Kashf Journal of Multidisciplinary Research
Vol: 03 - Issue 02 (2026)
P-ISSN: 3007-1992 E-ISSN: 3007-200X
https://kjmr.com.pk

DEVELOPMENT OF SUSTAINABLE BRICKS UTILIZING INDUSTRIAL WASTE

Faraz Ahwaz[1], Khawaja Adeel Tariq[2], Muhammad Shoaib Ashraf[3], Syed Kamran Hussain Shah[4], Ahmad Raza[5]

[1, 3]The University of Faisalabad Department of Civil Engineering
[2]University of Engineering and Technology Lahore, Narowal Campus
[4]National Institute of Transportation, Risalpur, National University of Science and Technology, Islamabad
[5]Harbin institute of Technology

*****Corresponding Author:*** (farazahwaz9@gmail.com)

DOI: (*https://doi.org/10.71146/kjmr827*)

Article Info

Abstract

The viability of clay bricks for construction applications is significantly influenced by their compressive strength and water absorption characteristics. This study evaluated the impact of various additives—including corncob ash (CCA), wheat husk ash (WHA), ceramic powder (CP), bagasse ash (BA), and rice husk ash (RHA)—on the mechanical and durability properties of clay bricks. The results indicated that although all bio-based ashes (CCA, WHA, BA, and RHA) contain silica, their effects on compressive strength vary due to differences in particle size, chemical composition, and interactions with the clay matrix. CCA exhibited a decreasing strength trend with increasing content, dropping from 14.27 MPa at 1.5% to 9.91 MPa at 12%, mainly due to increased porosity. WHA showed an initial increase in strength but declined at higher percentages, following a similar trend.

In contrast, CP enhanced compressive strength at all levels, peaking at 15.27 MPa at 12%, attributed to its finer texture and ability to densify the brick matrix. BA and RHA followed a trend similar to that of CCA and WHA, in which strength increased slightly at lower percentages but decreased above 6%, primarily due to increased void formation. Water absorption analysis revealed that bio-based ashes increased porosity and water uptake, with CCA exhibiting the highest water absorption of 18.20% at 12%. WHA and BA showed similar patterns, leading to increased permeability. Conversely, CP significantly reduced water absorption across all percentages, reaching a minimum of 8.13% at 1.5%, due to its ability to enhance particle packing and reduce voids. Overall, CP proved to be the most effective additive for improving strength and water resistance, while excessive amounts of bio-based ashes compromised the structural integrity of bricks. These findings provide insights into optimizing additive proportions for sustainable clay brick production while balancing mechanical performance and durability.

Keywords:
Bricks, Sustainable Bricks, Industrial Waste, Agricultural Waste.

Introduction

Bricks are among the world's oldest and most significant building materials due to their longevity [1]. Clay, the primary component of bricks, is typically mixed with water and occasionally supplemented with sand, limestone, or ash. Due to its intrinsic versatility and broad availability, Brick is essential for use in the building industry in Pakistan and worldwide [2]. Due to the abundance of locally available clay, it is used extensively in construction projects in Pakistan [3], [4]. Architects and builders also prefer it for its versatility. [5]. The success of this material can be attributed to its visual appeal, intrinsic thermal insulation properties, cost-effectiveness, and ease of logistics [6], [7]. In brick production, Pakistan ranked the third-largest among South Asian countries, manufacturing approximately 45 billion bricks annually. Around 18,000 brick kilns employ around 4.5 million people [2].

In contrast, the annual global consumption of 1391 billion bricks underscores the material's indispensable role in the construction industry [1]. The production of clay bricks using conventional methods is energy-intensive and environmentally harmful [8]. This method releases toxic chemicals and particulate matter, particularly during fires, and consumes excessive energy [3], [9]. The firing of bricks consumes energy. Burning fossil fuels for energy production also perturbs the global radiation balance [10]. Additionally, it polluted the air with large quantities of human-created Air Pollutants, such as Carbon Monoxide (CO), Nitrogen Oxides (NO), and Sulphur Dioxide (SO2) [3], [11]. They are associated with various respiratory and cardiovascular diseases [12], [13]. In 2012, the World Health Organization (WHO) also mentioned Air Pollution as a leading cause of death, responsible for an estimated 3.7 million premature deaths (6.7 per cent of all global deaths [14]. The byproducts of agricultural activities, known as agro-waste or residues, pose significant environmental implications and are widespread in a nation such as India, where agriculture produces around 500 million tons annually [15]. The recycling of agricultural waste to develop sustainable building materials is currently under investigation, as conventional disposal methods, such as incineration, impose significant strain on urban waste management systems and exacerbate air pollution [14], [16].

A comparative study evaluated the potential of wheat husk and sugarcane bagasse for producing bio-bricks, with a primary focus on product design rather than structural integrity [17]. Similarly, a study investigating corncob ash as a cement substitute in fly ash bricks demonstrated that incorporating corncob dust at approximately 10% had no detrimental effect on compressive strength. However, ratios exceeding this threshold were associated with reduced strength [18]. Sugarcane bagasse ash (SBA) was evaluated as a pozzolanic substitute in the production of energy-efficient bricks. The study revealed that various mix ratios confirmed that SBA is an ideal material, exhibiting stability and effectiveness, particularly under high-temperature conditions [19]. Furthermore, research investigating the use of millings, oat husks, and barley husks as clay substitutes in fired ceramics demonstrated enhanced strength and reduced shrinkage [4].

The addition of tea waste to both sintered and unburnt bricks decreased density, accompanied by the formation of visible pores [20]. Likewise, the addition of SBA and rice husk ash to clay bricks reduced their weight and efflorescence while meeting compressive strength requirements; however, due to high water absorption, they were unsuitable for tropical hot climates [21]. These studies indicate that agro-waste can be used alongside other waste materials to promote sustainability in the construction industry. [16]. Due to its diverse uses, limestone is vital to the chemical and other industries and is widely extracted [22], [23]. A variety of limestones, known as marble, are extensively processed for decorative purposes. The cutting and polishing of marble generate significant waste, with marble dust accounting for up to 20 per cent of global marble production [24]. Global marble dust output exceeded 68 metric tons in 2011, posing environmental challenges primarily related to the use and disposal of landfill materials [25]. Pakistan produces more than 1 million tonnes of marble per month, primarily from Balochistan and Khyber Pakhtunkhwa, and has more than 300 billion tonnes of marble reserves [5], [22], [23]. Marble processing generates dust and slurry as waste. Inappropriate waste disposal pollutes land, water, and drainage systems, threatening human health and aquatic life [26], [27].

Improper disposal of marble waste into water and soil can disperse pollutants through wind and water, leading to contamination of soil and water. This can degrade soil quality and surrounding land, negatively impacting agriculture and posing risks to public health [17], [28]. Contaminated water sources were restricted from reaching consumers, while the already overloaded drainage systems exacerbated the risk of flooding. [29]. Regulated containment and recycling are urgent priorities for developing effective management systems to address these hazardous environmental problems. Implementing waste management practices in an environmentally responsible manner would require the involvement of industry, local governments, and environmental groups [30]. Moreover, the potential for recycling marble waste, particularly in civil engineering and construction, was explored to mitigate its environmental impact [31], [32].

This research focused on the formulation and optimization of eco-bricks made from various waste materials to mitigate the environmental impacts of traditional brick manufacturing. The study will incorporate waste materials such as ceramic powder, wheat husk ash, rice husk ash, corncob ash, and bagasse ash. It will evaluate the physical and mechanical properties of eco-bricks to ensure compliance with construction standards for strength, durability, and water absorption. The anticipated impact of this research is to demonstrate the economic feasibility of using eco-bricks in large-scale construction, with an emphasis on cost reduction and sustainable urban development.

Materials and Methods

Different waste materials were incorporated into clay mixtures to produce eco-friendly clay bricks. They include corncob ash, rice husk ash, sugarcane bagasse ash, ceramic powder, and wheat husk ash, added at 1.5%, 3%, 6%, and 9% by weight. All waste materials used in this study were sourced and processed to ensure suitability for eco-brick production, in accordance with brick manufacturing standards. This gradual process facilitates a comprehensive study of their property improvements, with lower waste replacement rates, while also highlighting that higher proportions can enhance properties such as compressive strength but reduce durability.

Corncob ash was sourced directly from a local corn-processing facility, where it is used as fuel after corn processing. Following collection, the ash was sieved to ensure uniform particle size and sealed in airtight containers to prevent contamination and moisture absorption. The ceramic waste powder was procured from a local tile factory in Faisalabad, Pakistan. The ceramic tiles were cleaned, crushed, and ground into a fine, uniform powder using a ball mill. The powder was then sifted to eliminate large particles and stored in a dry state to prevent moisture absorption. Similarly, the agricultural waste materials, including wheat husk, bagasse, and rice husk, were obtained from processing facilities in Pakistan. These wastes were dried, cleaned, and subjected to controlled combustion at 750°C for 2 h in a muffle furnace, as specified in ASTM D3174-12. The resulting ashes were sieved to achieve a uniform particle size and stored in sealed containers to prevent contamination. This systematic process ensured consistency in quality and particle size, enabling the reliable use of these ashes as sustainable construction materials in this study.

a. b.

c. d.

e.

Figure 1 a. Sugarcane/ bagasse ash b. Ceramic powder c. Wheat husk ash d. Corncob ash e. Rice hush ash

Table 1 Mineral Composition of Ashes

Component	**RHA**	**CCA**	**WHA**	**SBA**	**Ceramic Waste Powder**
SiO_2	85.3	60.2	55.1	50	65.1
Al_2O_3	5.1	10.4	20.3	15.2	18.3
Fe_2O_3	1.3	7.2	5.5	5.4	6.1
CaO	1.5	5.5	10.2	12.1	2.4
MgO	0.7	3.1	2.3	4.2	1.3
Na_2O	0.5	2.1	1.4	3.1	2.2
K_2O	1.2	1.7	2.1	2.3	1.4
SO_3	0.6	1.2	1.7	2.3	0.7
P_2O_5	0.6	2.3	1.3	3.2	0.9
Loss on Ignition (LOI)	3.2	6.3	4.1	2.2	2.6

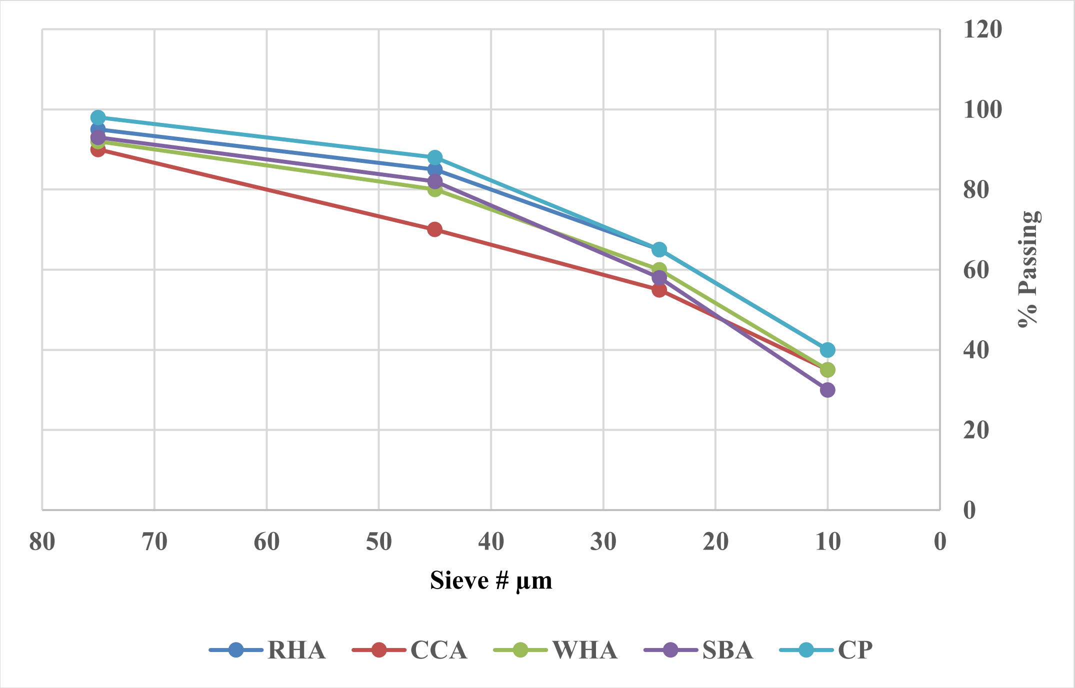

Figure 2 Particle size distribution of ashes

Testing

The mechanical and physical characteristics of the control bricks and those containing these ashes were evaluated using key properties, including compressive strength, density, and water absorption. These tests enable the optimization of brick formulations for sustainable construction applications.

Water Absorption

A water absorption test determines a brick's moisture absorption capacity, which affects its durability. In accordance with ASTM C140, the bricks were submerged in water for 24 hours, then dried and weighed. The sharp rise in mass upon drying indicates water absorption and indicates the porosity or permeability of the Brick.

Density

The brick density was determined in accordance with ASTM C67. The density of the Brick was obtained from the ratio of the Brick's mass to the Brick's volume. This test provides essential information on the brick's compactness and structural performance.

Compressive Strength

According to ASTM C67, a brick's compressive strength test measures its ability to withstand applied load. The load is increased until specimen failure, and the maximum load is divided by the brick's cross-sectional area to compute the brick's strength. The test is crucial to determine whether a brick is suitable as a structural material for walls and foundations. Bricks were tested at 28 days, after full curing and hydration, to accurately assess mechanical properties, with performance improvements linked to replacement levels.

Results

Effect of Density by Additives

The density of clay bricks is a crucial factor in their performance, and this study examined the impact of various additives, including corncob ash, wheat husk ash, ceramic powder, bagasse ash, and rice husk ash. Porosity plays a significant role in the mechanical strength and thermal insulation of bricks, depending on their density. Higher density is associated with denser structures, which provide the compressive strength required when the building has load-bearing walls, whereas lower density improves thermal performance but reduces strength.

The average density of the additive-free control brick sample was 1827.03 kg/m³. As the percentage of CornCob Ash increased, the brick density decreased. At an ash content of 1.5%, the density was 1779.56 kg/m³; at 12%, it was 1592.33 kg/m³. This indicated that using CornCob Ash makes bricks more porous by displacing denser clay particles. The density of the bricks was also reduced by adding Bagasse Ash, CornCob Ash, and Wheat Husk Ash. The density was 1747.41 kg/m³ at 1.5% content, and 1547.17 kg/m³ at 12%. The density of Rice Husk Ash also followed a similar pattern, decreasing from 1694.57 kg/m3 at 1.5% to 1494.34 kg/m3 at 12%. Rice Husk Ash bricks are more suitable for lightweight applications, but not for heavy structural load-bearing applications.

However, the addition of ceramic Powder increased the brick's density. Bricks are better for load-bearing, but are not necessarily the most energy-efficient. Although the CornCob Ash-modified bricks are not suitable for high-strength applications, the significant advantage lies in energy efficiency. Because of their lighter weight, these bricks are ideal for use under non-load-bearing walls or structures that require insulation.

Although wheat husk ash reduces brick bulk density, it is similar to corn cob ash in this regard. At a concentration of 1.5%, the density was 1723.83 kg/m³; at 12% concentration, it decreased to 1523.59 kg/m³. Wheat husk ash, like corn cob ash, increases brick porosity and decreases mechanical strength.

Adding ceramic Powder increased the density of the bricks compared to the other ashes. The density increased to 1834.81 kg/m³ at 1.5% content and to 1952.79 kg/m³ at 12%. The density of the bricks was reduced by adding Bagasse Ash, Corn Cob, and Wheat Husk Ash. The density was 1747.41 kg/m³ at 1.5% content, and 1547.17 kg/m³ at 12%. A decrease in density indicates an increase in porosity. The density of Rice Husk Ash also followed a similar pattern, decreasing from 1694.57 kg/m3 at 1.5% to 1494.34 kg/m3 at 12%.

The analysis revealed a clear trend in the utilization of different ashes for brick density and ceramic powder, namely corn cob ash, wheat husk ash, bagasse ash, and rice husk ash. Organic ashes generally reduce density and improve thermal insulation at some loss in crushing strength. Other applications in building structures, particularly in energy-efficient designs, further enhance the potential for deployment in nonstructural or insulating applications. However, increasing the density of ceramic powder can improve strength but reduce thermal insulation. The bricks are effective for load-bearing, but are not necessarily the most energy-efficient.

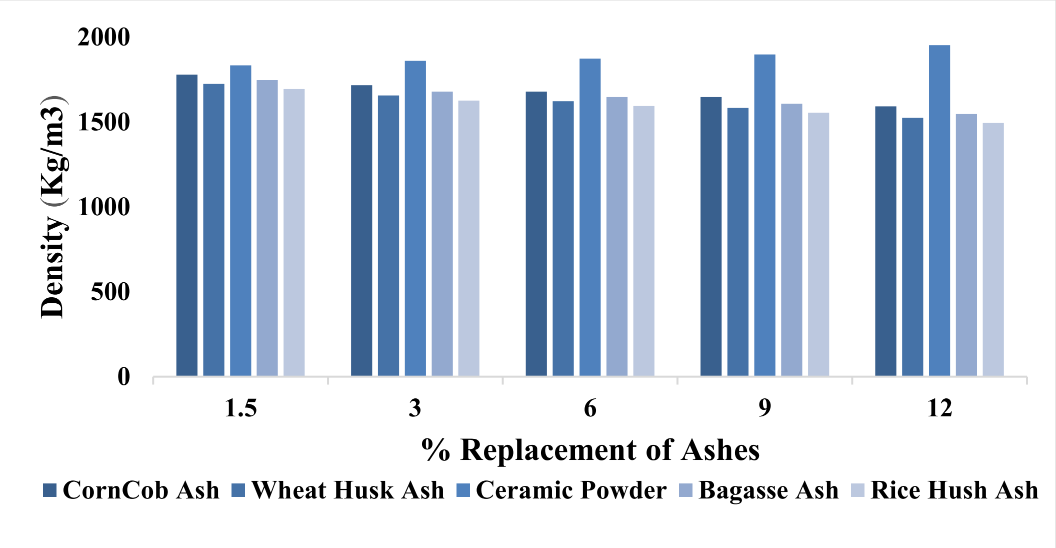

Figure 3 Density Comparison of Ashes

Water Absorption

One of the most critical factors affecting the strength, longevity, and environmental compatibility of clay bricks is their water absorption capacity. When water absorption is excessive, bricks become weaker and more susceptible to weathering, and their service life may be reduced. Adding additives such as CornCob Ash, Wheat Husk Ash, Ceramic Powder, Bagasse Ash, and Rice Husk Ash alters water absorption behavior by altering porosity and microstructure. In this critical analysis, each additive is examined with respect to its impact on water absorption, and trends in water absorption across materials are examined.

The amount of corn cob ash, an agricultural byproduct, was directly correlated with the impacts on water absorption. Water absorption increased slightly (between 14.49% and 15.15%) relative to the control at the lower concentrations (3% and 1.5%), then declined slightly from the control's maximum water absorption. The resulting trend indicates that the CornCob Ash mechanically increases the porosity in the brick matrix. It is likely that, because corn cob ash particles are highly porous, mixing them into the clay creates additional voids in the structure. This value provides a background understanding of how different additives affect water absorption.

The impact of corn cob ash, an agricultural byproduct, on water absorption was directly correlated with its concentration. Water absorption increased slightly at lower concentrations (1.5% and 3%), from 14.49% to 15.15% relative to the control. These trends indicate that CornCob Ash increases porosity in the brick matrix. In this instance, we attribute it to the naturally porous characteristics of

CornCob Ash particles, which generate more voids in the edifice when mixed into the clay. Mixing it with clay would increase the number of voids in the structure and increase water absorption. Therefore, more water is absorbed at such levels.

Water absorption continued to increase as the percentage of CornCob Ash increased to 6%, 9%, and 12%, with a maximum of 18.20% at 12%. His consistent rise indicates that greater corn cob ash content yields a more porous structure, thereby further improving water absorption. While CornCob Ash's benefits of reduced weight and environmental sustainability have both trended exceptionally well recently, it is less appropriate for areas prone to moisture because it enhances the Brick's water resistance.

Similarly, another biowaste material, Wheat Husk Ash, exhibited a trend similar to CornCob Ash, with a less pronounced effect on water absorption. Water absorption values of approximately 14.17% were observed, indicating a slight increase in porosity. This pattern suggests that adding wheat husk ash introduces porosity into the brick matrix, though it appears less pronounced than that caused by corn cob ash.

As the percentage of Wheat Husk Ash increased to 3%, 6%, 9%, and 12%, water absorption values remained within the range of 15.14%-17.25%. As with other bio-based ashes, higher additive percentages are associated with greater water absorption. Because of its porosity, Wheat Husk Ash allows more water to penetrate it, as there are greater void spaces within the Brick. However, wheat husk ash may absorb less water at a percentage similar to that of corncob ash due to its finer particle size or different chemical makeup.

A contrasting trend was observed for Ceramic Powder (a non-bio waste material) compared with the bio-based ashes. Water absorption decreased significantly at lower concentrations (1.5% and 3%), ranging from 8.13% to 10.81%, which is considerably lower than that of the control group. This decrease is explained by the ceramic Powder's solid, non-porous structure, which likely fills gaps in the clay matrix, producing a denser, less porous brick. Therefore, the available space for water in the Brick to fill would be reduced, thereby reducing water absorption.

Water absorption remained lower than that of the control group, even at higher concentrations (6%, 9%, and 12%), peaking at only 9.41% at 9%. This trend indicates that water absorption decreases as the Ceramic powder percentage increases. As an excellent additive, Ceramic Powder can improve the water resistance of bricks. According to the trend, adding ceramic Powder reduces permeability and compacts the brick structure, greatly enhancing its resistance to moisture penetration.

The Bagasse Ash obtained from sugarcane showed a trend similar to that of corn cob ash, but with a smaller effect on water absorption. Water absorption values slightly increased in the 1.5% and 3% sample series, from 12.58% to 13.98%. The modest increase in water absorption at these concentrations suggests that bagasse ash contributes to the brick matrix's porosity, much like other bio-waste products.

Water absorption increased significantly at higher concentrations (6%, 9%, and 12%), with a maximum of approximately 16.28% at 12%. The trend here is clear: As the Bagasse Ash content increases, water absorption follows the same trend as CornCob and Wheat Husk Ash. Increasing water absorption is based on the fact that Bagasse Ash particles are porous; hence, this creates more voids within the Brick structure, which can hold more water.

Water absorption was most strongly affected by rice husk ash, particularly at higher concentrations. The water absorption values were higher than the control, averaging 17.38% and 1.5%. Water absorption increased rapidly above 23% Rice Husk Ash, even at 12%. The highly porous nature of Rice Husk Ash leads to high water absorption, introducing numerous voids into the brick matrix and causing this sharp increase.

Higher concentrations of rice husk ash result in greater water absorption. Rice Husk Ash is a porous material, which means it is readily permeable to water, making bricks with higher percentages of this additive less suitable for environments with high water resistance. Rice Husk Ash offers benefits in other areas, such as thermal insulation and reduced weight, but its high porosity does not provide the low water absorption often required.

The outcomes of the water absorption analysis indicate the importance of the additive choice for the water resistance of clay bricks. The porosity of bio-waste materials such as CornCob Ash, Wheat Husk Ash, Bagasse Ash, and Rice Husk Ash generally increases with increasing water content. Among these, Rice Husk Ash showed the most pronounced increase in water absorption, whereas Bagasse Ash showed a moderate effect.

On the other hand, Ceramic Powder was the most effective additive for increasing water resistance, consistently reducing water absorption across all percentages. Ceramic Powder is a valuable additive for construction applications, particularly where moisture resistance is critical. The outcomes reveal that although bio-waste materials are beneficial for sustainability and other properties, such as thermal insulation, they are detrimental to water resistance and should be used with caution in areas prone to moisture.

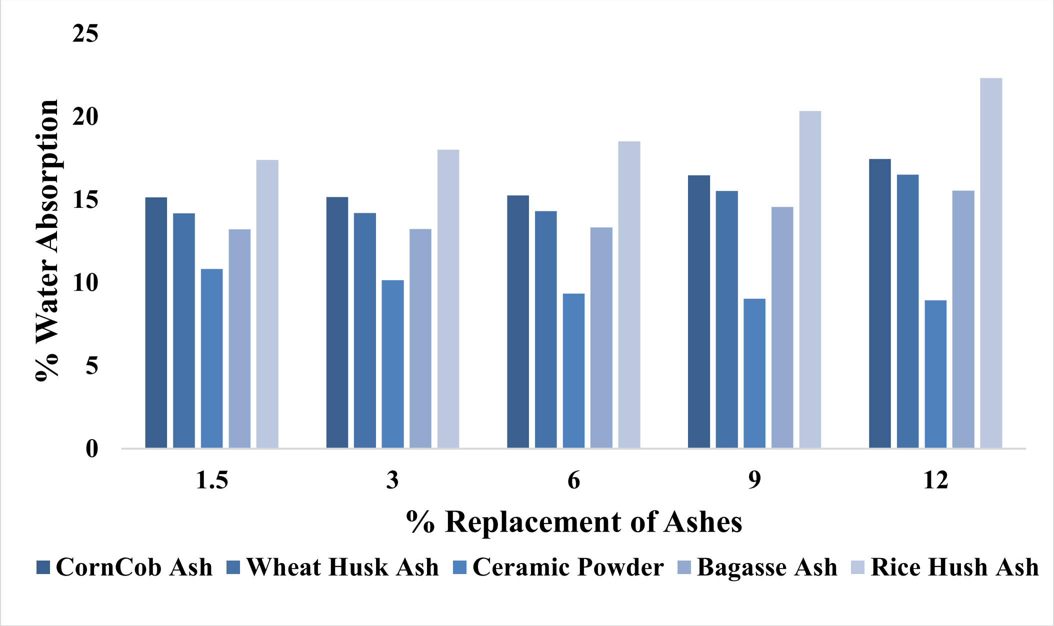

Figure 4 Water Absorption Comparison of Ashes

Compressive Strength

One important consideration when evaluating the viability of clay bricks for construction applications is their compressive strength. The compressive strength of the bricks was significantly affected by various additives, including corncob ash, wheat husk ash, ceramic Powder, bagasse ash, and rice husk ash. The structural integrity of each additive within the Brick was found to be unique to that additive, and each additive increased the amount added; however, the trends differed. The chemical compositions and physical properties of the additives, as well as their interactions with the clay matrix, were shown to drive the trends.

CornCob Ash is known to contain silica, which contributes to its pozzolanic activity and enhances material strength. However, the data showed a consistent decrease in crushing strength with increasing CCA percentage. 1.5% CCA: The crushing strength measured at this level was slightly lower than that of the control sample, with an average strength of 14.27 MPa. The marginal reduction showed that a tiny amount of CCA did not significantly weaken the bricks.

3% to 12% CCA: Crushing strength of the concrete decreased swiftly as the content of CCA increased. The strength dropped from 12.71 MPa at 3% to 9.91 MPa at 12%. The excessive addition of Ash led to a decrease, as it disrupted the brick matrix's compactness and adhesive properties. The Ash trace in our composites introduced additional voids, resulting in a more porous structure and reduced strength.

Although wheat husk ash contains silica, as in CCA, its effect on crushing strength was somewhat different.

1.5% to 3% WHA: Crushing strength was relatively high (13.58 MPa for 1.5% and 12.65 MPa for 3% of binders) at lower percentages. WHA exhibited sufficient bonding strength at moderate levels, possibly due to improved particle packing and a more cohesive brick structure. 6% to 12% WHA: Crushing strength decreased above 3% in comparison. It had reduced to 11.28 MPa at 6%, dropping to 9.23 MPa at 12%. The presence of Ash was linked to this reduction and, consequently, the formation of a more porous brick. Excess WHA interference disrupted the clay matrix by reducing density and weakening interparticle bonds.

Ceramic powder with a finer particle size and appropriate chemical composition improved the brick's crushing strength. It improved particle packing and increased matrix density.

1.5% to 6% Ceramic Powder: Crushing strength of the rubberized cement increased to 14.07 MPa at 1.5% and to 14.58 MPa at 6%. The strength improvement was attributable to the Powder's ability to fill micro voids within the Brick, creating a denser, more substantial structure. 9% and 12% Ceramic Powder: Despite higher percentages, Ceramic Powder also increased the crushing strength, peaking at 15.27 MPa (12%). The fine texture of the powder, which led to improved bonding between clay particles, and the presence of alumina and silica, which enhanced overall strength, all contributed to this sustained improvement.

The presence of silica, calcium, and aluminum influences the compressive strength of bricks composed of Bagasse Ash.

1.5% Bagasse Ash: Crushing strength at this level of 13.51 MPa was close to the control. Only a tiny amount of Bagasse Ash had a negligible impact on the Brick's structural integrity. 3% to 6% Bagasse Ash: Strength increased slightly at the 3% ash level to 14.07 MPa, indicating that ash can enhance the brick matrix at moderate ash content. However, at 6%, the strength went down to 11.28

MPa. 9% to 12% Bagasse Ash: Crushing strength significantly diminished as Bagasse Ash percentages increased, with values of 10.42 MPa and 9.66 MPa at 9% and 12%, respectively. The greater the amount of ash, the more pores are present within the structure, thereby weakening the overall strength. Excessive ash interfered with compaction, reducing brick density and bond strength.

Rice husk ash contains high levels of silica, which typically increases the strength of cementitious materials. However, it was observed that the impact of RHA on crushing strength depended on the percentage used.

1.5% to 6% RHA: Crushing strength of 12.73 MPa and stability at 11.75 MPa for 3% and 10.67 MPa for 6%, respectively, were recorded at 1.5%. This suggested that up to 6% RHA may be required to achieve sufficiently strong results by densifying the brick matrix. 9% and 12% RHA: Crushing strength significantly declined at higher percentages. The strength dropped to 9.96 MPa at 9% and 9.38 MPa at 12%. Lower strength resulted from higher porosity and weaker bonding caused by the overabundance of RHA.

Overall, across all additives, compressive strength either did not change or increased slightly at lower additive percentages (1.5-3 per cent). Nevertheless, the reduction in compressive strength for most additives began after the percentage of additives exceeded 6%; however, the crushing strength of ceramic powder continued to increase at all levels.

The increased percentages of CornCob Ash, Wheat Husk Ash, Bagasse Ash, and Rice Husk Ash reduced the crushing strength, primarily because of increased porosity and, consequently, reduced density due to the excess ash content. The brick matrix developed cavities due to these organic additions, weakening the interparticle binding and reducing Brick's overall strength. In contrast, Ceramic Powder's finer particle size and chemical composition allowed better particle packing and stronger bonding, enhancing compressive strength even at higher percentages.

Table 2 Compressive strength results of bricks

Additive Name	**Additive %**	**Density**		**Water Absorption**				**Compressive Strength (MPa)**	
		Density (kg/m3)	**Average Value**	**Weight Before**	**Weight After**	**% Water**	**Average Value**	**Strength Value**	**Average Value**

			(kg/m3)			**Absorption**			
Control	0	1835.2	1827	2.9	3.2	10.35	12.37	14.39	14.26
		1805.1		2.9	3.5	12.56		13.9	
		1840.8		3.13	3.24	14.2		14.51	
Corncob Ash	1.5	1792.6	1779	2.77	3.3	14.49	15.12	13.6	13.48
		1780.3		2.85	3.2	15		13.4	
		1765.8		2.85	3.29	15.87		13.45	
	3	1745.2	1716.1	2.67	3.15	14.52	15.14	12.9	12.7
		1710.6		2.71	3.13	15.02		12.7	
		1692.5		2.66	3.25	15.90		12.54	
	6	1685.2	1679.2	2.41	3.31	14.62	15.24	11.5	11.4
		1670.3		2.31	2.79	15.12		11.68	
		1682.3		2.82	2.84	15.99		11.23	
	9	1670.5	1647	2.34	2.83	15.83	16.46	10.9	10.77
		1650.2		2.3	2.79	16.33		10.84	
		1620.4		2.38	2.89	17.21		10.57	
	12	1590.2	1592.3	2.18	2.82	16.82	17.44	10.15	9.91
		1601.4		2.23	3.18	17.32		9.75	
		1585.4		2.28	3.29	18.19		9.84	
Wheat Husk Ash	1.5	1736.8	1723.8	2.49	2.9	13.54	14.17	13.8	13.58
		1724.5		2.57	3.01	14.04		13.54	
		1710		2.51	2.93	14.92		13.41	
	3	1685.4	1656.3	2.47	2.98	13.57	14.19	12.78	12.71
		1650.8		2.52	3.01	14.07		12.65	
		1632.7		2.54	2.93	14.94		1271	
	6	1629.1	1623.1	2.4	2.93	13.66	14.29	11.25	11.27
		1614.2		2.36	2.83	14.169		11.43	
		1626.2		2.44	2.88	15.04		11.15	
	9	1606.7	1583.2	2.21	2.74	14.88	15.50	10.15	10.07
		1586.4		2.24	2.79	15.38		9.98	
		1556.6		2.19	2.74	16.26		10.1	
	12	1521.4	1523.5	2.11	3.02	15.86	16.49	9.3	9.23
		1532.6		2.03	3.03	16.36		9.21	
		1516.6		2.21	3.05	17.24		9.18	

Ceramic Powder	1.5	1847.8	1834.8	2.72	3.11	8.79	10.81	14.1	14.06
		1835.5		2.93	3.18	11		13.98	
		1821		2.82	3.2	12.64		14.12	
	3	1873.3	1860.3	2.84	3.36	8.13	10.15	14.65	14.63
		1861.0		2.86	3.21	10.34		14.52	
		1846.5		2.85	3.19	11.98		14.73	
	6	1886.9	1873.8	2.58	3.09	9.14	9.34	15.14	14.57
		1874.6		2.56	2.87	9.35		15.28	
		1860.1		2.76	2.9	9.54		13.31	
	9	1910.5	1897.5	2.87	3.11	8.54	9.03	15.32	15.37
		1898.2		2.83	3.17	9.14		15.38	
		1883.7		2.82	3.18	9.41		15.41	
	12	1965.8	1952.7	3.06	3.32	8.44	8.93	15.31	15.26
		1953.5		2.81	3.16	9.05		15.28	
		1939		3	3.32	9.31		15.21	
Bagasse Ash	1.5	1760.4	1747.4	2.88	3.29	12.58	13.23	13.6	13.51
		1748.1		2.93	3.28	13.08		13.52	
		1733.6		3.01	3.31	13.95		13.41	
	3	1709	1679.9	2.8	3.44	12.60	13.23	12.87	14.06
		1674.4		2.82	3.22	13.10		12.71	
		1656.3		2.87	3.3	13.98		16.62	
	6	1652.7	1646.7	2.74	3.35	12.70	13.32	11.42	11.36
		1637.8		2.9	3.28	13.20		11.37	
		1649.8		2.85	3.19	14.08		11.31	
	9	1630.3	1606.8	2.64	3.1	13.91	14.54	10.52	10.41
		1610		2.85	3.2	14.41		10.42	
		1580.2		2.72	3.17	15.29		10.31	
	12	1545.0	1547.1	2.76	3.2	14.90	15.52	9.81	9.66
		1556.2		2.73	3.11	15.40		9.45	
		1540.2		2.78	3.16	16.28		9.72	
Rice Husk Ash	1.5	1707.6	1694.5	2.94	3.38	16.75	17.38	12.74	12.73
		1695.3		2.73	3.17	17.25		12.84	
		1680.8		2.85	3.29	18.13		12.62	
	3	1656.2	1627.1	2.89	3.51	17.38	18.00	11.84	11.75

		1621.6		2.74	3.28	17.88		11.72	
		1603.5		2.73	3.18	18.75		11.69	
	6	1599.8	1593.9	2.65	3.37	17.88	18.50	10.85	10.67
		1584.9		2.64	3.28	18.38		10.65	
		1596.9		2.6	3.16	19.25		10.51	
	9	1577.5	1554	2.57	3.18	19.69	20.32	10.1	9.96
		1557.2		2.43	3.26	20.19		9.95	
		1527.4		2.48	3.33	21.07		9.84	
	12	1492.2	1494.3	2.2	2.83	21.68	22.30	9.47	9.37
		1503.4		2.24	2.87	22.18		9.35	
		1487.4		1.7	2.39	23.05		9.31	

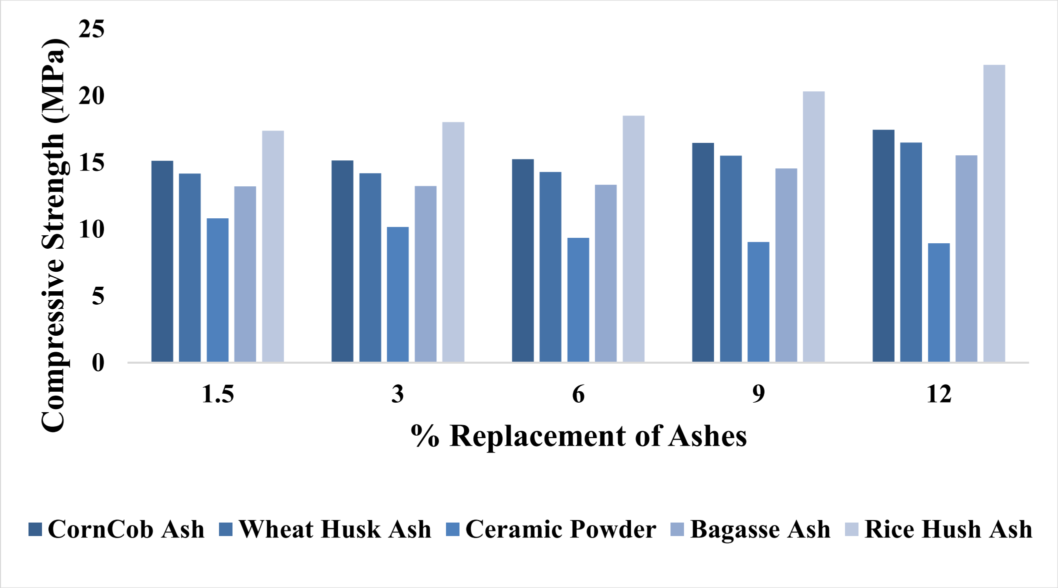

Figure 5 Compressive strength of bricks

Conclusion

Utilization of Agricultural and Industrial Waste:

Important properties such as density, compressive strength, and water absorption are significantly affected when clay bricks are manufactured using corn cob ash, wheat husk ash, bagasse ash, rice husk ash, and ceramic Powder. Agricultural waste increases porosity and water absorption while reducing density and improving thermal insulation, making it suitable for non-load-bearing, energy-efficient applications. Ceramic Powder is suitable for load-bearing structures and moisture-prone areas because it increases density and compressive strength while reducing water absorption.

Trade-offs in performance

Although agricultural waste ashes are lightweight and environmentally benign, they require further development to address challenges related to strength and durability. Ceramic Powder offers superior mechanical and moisture resistance, but at the cost of lower thermal insulation. Additive mixes require fine-tuning to meet specific construction requirements and achieve a balanced performance profile.

Sustainability and Environmental Impact

This research contributes to the global trend toward sustainable construction by exemplifying the creative recycling of industrial and agricultural wastes into building materials. The strategy supports goals to prevent environmental deterioration and lower carbon emissions associated with building.

Prospects of the Future:

Advanced processing methods, complete life cycle analyses, and hybrid material systems should be the primary foci of future research. Waste-altered bricks must be validated and developed for diverse applications to fully realize their potential in green building technologies.

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