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Manufacturing of Ceramic Mud Brick Using Quarry Waste

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***Abstract*: The volume of industrial waste is steadily increasing over time, characterized as waste stemming from manufacturing or industrial operations. Ceramic waste is a notable category, with solid waste arising from various processing, fixing, transportation, and demolition activities, while ceramic powder waste originates from tile finishing processes. Quarry waste, another significant type, is a byproduct of aggregate production via rock crushing in rubble crusher units. Incorporating these materials into soil with Portland cement enables the evaluation of brick properties like compressive strength and water absorption. Efforts to address pollution issues across air, water, and land at industrial plants have led to initiatives utilizing ceramics waste. This approach, envisaged for mud brick production, not only addresses associated environmental concerns but also holds potential to enhance brick quality and reduce production temperatures compared to conventional bricks. Sustainable practices such as utilizing lateral soil, quarry waste, and ceramic powder waste as cement replacements can contribute to cost reduction in construction. The disposal of ceramic powder waste remains a major challenge in factories, underscoring the importance of reusing this waste as a viable solution to its disposal problem.**

***Keywords*: ceramic mud brick, kaolin powder, ordinary portland cement (53 grade), quarry dust.**

1. Introduction

Kaolin mud bricks are emerging as a sustainable building material in the construction industry due to their eco-friendly properties. This article provides a detailed exploration of their manufacturing process, covering raw material selection, production techniques, and environmental implications, aiming to assess the feasibility of integrating these bricks into modern construction practices. The foundation of successful manufacturing lies in selecting appropriate raw materials. Kaolin, a clay mineral known for its plasticity and cohesion, is the primary component of mud bricks, contributing to their structural integrity. The abundance of kaolin deposits in various regions enhances the sustainability of this resource. The manufacturing process involves extracting and purifying raw kaolin, then mixing it with water to form a malleable mud that is molded into bricks using hand or mechanical presses. Subsequent drying and firing processes ensure durability and strength. Kaolin mud bricks offer reduced environmental impact compared to traditional materials due to lower energy consumption during extraction and processing. The firing process can be optimized for energy efficiency, making these bricks a sustainable choice. Ceramic mud bricks, combining clay, water, and organic materials, undergo high-temperature firing to enhance durability. These bricks exhibit high compressive strength and low thermal conductivity, ideal for various construction applications. Case studies demonstrate successful utilization of kaolin mud bricks, highlighting their versatility in different architectural settings. Challenges such as regional availability and production expertise must be considered for widespread adoption. Overall, this article explores the manufacturing process and benefits of kaolin mud bricks, offering insights into their potential for mainstream construction practices in a sustainable era.

2. Materials and Methodology

A. Materials

The production of bricks incorporating cement, kaolin powder, 6mm-sized quarry waste, and laterite soil involves a unique blend of materials aimed at enhancing both sustainability and structural integrity. Cement serves as the binding agent, ensuring cohesion and strength in the final product. Kaolin powder, known for its plasticity and contribution to clay-based materials, adds finesse and workability to the mixture. The inclusion of 6mm-sized quarry waste not only reduces environmental impact by utilizing waste materials but also enhances the bricks' durability and thermal properties. Laterite soil, abundant in many regions, offers natural stability and helps optimize the composition for brick manufacturing. This amalgamation of materials showcases a strategic approach to sustainable construction, emphasizing resource efficiency and performance in the production of durable and environmentally conscious bricks.

1) Cement

OPC 53 grade cement is a high-quality product known for its strength and durability in construction applications. This type of cement, characterized by its high compressive strength, is ideal for use in reinforced concrete structures and projects requiring superior performance. Dalmia OPC 53 grade cement offers excellent early strength development, ensuring faster construction progress and reliable structural integrity. Its superior quality and consistency make it a preferred choice

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among builders and contractors seeking high-performance cement for demanding construction projects.

2) Kaolin powder

Kaolin powder plays a crucial role in the manufacturing of bricks due to its unique properties and contributions to the clay mixture. As a fine clay mineral, kaolin enhances plasticity and workability, allowing for easier shaping and molding of bricks during production. It also improves the overall strength and durability of the bricks once fired, helping to create a solid and stable structure. Kaolin's presence in brick manufacturing helps optimize the composition of raw materials, leading to high-quality bricks with excellent thermal insulation properties. Additionally, kaolin is abundant and widely available, making it a sustainable choice for enhancing the performance and aesthetics of modern brick production.

3) Laterite soil

Laterite soil is a key ingredient used in the manufacturing of bricks due to its unique characteristics and suitability for construction purposes. This naturally occurring soil, rich in iron oxides and aluminum hydroxides, provides excellent binding properties when mixed with other materials like clay and cement. Laterite soil is known for its durability and stability, making it ideal for producing robust bricks that can withstand weathering and environmental factors. Its reddish coloration adds aesthetic appeal to the finished bricks, making them popular for various architectural applications. Moreover, laterite soil is abundant in many regions, contributing to the sustainability and cost-effectiveness of brick manufacturing processes. Overall, the incorporation of laterite soil in brick production enhances both the structural integrity and visual appeal of the final product.

4) Quarry waste

Quarry waste, specifically 6mm-sized aggregates obtained from the crushing process of rocks in rubble crusher units, is a valuable resource in the manufacturing of bricks. This waste material, often considered a byproduct of aggregate production, serves as a sustainable alternative to conventional raw materials. When incorporated into brick manufacturing, quarry waste enhances the structural strength and durability of the bricks. Its angular shape and varied composition contribute to improved bonding with other materials like cement and clay, ensuring a robust and reliable end product. By utilizing quarry waste in brick production, manufacturers not only reduce environmental impact by repurposing waste but also create bricks that exhibit excellent mechanical properties suitable for construction applications. This approach highlights the potential of leveraging quarry waste to enhance sustainability and efficiency in brick manufacturing processes.

Table 1
Material test

Test Name	Kaolin powder	Cement
Fineness	5%	6%
Standard consistency	34	34
Specific gravity	2.59	2.83 g/cc
Setting time	6 to 12 hours	45 min

3. Methodology

There are six steps involved in Ceramic Mud Brick manufacturing process. They are Preparation of soil mixture, Consistency of mixture, filling the chamber, Uniform distribution, levelling and soft compaction, Hydraulic compression. Here M represents the real mud brick, M1 represents the ceramic mud brick as 90% laterite soil to the ratio of 10% quarry as the same it continues as M2 for 80% to 20%, M3 for 70% to 30%, M4 for 60% to 40% and M5 for 50% to 50% respectively.

a) Preparation of soil mixture
b) Consistency of mixture
c) Filling the chamber
d) Uniform distribution
e) Levelling and soft compaction
f) Hydraulic compression

A. Preparation of soil mixture

Before loading the soil mixture into the hydraulic compression machine, the soil, cement, and water need to be mixed thoroughly. The proportions of each component must be carefully controlled to ensure the desired properties of the bricks, such as strength and durability.

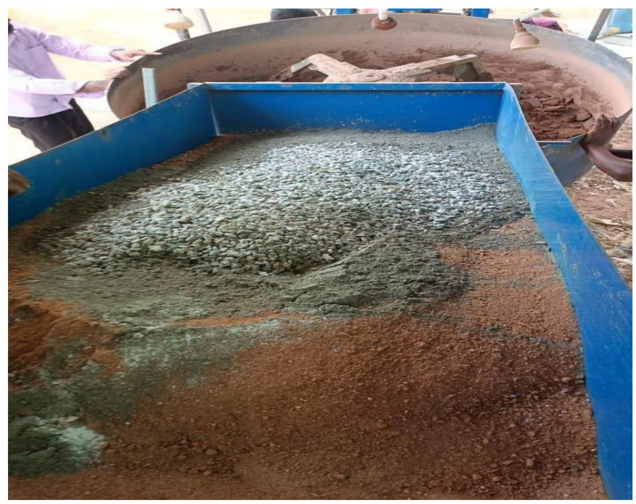

Fig. 1. Preparation of soil mixture

B. Consistency of mixture

The soil mixture should have the right consistency to facilitate proper compression. It should be moist enough to hold together when compressed but not too wet that it becomes overly plastic or difficult to handle.

Fig. 2. Consistency of mixture

C. Filling the chamber

Most hydraulic compression machines have a hopper or chamber where the soil mixture is loaded. This can be done manually by scooping the mixture into the chamber. The consistency of the material mix and its uniform distribution directly influence the efficiency of this process and the properties of the final product.

D. Uniform distribution

It's essential to ensure that the soil mixture is evenly distributed within the chamber to achieve consistent compression across all bricks. Uneven distribution can lead to variations in brick quality and appearance. The uniform distribution of materials in a hydraulic machine for brick manufacturing is crucial for several reasons, significantly impacting the quality, durability, and overall performance of the bricks. Hydraulic brick-making machines compress the brick material under high pressure to form bricks. The consistency of the material mix and its uniform distribution directly influence the efficiency of this process and the properties of the final product.

E. Levelling and soft compaction

Once the soil mixture is loaded into the machine, it may need to be leveled and softly compacted with hand to ensure uniform density within the mould inside the machine. This can be done manually or through automated systems within the machine. Leveling involves preparing the mold 25 or formwork used for shaping the bricks. It's essential to create a level and even surface within the mold to ensure that each brick is of uniform thickness and shape. Proper leveling helps prevent variations in brick dimensions, which can affect structural integrity and the overall appearance of the finished product. Brick makers typically use tools like a spirit level or straight edge to achieve precise leveling of the mold. Soft compaction refers to the gentle pressing or compacting of the raw brick material (such as clay or clay mixtures) within the leveled mold. This step is critical for achieving good density and strength in the brick while maintaining its desired shape. Soft compaction involves applying just enough pressure to compress the material without causing excessive deformation or damage. It helps to remove air voids and ensures that the brick material fills the mold uniformly. During soft compaction, skilled brick makers use techniques such as hand tamping or using a mechanical press with controlled pressure to compact the material effectively. The goal is to achieve a solid yet not overly dense brick that retains its shape after being removed from the mold.

F. Hydraulic compression

The hydraulic compression machine applies pressure to the soil mixture, compacting it into solid bricks. The pressure is controlled and monitored to ensure consistent compression across all bricks. Depending on the capacity of the machine and the production requirements, the loading and compression process may be repeated multiple times to produce a batch of bricks. Overall, loading the soil mixture into the hydraulic compression machine requires attention to detail and proper handling to ensure the quality and consistency of the resulting M bricks. Proper loading techniques contribute to efficient operation and the production of high-quality bricks for construction purposes.

Fig. 3. Hydraulic compression machine

4. Experimental Investigation

Brick made with laterite soil, quarry waste, cement and kaolin powder as the variation of M-brick. The brick are of size 12in*8in*6 in. After testing collection of results and discussion are done followed by overall conclusion.

Here we are using 5% the optimum value of kaolin (ceramic dust) keeping as constant therefore; 5% of 1.42 =0.071 Kg is used. Quarry waste of 6mm size are used in different ratios as 10%, 20%, 30%, 40% and 50%. Meanwhile the soil is replaced with quarry waste in the ratio 90%, 80%, 70%, 60% and 50%.

The conducted tests are;

1. Compression test
2. Water absorption test
3. Free fall of specimen
4. Shape test
5. Soundness test

1) Compression test

Fig. 4. Specimen in compression testing machine

The brick of size 12 in* 8in * 6 was placed in compression testing machine (CTM) shown in figure above. The test was done mainly to find the compressive strength value. Generally, many specimens of bricks are taken to laboratory for testing and tested one by one. In this test Ceramic mud brick were put on compressive testing machine and pressure are applied till the sample breaks. The brick manufacturing by waste materials of different proportions of waste materials are tested one by one and found that one sample gives high compressive strength value. And the compressive strength value is compared to normal M-brick.

Compressive strength = Load/Area

Where, P- Maximum load (KN)

A-Area of specimen (sq.mm).

2) Water absorption test

In this test, bricks are weighed in dry condition and let them immersed in fresh water for 24 hours. After 24 hours of immersion, those are taken out from water and wipe out with cloths. Then, brick is weighed in wet condition. The difference between weights is the water absorbed by brick. The percentage of water absorption is then calculated. The less water absorbed by brick the greater its quality. Good quality brick doesn't absorb more than 20% water of its own weight. Where, W1-Weight of dry brick (kg).

Fig. 5. Specimen for water absorption test

3) Free fall of specimen

The ceramic mud brick from different ratios of 90%-10%, 80%-20%, 70%-30%, 60%-40%, 50%-50% are collected and allowed to free fall from a height of 3 meter. After falling each brick from the specified height, the brick belongs to 3rd and 4th ratio only have slight damage.

4) Shape test

Fig. 6. Specimens for shape test

Bricks is perfect for construction projects. Use it build a wall or other structure, or as a fence post. Made from superior materials, it is strong and sturdy enough to last through the ages. Size: 12 In 30 X 6 In X 8 In Color: Red, Bricks that had helped builders reduces the amount of building materials, cost of construction and the time taken to complete the construction. One of the most amazing advantages of our bricks is that they have shiny outer surfaces which do not require cement plastering. It helps reduce the cost of construction of the walls up to 30% to 40%. These bricks are as strong as the regular mud blocks or the laterite stones and can bear huge weight as well. So, it could be used to build load bearing walls or multistoried buildings. When percentage of quarry waste increases the surface roughness increases.

5) Soundness test

Soundness test of bricks shows the nature of bricks against sudden impact. In this test, 2 bricks are chosen randomly and struck with one another. Then sound produced should be clear bell ringing sound and brick should not break, then it is said to be good brick. The soundness test on bricks is a method used to determine the ability of bricks to withstand volume changes due to wetting and drying under specified conditions. It assesses the durability and quality of the bricks by subjecting them to cycles of soaking in water and then drying.

5. Test Result

A. Compressive Strength Test Result

Compressive strength for real mud brick (M) and ceramic mud bricks of different ratios M1, M2, M3, M4 and M5 are obtained and result are listed in table: 9 below. After water absorption test the result has been graphically plotted and obtained the result as M3 better compared to other ratios.

Table 2
Compression test result

Ratio	Variation in (%) (laterite: quarry)	Compressive strength
M	Real m brick	3.74
M1	80:20	4.17
M2	80:20	5.19
M3	70:30	5.32
M4	60:40	4.60
M5	50:50	4.78

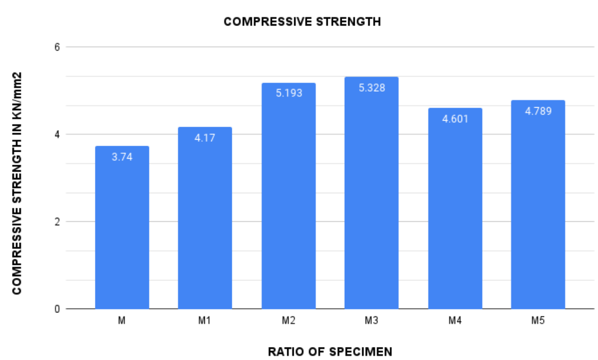

Fig. 7. Graphical representation of compressive strength test result

B. Water Absorption Test Result

Water absorption test is conducted for real mud brick (M) and ceramic mud bricks of ratios M1, M2, M3, M4 and M5.

Finally observed that after the water absorption test M2 is better compared to all other bricks.

The data's are tabulated in table. After water absorption test the result has been graphically plotted and obtained the result as M2 is better compared to other ratios.

Table 3
Water absorption test result

Ratio	Variation in (%) (laterite: quarry)	Water absorption
M	Real m brick	5.67
M1	80:20	6.88
M2	80:20	3.88
M3	70:30	3.89
M4	60:40	4.09
M5	50:50	4.68

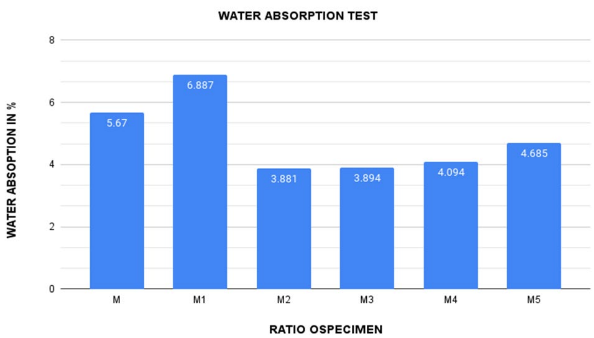

Fig. 8. Graphical representation of water absorption test

C. Free Fall of Specimen Test Result

Ceramic mud brick of different ratios M1, M2, M3, M4 and M5 are allowed to fall from a height of 3 meter above from the ground surface and obtained that the specimen of ratio M3 and M4 are better compared to other bricks. The specimen after free fall is shown in figure 9.

Fig. 9. Specimen after free fall from 3 meter

D. Shape Test Result

The shape test is another critical evaluation to assess the quality of a brick. In conclusion, ceramic mud brick based on the results of a shape test consistent dimensions, straight and uniform edges, parallel faces, and a smooth surface without cracks or deformities. These characteristics ensure that the brick will perform well and integrate effectively in construction applications.

E. Soundness Test Result

The soundness test is an important evaluation for determining the durability and quality of a brick. Based on the results of a soundness test, the exhibit a clear, ringing sound when struck, indicating uniform density and structural integrity. Visual inspection confirmed that the brick is free from visible defects. Any deviation from these characteristics may suggest a lower quality or less durable brick.

6. Conclusion

This study focuses on examining the properties of Ceramic Mud Bricks, a sustainable building material derived from ceramic and quarry waste. With industrial waste on the rise, ceramic waste primarily composed of kaolin powder and quarry waste present viable materials for innovative construction solutions. Kaolin powder's unique characteristics, including high heat resistance and absorbency, contribute significantly to the performance of Ceramic Mud Bricks. Combining kaolin powder with laterite soil and Ordinary Portland Cement (OPC) enhances the economic and environmental benefits of brick production. Laterite soil, abundant in tropical regions, provides strength, while OPC of 53 grade ensures durability and stress resistance. Incorporating quarry waste and OPC improves compressibility, making these bricks ideal for construction purposes. The affordability and accessibility of these materials make Ceramic Mud Bricks a compelling choice for builders, reducing material costs, construction time, and environmental impact while offering enhanced thermal properties.

One of the most amazing advantages of our bricks is that they have shiny outer surfaces which do not require cement plastering. It helps reduce the cost of construction of the walls up to 30% to 40%. These bricks are as strong as the regular mud blocks or the laterite stones and can bear huge weight as well. So, it could be used to build load bearing walls or multistoried buildings.

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