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Research Article

Effect of Rice Husk Ash on The Strength Characteristics of Cement Blocks

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Keywords

Cement blocks, Compressive strength, Ordinary Portland Cement (OPC), Rice Husk Ash (RHA).

Abstract

Rice husk ash (RHA) is a promising pozzolanic alternative material for partial replacement of ordinary Portland cement to increase the durability and strength of concrete. This study examines the use of Rice Husk Ash (RHA) as a partial replacement for Ordinary Portland Cement (OPC) in the production of hollow cement blocks. The aim is to evaluate the impact of RHA on the compressive strength, workability, and water absorption properties of the blocks. RHA was introduced as a replacement for OPC at levels of 0%, 25%, and 50%, and tests were conducted after 7 and 14 days of curing. The results indicate that increasing RHA content leads to a reduction in compressive strength, with the 50% RHA mix exhibiting the lowest strength. This is attributed to the porous nature of RHA, which weakens the cementitious matrix. However, workability improved as RHA content increased, due to its water-reducing properties. The water absorption of the blocks also increased with higher RHA content, corresponding to the increased porosity. Despite the strength reduction, the pozzolanic activity of RHA suggests potential for long-term strength gains. The findings demonstrate that RHA can be a viable alternative for cement in non-structural applications, contributing to sustainable building practices by utilizing agricultural waste and reducing the reliance on cement. This research supports the integration of RHA into the construction industry as an eco-friendly material, promoting both waste management and carbon footprint reduction.

1. Introduction

In the last few decades, increasing population growth augmented the demand for housing and infrastructure. This growth in construction increases the use of Portland cement. This was predicted to significantly increase CO2 emissions levels from current levels, but recent data highlights a growing awareness of reducing emissions in cement production through alternative materials [1]. In 2018, it was estimated that almost 769.9 million tons of rice paddy is produced annually worldwide [2]. After peeling, about 78% of the weight is received as rice, broken rice, and bran. The remaining 22% of the weight of the paddy is received as rice husk [3]. The husks typically contain cellulose, silica, and lignin. Without processing, the husks are used as animal food, thermal energy, or landfilling. Therefore, combustion is a common option [3-4].

After combustion, about 25% of the weight of the husk is received as RHA [3]. The ash produced from rice husk contains a vast amount of silica, which is not easily bio-degradable [3,5]. Hence, it becomes a disposal problem and eventually leads to environmental pollution. To reduce these problems, RHA could be used as cement-substituted materials because it contains an enormous amount of amorphous silica, which has pozzolanic action and possesses cementitious properties. In addition, the agricultural by-product RHA has already been substantiated as a pozzolanic material. It is expected to add pozzolanic values in cement hydration, which, in turn, enhances strength and durability over a longer period. RHA could also reduce the cost of construction materials. Currently, numerous wastes, such as blended waste, clay brick, expanded clays, shales, pumice perlite, rubber, plastic and palm oil shells, are used to make the lightweight aggregate, thereby producing lightweight concrete. Even the road construction industries try to utilize a considerable quantity of marble waste aggregate as coarse aggregate in the base course and use the waste materials (such as marble dust, rice husk ash, and cement) to improve the soil subgrade for minimizing the construction cost, natural resources, dumping problem, and environmental pollution.

Numerous attempts have been made to determine the correlation between the strength and durability properties of cement blocks containing RHA. Still, as far as the authors are concerned, the strength and durability parameters of containing RHA have not been correlated yet. On the other hand, some research has been done on the durability properties of cement blocks. However, these studies did not use RHA as a supplementary cementitious material, including crush blocks. Rendering to the aforementioned research gaps and limitations, this study intended to investigate the strength (compressive strength) and durability parameters (water absorption, porosity, chloride resistance, sulphate resistance, and acid resistance) of cement block incorporating rice husk ash as a partial replacement of cement. The study aims to investigate the effect of rice husk ash and the durability characteristics of cement block strength.

This study is restricted to assessing the strength and durability parameters of cement blocks incorporating rice husk ash (RHA) as a partial replacement of cement at a mix proportion of 0%, 25% and 50% and a water-to-binder (w/b) ratio of 0.45. The study is limited to determining the consistency, setting time, workability, compressive strength and water absorption of Rice-Husk Cement Block (RHBC).

The study will utilize the use of locally available waste in useful building materials since it is intended to investigate the strength (compressive strength) and durability parameters of block incorporating rice husk ash as a partial replacement of cement. This research contributes to the development of sustainable construction materials, reducing waste and environmental pollution. The use of RHA as a supplementary cementitious material enhances concrete

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strength, workability, and durability, promoting eco-friendly construction practices.

2. Materials and Method

2.1. Materials

The materials used for this research included;

- Rice Husk Ash (RHA),
- Ordinary Portland Cement (OPC),
- natural river sand and
- water

2.2. Methods

The Rice Husk used was obtained from Labana Rice Mills in Birnin Kebbi Metropolis, the required quantity was burnt in a furnace at the Metallurgical Engineering Department, Waziri Umaru Federal Polytechnic, Birnin Kebbi, under a controlled temperature of 600oC over a period of 2 hours [6] to obtain the Rice husk ash. The Ordinary Portland Cement used was procured from Local Dealers along Sani Abacha express way Road in Birnin Kebbi of Sokoto (BUA) Cement brand. Also, a clean river sand was procured from local sellers at Birnin Kebbi Central Market. Finally, physically clean water, free from dirt was obtained from Civil Engineering Concrete Laboratory in Waziri Umaru Federal Polytechnic, Birnin Kebbi. Hollow blocks of size 225 x 225 x 450mm were made by incorporating RHA as a partial replacement for Ordinary Portland Cement (OPC). The blocks were cast with varying percentages of RHA (0% RHA: 100% OPC and natural sharp sand, 25% RHA: 75% OPC, 25% RHA, and natural sharp sand and 50% RHA: 50% OPC, 50% RHA, and natural sharp sand) and a water-to-binder (w/b) ratio of 0.45 was adopted, the recommended procedures by the code [7] were adhered to in the production of the blocks. A total of eighteen blocks were cast, having three sets for each mix proportion. All specimens were cured by sprinkling method separately with water for a period of 7 days and 14 days, because blocks often have large surface areas exposed to the environment and the sprinkling method provides adequate hydration for cementitious materials without submerging the blocks, preventing cracking or deformation that might occur in immersion curing and also ensures that the surface remains moist while preventing waterlogging, which can be detrimental to lightweight materials such as those containing Rice Husk Ash. The test carried out to investigate the influence of RHA as a replacement of cement in the production of cement blocks are workability (slump), water absorption, setting time and compressive strength tests. The specific mixing ratio was: RHA replacement at 0%, 25%, and 50% by weight with a water-to-binder (w/b) ratio of 0.45.

2.3. Workability

To evaluate the workability of the mixes when partially replacing cement with Rice husk ash in for various percentage replacement the slump test was used in accordance to the specifications of the code [8].

2.4. Water Absorption Test

The water absorption test was carried out in accordance to the British standards [9]. The percentage of water absorption for each specimen was computed using equation 1.

$$\text{Water absorption (\%)} = \frac{W_s - W_d}{W_d} \times 100 \qquad (1)$$

2.5. Compressive Strength Test

The compressive strength test was determined with the UTM 2000kN compressive testing machine at the concrete laboratory of the Department of Civil Engineering, Waziri Umaru Federal Polytechnic, Birnin Kebbi and computed in accordance to the code [10], Figure 1 shows the compressive strength test on the specimens.

(a)

(b)

Figure 1. (a) Block sample subjected to compressive strength test, (b) Block sample showing failure crack

3. Results and Discussion

3.1. Properties of Cement, Sand and RHA

Some of the results obtained from cement tests are presented in table 1, all the results were compared with the codes provision [11,12 and 13] for the Soundness, consistency and fineness respectively and found to be within the limit provided by the codes.

Table 1. physical properties of cement

Parameter	Value
Soundness	2.1 mm
Consistency	29.85%
Fineness	5.92%

The Specific gravity of the sand was obtained as 2.57. The particle size distribution was conducted using the code [14], it was observed that 59.4 per cent of the sand passes BS sieve size 500µm which shows that the sand is classified as belonging to zone two gradation, characterized by medium sands, which is good for concrete in accordance to the code. Figure 2 shows the particle size distribution graph for the fine aggregates.

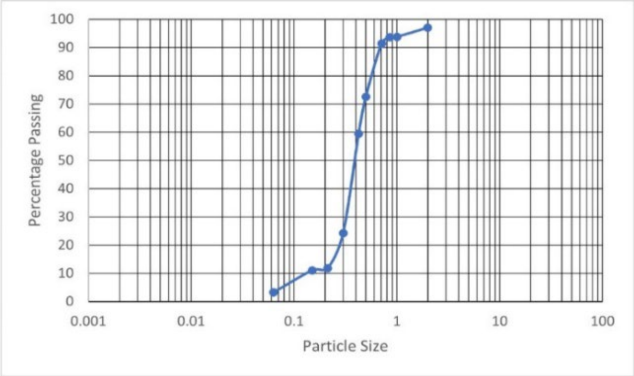

Figure 2. Particle size distribution of sand

Table 2 presents the X-ray fluorescence which shows the summarized oxide composition of the RHA used for this research. This oxide composition is in accordance to the code [15] specifications for a good pozzolanic materials which is having the silica + Al_2O_3 + Fe_2O_3 content summed to be 79.27 higher than 70% as specified by the ASTM code and is characterized as high reactive pozzolana.

Table 2. Oxide Composition of RHA

Oxide	Composition
Al_2O_3	2.0
SiO_2	76.1
Fe_2O_3	1.17
MgO	0.38
SO_3	0.61
CaO	2.9

3.2. Setting Time

Figure 3 illustrates the time it took for each concrete mix to set according to its different mix ratios, where the initial setting time for ratio 0% was 60 mins, but the mix ratio of 25% dropped to 50 mins, and finally, the mix ratio of 50% gave the least initial setting time. The drop in the initial setting time when cement is partially replaced with RHA is primarily due to the increased reactivity from the high silica content, smaller particle size, and pozzolanic nature of RHA. This pozzolanic reaction between RHA and calcium hydroxide produces additional calcium silicate hydrate (C-S-H). The rapid formation of C-S-H due to the high reactivity of RHA accelerates the setting process, causing the initial setting time to drop.

The final setting times for 0%, 25% and 50% were found as 80 mins, 85 mins and 90 mins, respectively. This is increased because the process of cement hydration is exothermic, which results to heat released during the reaction with water. RHA hydrates at a lower temperature than Portland cement. Consequently, slower hydration kinetics result from the reduction in total heat produced during the hydration process caused by replacing some of the cement with RHA. As the heat slows down the system's rate of reaching full hardness, the mix's lower temperature causes the final setting to be delayed. Also, RHA tends to absorb more water due to its porous structure and high surface area, while this can initially reduce the amount of free water in the mix (contributing to faster initial setting as observed earlier), it can also slow down the final setting by gradually releasing the absorbed water over time. This slow water release prolongs the hydration process and extends the time needed for the mixture to fully harden. Due to the slight increases in final setting times, the mix above 25% RHA replacement may requires careful handling and timing during casting to ensure effective workability.

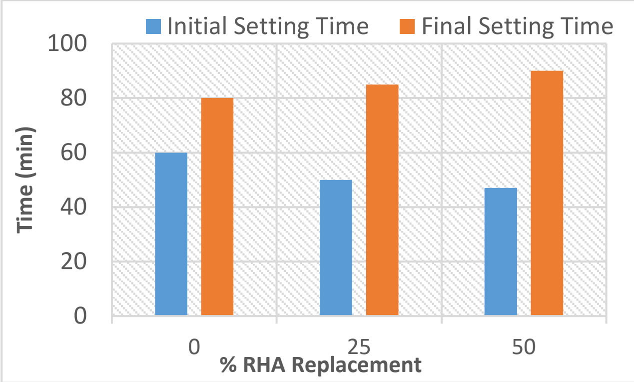

Figure 3. Setting time

3.3. Workability

Figure 4 shows that the slump values for 0%, 25% and 50% mix ratios were found as 148mm, 153mm and 178mm respectively, there was an increase in the slump value as the proportion of RHA increases. This clearly shows that the RHA replaced cement provided better workability than the control. Rice husk ash (RHA) is typically finer than cement and has a higher surface area. This characteristic allows it to distribute more evenly throughout the concrete mix. The fine particles of RHA can help improve the particle packing in the mix, allowing the concrete to flow more easily and increasing the slump value. RHA can improve the distribution of water within the concrete matrix. By holding water within its pores and releasing it slowly, RHA helps maintain moisture in the mix for a longer period, making the concrete more workable. So also, the pozzolanic reaction of RHA with calcium hydroxide takes place more slowly than the initial hydration of cement. This slower reaction means that, in the early stages, the concrete retains more water and maintains its fluidity for a longer period. The delayed reactivity of RHA contributes to maintaining workability and increases the slump value.

The workability increases by increasing the replacement of RHA in the mixture but higher percentage of RHA replacement can lead to reduced workability, likely due to increased fineness and absorption of moisture.

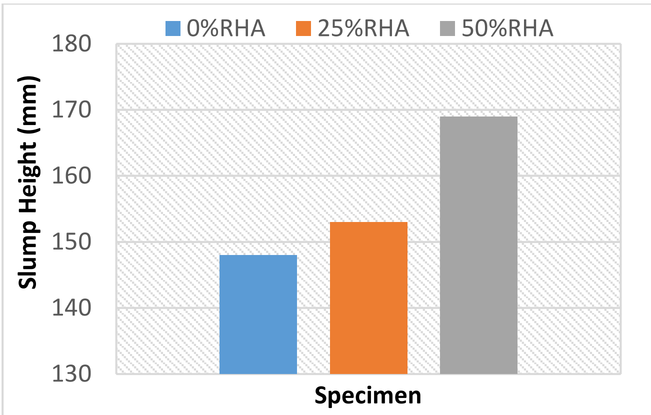

Figure 4. Slump test

3.4. Compressive Strength

Figure 5 presents the compressive strength test of cement block blended with RHA having various mix proportions. The compressive strength of the cement block was achieved in 7 and 14 days. At 7 days of curing the mean compressive strength of 0% mix ratio was 2.92MPa, there was a further increase in strength of 3.14MPa for 14 days. For the mix ratio of 25%, the mean compressive strength after 7 days of curing is 2.15MPa while 2.53MPa for 14 days of curing. The block kept on increasing in compressive strength for up to 14 days, for the mix with 50% replacement the 7 days' age mean compressive strength is 1.76MPa and 1.88Mpa for the 14 days curing. This block is presumed to achieve its desired strength after 14 days since it is not cured by immersion; it means the block can no longer require much water.

RHA is rich in amorphous silica, which is highly reactive with calcium hydroxide, a byproduct of cement hydration. This pozzolanic reaction produces additional calcium silicate hydrate, which is the primary binding compound responsible for the strength and durability of concrete. The formation of more C-S-H enhances the concrete's compressive strength, particularly in the later stages of curing. The fine particle size of RHA also allows it to act as a filler, improving the particle packing in the concrete mix. By filling the spaces between larger cement particles and aggregates, RHA contributes to a denser and more compact matrix, which enhances compressive strength.

Overall, while the compressive strength increases with increasing curing period, it decreases with the rise in mix ratio, this is because, at higher replacement levels, the available calcium hydroxide become insufficient to fully react with the larger amounts of RHA. Since RHA itself does not contribute directly to early stage strength (unlike cement), the presence of excess unreacted RHA can lead to a weaker matrix. This reduces the strength compared to mixes with lower RHA content, where the pozzolanic reaction is more balanced. The results agreed with the findingds from the literature [16,17,18 and 3]in which at 25% replacemt the compressive strength of 2.53MPa meets the minimum standard required for building construction.

The optimum percentage replacement with an increase in strength relatively close to the 0% replacement is the mix ratio with the 25% replacement and this was compared to as reported by [19]that using upto 30% RHA as a replacement of part of cement could be considered optimum for all W/C ratios in investigated motars because of its high value of compressive strength. The blocks casted with higher replacement levels (25%) also satisfy the IS specification for load bearing cement blocks as reported by [20]. The pozzolanic effect of RHA promoted the generation of more hydration products and thus increased the strength of concrete. Both from the findings and the literature indicates that moderate levels of RHA lead to a denser concrete matrix, which improves strength due to reduced porosity and better particle packing.

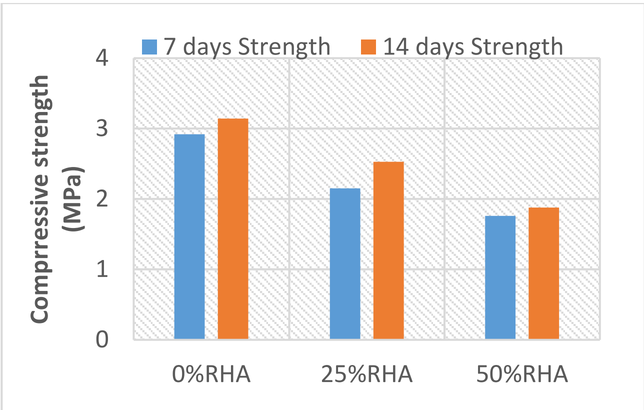

Figure 5. Compressive strength

3.5. Compressive Strength

Figure 6 shows the variation in water absorption with RHA contents. The result obtained shows that there is an increase in water absorption from the control mix ratio of 0% to the mix ratio of 50%, the increase in water absorption is as a result of the high porosity nature of the RHA, because RHA has a much higher surface area compared to cement, owing to its fine particle size and irregular shape. This increased surface area requires more water to wet the particles. As a result, the overall water demand of the mix is higher, which lead to increased water absorption if the mix is not adjusted with the appropriate water-reducing agents or admixtures.

This was compared to a study by [21] which reported that water absorption increases as RHA content increases beyond 10% replacement. This is attributed to the increased porosity and the fine particle size of RHA, which contributes to more capillary pores within the concrete mix.

Moreover, the higher water absorption observed with increased RHA content is consistent with previous studies that identified RHA's porosity as the primary cause of this behavior [5,22]. The code [7] recommended that the water absorption should not exceed a maximum of 12% for all Sandcrete block types. A good look at Figure 5 shows that all block samples meet this requirement.

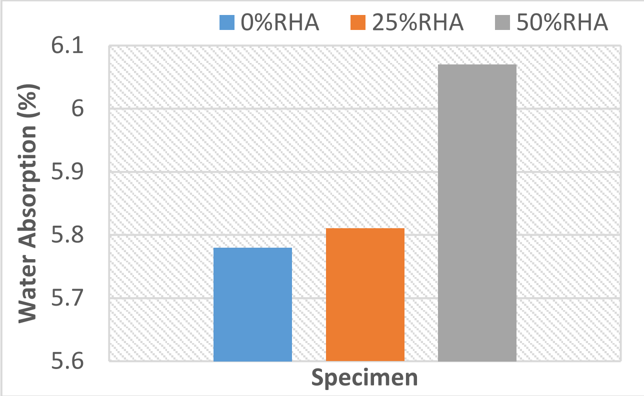

Figure 6. Water Absorption

3.6. Contribution to Concrete Technology

This study contributes to concrete technology by demonstrating the feasibility of using rice husk ash (RHA) as a sustainable alternative to ordinary Portland cement in the production of non-structural blocks. The use of RHA not only reduces reliance on OPC but also helps mitigate CO_2 emissions associated with cement production. Furthermore, RHA can be sourced from agricultural waste, promoting sustainable practices in the construction industry.

4. Conclusion

The study concludes that rice husk ash (RHA) can be effectively used as a partial replacement for ordinary Portland cement in non-structural applications. While increasing RHA content results in lower compressive strength, it significantly improves workability. RHA also contributes to sustainability in construction by utilizing agricultural waste and reducing the carbon footprint of cement production. Future research should explore the long-term strength and durability of RHA-based building materials.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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