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An Experimental Study on the Reuse of Waste Water Treatment Plant Sludge in the Manufacturing of Bricks

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Abstract - *The disposal of sewage treatment plant waste, specifically sewage sludge, has raised significant environmental concerns. This research focuses on investigating the suitability of different soil types (Kanota soil, Samodh soil, and Black cotton soil) obtained from diverse locations, in combination with wet and dry forms of sludge collected from Dehlawas (unit-1), ASP(Activated Sludge Process) based ,Sewage treatment plant Jaipur. The objective is to identify optimal clay-sludge combinations that can be utilized as environmentally friendly construction materials. The study evaluates six distinct scenarios encompassing various combinations to determine the most viable clay-sludge combination. Challenges encountered in the experimentation include cracking during the drying process and the onset of anaerobic decomposition, etc. Notably, the second scenario involving Kanota soil with dry sludge demonstrated significant issues, with all 70 bricks exhibiting cracks, emitting odor, and experiencing breeding problems. Conversely, the third scenario utilizing fresh wet sludge with Kanota soil yielded favorable outcomes. In the fourth scenario, the utilization of burnt sludge with Black cotton soil led to a shrinkage problem, causing a substantial reduction in brick length of approximately 1 inch, attributable to the nature of the clay, i.e., Black cotton soil. The sixth scenario, involving fresh wet sludge with Samodh soil, also proved successful, as bricks with 5%, 10%, 15%, and 20% wet sludge replacement (by weight) exhibited no cracks, while minor cracks were observed with a 30% wet sludge replacement. Furthermore, it was observed that the compressive strength of the bricks decreased as the sludge content percentage increased.*

Key Words*: *Sewage treatment plant waste; sludge; Kanota soil; Samodh soil; Black cotton soil; anaerobic decomposition; compressive strength.

1. INTRODUCTION

For thousands of years, bricks have played an important part in building and construction. Despite its dependability and accessibility, it is commonly acknowledged that manufacturing burnt clay brick remains an energy- and highly resource-intensive operation. Many academics have been undertaking a wide range of studies on sustainable and creative bricks in order to reduce the brick industry's significant carbon impact.

Brick manufacture contributes to Green House Gases and Black Carbon emissions, both of which have a substantial influence on human health and climate change. Furthermore, the brick manufacturing industry is distinguished by the extensive exploitation of natural resources such as clay reserves.

Global representatives discussed the unprecedented challenge of climate change at the United Nations Climate

Change Conference of Parties in Glasgow and Sharm El-Sheikh (Egypt), because the climate crisis, sustainability, and food security are essential and urgent topics in all countries.

2. NECESSITY OF STUDY IN INDIA CONTEXT

The building and maintenance sector is a critical economic driver in India. The industry is vital to India's overall growth, and the government places a high priority on implementing laws that will assure the country's timely building of world-class infrastructure.

According to NITI Aayog, the Indian real estate sector would be worth $1 trillion by 2030 and will contribute for 13% of India's GDP by 2025.

According to the Union Budget of India, during the fiscal year 2022-23, 80 lakh dwellings would be completed for the identified qualified beneficiaries of the PM Awas Yojana, in both rural and urban areas, to facilitate cheap housing, with traditional fire bricks being used in most cases.

3. STATUS OF WASTE WATER TREATMENT FOR RAJASTHAN STATE

Rajasthan State was one of the states that announced its own State Sewage and Waste Water Policy in 2016, with a focus on the reuse of treated wastewater and the promotion of public awareness programs.

According to information available from the concern department of Government of Rajasthan, and RSPCB (Rajasthan State Pollution Control Board) Jaipur, total sewage generation is approximately 1550.00 MLD from 116 operational STPs in 33 towns across the state, and total sewage treated through STPs (Sewage Treatment Plants) is approximately 723.00 MLD. As a result, the proper disposal of sludge created by these treatment plants remains a major task for municipal governments.

4. SIGNIFICANCE AND RELEVANCE OF THE STUDY

One of the most frequent building materials is brick. The majority of brickfields absorb soil from surrounding agricultural land, posing a danger to food crop production. On the other hand, sustainable consumption and production are prerequisites for meeting the United Nations' Sustainable Development Goals.

Nearly 50% of global manufacturers include some type of waste in brick production to lessen the impacts of natural resource exploitation, lower production costs, and achieve a greater level of environmental sustainability. A suitable disposal method for sewage sludge from Waste Water Treatment Plants (WWTPs) is a global issue.

Because of the increasing volume of sludge produced by wastewater treatment plants, there is a strong demand for ecologically safe reuse and effective disposal solutions for sludge. Barging to sea, incineration, land filling, and spreading on agricultural land are all current strategies. The environmental impact of each of these disposal and treatment methods varies. Sludge disposal will become more complicated as the amount of sludge produced increases with the construction of waste-water treatment facilities. It has been recommended that sewage sludge and other materials be combined to create a material suitable for brick production.

5. POTENTIAL ADVANTAGES OF THIS SYSTEM

The utilization of waste products can transform them from liabilities into valuable assets. Collaborative efforts can lead to shared benefits arising from these outcomes.

Compared to other methods of disposing of sludge, this approach aims to minimize environmental consequences. For instance, there will be no pollution resulting from sludge incineration, and the accumulation of harmful heavy metals, which poses a risk when sludge is applied to agricultural land, will be reduced.

The production of such bricks is expected to significantly reduce energy costs by up to 50% when compared to traditional clay bricks. This substantial reduction in operational expenses is particularly advantageous for large-scale manufacturing of cost-effective bricks.

The resulting lightweight bricks offer advantages in terms of transportation and construction. These aspects provide substantial benefits for our environmentally conscious society, which also aims to minimize energy consumption.

6. OBJECTIVES OF THE STUDY

The thesis aims to achieve the following specific objectives:

- Develop an effective and environmentally conscious approach for reutilizing sludge while ensuring the quality of bricks by proposing an optimal clay-sludge mixture ratio.
- Investigate the impact of incorporating sewage sludge into the clay mixture on the strength and various physical properties of bricks.
- Identify the suitable type of sludge and the appropriate clay composition to be used in conjunction with sewage sludge, considering both dry and wet forms.
- Draw conclusions based on the results of experiments and outline potential future advancements for further exploration in this research field.

7. COLLECTION OF SEWAGE SLUDGE

Sewage sludge samples are taken at the Dehalawas (Unit-01) Sewage Treatment Plant in Jaipur. The STP uses the Activated Sludge Process (ASP) and has a capacity of 62.5 MLD (under upgradation). The STP collects water from a 25-kilometer radius using gravity flow, and no pumping is used for sewage upliftment before transferring it to the plant, which is a significant accomplishment for its engineers. (Fig. 1.) The STP extends from Vidhyadhar Nagar to Pratap Nagar in Sanganer. Sludge collected at various stages of the operation is directed to the sump and then to the digester dome. Centrifugal pumps are used to dewater the sludge, and the thicker sludge is transferred to a dome for anaerobic digestion. This method produces biogas and digested sludge, which farmers utilize as manure. Also, this digested sludge can be mixed in proportionate quantity with the clay available and can be used in the brick manufacturing. The gas produced is used for revenue collection.

Fig. 1. Photograph of - Sludge collection at Dehlawas STP, Jaipur

For the research work, three types clayey soil were collected one from Kanota, Jaipur, Rajasthan, the other one from Samodh, Rajasthan and the last one Black cotton soil from a black smith shop Jaipur, Rajasthan. These places are the major hub for brick making and from here bricks are supplied not only to Jaipur but also to other districts.

7.1 Preparation of Bricks

In a typical brick kiln, a batch of clay-filled bricks was created. In India, there are two types of brick-making processes: manual forming and automatic forming. The clay bricks are hand-carved, and the bricks are shaped using traditional wooden molds. Clay brick samples with lengths of 230 mm, widths of 110 mm, and heights of 70 mm were made. On-site, clay mixture samples (as controls) were generated in various ratios (5%, 10%, 15%, 20%, and 30%), Subjected to numerous tests to identify technical and general features in order to obtain a product suitable for usage as a construction material.

Several trails were run during the brick-making process to ensure that the correct mixture of sewage sludge and clay was used. Three various kinds of clays and two types of sludge are utilized in this, one in dry form and the other in wet form. Six scenarios have been addressed on how dry and wet sludge are employed in three different types of clay to produce the required brick. The weight of 1 brick is approximately 3 - 3.5kg, and in the research work, I used 3.5kg as the weight of a single brick to have enough.

7.2 Result and Discussion

The characteristic of sludge and both clays are shown in table 01 below. As you can see the pH vale for sludge is 3.14 which means that it is acidic in nature. Now if we look at the pH value of both the clay it is 8.14 and 7.91, since these values are greater than 7 so they will come under basic category. The moisture content of dry sludge is 6.14% and loss of ignition is 49.2% this means that sludge has lot of volatile organic matter as compare to both the clay, as in clay its only 8.7% and 8.1% which is quite low.

Table 01:- General Characteristics of Sludge and Clay

Parameter	Sludge	Clay (Samodh)	Clay (Kanota)
pH	3.14	8.14	7.91
Moisture Content (%)	6.14	3.67	3.52
Loss of Ignition (%)	49.2	8.7	8.1

8. CHEMICAL COMPOSITION OF CLAY AND SLUDGE

The X-Ray Fluorescence test is employed to analyze the chemical composition of substances, including sludge and clay. The results reveal that silica oxide constitutes the highest percentage in these materials. Silica oxide is a crucial component as it contributes to the strength and durability of bricks when present in an appropriate proportion. Its presence minimizes the likelihood of cracks, shrinkage, and expansion.

9. ATTERBERG'S LIMIT

The amount of water we add to any soil has a catastrophic impact on the entire system. The Liquid Limit is the boundary between the semi-solid and liquid states, whereas the Plastic Limit is the boundary between the solid and liquid states. Now, as shown in Table 02 below, the soil has some form of liquid limit, that is, the inclination to flow may be seen from silty soil to clay. So, in order for the soil to be in that state, it must have at least a 25% liquid restriction, or it will be classified as non-plastic. Now for the plastic limit, if we see the table below, the soil should have at least 15% as plastic limit to be in that zone to behave as plastic material otherwise the soil will be called as non-plastic.

Additionally, In table no. 03, the liquid limit for the "Samodh clay" at 25 blows is 35% and the plastic restriction from the 3mm thread is 18%, putting it in the low plasticity to intermediate plastic class. Now, if we look at the data for "Kanota clay," the liquid limit at 25 blows is 29% and the plastic limit is 15%, which is quite low when compared to "Samodh clay," indicating that the Kanota soil has more silt content and hence clay with less plasticity. This result will undoubtedly cause some difficulties in producing decent bricks from both clays.

In the second case of my study, we can observe that while utilizing Kanota clay, all of the bricks had major cracks, and this is the explanation for it. Because clay has limited plasticity, adding some foreign substance with no plasticity can only result in the breakdown of the entire system. This brings up another point: brick manufacturers in Kanota utilize chemicals to increase the binding property of clay in order to build good bricks.

Table 02:- Standard limits of Liquid limit

Type of Soil	Plastic Limit (W_P)	Liquid Limit (W_L)
Gravel	Non plastic	Non plastic
Sand	Non plastic	Non plastic
Silt	22 – 23 %	35 – 50 %
Clay (low plasticity)	15 – 22 %	25 – 35 %

Clay (medium plasticity)	18 – 25 %	40 - 50 %
Clay (high plasticity)	20 – 35 %	60 – 85 %

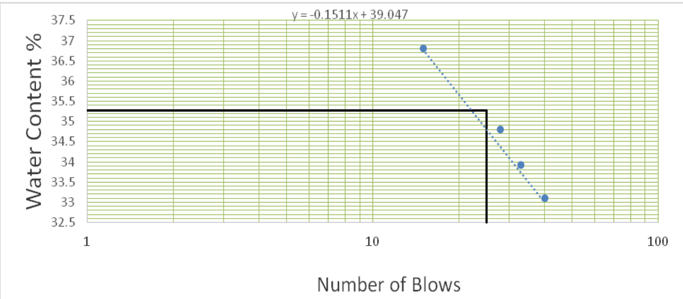

Chart 1:- Liquid Limit at 25 blows for Samodh Clay

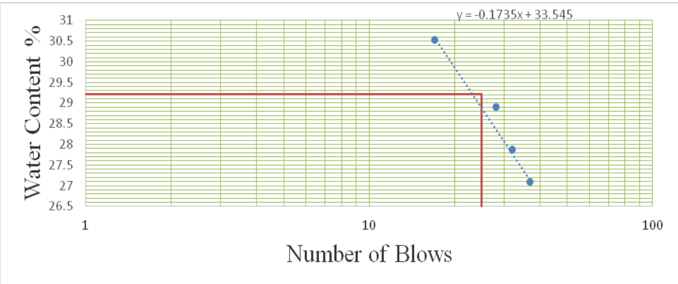

Chart 2:- Liquid Limit at 25 blows for Kanota Clay

Table 03:- Atterberg Limits of both clays

Parameter	Clay (Samodh)	Clay (Kanota)
Optimum Moisture Content (%)	20	17
Liquid Limit (%)	35	29
Plastic Limit (%)	18	15
Plasticity Index (%)	17	14

The ideal moisture content is crucial for the production of bricks. When water is added, the soil becomes more rigid, leading to increased resistance during compaction and preventing it from reaching a denser state, resulting in lower dry density. According to Table 03, the optimum moisture content for Samodh clay is approximately 20%. This indicates that at this level of water content, the clay achieves optimal lubrication, allowing for maximum dry density and compressibility. Thus, by providing the appropriate amount of water, the clay can be molded into any desired shape. In this if the sludge content is increased then OMC will increase and dry density will decrease. Liquid limit will increase and plasticity index will decrease. This clearly states that sludge is non-plastic material and if added to clay it will decrease its plasticity properties.

10. CONCLUSION

This report focuses on investigating the utilization of sludge (both dry and wet forms) in clay for the production of fired clay bricks. The research aims to analyze the physical and mechanical properties of the resulting burnt sludge-clay bricks. Three different types of clay were employed, with varying percentages of sludge incorporation ranging from 0% to 30%, in order to identify the most suitable clay-sludge combination.

Key findings of this study are as follows:-

i. The Atterberg's limit test revealed that the Plasticity Index of "Samodh clay" exceeded that of "Kanota clay," leading to the occurrence of cracks during the drying process for the latter.

ii. During visits to the Kanota region, brick manufacturers mentioned using chemicals to enhance the binding properties of clay. This suggests that the silt and sand content in the clay is relatively high, necessitating the use of such chemicals.

iii. Incorporating dry sludge increased the water requirement as the sludge content rose.

iv. In the second trial, where dry sludge was mixed with clay and water and left overnight, anaerobic conditions developed. Consequently, the entire mixture emitted a foul odour due to the presence of gases like methane, carbon dioxide, ammonia, and hydrogen sulphide. Additionally, bugs and mosquitoes were attracted to the mixture.

v. The only viable solution to eliminate organic matter is through burning, as done in the third trial. However, this approach incurs additional energy consumption, which increases costs. On the positive side, burning eliminates odour and breeding issues in the sludge-clay mixture.

vi. Utilizing wet sludge offers certain advantages. Firstly, it eliminates the need for extra water. Secondly, the mixing process becomes easier. Thirdly, there is no requirement for sun drying and grinding, which were necessary with dry sludge. These observations were made in the fourth trial.

vii. The optimal replacement ratio without encountering cracks is 20% sludge (by weight). "Samodh clay" is particularly suitable for producing sludge-incorporated bricks as no cracks were observed, and there was no odour emanating from the dried bricks.

viii. Water absorption increased from 11.4% for 0% sludge replacement to 21.1% for 15% sludge replacement. This was attributed to the presence of pores in the bricks formed by burnt organic matter during firing.

ix. Compressive strength decreased from 12.8 N/mm^2 for 0% sludge replacement to 5.2 N/mm^2 for 15% sludge replacement. However, even with increasing sludge percentage, the compressive strength remained above the minimum required value of 3.5 N/mm^2 for qualifying as a brick.

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BIOGRAPHIES

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