 mm, resulting in a higher compactive effort than the standard Proctor test. The compacted soil is then weighed and its density calculated by dividing the weight by the mold volume., allowing for the determination of the soil's maximum dry density.

Figure 10 Density of sludge

Table 9 Density of sludge by modified proctor test

Sl.no	Particulars	Trial 1	Trial 2	Trial 3	Trial 4
1	Water content (%)	10	18	20	22
2	Mass of mould + compacted sludge (g) (M_1)	6668	6654	6780	6825
3	Mass of mould (g)(M_2)	4935	4935	4935	4935
4	Mass of compacted sludge (g)(M_1-M_2)	1728	1165	1144	1885
5	Bulk unit weight of compacted sludge (g/cm^3) (M/V) [where V=944.88]	1.75	1.71	1.92	2.01
6	Water content (%)	16.3	18.8	19.4	22.8
7	Dry unit weight $\gamma_d \frac{\gamma_t}{1+W}$	1.52	1.54	1.67	1.64

CHAPTER 5
EXPERIMENTAL DESIGN ANALYSIS

5.1 Mix Design

Table 10 Mix Design

Different sludge percentage	Soil (kg)	M-Sand (kg)	Fly ash (kg)	Water (l)
10	11.25	6.25	3.125	3.125
15	10.625	6.25	3.125	3.125
20	10	6.25	3.125	3.125
25	9.375	6.25	3.125	3.125
30	8.75	6.25	3.125	3.125

5.2 Mixing

Working on site with the use of brick-making material mix design (Soil, dry sludge, M-Sand and fly ash). To mix the block mix, combine the following ingredients soil, sand, fly ash, dry sludge and water. Start by mixing the dry ingredients (soil, sand, dry sludge and fly ash) thoroughly by hand, until a uniform color and texture are achieved. Gradually add the water to the dry mixture, mixing continuously until a workable consistency is reached, typically a moist but not soggy mixture that holds its shape when molded. The mixing process should be done in a way that minimizes air pockets and ensures a uniform distribution of the ingredients as per the mix design shown in above. To cast mud blocks using a brick presser, fill the brick presser mold with the mixture, compacting it lightly to remove air pockets, and ensure the mold is level. Apply a consistent pressure to the mixture using the brick presser, following the manufacturer's guidelines. After releasing the pressure, carefully remove the block from the mold and place it on a flat surface to cure, protecting it from the elements and monitoring its moisture levels, allowing it to cure for several days to achieve the desired strength and durability.

Figure 11 Dry mix

Figure 12 Wet mix

Figure 13 Brick making

Figure 14 Brick obtained after pressing

Figure 15 Finished bricks kept for drying

CHAPTER 6

RESULTS AND DISCUSSIONS

To assess the quality and suitability of the bricks the compression test, water absorpttion test, density test, hardness and soundness tests were conducted on the bricks. The table below shows the results of various tests conducted on the bricks.

Table 11 Mix design results

Mix Designation	Water Absorption (%)	Compressive Strength (N/mm^2)	Density (Kg/m3)
10SL+50S+15FA+25MS	16.18	3.89	1978
15SL+45S+15FA+25MS	17.67	3.56	1856
20SL+40S+15FA+25MS	19.32	3.11	1824
25SL+35S+15FA+25MS	20.94	3.08	1795
30SL+30S+15FA+25MS	21.47	2.92	1777

6.1 Variation of Water Absorption

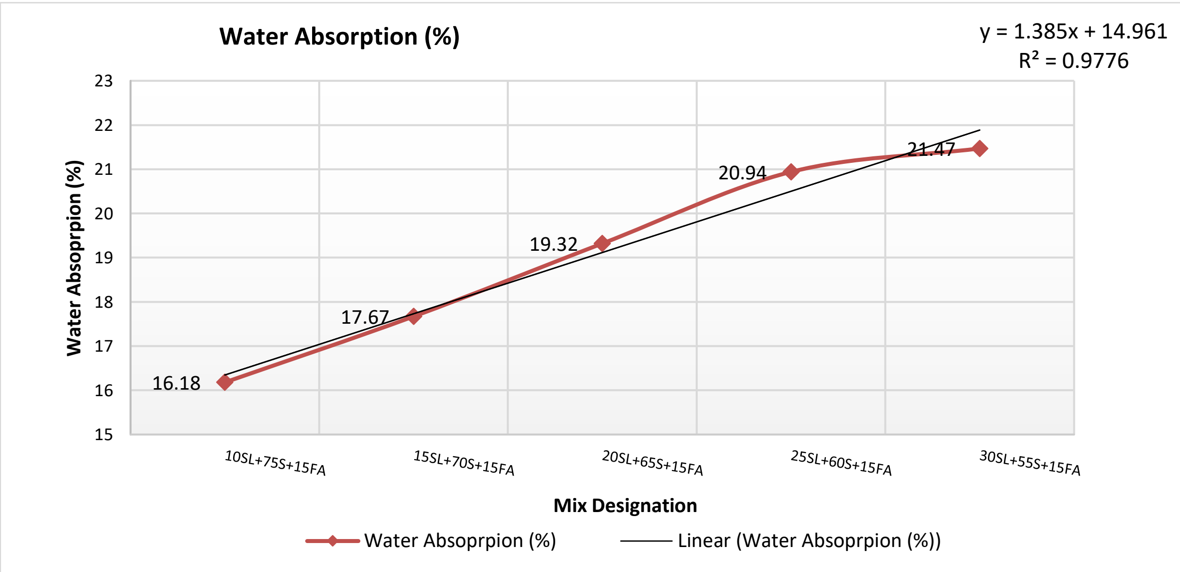

Figure 16 Variation of Water Absorption

The water absorption of bricks increases with rising sludge content due to several factors. The addition of sludge introduces organic matter, increasing porosity and creating capillary pathways that enhance water infiltration. Sludge particles also expand the brick's surface area, allowing more water to be absorbed. Furthermore, the chemical composition of sludge may contain hydrophilic substances that attract water. The regression equation (y = 1.385x + 14.961) was developed for the compressive strength with R-squared value of 0.9776 indicates that the model explains the distribution of the data well.

6.2 Variation of Compressive Strength

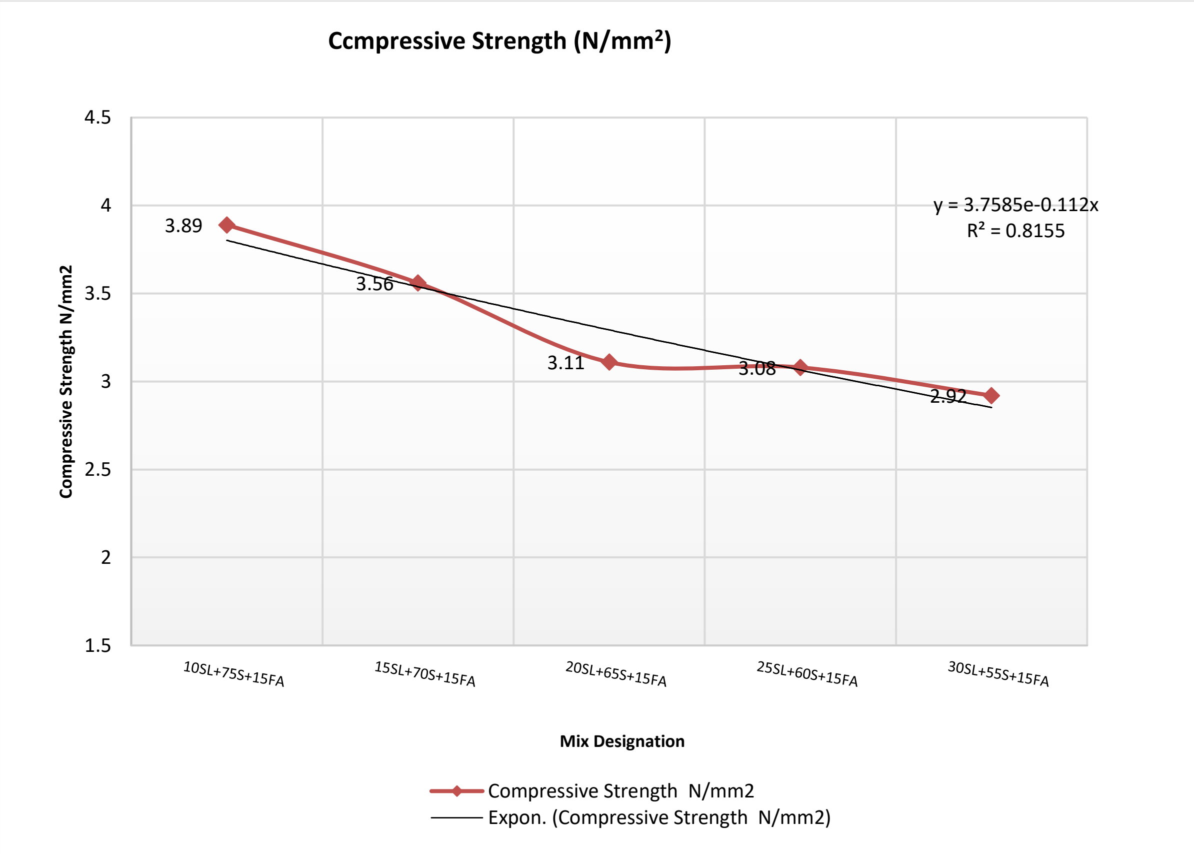

Figure 17 Variation of compression strength

The compressive strength of mud bricks decreases with increasing sludge content. The sludge mainly contains organic matter which will degrade the soil cohesion increase porosity and exhibit reduced compressive strength. The regression equation ($y = 3.7585e^{-0.112x}$) was developed for the variation of compressive strength and R-squared value obtained is 0.8155 which represents that the regression model explains the distribution of the data well.

6.3 Variation of Density of Bricks

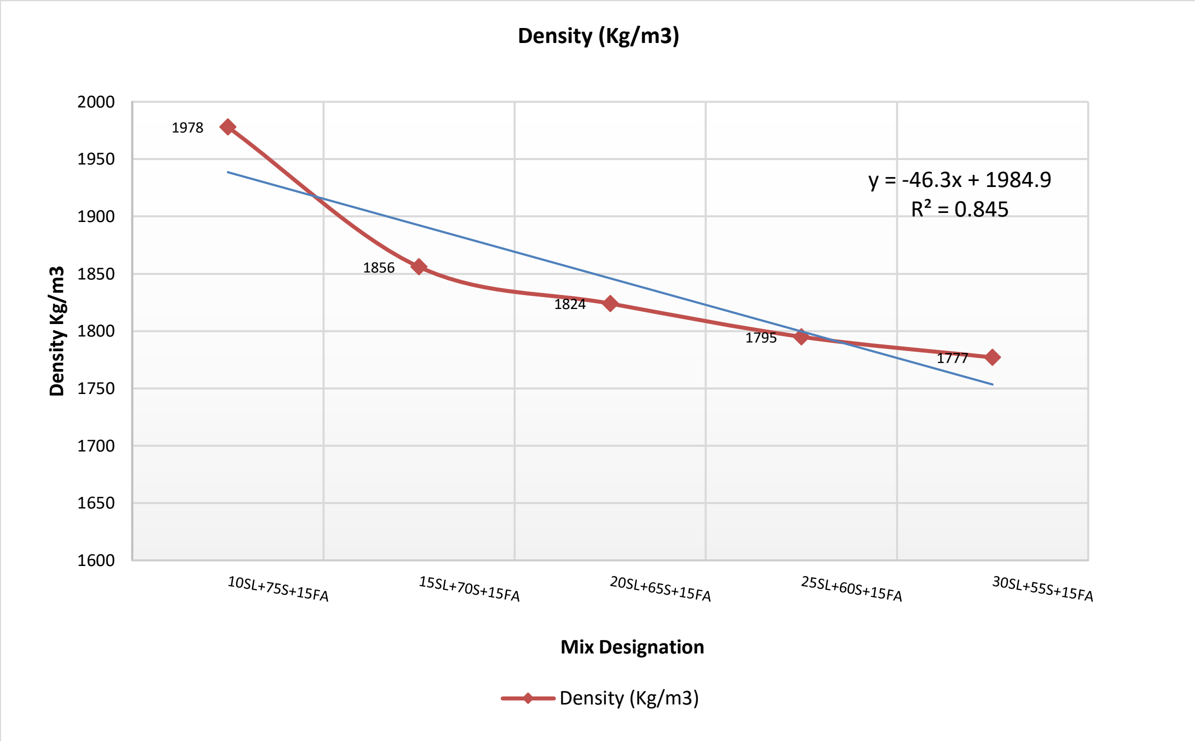

Figure 18 Variation of Density

The density of mud bricks decreases with increasing sludge content due to increased porosity, and lower specific gravity. Sludge's organic matter and water replace denser soil particles, introducing pores and reducing overall weight. Higher sludge levels increase water retention, but excess water evaporates during drying, further reducing brick weight which intern reduces the density. Additionally, sludge particles displace heavier soil particles, and organic matter decomposes over time, contributing to weight loss. The regression equation (y = -46.3x + 1984.9) was developed for the variation of density and R-squared value obtained is 0.845 which represents that the mathematical model developed fits the data well.

6.4 Hardness of Bricks

To test hardness of bricks a hard needle having 2 mm diameter was used. A scratch is made on the surface of the bricks. The extent of the scratch in terms of width and depth of the scratch was checked by visual observation. It was observed that the impact of the scratch was found to be high with increasing contents of sludge. The root cause of this nature of result is discussed in section 6.2.

6.5 Soundness of Bricks

For testing soundness of bricks, to sample bricks with same mix proportion were taken and both the bricks were struck each other by holding in both hands. A clear ringing sound was observed for the bricks at all the replacement levels of sludge. And no failure was observed when the bricks were struck each other. No considerable variation in the ringing sound was noticed for the bricks at variable proportions under investigation.

Figure 19 Compression test and water absorption test

CHAPTER 7

CONCLUSION

In conclusion, incorporating sludge into mud bricks significantly impacts their physical and mechanical properties. While increasing sludge content reduces brick weight and enhances sustainability, it also decreases compressive strength and increases water absorption. The optimal sludge content balance is crucial to maintain structural integrity and performance. Below 10% sludge content, benefits of weight reduction and sustainability are achievable without compromising strength. However, exceeding this threshold compromises the strength. Careful control of production parameters, such as soil composition, compaction, and drying conditions, is essential to produce high-quality mud bricks with sludge. Further research on additives and stabilization methods can enhance the potential of sludge-based mud bricks as an eco-friendly, sustainable building material.

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