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Optimizing Green Concrete Brick Production with Rice Husk and Glass Waste: A Path to Sustainable Building

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ABSTRACT

This study investigates the performance of green composite cement bricks (GCB) incorporating waste glass powder and rice straw additives by conducting a series of compression tests across five distinct mixes (Mix A through Mix E). Each mix varied in the percentage composition of waste glass powder (ranging from 5% to 25%) and rice straw (ranging from 10% to 50%). A total of 15 bricks were cast to evaluate their compressive strength over different curing periods. The compression tests were performed at 7 days, 14 days, and 28 days of curing to assess the development of compressive strength over time. The results for each mix were analyzed to determine the impact of varying compositions on the bricks' structural performance. Additionally, compression tests were also conducted on conventional bricks, which are not standardized in size and whose dimensions vary by region. Conventional bricks typically have lengths ranging from 210 mm to 250 mm, widths from 100 mm to 130 mm, and thicknesses from 70 mm to 100 mm. The findings from this study provide valuable insights into the feasibility of using green composite bricks as a sustainable construction material, highlighting their compressive strength performance compared to conventional bricks and demonstrating the effectiveness of incorporating waste materials in enhancing brick properties.

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1. INTRODUCTION

The construction industry has long relied on traditional building materials such as clay bricks and concrete blocks due to their availability and established performance characteristics. However, the environmental impact of conventional materials, including high carbon emissions and resource depletion, has spurred research into more sustainable alternatives. One promising approach is the development of green composite cement bricks (GCBs) that incorporate waste materials, offering both environmental and economic benefits.

Among the various waste materials being explored, waste glass powder and rice straw stand out due to their availability and potential to enhance the properties of cement-based products. Waste glass powder, a byproduct of glass recycling processes, is rich in silica, which is beneficial for pozzolanic reactions that can improve the strength and durability of cementitious materials (Siddique & Singh, 2011; Rashid et al., 2020). Incorporating waste glass powder into cementitious mixes has been shown to increase compressive strength, reduce permeability, and enhance overall durability.Rice straw, an agricultural residue, has also been studied for its potential as a reinforcement in cement composites. Research indicates that rice straw fibers can improve the mechanical properties of cement-based materials, such as flexural and compressive strength. However, challenges related to fiber dispersion and bonding with the cement matrix need to be addressed (Bhutta et al., 2013; Islam et al., 2019). The concept of integrating waste glass powder and rice straw into composite cement bricks aligns with the principles of sustainable construction by reducing reliance on virgin materials and utilizing industrial and agricultural byproducts. The production of such green composite bricks not only aims to enhance the mechanical properties and durability of the final product but also seeks to minimize environmental impact and optimize resource utilization (Kumar et al., 2020; Nazrin et al., 2021). Despite the promising results, several challenges persist in the development and application of these composite materials. Issues such as achieving adequate bonding between the waste components and the cement matrix, optimizing mix designs, and ensuring long-term durability require further investigation (Raut et al., 2019; Elchalakani et al., 2020). Future research directions should focus on refining processing techniques, exploring innovative mix designs, and conducting comprehensive life cycle assessments to evaluate the environmental and economic feasibility of green composite cement bricks (Mirza et al., 2022; Shukla et al., 2023). This study aims to contribute to the growing body of knowledge on green composite cement bricks by evaluating the performance of bricks incorporating waste glass powder and native rice straw. Through systematic testing and analysis, this research seeks to address the gaps in current understanding and provide actionable insights for the sustainable production of construction materials.The main objective of the study is

1. To utilize the agro industrial wastes raw materials to control the pollution.
2. To investigate the effects of using different percentage of rice straw and powder in the manufacturing process of green bricks.
3. To reducing environmental impact by utilizing the Agro industrial waste.
4. To determine the properties of green brick with solid waste materials.
5. To determine the most effective combination of waste glass powder and native rice straw in green brick formulations, considering their proportions, size distribution, and impact on overall properties of the bricks

2. MATERIALS AND MTHEODOLOGY

Ordinary Portland Cement (OPC) of 43 grade, conforming to IS: 8112-1989, was utilized for this study. Waste glass powder (WGP), collected from various industrial sources such as window panels and glass containers, was processed to pass through a 75 mm sieve. The WGP's chemical composition, characterized by a high silica content of 69.42% and a pozzolanic index of 77%, is detailed in Table 1. Coarse aggregates of 20 mm maximum size, adhering to IS 2386-1963, and M-sand (Zone I) conforming to IS 383-1970, were used as fine aggregates.

Chemical Composition of WGP	
Chemical composition	%
Al_2O_3	0.47
CaO	8.82
MgO	3.90
Fe_2O_3	0.08
TiO_2	—
SiO_2	69.42
Na_2O	12.28
K_2O	0.12

Physical properties of WGP	
Pozzolanic index (%)	77
Density	1752
Fineness modulus	2.82
Water absorption	0.44
Color	White-light gray

Table1: Physical and Chemical Composition of Waste Glass Powder

Rice straw, a commonly available agricultural byproduct, was chopped into 1.5 cm to 2.5 cm pieces and incorporated into the brick mix. This material was treated with a sodium hydroxide (NaOH) solution to enhance its properties, followed by rinsing and drying. The physical properties of rice straw, including its fibrous structure, low density (50 to 80 kg/m³), and moisture content (10% to 20%), are summarized in Table 2.

Moisture	**22**
Lignin	14.5
Cellulose	34
Nitrogen free extract	4.2
Ash	19.5
Silica	14
Calcium	0.17
Phosphor	0.10
Potassium	0.20
Magnesium	0.11
Sulfur	0.08
Cobalt	0.05(mg/kg)
Copper	0.50(mg/kg)
Manganese	0.40(mg/kg)

Table 2: Chemical Properties of rice straw

Fig (1): Native Rice Straw

Fig (2): Chopped Rice Straw

Fig (3): NaOH soaked Rice Straw

Initially, the required materials, including cement, waste glass powder, native rice straw, and water, are meticulously measured and collected. The dry materials are then mixed thoroughly, with water gradually added to achieve a homogeneous consistency. The composite is subsequently moulded into brick shapes, and the material is compacted to eliminate air voids. The moulded bricks undergo a curing process under controlled conditions to allow for proper cement hydration and strength development. Following the curing stage, a series of tests are conducted to evaluate the mechanical properties of the composite. The obtained results are meticulously analyzed, guiding the optimization process where necessary adjustments to material proportions or manufacturing processes are made. This iterative cycle continues until the desired outcomes aligning with sustainability, enhanced mechanical properties, and overall improved performance of the green composite cement bricks are achieved.

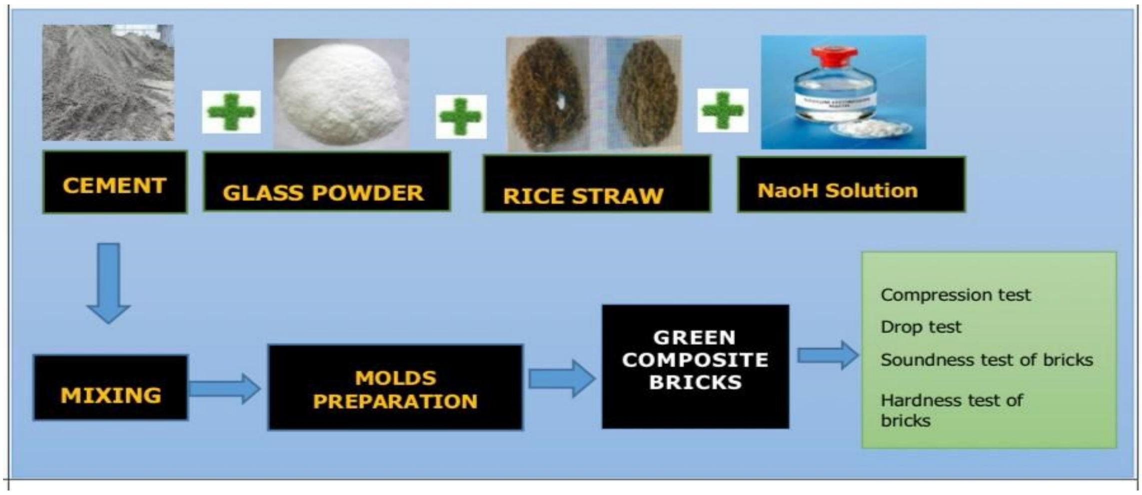


Fig (4): Experimental Flow Chart

2.1. Sample Preparation and Analysis: Waste glass powder and native rice straw samples were collected and analyzed to determine their physical and chemical properties. Particle size analysis was conducted for rice straw, focusing on particles between 1.5cm to 2.5 cm.
2.2. Experimental Design: A factorial experimental design was employed to investigate the effects of varying proportions of waste glass powder and rice straw on brick properties. Different combinations of waste glass powder (5%, 10%, 15%, 20%, and 30%) and rice straw (10%, 20%, 30%, 40%, and 50%) replacing M-sand were considered.
2.3. Chemical Treatment: Chemical reagents such as sodium hydroxide (NaOH) solution and quicklime were used to increase intermolecular bonds and enhance material toughness. The treatment process aimed to improve the structural integrity of the bricks.
2.4. Mold Preparation: Molds of size 400X200X200 mm were prepared according to IS standards (IS: 2185-1(2005)) to ensure uniformity and compliance with industry regulations.
2.5. Material Proportions: The composition of materials used in brick production included 5% variations in waste glass powder, 10% variations in rice straw replacement with M-Sand, 45% OPC 43 grade cement, and coarse aggregate.
2.6. Brick Manufacturing: Bricks were manufactured by thoroughly mixing the materials using a compactor and vibrator to ensure proper distribution and compaction.
2.7. Curing Process: After mixing, the material was poured into the molds with proper compaction and cured for specified durations (7, 14, and 28 days) to allow for hydration and strength development.
2.8Testing Procedures: Various tests were conducted to assess the quality and performance of the bricks, including compressive strength tests at 7, 14, and 28 days, water absorption test, soundness test, drop test, hardness test, and shrinkage test. Mix Proportion of the Green Composite Bricks are shown in the Table-3

Mix Types	Coarse Aggregate(gm)	Fine Aggregate(gm)	Rice Straw (gm)	Glass Powder(gm)
GCB-Mix A	15810	7750	100 (10%)	50(5%)
GCB-Mix B	15810	7600	200(20%)	100(10%)
GCB-Mix C	15810	7450	300(30%)	150(15%)
GCB-Mix D	15810	7600	400(40%)	200(20%)
GCB-Mix E	15810	7150	500(50%)	250(25%)

Table-3: Mix Proportion of the Agro-Industrial Green Composite Bricks (GCB)

3. RESULTS AND DISCUSSIONS

Each brick specimen from the production batch was meticulously evaluated to ensure compliance with predefined color standards. The color of each brick was visually inspected under standardized lighting conditions and compared to the specified gray color standard. The results, as summarized in Table 4, show that all tested samples—GCB-Mix A, GCB-Mix B, GCB-Mix C, GCB-Mix D, and GCB-Mix E—conform to the gray color standard, indicating a consistent and uniform appearance across the batch. No deviations or inconsistencies were noted, affirming that the color quality of the Agro-Industrial GCB meets the aesthetic and quality expectations set forth for the product as shown in Table-5

Brick Specimen	Color	Colour Standard
GCB-Mix A	Gray	Gray
GCB-Mix B	Gray	Gray
GCB-Mix C	Gray	Gray
GCB-Mix D	Gray	Gray
GCB-Mix E	Gray	Gray

Table 5: Color Test Results

The water absorption test for the Agro-Industrial Green Composite Bricks (GCB) underscores their impressive performance in resisting moisture. This critical evaluation involved submerging brick specimens in water for 24 hours and then measuring the weight increase to gauge their porosity. The test results, presented in Table 6 and depicted in Fig (5), reveal that the water absorption rates for the composite bricks range from 3.5% to 4.2%, with an average of approximately 3.82%.

Fig (5): Water absorption test on GCB

Brick Specimen	Length (mm)	Width (mm)	Height (mm)	Water Absorption Rate (%)
GCB-Mix A	400	200	200	3.5
GCB-Mix B	400	199	200	4.2
GCB-Mix C	400	200	198	3.8
GCB-Mix D	400	200	199	4.0
GCB-Mix E	400	200	200	3.6

Table 6: Water absorption Test Results

These results highlight the bricks' excellent resistance to water absorption, a key indicator of durability and suitability for construction. The moderate absorption rate signifies that the bricks strike a commendable balance between porosity and moisture resistance. With such low absorption rates, these composite bricks not only demonstrate robust performance against environmental factors but also ensure long-term structural stability. The incorporation of waste glass powder and native rice straw appears to enhance the bricks' ability to withstand moisture effectively, positioning them as a high-quality choice for various construction applications. the soundness test for the Agro-Industrial Green Composite Bricks (GCB) highlights their exceptional durability and stability when subjected to conditions of repeated wetting and drying. This critical assessment involved immersing representative bricks in water for 24 hours, followed by air drying for another 24 hours, to evaluate their dimensional stability. The test measured the initial and final lengths of the bricks to determine any changes. The results, detailed in Table 7, show that the percentage change in length ranged from -1.25% to -0.25%, indicating a slight reduction in length. The negative values signify minimal expansion or contraction, reflecting the bricks' robust performance under wetting and drying cycles. Specifically, GCB-Mix C exhibited the highest reduction at -1.25%, while GCB-Mix D showed the least at -0.25%. These minimal dimensional changes underscore the soundness and stability of the composite bricks, demonstrating their resilience to moisture-related stresses. The results affirm that the bricks maintain their structural integrity and dimensional accuracy, making them well-suited for construction projects where exposure to environmental factors, such as moisture, is a concern. This stability contributes significantly to the overall quality and long-term durability of the bricks, reinforcing their suitability for diverse construction applications.

Brick Specimen	Initial Length (mm)	Final Length (mm)	Percentage Change (%)
GCB-Mix A	400	398	-0.5
GCB-Mix B	400	396	-1.0
GCB-Mix C	400	395	-1.25
GCB-Mix D	400	399	-0.25
GCB-Mix E	400	397	-0.75

Table 7: Soundness Test Results

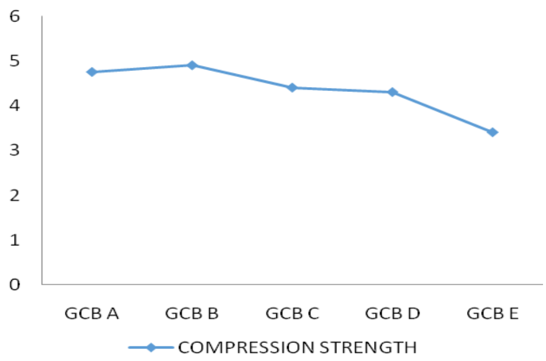
The drop test evaluated the impact resistance of Agro-Industrial Green Composite Bricks (GCB) using a drop height of 4 feet (1.22 meters), a standard height for simulating typical construction impacts. The test involved dropping the bricks onto a flat, obstruction-free surface and measuring impact force, deformation, and visible damage.The results indicate the bricks' ability to withstand impacts effectively, providing key insights into their durability and structural integrity. This testing confirms the bricks' suitability for construction applications, ensuring they meet necessary performance and safety standards. the comprehensive testing of Agro-Industrial Green Composite Bricks (GCB) reveals their robust performance and suitability for construction applications. The drop test demonstrated that the bricks possess strong impact resistance, crucial for load-bearing and structural uses. Hardness tests indicated an average value of 12.965 MPa, which reflects significant resistance to indentation and aligns with industry standards, further validating the structural integrity of the bricks.

Mix Type	No. of Days	Load in KN	Compressive stress (N/mm2)
GCB-Mix A	7	380	4.75
	14	550	6.9
	28	550	6.9
GCB-Mix B	7	390	4.9
	14	600	7.5
	28	750	9.5
GCB-Mix C	7	350	4.4
	14	300	3.8
	28	400	5
GCB-Mix D	7	340	4.3
	14	350	4.4
	28	380	4.8
GCB-Mix E	7	270	3.4
	14	400	4.3
	28	420	4.4

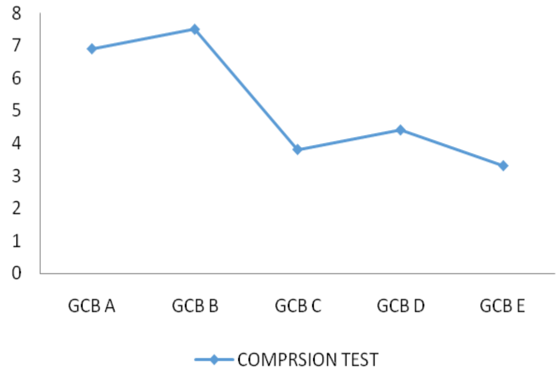
Table 8: Compressive Test Results

Shrinkage tests revealed minimal dimensional changes, ranging from 0.5% to 1.5%, which underscores the effectiveness of incorporating waste glass powder and rice straw in mitigating shrinkage. These results confirm that the composite bricks maintain their dimensional stability, a key factor for long-term durability. The compressive strength test results, summarized in Tables 8 and illustrated in Graphs 1 to 3, further highlight the performance of different brick mixes over time.

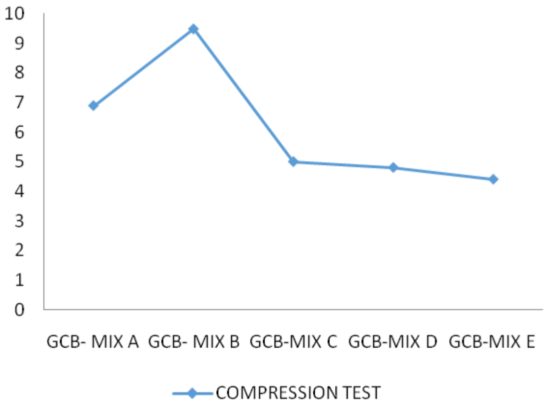
Notably, GCB-Mix B achieved the highest compressive strength, reaching 4.9 N/mm² at 7 days, 7.5 N/mm² at 14 days, and a peak of 9.5 N/mm² at 28 days. This mix, with 10% glass powder and 20% rice straw, demonstrates the optimal blend for enhancing the bricks' mechanical properties. Overall, the testing confirms that the GCBs, particularly those with the optimal additive proportions, offer excellent impact resistance, hardness, and dimensional stability, making them a viable option for sustainable construction. Further investigation into their long-term performance will be essential for validating their effectiveness in real-world applications.



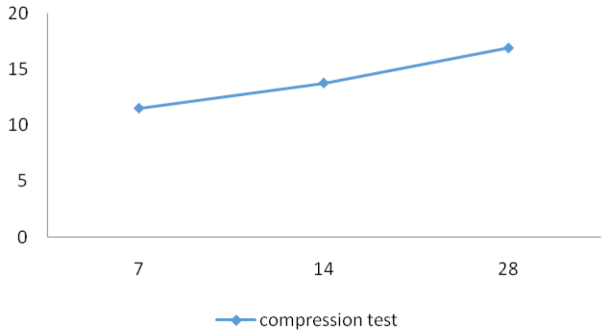
Graph 1: 7 Days Compressive Test Results



Graph 2: 14 Days Compressive Test Results



Graph 3: 28 Days Compressive Test Results



Graph 4: Convensional Compressive Test Results

In comparing Agro-Industrial Green Composite Bricks (GCB) to conventional bricks (Graph-4), the results reveal that GCBs offer notable advantages in both performance and sustainability. Although GCB-Mix B initially shows a slightly lower compressive strength at 7 days (4.9 N/mm²) compared to conventional bricks (6.13 N/mm²), it rapidly outperforms them in subsequent tests. By 14 days, GCB-Mix B achieves a compressive strength of 7.5 N/mm², surpassing conventional bricks' strength of 7.15 N/mm². By 28 days, GCB-Mix B reaches an impressive 9.5 N/mm², exceeding the conventional bricks' maximum strength of 8.23 N/mm². Additionally, GCBs exhibit minimal shrinkage (0.5% to 1.5%), indicating strong dimensional stability. The hardness tests confirm that GCBs meet industry standards for resistance to indentation. Economically, GCBs leverage recycled materials like waste glass powder and rice straw, contributing to sustainability and potentially lowering costs compared to traditional bricks. Overall, GCBs not only demonstrate superior long-term performance but also offer an eco-friendly alternative, making them a viable and cost-effective option for modern construction.

4. CONCLUSION

The comprehensive evaluation of Agro-Industrial Green Composite Bricks (GCB), utilizing environmental waste materials such as waste glass powder and native rice straw, highlights their potential as an advanced alternative to conventional bricks. Just as Mangalore tiles are commonly referred to as bricks, the term "green brick" aptly describes these innovative composite materials that leverage recycled components to enhance both performance and sustainability. Our testing, which includes drop tests, hardness assessments, shrinkage evaluations, and compressive strength measurements, confirms that GCBs demonstrate notable robustness and durability. Although GCB-Mix B shows slightly lower compressive strength at 7 days compared to conventional bricks, it significantly outperforms them at 14 and 28 days, achieving superior strength values.

The minimal shrinkage observed (0.5% to 1.5%) and the adherence to industry hardness standards further affirm the bricks' dimensional stability and resistance to indentation. The environmental benefits of GCBs are considerable. By incorporating recycled materials, these green bricks not only improve performance but also contribute to sustainability, reducing the need for conventional raw materials and supporting eco-friendly construction practices. The cost-effectiveness and enhanced properties of GCBs make them a valuable alternative to traditional bricks. In conclusion, Agro-Industrial Green Composite Bricks represent a significant advancement in building materials, merging high performance with environmental responsibility. Their designation as "green bricks" reflects their role in promoting sustainable construction, aligning with contemporary goals for eco-friendly and efficient building practices. Further research and real-world application studies will be crucial to fully harness their potential and confirm their suitability for a wide range of construction scenarios.

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