

An Experimental Investigation into the Production of Geopolymer Bricks Utilizing Industrial Waste Materials for Sustainable Construction

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ABSTRACT

Masonry, an ancient construction technique, involves systematic placement and joining of individual units such as bricks, stones, and concrete blocks with mortar. This study focuses on the development of sustainable masonry products utilizing alternative materials, including lime, fly ash, Ground Granulated Blast Furnace Slag (GGBS), and red mud. The primary objective is to address the environmental challenges posed by traditional masonry materials, which are often energy-intensive and contribute significantly to greenhouse gas emissions.

The research emphasizes the importance of utilizing locally available resources and industrial by-products to create economically viable and durable masonry units that promote a circular economy in construction. By exploring innovative applications of these materials, the study aims to reduce the ecological footprint of masonry construction while maintaining structural integrity and aesthetic appeal.

Various tests were conducted to evaluate the mechanical properties and performance characteristics of the developed masonry units. The findings indicate that the innovative use of lime, fly ash, GGBS, and red mud can lead to the production of high-strength masonry units with reduced environmental impact. The results demonstrate the potential for these sustainable materials to be integrated into modern construction practices, highlighting the importance of advancing sustainable building solutions in industry.

In conclusion, this research contributes to the growing body of knowledge on sustainable construction materials and practices, offering valuable insights for future studies and applications in the field of masonry. The successful development of these alternative masonry products underscores the need for continued innovation and collaboration in addressing the environmental challenges faced by the construction industry.

Keywords - *Geopolymer bricks, Waste materials, Sustainable Construction.*

I. INTRODUCTION

Masonry, in essence, is the ancient art of building structures by methodically placing and joining individual units, like bricks, stones, concrete blocks, or tiles, with mortar as a binding agent. This method has been central to construction for thousands of years, seen in famous buildings across the globe, from Egyptian pyramids to Roman aqueducts and medieval fortresses. Far more than a means of construction, masonry is an art that unites structural durability with aesthetic beauty, using the inherent characteristics of the materials to produce strong, fireproof, and frequently beautiful structures. The choice of masonry materials and bond systems has a considerable impact on a structure's strength, stability, and visual appeal, and is thus a flexible and long-lasting form of building.

Masonry building essentially depends upon the union of masonry units and mortar. Over the ages, various cultures around the world have cleverly used locally accessible materials for both. This economic practice, inspired by environmental circumstances and functional needs, has given rise to the creation of an extensive and varied array of quality and durable mortars, each typically specially modified to suit the requirements and resources of its area. The construction industry depends on essential factors such as equipment, labor, and supplies,

but material choice is the most important because it has a direct impact on the cost of construction and the durability of buildings. Although traditional masonry materials such as burnt bricks and other concrete blocks are commonly used, the energy-intensive manufacturing of large-scale conventional blocks is a major source of greenhouse gas emissions. This ecological issue, combined with the need for cost-savings and longevity, requires and promotes the creation of new, innovative materials that can supplement or even entirely supplant these old, environmentally damaging masonry units.

The traditional cement used in masonry can be replaced with a variety of raw materials, including lime, GGBS, industrial wastes like fly ash and slag, and recycled bricks. More ecologically friendly masonry units can also be made using locally dug soil, which is all too frequently exhausted during the extraction of traditional bricks and blocks. Customers are thus given a wide range of reasonably priced and ecologically appropriate solutions for their building needs. Even with the application of reinforced concrete frames, solid and hollow concrete blocks continue to be of significant influence in the construction sector, particularly for wall construction. Nonetheless, the conventional production of mortars and bricks poses serious challenges to the depletion of natural resources, and thus there is an urgent need for innovative materials. As a result, present studies in construction materials are significantly aimed at designing sustainable substitutes, for example, masonry products manufactured from locally available resources and low energy, with sustainable development as a main aim. This study is specifically aimed at designing substitute masonry products by making use of substitute materials like lime, fly ash, Ground granulated blast furnace slag (GGBS), and red mud of the construction sector.

Lime, perhaps our early "cement," was in use even before Portland cement, having united some of the world's most long-lasting architectural wonders. This ancient binder has been central, particularly in brick construction, and cleverly mixed with clay burned or brick as "surkhi" for stable load-bearing masonry. Outside of bricks, lime has traditionally constituted structural concrete and even led to soil stabilization in roadbuilding, demonstrating its adaptable and core position in building innovation over the centuries.

Lime, an inorganic compound consisting mainly of calcium oxides and hydroxides (calcium oxide, CaO , or quicklime), is manufactured by the heating of calcium carbonate (which occurs in limestone or chalk) in a furnace. This calcination creates a very reactive compound that, upon addition of water, turns into slaked lime or hydrated lime (calcium hydroxide, $\text{Ca}(\text{OH})_2$). From its original application in mortar (meaning "sticking"), lime and its products remain essential in steel production, building (including cement and concrete), chemical processing, sugar refining, and sewage treatment, with its industrial application dating back to prehistoric times. In farming, "lime" generally means crushed limestone, not kiln-made lime. The word "geopolymer" has two separate meanings, the first being that of natural organic macromolecules and the more common one meaning inorganic substances with cementitious or ceramic-like characteristics. In this later meaning, a geopolymer is a chemical compound or mineral mixture with periodic units such as silico-oxide or silico-aluminate, developed by repolymerization, a mineral production idea developed by Davidovits in 1976. Within the inorganic context as well, definitions also differ, being a variety of low-temperature synthesized solids, with a normal geopolymer being produced when metakaolin reacts with a solution of an alkali silicate to form a highly cross-linked, amorphous network of negatively charged tetrahedral oxide groups counterbalanced by alkali ions.

II. LITERATURE REVIEW

2.1 INTRODUCTION

An extensive review of the available research about lime and marginal materials was conducted, collecting concurrently on collecting information on regional resources and construction methods, since these factors were the primary basis on which our present project operations were being carried out. Brief examinations of relevant research provide context for the current topic.

2.2 LITERATURE FINDINGS

1. Eva Vejmelková *et al.* (2011) explore the historical significance and evolution of lime and pozzolanas in construction, emphasizing their long-standing importance.

The use of lime as a construction material dates to around 4000 BC in Egypt, where it was utilized for plastering the pyramids, showcasing its historical relevance. In ancient Mesopotamia, lime mortars were employed around 2450 BC, as archaeological findings indicate a transition from asphaltic mixtures to slaked lime, reflecting advancements in construction materials. The integration of pozzolanic additions to lime mortars became prominent in the 1st century BC in ancient Rome, where Vitruvius provided guidelines for lime mortar mixes, highlighting the innovative use of pozzolanas in construction practices. Research by Moropoulous *et al.* has extensively analyzed ancient mortars from various historical periods, focusing on their composition, physical properties, and

strength, with samples taken from significant Mediterranean structures that demonstrate the durability of lime-based mortars. The paper also discusses the use of volcanic materials as natural pozzolanas in ancient Rome and the adaptation of artificial pozzolanas like crushed bricks when natural materials were scarce, showcasing the resourcefulness of ancient builders. Furthermore, the study introduces a specific type of clay shale from the Czech Republic, which, when burnt, exhibits pozzolanic properties, indicating its potential for modern applications in lime-pozzolana binders. The findings suggest that the new lime-pozzolana composites developed in this research have superior mechanical and durability characteristics compared to traditional lime composites and lime-metakaolin composites, making them viable alternatives in contemporary construction practices.

2. Freidin *et al.* (2013) systematically studied the durability and leaching behavior of mine tailings (MT)-based geopolymer bricks, highlighting their potential as an environmentally friendly construction material. The research indicates that while immersion in acidic solutions (pH = 4 and 7) leads to substantial strength loss, the water absorption and weight loss of these bricks remain relatively minor, demonstrating their durability under adverse conditions. The study emphasizes the effective immobilization of heavy metals within the geo polymeric network, which is crucial for mitigating environmental risks associated with mine tailings. Furthermore, the authors utilized a first-order reaction/diffusion model to describe the leaching behavior of heavy metals, suggesting that solubility and reaction rates are significant factors influencing this process. Overall, the findings support the use of MT-based geopolymer bricks as a sustainable alternative to traditional cement-based materials, addressing both mechanical performance and environmental concerns.

3. D. Ram Rahul and N. Lingeshwaran (2020) conducted an experimental and comparative study on hollow brick walls reinforced with truss and ladder type arrangements under axial loading. To better understand the engineering characteristics of these brick walls, their study focused on how well various forms of reinforcing may increase the walls' stiffness and strength. Materials were gathered, hollow brick walls were built, and extensive testing was done to determine the causes of fracture failure and the general structural behavior. The results showed that the ductility and energy dissipation capacity of the walls were greatly enhanced by the presence of reinforcement, underscoring the significance of employing suitable reinforcement in masonry construction.

4. Jitha P T *et al.* (2020), the strength development and masonry properties of geopolymer stabilized soil-lime-pozzolana cement (LPC) mixes. The research highlights the potential of using locally available materials and industrial by-products to create sustainable masonry products that can serve as alternatives to traditional Portland cement. The findings indicate that these geopolymer mixes exhibit high compressive and shear strength, making them suitable for low-rise load-bearing masonry buildings. Additionally, the study emphasizes the effectiveness of solar curing and the adobe process in producing these masonry products efficiently.

5. Harsimranjit Singh *et al.* (2021), an experimental study was conducted on bricks manufactured with various mineral additives to address the exhaustion of clay, which is traditionally used as the main component in brick making. The researchers tested the compressive strength and water absorption rates of brick specimens (230 x 110 x 70 mm) made using varying ratios of alternative ingredients, such as fly ash, sand, lime, and plaster of Paris, at various curing ages. Their research showed that in fly ash-based bricks, the compressive strength rose with higher proportions of sand and lime but fell with increasing fly ash percentages. Likewise, when fly ash content rose, water absorption rose, but when sand and lime percentages rose, it fell. Additionally, study 57 1 included a cost-effective mix design analysis, showing that high-strength bricks with the right proportions could be made cheaply for about 1.47 rupees per unit.

III. SCOPE, AIM AND OBJECTIVES OF THE STUDY

3.1 AIM

The aim is to produce recyclable masonry units by recycling industrial waste products, reducing the environmental impact while manufacturing economically viable construction products with suitable structural characteristics and durability, thus promoting the circular economy in construction.

3.2 OBJECTIVES OF THE WORK

1. To examine the various mixing ratios to enhance the properties and determine the mechanical characteristics of alternative masonry units.
2. To study mineral properties through XRD and SEM analysis.
3. Evaluation of masonry prisms and triplets.

3.3 PROPOSED METHODOLOGY

1. Procurement and characteristics of raw materials – Limestone, Flyash, GGBS, Red mud, Waste foundry sand.
2. Trial Mixes to produce lime pozzolana cement by Dry integrated.
3. Arriving at optimum proportions to achieve the required target strength is 5MPa.
4. Production of masonry units.
5. Evaluation of masonry units for strength and elastic properties.

IV. MATERIAL CHARACTERIZATION

4.1 LIME



Fig 4.1: Limestone

4.2 FLY ASH

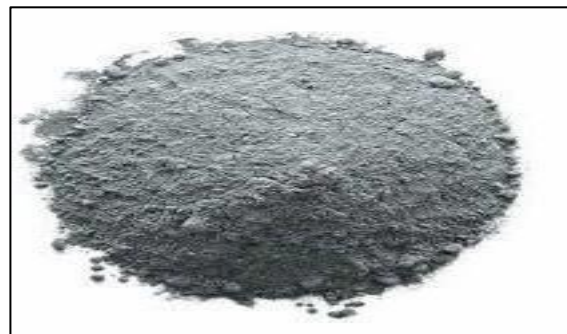


Fig 4.2: Fly ash

4.3 GGBS



Fig 4.3: GGBS

4.4 RED MUD



Fig 4.4: *Red Mud*

4.5 WASTE FOUNDRY SAND



Fig 4.5: *Waste Foundry Sand*

4.6 ALKALINE SOLUTION

In this project, we have prepared an alkaline solution using Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3). This combination is commonly used in various industrial and research applications such as geopolymer concrete, adhesives, cleaning agents, and fireproofing materials.

4.6.1 Sodium Hydroxide



Fig 4.6: *Sodium Hydroxide*

4.6.2 Sodium Silicate

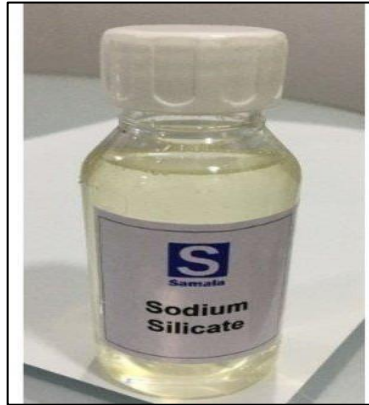


Fig 4.7: Sodium Silicate

4.9 MIX PROPORTIONING

A mixed proportion of 1: 3.5: 5.5. As a result, the ratio of binding material to filler material in the current investigation was 1: 5.5. Below is a description of the process used to measure the materials for the casting the specimen.

$$\begin{aligned}\text{Mortar density} &= 2200 \text{ kg/m}^3 \\ \text{Size of cube is} &70 \times 70 \times 70 \text{ mm} \\ \text{Volume of cube} &= 0.070 \times 0.070 \times 0.070 \\ &= 3.43 \times 10^{-4} \text{ m}^3\end{aligned}$$

$$\text{Mass} = \text{Density} \times \text{Volume}$$

Consequently, the quantity of resources needed to make one cube $= 2200 \text{ kg/m}^3 \times 3.43 \times 10^{-4} \text{ m}^3 = 0.754 \text{ kg}$.

For each cube, it takes approximately 800g of material, taking waste in account. The images below show the process of slaking of lime.

4.10 MIXING OF INGREDIENTS

The ingredients are mixed in a vessel in the ratio specified and agitated for nearly a minute while in their dry form such that the mixture is homogeneous. It was a manual mixing, but planetary mixer can also be employed if needed. To achieve a close-nit blend of the ingredients, water is incorporated. For every combination that is easy to manage and shape into cubes, a flow test is done to ascertain the required quantity of water.

STAGE 1

In Stage 1, water-based mixing was carried out for 3 combinations of cubes in the ratio of 1:5.5 that is using lime, GGBS and red mud. 3 cubes were cast per combination. As a result of which total cubes of mortar were cast in total for different combinations and the 3 days wet compressive strength was evaluated to proceed further.

Table 4.1: Trial mix water-based mortar

Compression Test Result on Water Cubes					
Test	Binder 1 in (%)	Binder 2 in (%)	Binder 3 In (%)	Filler in (%)	Compression Strength in (MPa)
Test 1	GGBS (10)	Lime (10)	-	Red Mud (80)	1.28
Test 2	-	Lime (10)	Flyash (10)	Red Mud (80)	1.20
Test 3	GGBS ;(10)	Lime (15)	-	Red Mud (70)	1.75
Test 4	-	Lime (15)	Flyash (10)	Red Mud (70)	1.90

4.12 CASTING

70 mm cubes are cast with a thoroughly mixed filler and binding material in a three-layer process. Each layer is pressed with 25 blows, and the surface is smoothed. The cubes then harden for approximately 24 hours before they

are labeled for identification.



Fig 4.12: Casting of cubes

4.13 THERMAL CURING OF SPECIMEN

The lime cycle illustrates the essential roles of both carbonation and hydration in restoring the substance to its original state. To facilitate this process, thermal curing was implemented for curing the bricks.



Fig 4.13: Thermal Curing

4.14 FEASIBILITY STUDY SUMMARY

In the trial mixes, GGBS demonstrated high strength mortars compared to fly ash and brick powder. However, the mix of lime, fly ash, and red mud achieved only 5 MPa, falling short of the 6 MPa target. Consequently, we advanced to the second stage, substituting water with geopolymer while keeping the proportions of lime, GGBS, and red mud consistent, and focused on creating mixtures with modest amounts of these components.

V. PRODUCTION OF GEOPOLYMER BRICKS

5.1 FINALISED MIX

From cube test results, we came to know that mortar cubes with 2M gave more strength compared to 1M. Test 5 which had 100% replacement of sand with red mud, exhibited maximum strength. Hence, it was selected as the best combination for casting bricks. The size of the mold is 230*115*90mm for casting sample bricks.

5.2 MIX PROPORTION

In the final mix design, red mud, lime, and ground granulated blast furnace slag (GGBS) were used in the ratio of 80:10:10 by weight. The alkaline activator solution was prepared using 1 liter of distilled water, to which 80 grams of sodium hydroxide (NaOH) and 1 kilogram of sodium silicate (Na_2SiO_3) were added. This solution provided the necessary alkali environment to initiate geo polymerization. For each batch, the dry materials (red mud, lime, and GGBS) were first dry mixed for three minutes to ensure uniformity. Subsequently, the alkaline solution was added gradually, and the mix was thoroughly blended until a homogenous paste was achieved. The resulting mix was cast into brick molds measuring $230 \times 105 \times 75$ mm. The molds were removed approximately 35 minutes after casting. Curing was performed by sealing the specimens in airtight covers and exposing them to natural sunlight, which provided mild heat and retained internal moisture — a condition favorable for geopolymer curing. This method produced bricks with an excellent surface finish and dimensional stability. Bricks with 100% red mud as the primary filler exhibited a reddish- brown color and were visually attractive, indicating potential for both structural and aesthetic applications.

5.3 ALKALINE SOLUTION

Sodium hydroxide and sodium silicate solution combined to form an alkaline solution with a NaOH: Na₂SiO₃ ratio of 1. NaOH solution of 1 molar was utilized. Before adding to the dry materials, the alkaline solution was made the day before and then used.

TEST ON RED MUD BRICKS, TRIPLETS AND PRISMS

6.1 TESTS ON REDMUD BRICKS

Red mud bricks are made utilizing GGBFS, red mud, Fly ash, Limestone, and an alkaline solution of 2M. These elements must all meet standards for bricks to be accepted as building units. According to IS 3495-(1992), the physical characteristics of red mud bricks were assessed.

The following were the tests performed on bricks:

1. Dimensionality test (IS 1077 (1977))
2. Brick density test (IS 3495 (1976))
3. Water absorption test (IS 3495-2(1992))
4. Compressive strength (IS 3495-1(1992))
5. Flexure test on masonry unit. (ASTM C348-2014)

6.1.1 Dimensionality Test

Table 6.1: *Dimensionality test results of Masonry Bricks*

Sl. No.	Dimension	Length of 10 bricks (mm)	Average of 10 bricks (mm)
1	Length	2300	2310
		2320	
		2310	
2	Width	1050	1050
		1040	
		1060	
3	Depth	880	880
		850	
		910	



Fig 6.1: *Dimensionality Test of Red Mud Bricks*

6.1.2 Brick Density Test

Table 6.2: *Density Test on Bricks*

Sl. No	Mass of brick in kg	Volume of brick in m ³	Density in kg/m ³	Average density in kg/m ³
1	3.73	2.3x 10 ³	1621.17	1620.1
2	3.77	2.3x10 ³	1639.13	
3	3.68	2.3x10 ³	1600.00	

Result: Average density of Masonry Brick = **1620.1 kg/m³**.



Fig 6.2: Brick density of red mud brick

6.1.3 Water Absorption Test

$$\text{Water Absorption (\%)} = [(W_w - D_w)/D_w] \times 100$$

Where,

W_w = Wet Weight of Brick

D_w = Dry Weight of Brick

Table 6.3: Water absorption test of Red mud bricks

Specimen No.	Dry Weight (kg)	Wet Weight (kg)	Water Absorption (%)	Average Water Absorption (%)
1	3.73	4.12	11.11	11.12
2	3.77	4.22	11.19	
3	3.68	4.08	11.08	

Result: Average water absorption of clay brick = **11.12%**. (IS Tolerance limit: 20%)



Fig 6.3: Water absorption test on masonry unit

6.1.4 Compressive strength test on bricks

Table 6.4: Compression Strength on Red mud bricks

Sl. No.	Ultimate Load in kN	Compressive Strength in MPa	Average Wet Compressive Strength in MPa
1	160 (3 days)	6.05	5.67
2	140 (3 days)	5.29	
3	280 (7 days)	10.24	10.37
4	310 (7 days)	10.5	
5	368 (28 days)	13.91	14.74
6	412 (28 days)	15.57	

Result:

Average compression strength of red mud brick for 3 days = **5.67 MPa**

Average compression strength of red mud brick for 7 days = **10.37 MPa**

Average compression strength of red mud brick for 28 days = **14.74MPa**



Fig 6.4: Compression Test on Red mud bricks

6.1.5 Flexural Strength Test

Preparation of samples bricks for testing: The brick specimen is submerged in water that is at room temperature. As depicted in Fig 6.5, the test specimen is positioned in the center of the testing apparatus by using self-aligning bearers. Through the center hinge, a constant load of not more than 300N/min is applied. The individual breaking load is recorded, and the flexural strength is calculated by the formula given below.

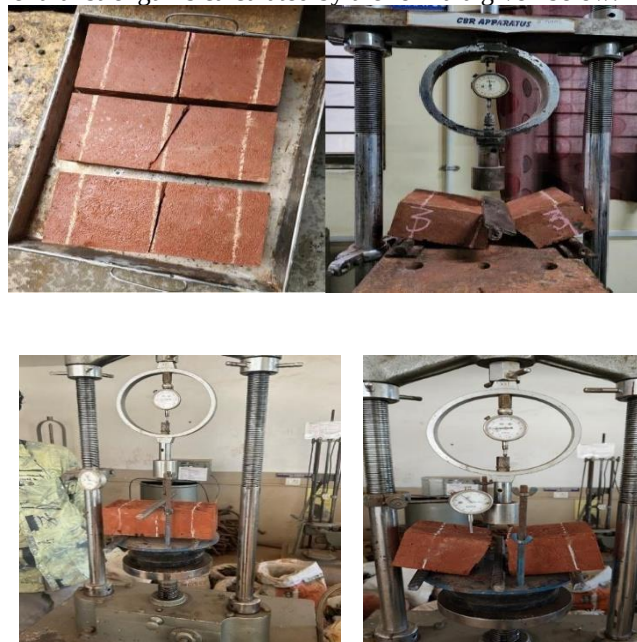


Fig 6.5: Flexure Test on Brick

Table 6.5: Flexural Strength on Red Mud Brick

Specimen Name	No of Divisions	Load in kg	Load in N (load in kg x 9.81)	Size of specimen in (mm)	Effective length L in mm	Flexural Strength (MPa)	Avg. Flexural Strength (MPa)
LGR3-1	69	125.55	1231.64	230x115x90	170	0.337	0.35
LGR3-2	70	137.64	1350.24	230x115x90	170	0.369	
LGR7-1	115	172.25	1689.77	230x115x90	170	0.46	0.46
LGR7-2	120	176.35	1729.99	230x115x90	170	0.47	
LGR28- 1	139	240.12	2355.37	230x115x90	170	0.64	0.66
LGR28- 2	150	255.75	2508.9	230x115x90	170	0.68	

Result: Average flexural strength of brick after 3 days is = **0.35MPa** Average flexural strength of brick after 7

days is = **0.46MPa** Average flexural strength of brick after 28 days is = **0.66MPa**

6.1.6 XRD and SEM of red mud brick sample

Mineralogical Characterization

X-ray Diffraction (XRD) analysis was conducted to characterize the crystalline phases present in the geopolymer bricks synthesized in this study. The bricks demonstrated a compressive strength of 10.5N/mm² (value to be inserted), indicating adequate mechanical performance for structural or construction applications. The XRD pattern revealed prominent peaks at 2θ values of 24.3, 42.8, and 62.7, which correspond to the crystalline phase of sodium aluminosilicate hydrate (NaAlSiOH). These peaks matched the standard diffraction data reported in the Joint Committee on Powder Diffraction Standards (JCPDS) cards 42-0216 and 10-0420, confirming the presence of geo polymeric reaction products. The formation of NaAlSiOH suggests successful geo polymerization involving the aluminosilicate source material and the alkaline activator. The identified crystalline phases contribute to the development of a stable microstructure and are associated with the mechanical strength observed in the brick samples. This analysis confirms that the geopolymer matrix is well- formed and contains the expected reaction products, supporting its suitability for construction applications.

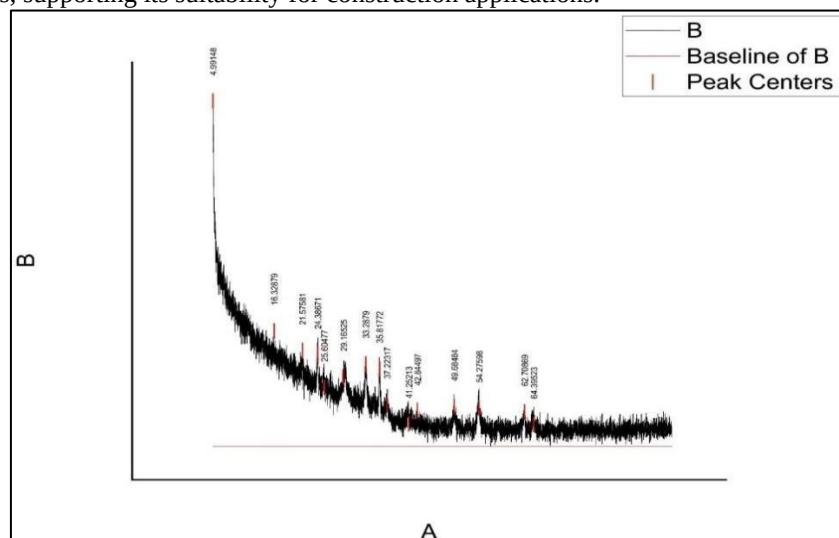
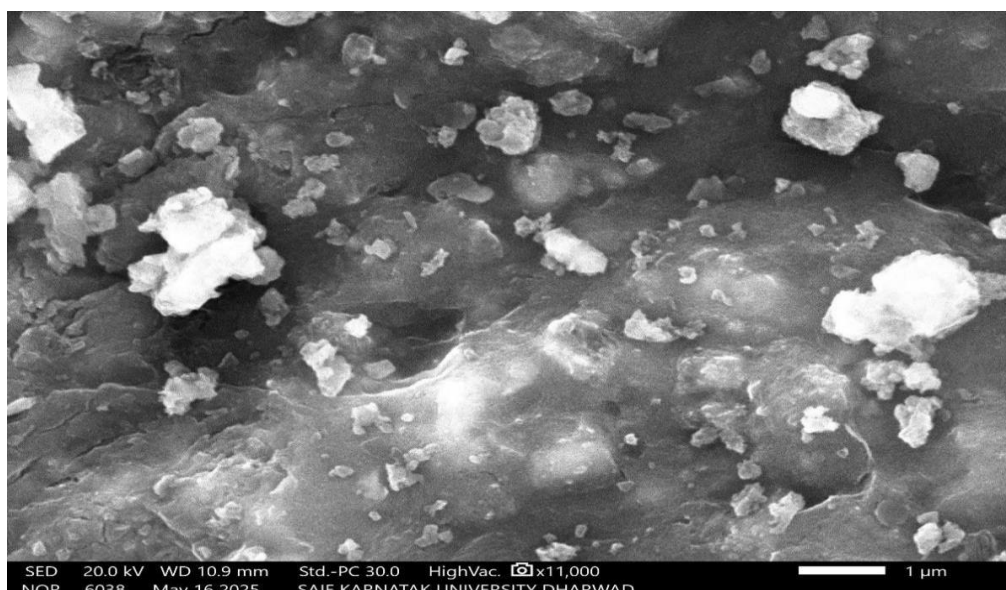


Fig 6.6: XRD Analysis of Geopolymer Bricks with Red mud, GGBS and Lime



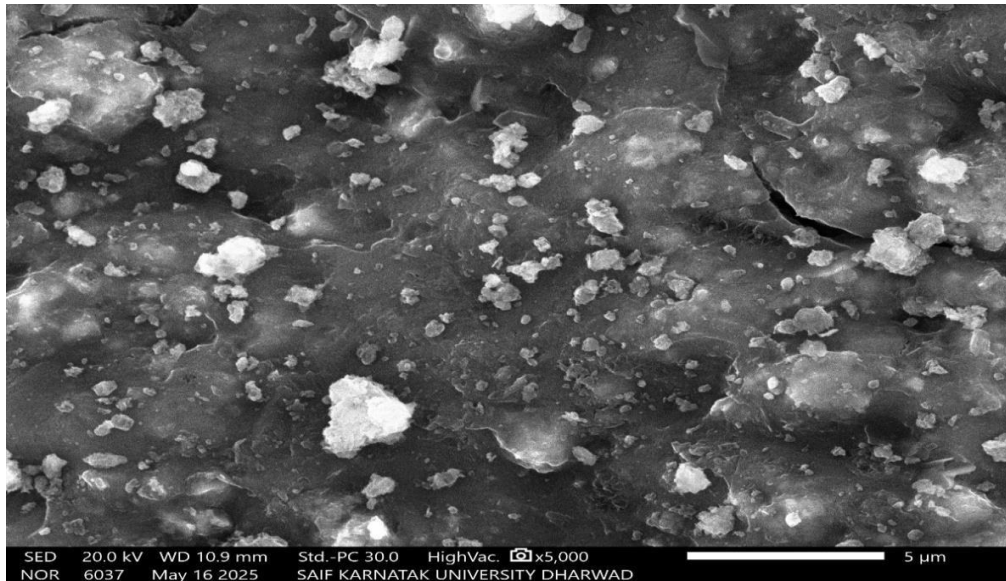


Fig 6.7: SEM analysis

6.2 REDMUD BRICK MASONRY PROPERTIES



Fig 6.8: Casting And Curing of Prism and Triplet

6.2.1 Compression Test on Masonry Prism

Table 6.6: Compression Test on Prism with a dimension of 384 X 230 X 115

Sl. No.	h/t ratio	Correction factor for h/t ratio	Compressive load (kN)	Compressive Strength (MPa)	Corrected Compressive Strength (MPa)
1	3.39	0.997	125	4.72	4.705
2	3.41	1	85	3.21	3.21

Result: Average compressive strength of Prism is = 3.95MPa



Fig 6.9: Testing of Prism

6.2.2 Modulus of elasticity of prism

The tangent modulus of elasticity is the slope of the tangent of any point in the stress-strain curve. Another name for it is the elasticity modulus' immediate value. The first modulus of tangent: It is the origin's slope of the stress-strain curve. Known as the modulus of elasticity at origin, it is sometimes called the dynamic modulus of elasticity. When a structure experiences dynamic loading, such as an earthquake or wind stress, this modulus of elasticity comes into play.

Secant modulus: The stress strain graph is plotted until 25% of the maximum stress is reached, and the slope of the linear line that emerges from the (0, 0) intercept is reported as SM.

Chord modulus: The slope of the linear line drawn for values in the 5% to 33% stress range on the stress strain graph is known as CM [13].

Table 6.7: MOE test results of specimen 1

Sl. No.	Load (kN)	Dial Gauge length (mm)	Change in Length	Strain	Stress
1	5	236	2.36	0.0052	0.189036
2	10	298	2.98	0.0066	0.378072
3	15	326	3.26	0.0072	0.567108
4	20	356	3.56	0.0079	0.756144
5	25	374	3.74	0.0083	0.94518
6	30	390	3.9	0.0087	1.134216
7	35	406	4.06	0.009	1.323251
8	40	425	4.25	0.0094	1.512287
9	45	436	4.36	0.0097	1.701323
10	50	445	4.45	0.0099	1.890359
11	55	462	4.62	0.0103	2.079395
12	60	471	4.71	0.0105	2.268431
13	65	481	4.81	0.0107	2.457467
14	70	495	4.95	0.011	2.646503
15	75	510	5.1	0.0113	2.835539
16	80	525	5.25	0.0117	3.024575
17	85	550	5.5	0.0122	3.213611
18	90	580	5.8	0.0129	3.402647
19	95	610	6.1	0.0136	3.591682
20	100	640	6.4	0.0142	3.780718
21	105	684	6.84	0.0152	3.969754
22	110	706	7.06	0.0157	4.15879

23	115	745	7.45	0.0166	4.347826
24	120	779	7.79	0.0173	4.536862
25	125	804	8.04	0.0179	4.725898

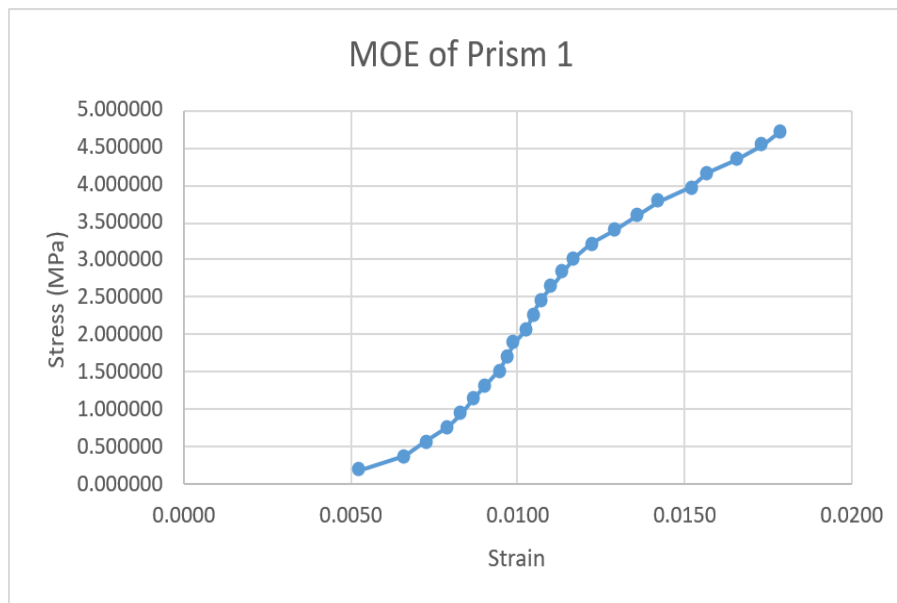


Fig 6.10: Stress strain curve of prism specimen 1

Table 6.8: MOE test results of specimen 2

Sl. No.	Load (KN)	Dial Gauge length (mm)	Change in Length	Strain	Stress
1	2.5	390	3.9	0.0087	0.094518
2	5	410	4.1	0.0091	0.189036
3	7.5	456	4.56	0.0101	0.283554
4	10	482	4.82	0.0107	0.378072
5	12.5	513	5.13	0.0114	0.47259
6	15	545	5.45	0.0121	0.567108
7	17.5	569	5.69	0.0126	0.661626
8	20	581	5.81	0.0129	0.756144
9	22.5	593	5.93	0.0132	0.850662
10	25	603	6.03	0.0134	0.94518
11	27.5	624	6.24	0.0139	1.039698
12	30	651	6.51	0.0145	1.134216
13	32.5	669	6.69	0.0149	1.228733
14	35	674	6.74	0.015	1.323251
15	37.5	704	7.04	0.0156	1.417769
16	40	726	7.26	0.0161	1.512287
17	42.5	736	7.36	0.0164	1.606805
18	45	750	7.5	0.0167	1.701323
19	47.5	767	7.67	0.017	1.795841
20	50	789	7.89	0.0175	1.890359
21	52.5	802	8.02	0.0178	1.984877
22	55	812	8.12	0.018	2.079395
23	57.5	835	8.35	0.0186	2.173913
24	60	861	8.61	0.0191	2.268431
25	62.5	902	9.02	0.02	2.362949
26	65	931	9.31	0.0207	2.457467
27	67.5	965	9.65	0.0214	2.551985
28	70	981	9.81	0.0218	2.646503
29	72.5	999	9.99	0.0222	2.741021
30	75	1039	10.39	0.0231	2.835539

31	77.5	1059	10.59	0.0235	2.930057
32	80	1090	10.9	0.0242	3.024575
33	82.5	1113	11.13	0.0247	3.119093
34	85	1136	11.36	0.0252	3.213611

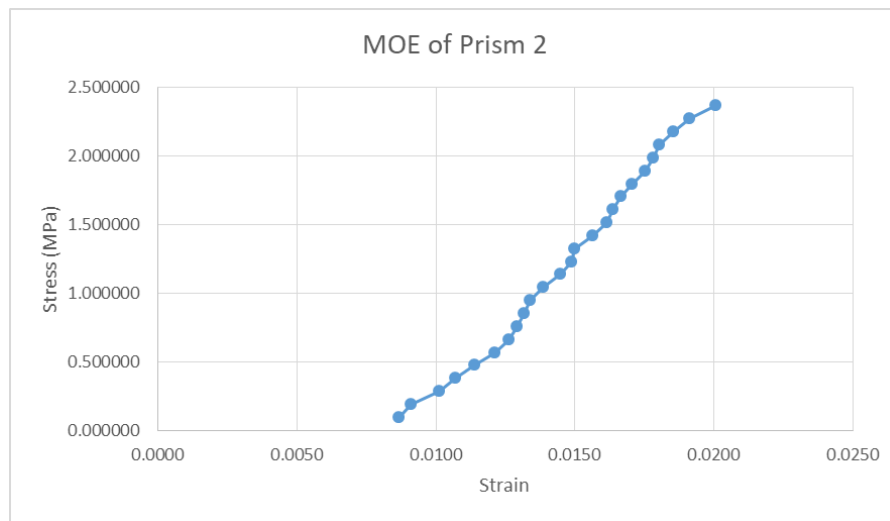


Fig 6.11: Stress strain curve of prism specimen 2

Table 6.9: ITM, SM, CM values of prism

SL. No.	1	2
Specimen No.	LGR-1	LGR-2
Ultimate stress (MPa)	4.72	3.21
5% (MPa)	0.236	0.16
Strain at 5%	8.95×10^4	1.26×10^3
25% (MPa)	1.18	0.8
Strain at 25%	4.47×10^3	6.3×10^3
33% (MPa)	1.55	1.055
Strain at 33%	5.90×10^3	8.31×10^3
ITM (MPa)	900-1100	700-900
SM (MPa)	180-230	140-190
CM (MPa)	300-400	220-320

6.2.3 Shear bond strength (triplet test)

Three samples were tested in a triplet with joints that were each 10 mm thick to calculate the average shear bond strength. The brick failed as seen in Fig. 6.12, but failure did not occur at the brick-mortar contact in any of the LGR- 1 mix samples. Brick masonry triplets, solid concrete brick masonry triplets, and hollow concrete brick masonry triplets have all had their shear bond strengths studied under a range of typical stress levels, according to Keshava (2012). The figures from Keshava's research (2012) are like the LGR-I results.

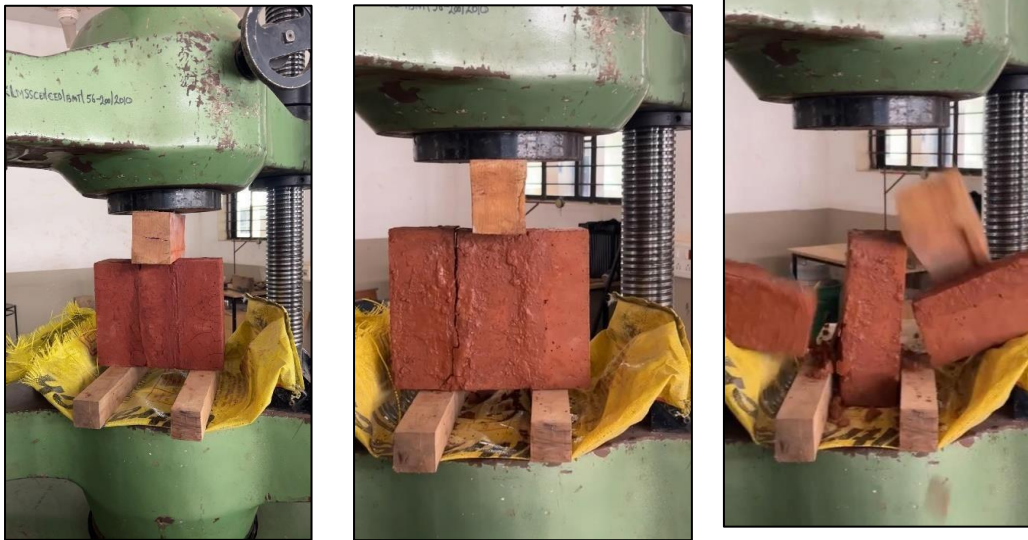


Fig 6.12: Testing on triple

Table 6.10 Shear bond strength

Test	Load in kN	Shearing Area	Shear Bonding Strength MPa	Avg. Shear Bonding Strength MPa
LGR-1	13	230 x 115	0.49	0.68
LGR-2	23	230 x 115	0.87	
LGR-3	18	230 x 115	0.68	

Result: Avg. Shear Bonding Strength is = **0.68MPa** (As per IS 0.4 to 0.8MPa)

VII. SUMMARY AND RESULTS

The resulting red mud bricks were examined for dimensionality, compressive strength, flexural strength, and initial rate of water absorption. The table below contains the average values that were thus determined.

Table 7.1 Test Results of Red mud Brick 1

Test	Result
Dimensionality	230mm x 115mm x 90mm
Density	1620.1 kg/m ³
Water absorption	11.21%
Compressive strength (3 days)	5.67 MPa
Compressive strength (7 days)	10.37 MPa
Compressive strength (28 days)	14.74 MPa
Flexure strength (3 days)	0.35 MPa
Flexure strength (7 days)	0.46 MPa
Flexure strength (28 days)	0.66 MPa

To determine their compressive strength, modulus of elasticity, and shear strength, red mud brick prisms made of four bricks and triplets made of three bricks were cast and put through testing. The outcomes are displayed below.

Table 7.2: Test results of Red mud brick 2

Test	Result
Compressive strength on prism	3.95 MPa
Modulus of Elasticity (ITM)	800-1200 MPa
Shear bond strength	0.68 MPa

7.1 CONCLUSION

The results of this study, which investigated the use of red mud, a significant industrial waste, as a crucial component in the production of sustainable bricks, were quite encouraging. We created bricks that not only satisfied the mechanical strength standards of the construction industry but also had a pleasing appearance by mixing 80% red mud with 10% lime and 10% GGBS and employing a 2M alkaline solution composed of distilled water, sodium hydroxide, and sodium silicate.

Red mud may effectively replace conventional clay as a filler material, according to the analysis, which could greatly lessen the environmental impact of brick manufacture. Although the bricks' strength was enhanced by 100% Red mud content, we did observe that more shrinkage fractures were caused by greater Red mud levels. However, by increasing elasticity and overall compressive strength, the addition of GGBS and lime helped to balance this.

In summary, the study demonstrated that red mud and other industrial by- products, such as GGBS, may be efficiently utilized to produce robust, environmentally friendly, and sustainable bricks. This provides a more environmentally friendly option for development in the future in addition to assisting in the more responsible management of industrial waste. The test results that back up this conclusion are as follows:

1. Dimensionality test of geopolymer bricks for length is 2.31m, width is 1.05m and depth is 0.88m which satisfies IS code 1077:1977.
2. Brick Density test of geopolymer bricks was 1620.1 kg/m³ which satisfies IS code 3495 :1976.
3. Water absorption of geopolymer bricks was around 11.12% and it is not higher than 20%, which satisfies IS code 3495 (Part 2):1992.
4. Compressive strength test of geopolymer bricks for 3days is 5.67MPa, 7days is 10.37MPa and 28days is 14.74MPa which satisfies the IS 3495 (Part 1):1992.
5. Flexural Strength of geopolymer brick for 3days is 0.35MPa, 7days is 0.46MPa and 28days is 0.66MPa which satisfies the ASTM C348:2014.
6. The X-ray Diffraction (XRD) analysis successfully identified the crystalline phase of sodium aluminosilicate hydrate (NaAlSiOH) in the synthesized geopolymer bricks.
7. The prominent XRD peaks at 2θ values of 24.3°, 42.8°, and 62.7° correspond to the expected crystalline phases, matching the standard diffraction data from JCPDS cards 42-0216 and 10-0420.
8. The presence of NaAlSiOH confirms the successful geopolymerization process, indicating effective interaction between the aluminosilicate source material and the alkaline activator.
9. Compression test on prism of geopolymer bricks is 3.95MPa and Shear Bonding Strength is 0.68MPa.
10. The study emphasizes Red Mud's potential as a sustainable substitute in the brick sector, offering a workable way to control waste while maintaining the performance and mechanical integrity of masonry products.

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