Properties of Foamed Concrete Produced with Rice Husk Ash as a Partial Replacement for Cement

[1]Shamsudeen A. Agboola, [1]Abdulraheem A. Aliyu, [1]Abdulhakeem K. Musa, [1]Khadijah I. Abbas, [1]Shabi, O. Moshood, [1]Abdulmutakabir Sanusi.
[1]Department of Building, University of Abuja, FCT, Nigeria
deenlegit@gmail.com

Received: 21-DEC-2023; Reviewed: 09-APRIL-2024; Accepted: 10-APRIL-2024
https://dx.doi.org/10.4314/fuoyejet.v9i2.26

ORIGINAL RESEARCH

Abstract— This study investigated foamed concrete strength characteristics produced with rice husk ash (RHA) as a partial replacement for cement. RHA is used as cement replacement to help reduce the amount of solid waste released into the environment, reduce greenhouse gas release into the atmosphere as a result of cement production, and reduce the amount of cement used in concrete production. The study examined workability, plastic and testing densities, split tensile and compressive strength, and modulus of rupture at an intended design density of 1600 kg/m^3. A cube specimen measuring 100 mm was used to measure the density and compressive strength, 100 x 200 mm cylinder specimens were used for splitting strength, and unreinforced beams measuring 100 x 100 x 500 mm were used for the modulus of rupture test. A known-volume container was used to study the plastic's density, and the spread test was used to assess its stability. RHA was added to foamed concrete (FC) at various percentage replacements of 0% (control), 5, 10, 15, 20, 25, and 30% by weight of cement, and cured in a membrane (sealed) curing condition for 7, 14, 28, 56, and 90 days. The findings show that an increase in RHA content reduces the density of foamed concrete in both wet and dry states. The control sample compressive strength value is 15.22 N/mm^2, the modulus of rupture value was 2.51 N/mm^2, and the split tensile strength was 1.68 N/mm^2, at 28 days of curing. The results of this investigation demonstrate that, whereas other percentage levels indicate decreased strength, FC with rice husk ash percentages up to 10% did not significantly differ in strength from the control concrete. The study concluded that FC used for this study has potential for structural applications up to 15% RHA and up to 30% for non-structural purp
oses.

Keywords— Compressive Strength, Density, Foamed Concrete, Rice Husk Ash, Tensile Strength, Workability.

1 Introduction

Concrete is regarded as one of the essential construction materials, owing to its versatility and offering diverse forms of construction. Materials like cement, sand and needed aggregate in the production of concrete are globally and readily available. Concrete as a construction material is extensively used due to its excellent qualities such as functionality, sufficient strength, durability, and easy accessibility of raw materials used in its production (Mehta & Monteiro, 2006). The traditional production process for concrete is highly intricate and involves multiple processes, including batching, proportioning, mixing, placing, compacting, finishing, and curing. Although, normal-weight concrete has high compressive strength and high permeability, but with high density which makes concrete products rigid. Concrete can be delivered a long distance in a plastic state for placement, and it is the only construction material with such desirable properties. This unique quality makes concrete desirable as a building material because it can be produced in different forms or shapes with different properties. There is a concern for more understanding of the application of concrete and to improvement of its properties. Concrete has advantages including high compressive strength, durability, workability, and functional performance (Jackson, 2015).

Normal concrete possesses a density of between 2200 and 2600 kg/m^3 (Nevile, 2000); however, this makes it an expensive material. Past research has attempted to increase the efficiency of concrete by reducing its self-weight (Akshata & Dilip, 2018).

The application of foamed concrete can accomplish this. By adding up air bubbles to the concrete mixture, foamed concrete can be produced without typically using coarse aggregate at all, on the other hand, foamed concrete can be produced using light aggregate. Neville (2011) states that two methods are available for producing foamed concrete: the pre-formed foam method, which includes adding a solid pre-formed foam to the unfoamed mix while mixing, or the mixture-foam method, which involves adding a gas-entraining agent to the mix of concrete to create bubbles of air when mixing at a high speed (Neville, 2011). According to (Akshata & Dilip, 2018), aerated concrete is prepared by the inclusion of air or gas into a mix containing Portland cement or lime and finely crushed siliceous filler so that when the mix sets and hardens, a uniformly cellular structure is formed. It is a mixture of water, sand and cement. It is also called gas or foam concrete. Akshata & Dilip, (2018) cite several methods for producing aerated concrete, such as the formation of gas, mixing foam, or adding finely metal powder (often aluminum powder) to the slurry and allowing it to react with calcium hydroxide that is released during the process of hydration to produce a significant amount of hydrogen gas. The cellular structure is provided by the hydrogen gas present in the slurry mixture. Hydrogen peroxide, bleaching powder, and zinc

*Corresponding Author
Section B- CIVIL ENGINEERING & RELATED SCIENCE
Can be cited as:
Agboola A.S. , Aliyu A.A., Musa A.K., Abbas I.K., Moshood O.S. Properties of Foamed Concrete Produced with Rice Husk Ash as a Partial Replacement for Cement. FUOYE Journal of Engineering and Technology (FUOYE**JET**), **9(2), 346-353.** https://dx.doi.org/10.4314/fuoyejet.v9i2.26

powder can be used. In the second procedure, a foam is mixed with cement and sand leading to cellular structure, after setting. Additionally, cellular aerated structures can be introduced into the concrete by air-entrained agents (Akshata & Dilip, 2018). According to ACI, 523 (1975), "foamed concrete can be defined as a lightweight material consisting of Portland cement or lime with fine sand, and slag, or fly ash, mixed with water to form a homogeneous void paste or cell structure. The foamed concrete cellular structure can be achieved by basically introducing macroscopic voids which result from a gas-releasing chemical reaction or the mechanical inclusion of air or other gases". Neville (2011), demonstrated that the aerated concrete's cellular structure or foamed consists of 0.1–1 mm cell that are resistant to compaction, molding, and mixing. According to Ramamurthy *et al.* (2009), concrete foam needs to be stable in order to withstand mortar pressure while being mixed and placed till it reaches its initial set. Preformed foaming agents used in foamed concrete mix can be either wet or dry depending on the method of production.

Low self-weight, excellent flowability, controllable strength, and effective thermal insulation are properties of foamed concrete. Foaming concrete with densities ranging from 400 to 1600 kg/m^3 can be created and utilized for structural and partition walls when the foam dosage is appropriately managed (Ramamurthy *et al.*, 2009). Foam concrete's main advantage is its light weight, which economizes the construction of the supporting structures, such as the walls and foundation of lower floors. Foamed concrete is commonly used as a product material for insulation, but a recent development is that it may also be employed structurally (Narayanan & Ramamurthy, 2000). Furthermore, foamed concrete's sustainability potential is increased by the possibility of reusing it at the end of its lifespan and the viability of including secondary components such pozzolanic material (Jones & Zheng, 2012). However, as foamed concrete is frequently used as a large-volume filling agent, it is crucial to keep an eye on how it affects environmentally friendly building practices because it may high content of Portland cement, which could result to high CO_2 content (Jones and Zheng, 2012). This can be prevented by explicitly defining the design requirements, using foamed concrete density and the lowest feasible cement content, and adding secondary ingredients such as rice husk ash to the mix.

In addition, Future demands for environmentally friendly building materials with good performance regarding strength, economy, functionality, and longevity (Jones & McCarthy, 2005). Foamed concrete has gained fame in the construction industry due to its ability to produce a broad variety of densities (400-1600 kg/m^3), making it a viable solution for performance and sustainability needs (Jones & McCarthy, 2005; Tarasov, *et al.*, 2010). Because foamed concrete doesn't require coarse aggregate during production and secondary materials can be used in place of fine aggregate as well as cement entirely or partially, sustainability is improved (Jones & McCarthy, 2006). Agricultural or industrial debris are known as secondary or pozzolanic materials, and they have the potential to be substitute materials in the construction industry (Agboola, *et al.*, 2020a). It is profitable to use the solid wastes produced by the majority of manufacturing and agro-based sectors. Reusing solid waste has gained attention due to concerns about massive trash creation, preservation of resources, and material expenses (Islam, *et al.*, 2015). Among the pozzolana substituted in the making of concrete are fly ash, aluminum powder, slag from blast furnaces and rice husk ash. The most suitable waste material to cut down the cost of the construction budget as prioritized in this research is rice husk ash. Rice husk ash is a by-product of rice processing and is produced in large quantities globally every year (Chandra, 1997). About 500 million tons of rice paddy is produced in the world an annually; however, Rice milling generates a byproduct known as husk (Chandra, 1997). During milling of paddy about 78% of weight is received as rice, broken rice and bran, Rest 22% of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75% volatile matter which are organic and the balance 25% of the weight of this husk is converted into ash during the firing process which is known as rice husk ash (Nagrale, *et al.*, 2012). Rice is found virtually in all part of Nigeria but predominantly in the north. Research in this area can lead to major improvements in construction in both small and large scale without the need for massive governmental intervention. The chemical compounds of rice husk ash ability and other pozzolan is set in the ASTM C 618 standards, and depends mainly on the amount of Ca, Si and Al oxides present, the ratio between them and their reactivity (Agboola *et al.*, 2022a; Agboola *et al.*, 2020a; Pacheco-Torgal *et al*., 2008; Ravikumar, *et al.*, 2010; Billong *et al*., 2011). The ashes of rice husk ash are rich in amorphous SiO_2, having great pozzolanic properties (Agboola *et al.*, 2022a; Behak & Perez, 2008). Zhang & Malhotra, (1996) confirmed that reactive rice husk ash is similar to silica fume. The reactions between the chemical compounds lead to densification of cement matrix, which contributes to increased strength, reduced permeability and increased long-term durability (Agboola *et al.*, 2022b; Vitro-Minerals, 2006). It is worth to mention that the use of RHA in concrete may lead to the improved workability, reduced heat evolution, reduced permeability, and increased strength at longer ages (Agboola *et al.*, 2022b; Ganesan, 2007; Chindaprasirt, *et al.*, 2007; Gemma-Rodrýguez, 2006; and Mehta, 1978). Khassaf, *et al.* (2014) carried out research to on rice husk ash to replace cement with 10%, 20%, and 30% replacement, the result shows that 10% and 20% were the best replacement by achieving high strength.

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Agboola *et al.*, (2022a) carried out research to on rice husk ash to replace cement with 10%, 20%, and 30% replacement, the result shows that 5% and 10% were the best replacement by achieving high strength. Agboola *et al.*, (2022b) reported that rice husk ash as cement replacement leads to improved durability of concrete and the optimum strength is at 5% and 10% cement replacement with rice husk ash. According to Kishore, (2012), the 28 days' compressive strength of the foamed concrete varies according to its constituents, largely its air voids content, but usually from 1 to 25 N/mm^2 (Kishore, 2012). Studies conducted by Falade, *et al.*, (2013), have demonstrated that up to 20% of cement in foamed aerated concrete can be substituted with pulverized bone ash. More data from this study will be obtained to offer a workable method for producing foamed concrete in the future utilizing rice husk ash. The main goal of this research is to evaluate the foamed concrete's strength characteristics produced with rice husk ash.

2 MATERIALS AND METHODS

2.1 MATERIALS

According to BS 12 (1996), Ordinary Portland Cement was the primary binder employed in this investigation. Rice husk was obtained from a rice mill at Mudawal market in Bauchi metropolis, and rice husk ash was produced from it. River sand from Yelwa River in Bauchi metropolis was used as the fine aggregate passing through a 300-micron sieve size but retained on a 150-micron sieve aperture per BS 882 (1992). This was done to prevent coarser aggregate from settling in a lightweight mix and causing the foam to collapse during mixing. Protein-based foaming agent was used and portable tap water was used to prevent organic contamination which can harm the foam's quality and the concrete produced.

2.2 MIX PROPORTIONS

To achieve the target plastic density of 1600kg/m^3 (±50kg/m^3) a mix proportion was developed; with density being the design criterion in foamed concrete. Since there is no standard method for carrying out the mixed design of foam concrete, trial mixes were conducted using the available local materials to achieve the desired density and workability. The mix constituent proportions used in the production of foamed concrete are presented in Table 1.

Table 1: Mix Constituents Proportions for the Foam Concrete Mixes

%RHA*	Mix Constituents Proportions for the Foam Concrete Mixes in kg/m^3					
	Binder(kg/m^3)		Sand (kg/m^3)	Water for Base Mix (kg/m^3)	Foam Concentration	
	Cement	RHA*			Mixing Water (kg/m^3)	Foam (g/m^3)
0%	500.00	0.00	850.00	250.00	12.78	227.20
5%	475.00	25.00	850.00	250.00	12.6	224.00
10%	450.00	50.00	850.00	250.00	12.42	220.80
15%	425.00	75.00	850.00	250.00	12.24	217.60
20%	400.00	100.00	850.00	250.00	12.02	213.60
25%	375	125	850.00	250.00	11.84	210.4
30%	350	150	850.00	250.00	11.7	208

2.3 METHODS

To evaluate the workability of foamed concrete, a spread measurement test was conducted by ASTM-230 (2003). A truncated cone mould was filled with paste, placed on a metal plate, and lifted for varying water-cement ratios ranging from 0.4 to 0.6, along with percentage replacements of cement from 0 to 30%. This helped determine the acceptable viscosity and flow rate of the mix. The workability of the mix was indicated by the diameters of the flow.

The wet density foamed concrete was determined by BS EN 12350-6 (2000) by weighing a fresh concrete sample in a container of known volume and weight. This was done for each batch before it was cast in the mould. The density was then calculated by dividing the difference between the weight of the concrete-filled container and the weight of the empty container by the volume of the container.

To determine the compressive strength of foamed concrete, cube specimens of size 100 x 100 x 100 mm were used. The compressive strength was tested at 7, 14, 28, 56, and 90 days, by BS EN 12390-3 (2009) guidelines, using sealed curing methods. The foamed concrete was subjected to a loading rate of 120KN/min and three specimens for each of the curing ages were tested. The average of the three specimens was then taken, divided by the area of the specimens to obtain the compressive strength.

The split tensile strength of the foamed concrete was determined by carrying out a test per BS EN 12390-6 (2009) guidelines and concrete was tested at 7, 28, 56, and 90 days, using cylindrical specimens of size 100 x 200 mm. Equation 1 was used to get the tensile strength of splitting (Ts), involving a rate of loading of 120 KN/min until failure. The split tensile strength was then expressed to the nearest 0.05 MPa.

$$Ts = \frac{2F}{\pi \times L \times d} \quad \text{………………………..} \quad (1)$$

The modulus of rupture for foamed concrete was determined by conducting a simple unreinforced beam test subjected to a point loading. The beam specimens were produced, prepared, and tested following BS EN 12390-5 (2009) guidelines, and concrete was tested at 7, 28, 56, and 90 days. The test specimens were 100 x 100 x 500 mm beams and were tested under a single-point loading test. The flexural strength (Mr) was calculated using Equation 2, which involved measuring the width and depth of the specimen, as well as the length of the span on which the specimen was supported, and the maximum load applied to the specimen.

$$Mr = \frac{PL}{bd^2} \quad \text{………………………} \quad (2)$$

3 RESULTS AND DISCUSSION

3.1 WORKABILITY

The outcome of the spread test on foamed concrete-produced rice husk ash (RHA) as partial cement replacement is presented in Table 2. The observation indicates that when the amount of RHA increases, the spread width of foamed concrete reduces. The spread diameter for 0.4 water-cement ratio was observed not flowing due to low water content in the mix. The spread

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diameter of the control (0% replacement of cement), 5, 10, 15, 20, 25, and 30 % RHA for 0.5 water-cement ratios are 450, 450, 450, 425, 400, 375 and 320 mm, respectively. This observation can be attributed to particle size distribution, the specific gravity of sand, and the percentage of supplementary cementitious material present in the mix. The differences in the properties of sand, rice husk ash, water-cement ratio, and foam agent present in the concrete mix all affect the spread-ability of the foamed concrete. The inter-particle voids are decreased and the presence of supplementary cementitious materials increases the inter-particle forces in the mixes. Workability is strongly influenced by the water-cement ratio to overcome the friction between solid particles and bubbles and to maintain the adsorptive characteristics of RHA. The spread diameter of the control (0% replacement of cement), 5, 10, 15, 20, 25, and 30 % RHA for 0.6 water-cement ratio are 635, 625, 625, 580, 575, 515, and 475 mm respectively. Consequently, the higher the percentage amount of supplementary materials added to the mix, the higher the amount of water required to enable spreadability.

Table 2: Spread Test for Foamed Concrete

	Water Cement Ratio		
%RHA*	0.4	0.5	0.6
0%	Very sticky	450	635
5%	Very sticky	450	625
10%	Very sticky	450	625
15%	Very sticky	425	580
20%	Not flowing	400	575
25%	Not flowing	375	515
30%	Not flowing	320	475

3.2 WET DENSITY OF CONCRETE SPECIMEN WITH RICE HUSK ASH

The wet density for foamed concrete is presented in Figure 1. The density decreases with an increase in RHA content. In comparison to the control specimens, decreased densities are 0.4%, 0.4%, 0.9%, 1.7%, and 3.3% respectively for 5%, 10%, 15%, 20%, 25%, and 30% cement replacement with RHA.. The reduction in density of concrete produced with RHA can be attributed to the fact that cement has a higher specific gravity of 3.10 than that of RHA ash which is 2.10.

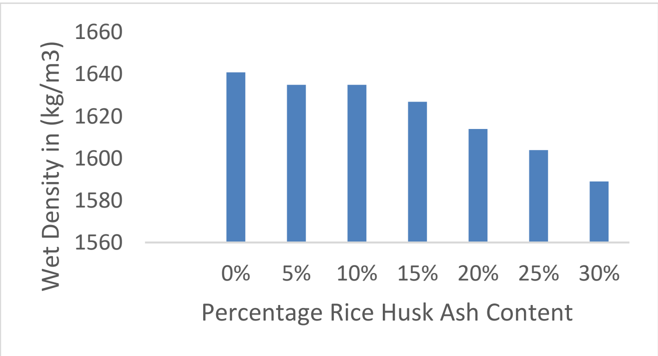

Figure 1: Effect of Rice Husk Ash on Wet Density of Foamed Concrete

3.3 DRY DENSITY OF CONCRETE SPECIMEN WITH RICE HUSK ASH

Figure 2 presents the effects of rice husk ash on the dry density of foamed concrete It is clear that as the proportion of rice husk ash in the mix increases, the dry density of the foamed concrete decreases. At 7 days of curing age, the dry density of the foamed concrete reduces as the amount of rice husk ash increases in the mix. The result of densities of the specimen for 0%, 5%, 10%, 15%, 20%, 25%, and 30% cement replacement with rice husk ash are 1570 kg/m³, 1565 kg/m³, 1545 kg/m³, 1540 kg/m³, 1530 kg/m³, and 1520 kg/m³, respectively. The foamed concrete's densities after 28 days of curing are 1665 kg/m³, 1660 kg/m³, 1665 kg/m³, 1635 kg/m³, 1625 kg/m³, 1620 kg/m³, and 1615 kg/m³ for 0%, 5%, 10%, 15%, 25%, and 30% cement replacement with rice husk ash, respectively. The same trend was noted for 90 days membrane cured foamed concrete. The variation in the behaviour of foam concrete density can be explained by the fact that rice husk ash has a lower specific gravity value than cement. Lower specific gravity of a material has been found to result in lower density (Terzaghi, *et al.*, 1996). Thus, increasing the replacement levels has the effect of making the resulting concrete lighter. This can also be observed in normal-weight conventional concrete which possesses the same characteristics as foam concrete, where higher pozzolanic concrete has reduced density as compared to control concrete or lower pozzolanic content concrete (Agboola *et. al.*, 2020b). Also, the dry density of foamed concrete at each percentage of cement with rice husk ash increased with an increase in curing age, but with a non-linear trend.

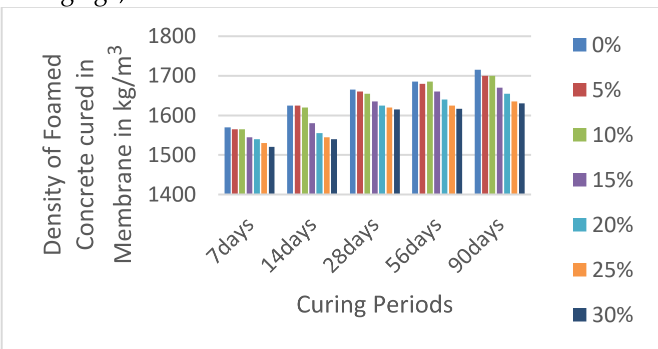

Figure 2: Density of Foamed Concrete Specimen Cured in Membrane

3.4 THE COMPRESSIVE STRENGTH OF CONCRETE SPECIMEN WITH RICE HUSK ASH

The compressive strength of foamed concrete produced at a density of 1600 kg/m³ produced with rice husk ash as partial replacement of cement at 5% to 30 % at an interval of 5%, cured at 7, 14, 28, 56, and 90 days is presented in Figure 3. The specimens with partial cement replacement with RHA develop lower strength as compared to the control specimens at all curing ages., according to the data. In 7 days, curing, the foamed concrete's compressive strength was measured at 8.85 N/mm², 8.83 N/mm², 8.82 N/mm², 8.28 N/mm², 7.92 N/mm², 7.35 N/mm², and 6.94 N/mm² respectively, while at 28 days strength achieved 15.22 N/mm², 15.22 N/mm², 15.22 N/mm², 14.84 N/mm², 12.87 N/mm², 11.51 N/mm², and 10.84 N/mm²

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respectively. This represents a 2.50%, 15.44%, 24.38%, and 28.78% reduction in strength of 15%, 20%, 25%, and 30% respectively as compared to the control concrete. Figure 4 shows a typical trend of strength increase against cement replacement with RHA at 7, 28, and 90 days of curing.

The result reveals that the compressive strengths increase when cement is replaced by RHA up to 15 % and which starts to decrease from 20% up to 30 %. The findings of this test are related to that of (ACI 213, 2003) which states that strength development up to 20% RHA levels in foam concrete still qualified to be classified as structural lightweight concrete. According to (Vitro, 2006), the alkalinity of water increases to pH 13 or even higher in concrete mix; and this enables the hydration of cement, during which tri-calcium silicates, (C_3S) and di-calcium silicates (C_2S) react to form calcium silicate hydrates (C-S-H), which is largely responsible for strength development. At this point, lime Ca $(OH)_2$, is thus liberated. It was also reported (Vitro, 2006) that high pH causes the silicate network of the RHA to break down into smaller units, which react with the Ca $(OH)_2$ to form more C-S-H binder. Reduction in strength was high in higher cement replacement with RHA, this is because when foam is introduced to the concrete, it not only creates air voids or pore spaces but also increases the total water quantity present inside the pore spaces within the concrete mass on a water/binder basis, but the water excess water is absorbed by higher cementitious material present in the mix and this subsequently affect the curing and also strength development of the foamed concrete.

Higher compressive strength of RHA concrete samples from early curing days also indicated that pozzolanic reaction started to occur even at early ages. The total effect of this is that the Ca $(OH)_2$ in the concrete, which does not possess the strength forming properties of its own, but during the pozzolanic reaction, converted by the RHA to form additional C-S-H binder, which enters the pore spaces. Additionally, the increasing percentage of rice husk ash in the concrete directly led to the declining percentage of Portland cement used in the proportion. On the other hand, pozzolanic material is supported in achieving a more consistent distribution of air voids by providing a uniform outside layer on each bubble thereby preventing the merging of bubbles. In addition, the replacement level of 0-10% RHA was found optimum to contribute to void distribution maximally and facilitate strength development. However, the strength development up to 20% rice husk ash content levels still qualified the foamed concrete to be classified as structural lightweight concrete (ACI 213R-03, 2003). At higher cement replacement levels, say 25% and 30%, the excess SiO_2 in the RHA leaches out and the RHA now acts just like an ordinary filler. The incorporation of a higher percentage of RHA beyond 20% in the mixture, makes the RHA fill up the voids within the concrete mass, and with the gradual decrease in the pozzolanic reaction, it results in the reduction of the compressive strength of the foamed concrete and this is in agreement with (Narayanan, *et al.*, 2014).

The results also confirm that the compressive strength of lightweight foamed concrete is mainly dependent on the binder/fine aggregate ratio, water/binder ratio, type and amount of foam, curing regime, type of sand, particle size distribution of the sand and the rice husk ash. However, the trend of 0%, 5%, and 10% levels gave the same and increased strength, but was different with 25% and 30% replacement levels which gives lower strength. The percentage increase in rice husk ash showed a decrease in strength due to the excessive water demand for the foamed concrete specimen needed for hydration purposes and strength development. The character of its pore structure in due to high RHA content led to excessive water absorption and yielded disordered foam distribution, which however, decrease the strength of the concrete. At the age of 28 days, the average normal strength of foam concrete without rice husk ash was found 89.53% of the required strength for structural lightweight concrete, which is 17 MPa. On the other hand, the foam concrete mixes containing 5, 10,15, 20, 25, and 30% RHA achieved 89.53%, 89.53%, 87.29%, 75.71%, 67.71%, and 63.76% of the strength classification for structural lightweight concrete. Overall, except for mixes with 25% and 30% which can be used in mass concrete production, the results suggest that the remaining mixes are all potentially suitable for use as lightweight concrete for semi-structural or structural purposes since their densities did not exceed 2000 kg/m³ and their 28-day compressive strengths are around 17 MPa (Neville, (2011); and exceed 15 MPa for (ACI 213R-03, 2003).

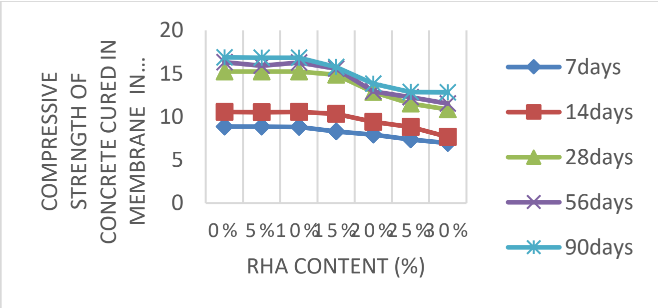

Figure 3: Compressive Strength of Foaming Concrete Specimen Cured in Membrane

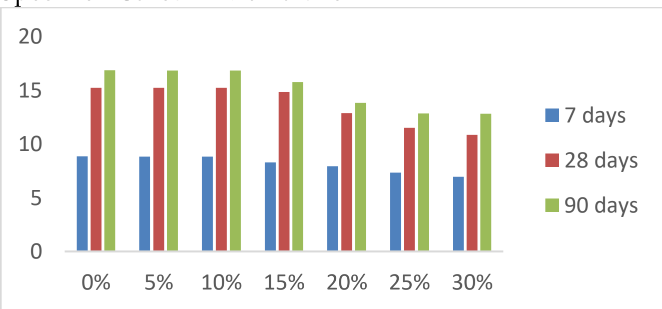

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Figure 4: Effect of Pozzolana on Strength Development of Foamed Concrete at Different Curing Age

3.5 SPLIT TENSILE STRENGTH OF CONCRETE SPECIMEN WITH RICE HUSK ASH

The investigation results for the split tensile strength of foamed concrete with a design density of 1600 kg/m³ produced with RHA are presented in Figure 5. It was observed that the splitting strength increased with curing age at all cement replacement levels with RHA. However, it also showed a decrease in splitting tensile strength as the rice husk ash content increased in foamed concrete.

At 28 days of curing age, the value of the control concrete was 1.68N/mm². This value was comparable to 1.8N/mm² for the same density that was earlier obtained by (Jones, 2000). The lowest split tensile strength was 1.33 N/mm² for 30% cement replacement with RHA at 28 days; this value was higher than 0.17N/mm² recommended by ASTM C869 (ASTM C869, 1991), for lightweight concrete. The reduction in splitting strength to the control may be due to a weak bond between the paste and the sand grains. Figure 6 shows a typical trend of splitting strength increase against cement replacement with RHA at 7, 28, and 90 days of curing.

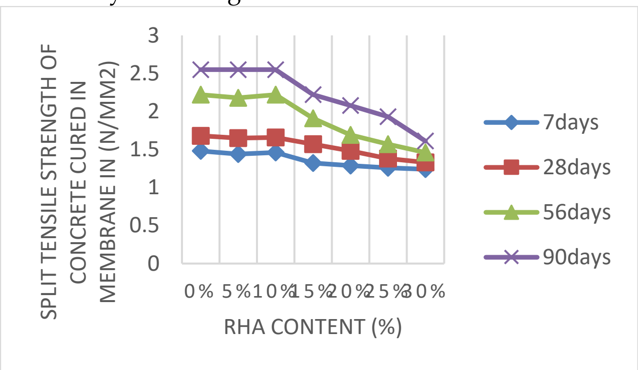

Figure 5: Split Tensile Strength of Foamed Concrete Specimen Cured in Air

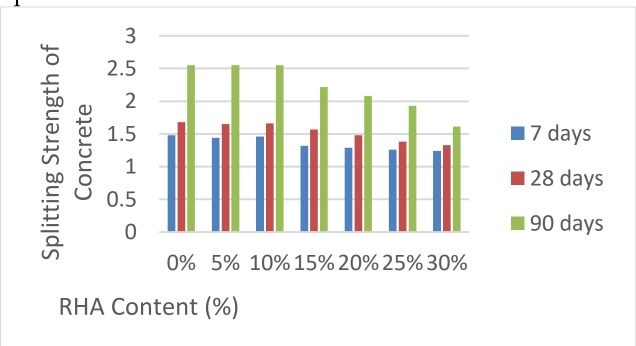

Figure 6: Effect of Pozzolana on Splitting Strength Development of Foamed Concrete at Different Curing Age

3.6 MODULUS OF RUPTURE OF CONCRETE SPECIMEN WITH RICE HUSK ASH

Figure 7 presents the modulus of rupture of foamed concrete with a design density of 1600 kg/m³ produced with different percentages of RHA. The results indicate that strength increased with an increase in curing age at all cement replacement levels with RHA, but showed a decrease in strength as the RHA content increased.

For flexural strength, the control had a value of 2.51 N/mm² after 28 days of curing age, which was higher than 1.0 N/mm² for the same density of foamed concrete obtained earlier by (Brady, *et al.*, 2001). The lowest measured strength was 1.94 N/mm² observed for 30% cement replacement with RHA at 28 days of curing, which remained higher than the value obtained by (Brady, *et al.*, 2001). The reduction in strength in relation to the control may be due to weak bond between the paste and the sand grains. Figure 8 shows a typical trend of the strength increase against cement replacement with RHA at 7, 28, and 90 days of curing.

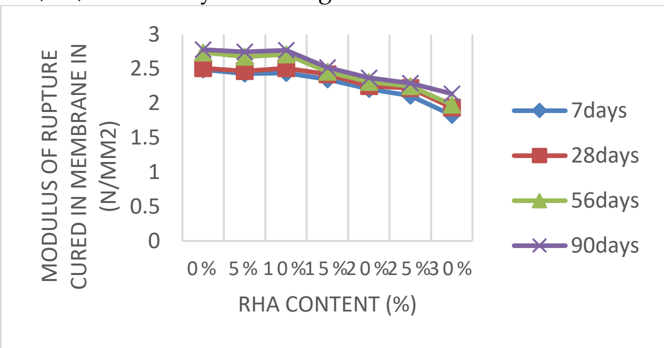

Figure 7: Flexural Strength of Foamed Concrete Specimen Cured in Membrane

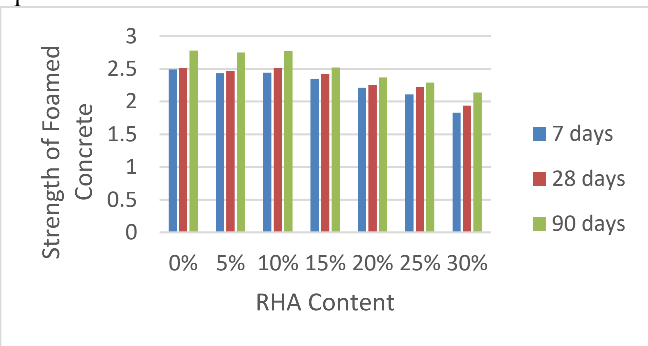

Figure 8: Effect of Pozzolana on Flexural Strength Development of Foamed Concrete at Different Curing Age

4 CONCLUSIONS

The density of foam concrete increases with its curing age, but reduces as the percentage of rice husk ash is increased, also concrete wet density increases as the percentage of rice husk ash is reduced, and wet density is reduced as the rice husk ash content increases in the concrete mix. The control foamed concrete used in this experiment, at the anticipated density of 1600 kg/m³, has a compressive strength of 15.22 N/mm² after 28 days, which satisfies the required minimum strength criteria for being designated as a structural lightweight, by ACI 213R for membrane (sealed cured) concrete. The 28-day split tensile strength of 1.68N/mm² of the foamed concrete meets ASTM requirements for lightweight concrete. The 28-day modulus of rupture value of foamed concrete, which is 2.51 N/mm², meets ASTM requirements for lightweight concrete. Rice husk ash aids in the strength development of foamed concrete, which is visible at later curing ages. Up to 30% RHA as cement replacement can be used in the production of foamed concrete. The addition of pozzolana into the concrete mix in optimal quantity reduces the inter particle spaces between the fine aggregate's particles and affects the degree of saturation and thus reduces the pore in foamed concrete, which improves the strength of concrete. As a lightweight material, foamed concrete has the advantage of ease of handling and low workmanship is required. It helps in the reduction of dead load; and increases the progress of the building due to its lightweight nature. The findings of this study in terms of strength are encouraging and results have shown the potential application of modified foamed concrete with pozzolana in semi-structural and structural applications. Further investigation needs to be carried out to examine the potential of using FC in reinforced structural elements such as beams, columns, slabs and reinforced walls. Further research is required to investigate the effect of SCM and admixture on the structural, functional properties and drying shrinkage of FC. Further investigation is required on the effect of lightweight aggregate, sizes and content on the properties of foamed concrete.

REFERENCES

ACI Committee 213 (2003). "Guide for Structural Lightweight Aggregate Concrete (ACI 213R-03), American Concrete Institute, Farmington Hills, MI.

ACI Committee 523, (1975). Guide for cellular concrete above 50 pcf and for aggregate concretes above 50 pcf with compressive strengths less than 2500 psi, ACI J. Proc. 72 (2).

Agboola, S.A., Umar Y., Tukur M., & Bappah H. (2022a). Strength Performance of Concrete Produced with Rice Husk Ash as Partial Replacement of Cement. *African Journal of Environmental Sciences & Renewable Energy. (AJESRE).* 5(1), 1 – 15. Retrieved from http://publications.afropolitanjournals.com/index.php/ajesre/article/view/183.

Agboola, S.A., Bappah H., Adamu S. A., & Tukur M. (2022b). Effect of Rice Husk Ash on the Durability Properties of Concrete Subject to Aggressive Chemical Environment. *African Journal of Environmental Sciences & Renewable Energy. (AJESRE).* 5(1), 16 – 37. Retrieved from http://publications.afropolitanjournals.com/index.php/ajesre/article/view/184.

Agboola, S.A., Mamman A.I., Musa A.K., & Bappah H. (2020a). Effect of Waste Glass Powder as a Pozzolanic Material in Concrete Production. International Journal of Engineering Research and Technology (IJERT). 9(2), 589 – 594, ISSN: 2278-0181. February 2020. DOI: https://doi.org/10.13140/RG.2.2.30078.56648.

Agboola, S.A., Mamman A.I., Tapgun J., & Bappah H. (2020b). Strength Performance of Concrete Produced with Volcanic Ash as Partial Replacement of Cement. International Journal of Engineering Research and Technology (IJERT). 9(3), 372 – 378, ISSN: 2278-0181. March 2020. https://doi.org/10.13140/RG.2.2.13367.68002.

Akshata A.M., & Dilip K.K. (2018). Lightweight Concrete. International Research Journal of Engineering and Technology. 5(5), 2592- 2593.

ASTM-Standard Specification for Flow Table for Use in Tests of Hydraulic Cement, ASTM-C230, 2003.

ASTM C869 (1991). "Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete".

Behak, L., & Perez, N. (2008). Characterization of a material comprised of sandy soil, rice husk ash and potentially useful lime in pavements. Journal Ingeniería de construcción. 23 (1), 34-41.

Billong, N., Melo, U.C., Kamseu, E., Kinuthia, J.M., & Njopwouo, D. (2011). Improving hydraulic properties of lime–rice husk ash (RHA) binders with metakaolin (MK), Construction and Building Materials, 25(4), 2157-2161.

Brady, K.C., Watts, G.R.A. & Jones, M.R. (2001) "Specification for Foamed Concrete - The Use of Foamed Concrete as Backfill". QSCE Geotechnics and Ground Engineering Highways Agency, TRL Limited, London.

BS EN 12390-3 (2009)''Testing Hardened Concrete: Compressive Strength of Test Specimens" British Standard Institution, London.

BS EN 12390-5 (2009) "Testing Hardened Concrete. Flexural Strength of Test Specimens". British Standard Institution, London.

BS EN 12390-6 (2009) "Testing Hardened Concrete. Tensile Splitting Strength of Test Specimens". British Standard Institution, London.

BS EN 12350: part 6 (2000) ''Testing Fresh Concrete - density" British Standard Institution, London.

BS 12 (1996) "Specification for Portland Cement". British Standards Institution, London.

BS 882 (1992) "Specification for Aggregates from Natural Sources for Concrete". British Standards Institution, London.

Chandra, S. (1997). "Waste Materials Used in Concrete Manufacturing". University of Technology Goteborg, Sweden.

Chindaprasirt, P., Rukzon S., & Sirivivatnanon V. (2007). "Strength, porosity and corrosion resistance of ternary blend Portland cement, rice husk ash and fly ash mortar", Construction and Building Materials.

Falade, Funso, Ikponmwosa, Efe., Fapohunda, & Chris. (2013)"Low-Cost Construction Through the Use of Pulverized Bone Foamed Aerated Concrete (PB-FAC)". The International Institute for Science, Technology, and Education: Journal of Civil and Environmental Research, 3(10), 108 – 113.

Gemma Rodrýguez de Sensale, (2006). "Strength development of concrete with rice husk ash", Cement & Concrete Composites, 28, 158–160.

Ganesan, K., Rajagopal, K., & Thangavel, K., (2007). "Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete", Construction and Building Materials, Article in Press.

Islam, U.I., Alengaram, M. M., Jumaat, U.J., & Bashar, I. I. (2015). "Usage of Palm Oil Industrial Wastes as Construction Materials, A Review." In *Proceedings of Sixteenth IIER International Conference*.

Jackson, K. (2015). Influence of Recycled Waste High-Density Polyethylene Plastic Aggregate in the Physico-Chemical and Mechanical Properties of Concrete. Masters (MPHIL) thesis in Polymer Science. Department of Chemistry, Kwame Nkrumah University of Science and Technology, Kumasi.

Jones M. R. (2000). "Foamed Concrete for Structural Use". One-day Awareness Seminar on 'Foamed Concrete: Properties, Applications and Potential' Held at University of Dundee, pp. 54-79.

Jones, M.R. & McCarthy, A. (2006). "Heat of hydration in foamed concrete: Effect of mix constituents and plastic density". Cement and Concrete Research, 36(6), 1032-1041.

Jones, M.R. & McCarthy, A. (2005). Behavior and Assessment of Foamed Concrete for Construction Applications, Thomas Telford, London, UK.

Jones, M.R., Zheng, L., Yerramala, A., & Rao, K.S. (2012). "Use of recycled and secondary aggregates in foamed concrete". Magazine of Concrete Research, 64(6), 513-525.

Khassaf, S.I., Jasim, A.T. & Mahdi, F.K. (2014). Investigation of the Properties of Concrete Containing RHA to Reduce Seepage in Canals. International Journal of Scientific and Technology Research. 3, 348-354.

Kishore, K. (2012) "Foamed Cellular Light Weight concrete", Concrete Engineering Research Papers, Civil Engineering Portal. (2012).

Mehta, P.K. & Monteiro, P.J.M. (2006) "Concrete: Microstructure, Properties and Materials", Third edition, McGraw-Hill, New York.

Mehta, P.K. (1978). "Siliceous ashes and hydraulic cements prepared therefrom", US Patent, 4105459.

Nagrale, S. D., Hajare, H., & Modak, P. R., (2012). "Utilization of Rice Husk Ash". International Journal of Engineering Research.

Narayanan P. S., Kalaikumar V, Yusoff M F, Anwar A, Haron M F, & Alias M. N. (2014). Properties of rice husk ash (RHA and MIRHA) mortars, Research Journal of Applied Sciences Engineering and Technology 7, 3872–3882.

Narayanan, N. & Ramamurthy, K. (2000). Structure and properties of aerated concrete: a Review, Cement. Concrete. Composite. 22, 321–329.

Neville, A.M. (2011). Properties of Concrete, 4th Edition, England; Longman.

Neville, A.M. (2000). Properties of Concrete, United Kingdom, England; Longman.

Pacheco-Torgal, F., Castro-Gomes J., & Jalali, S. (2008). Alkali-activated binders: A review: Part 1. Historical background, terminology, reaction mechanisms and hydration products, Construction and Building Materials, 22(7), 1305-1314.

Ramamurthy, K., Nambiar, E.K. & Ranjani, G.I.S. (2009). A classification of studies on properties of foam concrete, Cement Concrete Composition 31(6), 388–396.

Ravikumar, D., Peethamparan, S., & Neithalath, N. (2010). Structure and strength of NaOH activated concretes containing fly ash or GGBFS as the sole binder, Cement and Concrete Composites, 32(6), 399-410.

Tarasov, A.S., Kearsley, E.P., Kolomatskiy, AS. & Mostert, H.F. (2010). Heat evolution due to cement hydration in foamed concrete, Magazine. Concrete. Research. 62 (12), 895–906.

Terzaghi, K., Peck, R. B. & Mesri, G. (1996). "Soil Mechanics in Engineering Practice". John Wiley, New York, Third Edition.

Vitro, M, (2006). V A White Pozzolanas "Portland cement and Pozzolanas", Journal on Technical Background for the Effective Use of VCAS Pozzolanas in Portland cement Concrete (October 2006), 1-7.

Zhang, R.L., & Malhotra, V.M. (1996). "Rice Husk Ash Paste and Concrete: Some Aspect of Hydration and the Microstructure of the Interfacial one between the Aggregate and Paste," *Cement Concrete Research*, 26(6), 963-977.

http://dx.doi.org/10.46792/fuoyejet.v9i2.26