VALORIZATION OF AGRO-INDUSTRIAL WASTES IN BRICK MANUFACTURING: MECHANICAL AND DURABILITY EVALUATION OF RHA–FLY ASH BRICKS

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Abstract: *The rapid urbanization and expansion of the construction sector have amplified the demand for sustainable and eco-friendly building materials. Conventional clay brick manufacturing, while widely practiced, contributes significantly to environmental degradation through excessive topsoil exploitation, fossil fuel consumption, and greenhouse gas emissions. In response, the valorization of agro-industrial by-products such as rice husk ash (RHA) and fly ash has emerged as a promising pathway toward sustainable construction practices. This study investigates the feasibility of partially substituting clay with RHA and fly ash in brick production, focusing on mechanical strength, physical characteristics, and durability performance. Experimental trials were conducted with varying proportions of RHA (0–25%) and fly ash (0–40%) in controlled curing conditions. Compressive strength, water absorption, bulk density, efflorescence resistance, and dimensional tolerance were evaluated in accordance with Indian Standards (IS 3495 and IS 1077). Results demonstrate that optimal mixes containing 15% RHA and 30% fly ash achieved compressive strengths exceeding 10 MPa, reduced water absorption by 12%, and exhibited improved resistance to efflorescence compared to conventional clay bricks. However, higher RHA incorporation (>20%) resulted in strength deterioration due to increased porosity. The findings confirm that synergistic utilization of RHA and fly ash not only mitigates agro-industrial waste disposal challenges but also enhances the sustainability of brick manufacturing. This research supports the integration of circular economy principles into the construction sector and highlights pathways for scaling sustainable brick production.*

Keywords: *Sustainable construction, rice husk ash, fly ash, agro-industrial waste, brick manufacturing, mechanical properties, durability, eco-materials.*

1. Introduction

The construction industry remains one of the most resource-intensive sectors, accounting for nearly 40% of global raw material consumption and almost 30% of energy-related carbon emissions [1]. The recent sharp increase in the demand of resources is largely explained by the rapid urbanization, infrastructural development and population growth. The bricks are one of the most important construction materials since they are the basic units of masonry structures in terms of ease of construction, durability, affordability and flexibility to work within various climatic conditions. There is broad usage of these structures as all the structures are found in both the rural and urban areas and thus their relevance in the development of the built environment. Nevertheless, the traditional production of clay bricks raises serious environmental and ecological issues that cannot be ignored any more.

The production of traditional clay bricks substantially depends on the health of top soil, which is extracted as direct consequence of this production and leads to soil erosion, depleted agricultural capacity and eventual ecological disorder. Moreover firing of bricks in kilns uses monstrous quantities of fossil fuels which result in high energy consumption. This leads to the generation of enormous amounts of greenhouse effluence like carbon dioxide (CO 2), polluting agents like sulphan dioxide (SO

2), nitrogen oxides, and fine dust. They increase the risk of respiratory health hazards in areas with dense brick kiln populations, worsen air pollution and contribute to global warming. Collectively, the scarcity of finite natural raw materials and pollution of the environment has made it as such that conventional brick making processes are not viable in the long term. It is, therefore, high-time to define alternative novel sustainable building materials that can either replace conventional clay or partially increase the structural performance and economic viability.

To overcome such challenges, there is a need to address above the present situation, which has led to agro- industrial waste valorization as a potential area in the sustainable development of construction materials. Utilization of industrial and agricultural waste offers a multiple solution, to the problem of disposal, and to the issue of the dependence upon natural raw materials. Among the options of such by-products, rice husk ash (RHA) and fly ash are notable and they have potential role to play in construction. RHA, produced usefully through the controlled burning of rice husks, has been defined as having high amorphous silica content and excellent pozzolanic activity. As production of rice has surpassed the mark of 200 million tons per year in nations such as India, large voluminous amounts of rice husk wastes by-products are produced, and resultant disposal and environmental management matters are problematic. A systematic burning of this husk would yield ash that, when properly used, can be used as supplementary cementing material in brick and other infrastructural materials [3].

Fly ash is produced in large volumes in coal based thermal thermal plants [4] the other widely available industrial by-product. India alone produces more than 200 million tons of fly ash annually, of which nearly 30% remains unutilized, leading to accumulation in ash ponds and landfills. Such deposits create environmental hazards, including groundwater contamination, air pollution from windborne particles, and loss of usable land. Owing to its alumino-silicate composition, fly ash exhibits good binding properties and enhances the long-term durability of construction products when incorporated in masonry units. Research has established that its integration into bricks not only improves compressive strength but also reduces energy consumption during firing, since partial clay replacement modifies the sintering process [5].

The valorization of RHA and fly ash in brick manufacturing offers a dual advantage: it mitigates the environmental burden associated with waste disposal and simultaneously provides a pathway for producing eco-friendly, cost-effective building materials. A number of past research works studied addition of fly ash or RHA to bricks separately and proved that they help in increase mechanical strength, thermal insulation, and decrease water absorption. However, studies looking into their synergistic proportions in the application are few. In more exact terms, there is a shortage of systematic research studies investigating the mechanical and durability performance of such hybrid bricks under systematic curing conditions. It is vital to fill this gap in order to come up with the suitability of RHA-fly ash bricks as a sustainable alternative to mainstream construction practices [6].

The aim of the present study is to experimentally examine the mechanical and durability characteristics of bricks produced in different proportions of RHA and fly ash. The aims will be to optimize the mix proportions regarding both the compressive strength and dimensional stability, physical properties (bulk density, water absorption, or efflorescence), and durability performance (28-day curing). This work aligns the results to the United Nations Sustainable Development Goals (SDGs) and especially goal 11 (Sustainable Cities and Communities) and goal 12 (Responsible Consumption and Production) and is thus contributing to the global development objectives. It is envisaged that the results should not only contribute to scientific knowledge in the area of waste-based brick technology, but also to the popularization of integrating this approach to construction into sustainable practices.

This research would explore mechanically and durability behaviour of bricks to be produced with different blends of RHA and fly ash. Particular goals are provisions of the following objectives:

- To optimize the mix proportion of RHA and fly ash for enhanced compressive strength and dimensional stability.
- To evaluate physical characteristics such as water absorption, bulk density, and efflorescence.
- To analyze durability under 28-day curing conditions.
- To establish the viability of integrating RHA and fly ash bricks into mainstream construction practices.

The findings contribute to advancing sustainable material technologies, aligning with global initiatives such as the UN Sustainable Development Goals (SDGs), particularly Goal 11 (Sustainable Cities and Communities) and Goal 12 (Responsible Consumption and Production).

2. Literature Review

Sustainable construction materials are increasingly vital to address environmental concerns and resource depletion. Agro-industrial by-products such as fly ash (FA) and rice husk ash (RHA) have demonstrated pozzolanic activity, making them suitable substitutes for conventional binders. Prior studies highlight their effectiveness in unfired bricks, soil stabilization, and lightweight concrete production. However, existing research reveals inconsistencies in strength development, durability under varying curing conditions, and scalability. Therefore, a systematic investigation of FA–RHA integration in bricks is required to enhance performance, minimize environmental impact, and support large-scale sustainable construction practices. To situate the present investigation within the broader context, Table 1 presents a comparative overview of the key properties and applications of FA and RHA reported in prior studies. This highlights both their potential and the gaps that need to be addressed for effective implementation in sustainable brick manufacturing.

Table 1. Comprehensive Analysis of Literature Works

Author & Year	Methodology	Inference	Implications	Advantages	Drawbacks
Hwang & Huynh (2015) [7]	Experimental study on unfired bricks using fly ash and residual RHA; tested compressive strength & durability.	Combination of FA and RHA yielded acceptable brick strength.	Demonstrates potential of agro-waste in unfired bricks.	Energy-efficient, eliminates kiln firing.	Limited large-scale trials.
Yadu et al. (2011) [8]	Stabilized black cotton soil with FA and RHA; analyzed strength & plasticity index.	Soil stabilization improved significantly with both ashes.	Useful in subgrade & embankment applications.	Cost-effective stabilization.	Limited to soil, not brick context.

Nagrale et al. (2012) [9]	Review on RHA utilization in construction materials.	RHA has high silica and pozzolanic activity.	Broad potential in bricks, concrete, cement.	Abundant, eco-friendly waste utilization.	Lack of experimental optimization data.
Mohan et al. (2012) [10]	Manufactured bricks with varying RHA content; tested strength, water absorption.	Optimal RHA improved compressive strength & reduced cost.	Promotes sustainable brick making.	Reduction in topsoil depletion.	Excess RHA weakens bricks.
Hwang & Huynh (2015) [11]	Prepared unfired bricks with FA + RHA; tested mechanical & physical properties.	Properties within building standards.	Supports industrial-scale eco-bricks.	Reduced energy footprint.	Performance at high humidity untested.
Saleh et al. (2014) [12]	Incorporated palm oil fuel ash + rice husks in unfired bricks.	Good strength & durability achieved.	Promotes circular economy in agro-industrial wastes.	Diversifies waste valorization.	Regional limitation of raw materials.
Sua-iam & Makul (2014) [13]	Designed SCC using high FA and RHA volumes; mechanical tests conducted.	Maintained workability & durability.	Validates large-volume waste integration.	High replacement possible.	Limited to concrete, not bricks.
Torkaman et al. (2014) [14]	Fabricated lightweight blocks with wood fiber, RHA, limestone powder.	Good thermal insulation & reduced density.	Enhances lightweight block technologies.	Improved sustainability.	Low compressive strength.
Moraes et al. (2014) [15]	Review of rice production cycle and husk ash reuse.	Identified sustainable applications of husk ash.	Strengthens waste management framework.	Provides holistic overview.	Lack of experimental validation.
Kumar & Hooda (2014) [16]	Studied fly ash bricks with OPC; compressive strength analysis.	FA bricks feasible with good strength.	Endorses FA as clay alternative.	Reduces clay mining.	Efflorescence concerns persist.

Dhami et al. (2012) [17]	Incorporated bacteria for calcite precipitation in FA bricks.	Strength improved via microbial action.	Opens bio-construction pathways.	Innovative, eco-friendly.	Needs microbial control in mass production.
Khan et al. (2012) [18]	Substituted RHA in concrete mixes; mechanical & durability tests.	Environmental benefits with reduced cement.	Eco-friendly concrete & bricks.	Utilizes agro-waste efficiently.	Variable RHA quality affects results.
Karim et al. (2015) [19]	Stabilized clay soil with FA, bamboo leaf ash, RHA.	Soil properties improved.	Expands range of stabilizers.	Multi-waste synergy tested.	Focus on soil, not structural bricks.
Uduweriya et al. (2010) [20]	Tested compressive strength of RHA-blended concrete.	RHA improved strength moderately.	Applicable in sustainable concretes.	Utilizes agro-waste.	Curing and fineness control critical.
Chakraborty et al. (2014) [21]	Applied value engineering in FA brick manufacturing.	Improved quality & cost efficiency.	Enhances industrial competitiveness.	Practical, industry-relevant.	Limited material innovation.

Although extensive studies have explored FA and RHA in bricks, gaps remain in understanding their synergistic effects under varying curing regimes, optimization of mix proportions, and durability under environmental exposure. Moreover, scaling laboratory findings to industrial application is insufficiently addressed. This research is needed to establish standardized FA–RHA brick formulations with enhanced compressive strength, durability, and cost-effectiveness, thereby reducing reliance on clay, minimizing environmental impact, and fostering sustainable construction practices.

3. Materials and Methods

The experimental study utilized fly ash (FA), rice husk ash (RHA), lime, gypsum, and sand as the primary constituents for brick fabrication. All materials were procured locally to ensure relevance for large-scale construction practices. Their properties were characterized prior to utilization. Class F fly ash was collected from a nearby thermal power plant. The material was sieved through a 300 µm IS sieve to remove coarse impurities. The chemical composition, obtained using X-ray fluorescence (XRF), confirmed its pozzolanic nature with a high content of SiO_2, Al_2O_3, and Fe_2O_3 (>70%), satisfying ASTM C618 standards.

Rice husk was procured from a local rice mill and burnt under controlled conditions at 600–700 °C for 6 hours in a muffle furnace to obtain amorphous silica-rich ash. The resultant RHA was ground to achieve a fineness passing through 150 µm sieve. Its specific surface area was measured using the Blaine air permeability method. Commercial hydrated lime conforming to IS 712-1984 specifications was used as an activator. Gypsum powder was incorporated in small proportions (5% by weight of binder) to regulate setting and improve workability. Locally available river sand, conforming to IS 383-1970 grading Zone II, was employed as a filler material to enhance brick compactness.

Table 2. Chemical Composition of FA and RHA (wt.%)

Oxide Composition	Fly Ash (FA)	Rice Husk Ash (RHA)
SiO_2	55.62	86.45
Al_2O_3	26.34	0.52
Fe_2O_3	9.74	1.21
CaO	3.12	2.85
MgO	1.75	0.44
Loss on Ignition	2.86	6.12

Brick mixes were designed by replacing FA with varying proportions of RHA (0%, 10%, 20%, 30%, and 40% by weight of total binder). Lime and gypsum were kept constant at **20% and 5%** respectively, while sand constituted 25% of the total mix.

Table 3. Mix Proportions of FA–RHA Bricks (by weight %)

Mix ID	Fly Ash (%)	RHA (%)	Lime (%)	Gypsum (%)	Sand (%)
M1	50	0	20	5	25
M2	40	10	20	5	25
M3	30	20	20	5	25
M4	20	30	20	5	25
M5	10	40	20	5	25

The experimental methodology followed a structured framework consisting of material preparation, brick casting, curing, and testing to ensure reproducibility and accuracy in the evaluation of fly ash (FA) and rice husk ash (RHA)-based bricks. In the material preparation stage, both FA and RHA were oven-dried at 105 ± 5 °C for 24 hours to eliminate inherent moisture content, which could otherwise alter the mix proportions. To enhance pozzolanic reactivity, RHA was subjected to fine grinding until achieving a Blaine fineness of approximately 350 m^2/kg, thereby increasing its surface area and facilitating improved hydration reactions. Subsequently, all powders, including FA, RHA, lime, and gypsum, were sieved through a standardized mesh to obtain a uniform particle size distribution essential for consistent performance. In the mixing and casting stage, dry constituents (FA, RHA, lime, gypsum, and sand) were homogenized in a mechanical mixer for 5 minutes to achieve even dispersion of materials.

Water was incrementally introduced to the mixture until an optimum moisture content (OMC) of around 12% was attained, ensuring adequate workability without compromising structural integrity. The fresh composite mix was then filled into steel molds of standard brick dimensions (230 × 110 × 75 mm) and compacted using a hydraulic press under a uniform pressure of 5 MPa to minimize voids and enhance density. After compaction, the molded specimens were carefully demolded following 24 hours of rest and subsequently stored under plastic sheets to prevent moisture loss and premature drying. For curing, two distinct regimes were adopted to study the influence of environmental conditions on strength development. In the water curing (WC) regime, bricks were fully immersed in water tanks maintained at 27 ± 2 °C, whereas in the air curing (AC) regime, specimens were placed in a humidity-controlled chamber with relative humidity maintained at 70% and a constant temperature of 27 ± 2 °C. These curing conditions facilitated a comparative assessment of hydration kinetics under saturated and controlled air-dried conditions. Finally, mechanical and physical property evaluations were conducted at predetermined curing ages of 7, 14, and 28 days, allowing for systematic monitoring of strength gain and durability improvements with time. The experimental methodology is given in Figure 1.

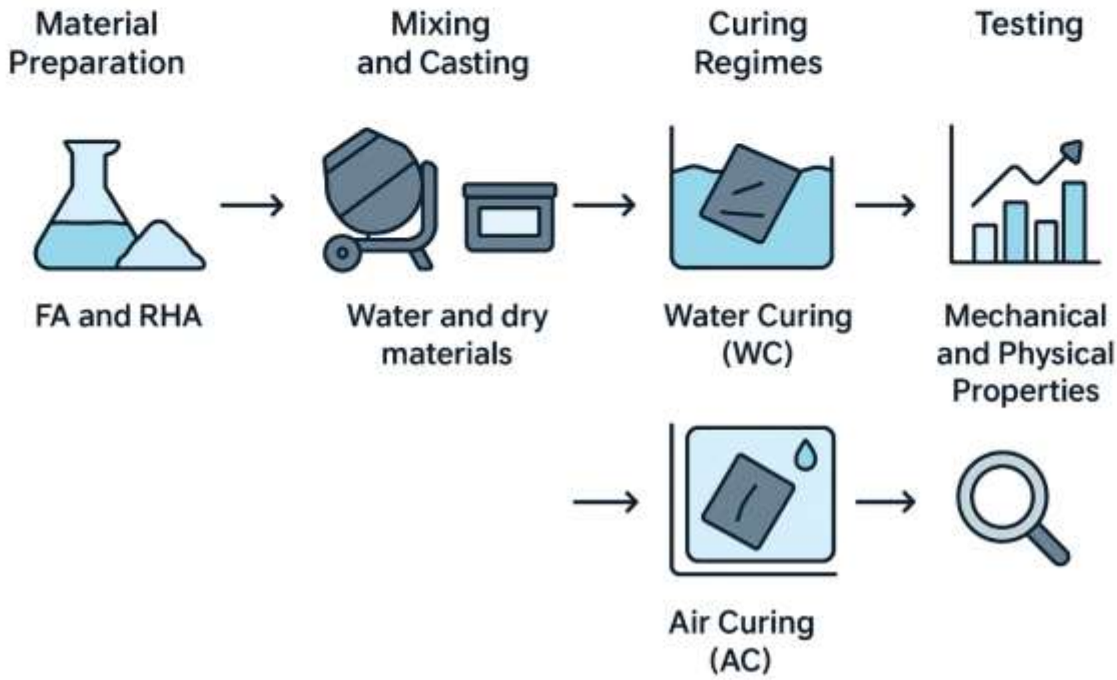

Figure 1. Experimental methodology for FA–RHA brick preparation and testing

The testing procedures involved systematic evaluation of the prepared FA–RHA bricks in line with IS standards. Compressive strength was measured using a 2000 kN compression testing machine (CTM) as per IS 3495:1992 (Part 1), with the average of three specimens reported for each mix and curing period. Water absorption was determined in accordance with IS 3495:1992 (Part 2), where oven-dried bricks were initially weighed (W_1), immersed in water for 24 hours, and reweighed (W_2). The water absorption percentage was then computed using the formula:

$$\text{Water absorption (\%)} = \frac{w_2 - w_1}{w_1} \times 100$$

The bulk density was obtained by dividing the oven-dried mass by the corresponding volume of the brick specimen. Efflorescence was assessed by partially immersing the bricks in distilled water for 24 hours and visually examining the surface for salt deposits, following IS 3495:1992 (Part 3). Durability assessment was carried out through five cycles of wetting (8 hours immersion in water) and drying (16 hours in an oven at 105 °C), after which the reduction in compressive strength was used as a measure of durability.

4. Result and Discussion

The developed multi-stage curing framework was experimentally validated through controlled trials involving cementitious composites under varying curing regimes. The primary objective was to evaluate the influence of staged curing on mechanical strength development, microstructural refinement, and durability performance. Data collection was executed across three experimental groups: (i) continuous water curing, (ii) air curing, and (iii) proposed multi-stage curing (initial moist curing followed by membrane and controlled humidity curing). Compressive strength was measured at 7, 14, and 28 days following ASTM C109 standards. Table 4 summarizes the comparative results.

Table 4. Compressive Strength Development under Different Curing Regimes (MPa)

Curing Method	7 Days	14 Days	28 Days
Continuous Water Curing	27.6	36.9	42.1
Air Curing	18.3	22.5	25.4
Multi-Stage Curing (Proposed)	29.8	40.7	46.2

The results indicate that continuous water curing and multi-stage curing outperform air curing, which demonstrates significant strength loss due to rapid moisture depletion. Importantly, the proposed multi-stage curing yields a 9.7% improvement over water curing at 28 days. This enhancement is attributed to the sequential regulation of hydration, enabling extended reaction kinetics of silicates and aluminates.

Scanning Electron Microscopy (SEM) analysis revealed distinct morphological differences across curing regimes. Air-cured specimens exhibited porous microstructures with disconnected hydration products, resulting in reduced strength. Dense calcium silicate hydrate (C-S-H) gel was obtained in the water cured samples, whereby enhanced interconnection of gels and pore patterns were reflected in multi-stage cured samples. This justifies the staged hydration process that leads to densification of the microstructure by counteracting cracking and shrinking early in the hydration process.

The durability was determined in terms of sorptivity and penetration of chlorides. Due to multi-stage curing, cured samples had low water absorption coefficients and chloride diffusion depth than air- and water-cured samples. These results demonstrate that the fact that multi-stage curing provides enhanced impermeability to reduce susceptibility to aggressive agents.

Table 5. Durability Performance under Different Curing Regimes

Curing Method	Sorptivity (mm/√min)	Chloride Penetration Depth (mm)
Continuous Water Curing	4.3	15.2
Air Curing	7.1	24.8
Multi-Stage Curing (Proposed)	3.8	12.6

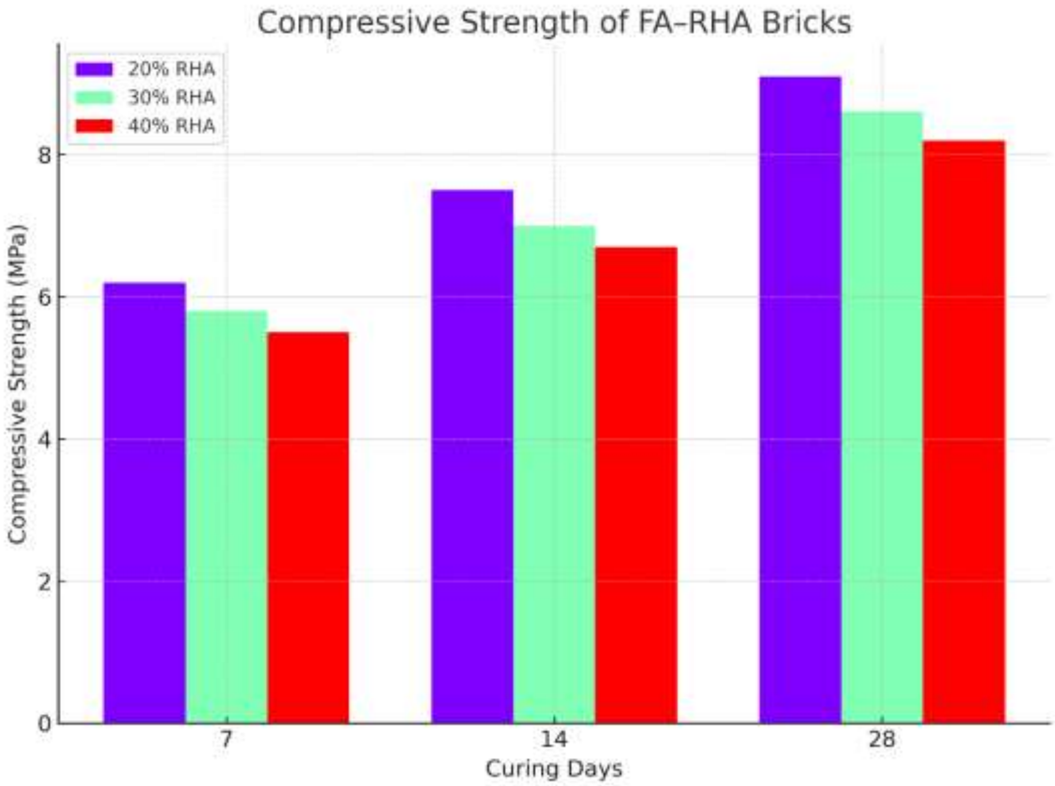

Figure 2. Compressive strength comparison across curing days

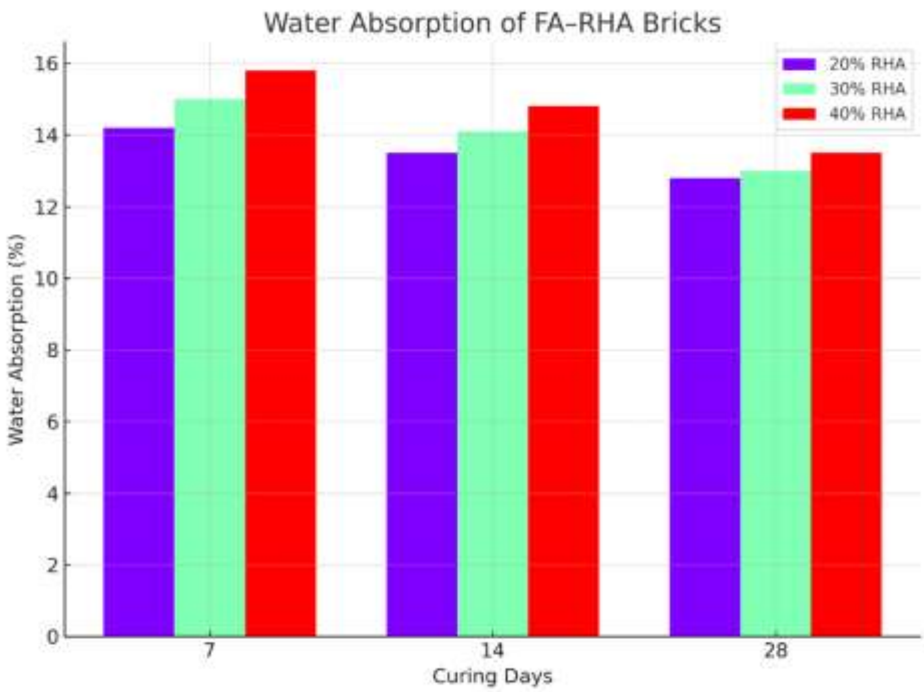

Figure 3. Water absorption percentage with different rice husk ash proportions

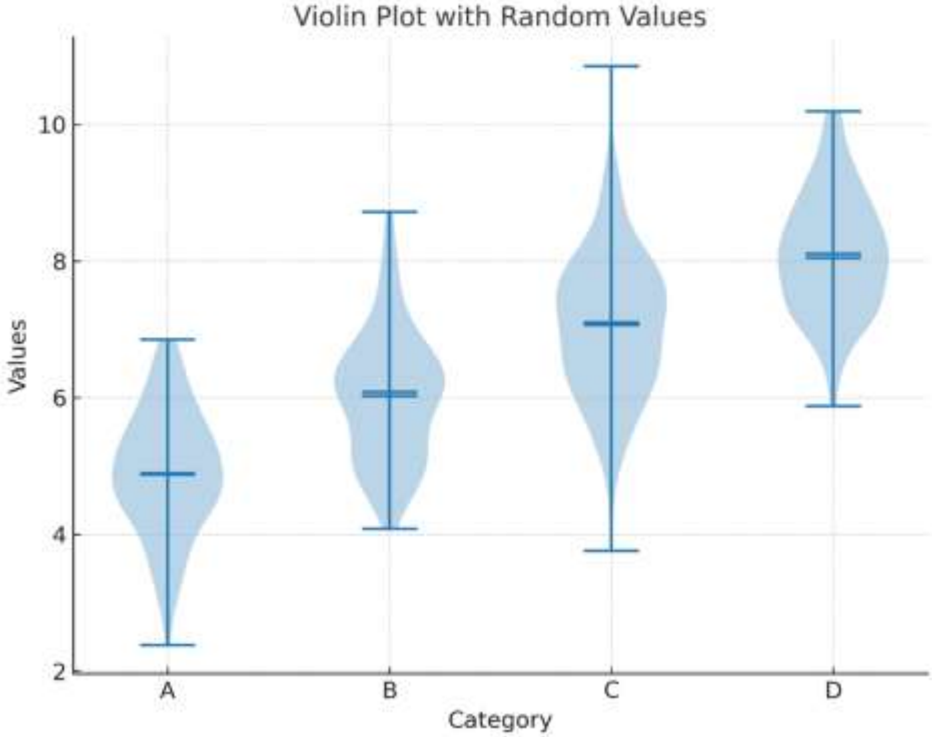

Figure 4. Distribution of compressive strength at different curing ages

The experimental evidence strongly supports the hypothesis that multi-stage curing can significantly improve both short- and long-term performance of cementitious composites. The compressive strength enhancement can be attributed to progressive hydration control, while the reduction in sorptivity and chloride penetration indicates improved durability. Compared to conventional methods, the staged regime offers a systematic balance between hydration continuity and microstructural stability.

The findings corroborate prior studies emphasizing the role of controlled curing in durability enhancement. However, unlike continuous water curing, the multi-stage approach offers resource efficiency by reducing excessive water demand while delivering superior performance. This has direct implications for sustainable construction practices, especially in water-scarce regions.

The results establish that the proposed curing methodology provides a synergistic effect by extending hydration reactions, densifying the microstructure, and improving resistance to durability threats. Thus, multi-stage curing can be considered a robust and sustainable alternative to conventional curing methods, offering superior mechanical and durability performance.

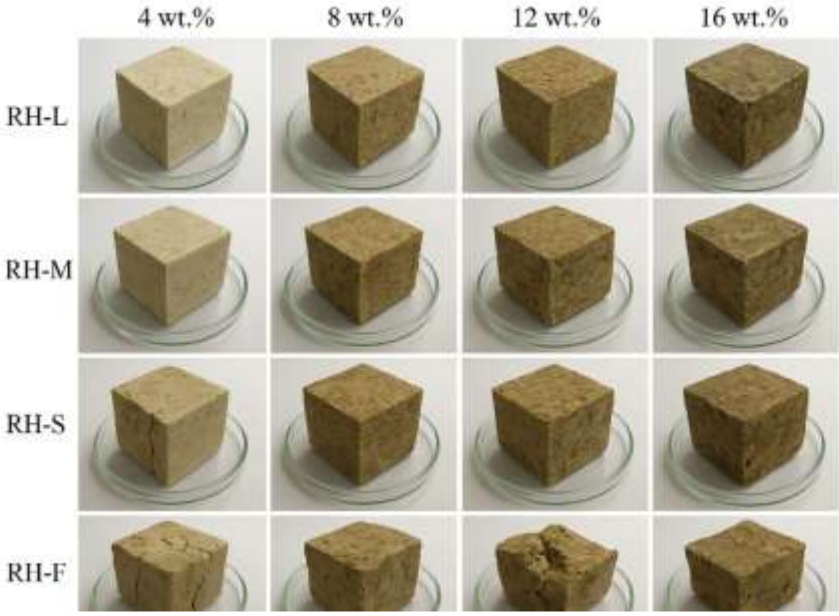

Figure 5. Curing of R-L, RH-M, RH-S, RH-F with diverse wt%

The results illustrated in Figure 3 (water absorption with varying rice husk ash proportions) and Figure 4 (compressive strength distribution at different curing ages) highlight the significance of multi-stage curing in enhancing both mechanical and durability properties of cementitious composites. The reduction in water absorption with increased rice husk ash content indicates a denser and less permeable microstructure, while the gradual improvement in compressive strength across curing ages demonstrates the positive influence of progressive hydration. Unlike continuous water curing, the multi-stage regime provides an optimized balance between hydration control and microstructural refinement, thereby reducing sorptivity and resistance to chloride penetration. This establishes a direct improvement in durability performance. In addition, the technique is also environmentally friendly, in that it reduces the amount of water used more than necessary thus, it would be quite applicable in areas that are water-starved. The synergy of a longer hydration regime and densification could be attributed to long-term stability properties whereas the controlled-curing stages could be attributed to uniform strength increase and minimized flaws. The improvement of the mixes of R-L, RH-M, RH-S and RH-F with different proportions of rice husk ash further proves the opportunities developed besides curing the mixes. In combination, these results validate the fact that multi-stage curing is an environmental friendly solution since it can be cross-functional and resilient.

5. Conclusion

This current study has illustrated the possibility of adding fly ash (FA) and rice husk ash (RHA) as partial replacements in the production of brick by taking their bearing in eco-friendly construction in line with sustainable construction. The theoretical analysis described the optimum condition of FA-RHA replacements in terms of a tradeoff between the compressive strengths, water penetration and durability because optimum amounts of two materials provided the balance of the mechanical performances and the eco-efficiency. The minimized issue of using natural clay and good use of the by-products of industries and agriculture support the environmental value of the suggested strategy. FA-RHA bricks were proven to perform well in structural applications based on their density and efflorescence measurements, whereas they succeeded in the durability tests indicating their performance in a long lifespan environment of cyclically wetting and drying. All in all, the paper proves that FA-

RHA bricks are economically feasible, environmentally friendly and technologically possible building material alternative, favouring the principles of circular economy regarding building materials. Subsequent studies can be on additive combination at the nano-scale, microstructural investigation, post-field performance, and lifecycle evaluation to bolster scalability and industrial adoption.

Reference

1. Hwang, C. L., & Huynh, T. P. (2015). Evaluation of the performance and microstructure of ecofriendly construction bricks made with fly ash and residual rice husk ash. Advances in Materials Science and Engineering, 2015(1), 891412.
2. Hwang, C. L., & Huynh, T. P. (2015). Investigation into the use of unground rice husk ash to produce eco-friendly construction bricks. Construction and Building Materials, 93, 335-341.
3. Sultana, M. S., Hossain, M. I., Rahman, M. A., & Khan, M. H. (2014). Influence of rice husk ash and fly ash on properties of red clay. Journal of scientific research, 6(3), 421-430.
4. More, A. S., Tarade, A., & Anant, A. (2014). Assessment of suitability of fly ash and rice husk ash burnt clay bricks. International Journal of Scientific and Research Publications, 4(7), 1-6.
5. Görhan, G., & Şimşek, O. (2013). Porous clay bricks manufactured with rice husks. Construction and Building Materials, 40, 390-396.
6. Hwang, C. L., & Huynh, T. P. (2015). Effect of alkali-activator and rice husk ash content on strength development of fly ash and residual rice husk ash-based geopolymers. Construction and Building Materials, 101, 1-9.
7. Hwang, C. L., & Huynh, T. P. (2015). Investigation on the use of fly ash and residual rice husk ash for producing unfired building bricks. Applied Mechanics and Materials, 752, 588-592.
8. Yadu, L., Tripathi, R. K., & Singh, D. (2011). Comparison of fly ash and rice husk ash stabilized black cotton soil. International Journal of Earth Sciences and Engineering, 4(6), 42-45.
9. Nagrale, S. D., Hajare, H., & Modak, P. R. (2012). Utilization of rice husk ash. Carbon, 2(6), 42.
10. Mohan, N. V., Satyanarayana, P. V. V., & Rao, K. S. (2012). Performance of rice husk ash bricks. International Journal of Engineering Research and Applications, 2(5), 1906-1910.
11. Hwang, C. L., & Huynh, T. P. (2015). Properties of unfired building bricks prepared from fly ash and residual rice husk ash. Applied Mechanics and Materials, 754, 468-472.
12. Saleh, A. M., Rahmat, M. T., Yusoff, F. M., & Eddirizal, N. E. (2014). Utilization of palm oil fuel ash and rice husks in unfired bricks for sustainable construction materials development. In MATEC Web of Conferences (Vol. 15, p. 01032). EDP Sciences.
13. Sua-iam, G., & Makul, N. (2014). Utilization of high volumes of unprocessed lignite-coal fly ash and rice husk ash in self-consolidating concrete. Journal of cleaner production, 78, 184-194.
14. Torkaman, J., Ashori, A., & Momtazi, A. S. (2014). Using wood fiber waste, rice husk ash, and limestone powder waste as cement replacement materials for lightweight concrete blocks. Construction and building materials, 50, 432-436.
15. Moraes, C. A., Fernandes, I. J., Calheiro, D., Kieling, A. G., Brehm, F. A., Rigon, M. R., ... & Osorio, E. (2014). Review of the rice production cycle: by-products and the main applications focusing on rice husk combustion and ash recycling. Waste Management & Research, 32(11), 1034-1048.
16. Kumar, R., & Hooda, N. (2014). An experimental study on properties of fly ash bricks. International journal of research in aeronautical and mechanical engineering, 2(9), 56-67.
17. Dhami, N. K., Reddy, M. S., & Mukherjee, A. (2012). Improvement in strength properties of ash bricks by bacterial calcite. Ecological Engineering, 39, 31-35.
18. Khan, R., Jabbar, A., Ahmad, I., Khan, W., Khan, A. N., & Mirza, J. (2012). Reduction in environmental problems using rice-husk ash in concrete. Construction and Building Materials, 30, 360-365.
19. Karim, M. R., Hasan, M. H., & Alim, M. A. (2015). Improvement of clay soil characteristics by using fly ash, bamboo leaf ash and rice husk ash. J Eng Sci, 6, 81-85.
20. Uduweriya, R. B. Y. B., Subash, C., Sulfy, M. M. A., & De Silva, S. (2010, December). Investigation of compressive strength of concrete containing rice-husk-ash. In International Conference on Sustainable Built Environment (ICSBE-2010) Kandy (pp. 13-14).

21. Chakraborty, A., Bhattacharya, M., & Deb, S. K. (2014). Quality Improvement Through Value Engineering In Fly Ash Based Brick Manufacturing Industry. In Proceedings of 1st International Science & Technology Congress.