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Strength Performance of Concrete Produced with Rice Husk Ash as Partial Replacement of Cement

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Abstract

Concrete is the most common construction material with its major constituent being cement. The production of this Cement results in a lot of environmental issues which include the constant emission of CO_2 gas. Reduction of this gas, preservation of natural resources needed in the production of the constituent of cement and subsequent sustainability of concrete structures have fueled the search for alternative cementing material to produce environment-friendly construction materials. Recently, supplementary cementitious materials like the agricultural by-products are used to replace a portion of the cement in concrete mixtures. The use of such CSM in concrete not only prevents these products from being land-filled which causes pollution but also enhances the properties of concrete in the fresh and hardened states. These supplementary cementitious materials with pozzolanic action react with hydration products in cement to form calcium silicate hydrate (CSH) thus enhancing and improving concrete quality and consequently reducing the cost of concrete production. One of such material is Rice Husk Ash (RHA). The study investigated the chemical composition of RHA as well as the specific gravity, workability, compressive strength, split tensile strength and flexural strength properties, with varying percentage of blended cement concrete and 100% cement concrete of mix ratio 1:2:4 and water-cement ratio of 0.5 were examined and compared. Slump test and compacting factor test was carried out to check the effect of RHA on the workability of fresh concrete. RHA partially replace cement in the order of 0%, 5%, 10%, 15%, 20%, 25% and 30% were cast. The concrete specimens were tested at the ages of 7, 14, 21 and 28 days. The optimal cement replacement was found to be at 10% RHA. This combination gave a compressive strength of 26.8 N/mm^2. This is close to the control concrete with compressive strength of 26.9 N/mm^2 at 28days hydration period. Therefore, rice husk ash can be used as a replacement for cement in concrete.

Keywords: Concrete; rice husk ash (RHA); specific gravity (SG); supplementary cementitious materials (SCM).

Introduction

Portland cement concrete is after water, the most utilized material in the world. Besides becoming one of the most widely used construction material in the world, concrete has demonstrated throughout the years to be an excellent material in term of forms, shape and performance.

The production of this cement is increasing year by year and a substantial percentage of the world's carbon dioxide emission is attributable to the cement industry. There is need to economize the use of cement as we cannot continue to produce more and more of it because of its significant contribution to the pollution of the environment. Various amounts of natural resources are consumed to manufacture this cement which produces considerable energy during its production and this emits numerous carbon dioxide into the environment which lead to environment pollution.

On the other hand, the climate change due to global warming is one of the greatest environmental issues which has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming (Mccaffrey, 2002). This means that the production of cement requires the burning of fuel which results in significant release of large amount of carbon-dioxide (CO_2). Patricija, Aleksandrs, and Valdemars, (2013), noted that cement does not only consume energy during its production, it is also accountable for a substantial part of man-made CO_2 emission, which leads to global warming. During the manufacturing of 1 ton of cement, 1 to 1⅓ ton of earth resources like lime stone is used up and at the same time, an equivalent amount of CO_2 is released into the atmosphere (Srinivasan, Sathiya, and Palanisamy, 2010). According to Jindal, and Kamal, (2015), production of Portland cement currently exceeds 2.6 billion tons per year worldwide and it increases at the rate of 5% each year thereby generating nearly 7% of atmospheric carbon-dioxide (CO_2) which contributes largely to the global warming. With the high cost of producing Portland cement and high consumption of natural resources like limestone, substantial energy and cost savings can be achieved when industrial and agricultural by-products are used as partial replacement for the energy intensive Portland cement. According to Ogunbode, and Hassan, (2011), problems of pollution and cost have led to researches on cement alternatives or substitutes that will fully or partially replace cement in the construction industry. However, Portland cement is still the main binder in concrete construction prompting a search for more environmentally friendly materials.

The use of concrete refers generally to the use of Portland cement and the related materials, such as water, fine and coarse aggregates, when mixed together to be capable of producing concrete with the desirable properties. In recent years the concept of concrete is no longer the same as it includes the major constituent of concrete plus admixtures.

Researches on eco-friendly materials like the supplementary cementitious material (SCM) in the production of concrete is inevitable. Efforts have been made by researchers to reduce the problem created when using Portland cement in concrete production whereby its quantity is partially replaced with supplementary cementing materials such as fly ash, ground granulated blast furnace slag, rice husk ash, corn cob ash, metakaolin, coconut shell ash, groundnut husk ash, volcanic ash, glass waste powder (Abdulazeez, 2019; and Utsev, & Taku, 2012). In this respect, a new material like the pozollana which is different from the major constituent of concrete need to be introduced into the concrete constituent to partially substitute the ordinary Portland cement in concrete (Abdulazeez, 2019). The

American Society for Testing and Material (ASTM C125-06), defined pozzolan as a siliceous or siliceous and aluminous material that in itself possesses little or no cementitious value, but that will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties. A considerable amount of pozollana application into concrete as an alternative binder to Portland cement shows improved and promising result (Agboola, Idi, Tapgun, Bappah, 2020). In terms of reducing the global warming, pozollana application could reduce the CO_2 emission to the atmosphere which is caused by cement product by considerable amount (Abdulazeez, 2019). ASTM C125-06 (2006), classified pozzolans as either natural or artificial pozzolan. Natural pozzolans include; clay and shales, opalinc cherts, diatomaceous earth, volcanic ash, volcanic tuffs and pumicites, Artificial pozzolans include; fly ash, blast furnance slag, silica fume, rice husk ash, metakaoline and surkhi. Out of the many different materials used in concrete rice husk ash, being one of the classifications of artificial pozzolans, is economical and accessible, sustainable, easy to obtain and locally produced material. The use of rice husk ash (RHA) as a pozzolan showed that a combination of its chemical constituents qualified it as a pozzollana. The use of rice husk ash as partial cement replacement in concrete is one potential means of generating affordable binder for construction and is a way of effectively converting the waste to wealth. However, rice husk is one of the major wastes littering the environment in Nigeria especially in the far north who plant in large quantity. Rice husk is an important food crop produced in large quantity in the savannah belt of Nigeria and West Africa. It presently ranks amongst the three major grain crops growing particularly in the northern states of Nigeria. The quantum of global production of paddy rice is close to 650 million tons per annum. Also, to put it differently, Production of rice is dominated by Asia, where rice is the only food crop that can be grown during the rainy season in the waterlogged tropical areas, which mean it is produced in large quantities in region where it grows. Rice is mostly harvested and processed manually for food, leaving the large volume of residue constituting waste in the farm, most of which are flared off in preparation for subsequent farming season.

The use of industrial and agricultural by-product as a pozollana in cement production is an environmentally friendly way of disposal of large quantities of materials that would otherwise pollute land, water and air. The incorporation of pozzolanic waste ash in concrete can significantly enhance the basic properties in both the fresh and hardened states (Agboola, *et. al.*, 2020). These materials known as pozollana greatly improve the strength and durability of concrete (Agboola, *et. al.*, 2020). The utilization of pozollanic material as partial replacement of cement has important economic, environmental and technical benefits such as the reduced amount of waste materials, cleaner environment, reduced energy requirement, durable service performance during service life, and cost-effective structures (Agboola, *et. al.*, 2020). Most concrete mixes can be engineered such that the SCM will give the mix certain properties (mechanical strength, workability, or durability) which it would not have without it.

Researches earlier carried out include using alternative cementitious materials such as fly ash, rice husk ash and ground granulated blast furnace slag contribute to improvement of concrete performance (for example, high strength, high durability and reduction of heat of hydration) as well as reduction of energy and carbon dioxide generated in the production of cement. Mukherjee, Mandal, and Adhikari, (2012), uses fly-ash to replace ordinary Portland cement with fly ash at 20%, 30%, 40%, 50%, 60% and 70%. The results showed that the compressive strength decreases at 3, 7 and 28 days as the replacement of fly ash approach 30% replacement. Research carried out on rice husk ash showed that rice husk ash possesses pozzolanic characteristics of artificial pozzolans and recommend that it can be used to partially replaced cement in concrete. Khassaf, Jassim, and Mahdi, (2014), carried out research on rice husk ash to replace cement with 10%, 20%, and 30% replacement, the result shows that 10% and 20% were the best replacement to achieve high strength. In other vein, Groundnut shell ash was used by Mahmoud, Belel, and Nwakaire, (2012), at 10%, 20%, 30%, 40% and 50% as a partial replacement of cement in sandcrete blocks production. The optimum replacement achieved at 20% with a corresponding strength of 3.58 N/mm^2. However, research carried out on volcanic ash by (Agboola, *et. al.*, 2020), is one out of many researches that is carried out on Jos Plateau volcanic rock to replace OPC with 5%, to 20%, volcanic ash, the results showed that 5% and 10% were the best replacement that achieve highest compressive strength. Currently world production rate of cement is increasing and is expected to grow significantly in the nearest future, also with the issue of pollution. This increasing demand for cement and pollution concern is expected to be met by partial cement replacement. This research therefore examined the strength performance of concrete produced with rice husk ash as partial replacement of cement.

Materials and Methods

All the materials used for laboratory experiment were procured from the immediate environment. The relevant standards were used in the process of conducting the experiments.

Materials

The materials used for this study include, coarse aggregate, fine aggregate, cement, rice husk ash and water. Rice husk ash was gotten from farmers within Bauchi, Bauchi state, Nigeria. The rice husk ash was burnt at a controlled temperature of 650^oC. The coarse aggregate was obtained from a quarry site within Bauchi metropolis. The fine aggregate was also obtained from Yelwa River-flow in Bauchi state. The ordinary Portland cement is the brand of Dangote of Grade 42.5 which was procured from vendors within Bauchi metropolis.

Methods

Specific Gravity

In determining the specific gravity of aggregate, a pycnometer (a vessel of 1-liter capacity with a metal conical screw top and a 5mm diameter hole at its apex, giving a water tight connection), tray, scoop, drying cloth and weighing balance were used. The test procedure was carried out in accordance to (BS 812-2, 1975). The apparatus used during the test include density bottle and stopper, funnel, spatula and weighing balance.

Mix Ratio

A 1: 2: 4 mix ratio was designed using a water cement ratio of 0.5. Rice husk ash was used to replace cement from 5% to 30%.

Workability Tests of the Wet Concrete

Slump test and compacting factor test were conducted in accordance with (BS 1881-102, 1983).

Figure 1: Workability Test (Slump Test)

Curing

The specimens were removed from mould after 24hours and taken to the water curing tank for the required days. The curing period include 7days, 14 days, 21 days and 28 days. After the required curing period, tests were conducted on the hardened concrete. Curing process is used in enhancing the hydration of cement in concrete and also to improve the performance of concrete.

Density Test

This was carried out prior to crushing of the concrete specimen. At the end of each curing period, the concrete specimens were weighed using an electric weighing machine balance and values recorded. Density is calculated as mass of concrete specimen in (kg) divided by volume of concrete cube (m^3) and expressed in kg/m^3.

Density $= \frac{m}{v}$

Figure 2: Measuring Specimen for Density Test

Compressive Strength Test of Concrete

The compressive strength test was conducted in accordance with (BS 1881-116, 1983). The cubes were cast and cured for 3days, 7 days, 14 days, 21 days and 28 days respectively. For each mix, 3 cubes were crushed to obtain the average strength of the concrete samples. The compressive strength is the ratio of the weight of cube and the cross sectional area.

Figure 3: Compressive Strength Test

Splitting Tensile Strength Test

The spilt strength test was conducted in accordance with (BS 1881-117, 1983). Tensile strength of concrete is determined by indirect method since it was very difficult to apply uniaxial tension to a concrete specimen. The splitting tensile strength was carried out using the compressive universal testing machine of 2000 KN capacity. The splitting tensile strength was calculated using the formula below;

$$ft = \frac{2p}{\pi Ld}$$

Where:

ft = splitting tensile strengths (N/mm^2)

P = failure load (KN)

d = diameter of cylinder (mm)

l = lenght of cylinder (mm)

Figure 4: Split Tensile Strength Test

Flexural Strength Test of concrete

The flexural strength test was conducted in accordance with (BS 1881-116, 1983). The beams were cast and cured for 7 days and 28 days repectively. For each mix, 3 beams were placed and subjected to breaking machine to obtain the average strength of the concrete samples and the maximum load was recorded. Result were then calculated with:

$$\boldsymbol{R = \frac{Mc}{I} = \frac{PL}{bd^2}}$$

R= flexural strength (N/mm^2), I= moment of inertia (mm^4), P= failure load (n) M= max. bending moment (Nmm), L=length (mm), B= average width (mm), C = d/2 (mm), d = average depth (mm).

Figure 5: Flexural Strength Test

Results and Discussion

Chemical Analysis

The Chemical properties of rice husk ash was investigated and presented in Table 1, the result showed that rice husk ash comprises of 81.47% Silicon Oxide (SiO_2), 1.61% Aluminum Oxide (Al_2O_3), 1.34%, Iron Oxide (Fe_2O_3), 1.22% Calcium Oxide (CaO), 1.46% Magnesium Oxide (MgO), 0.08% Sodium Oxide (Na_2O), 0.32% Potassium Oxide (K_2O) and 0.03% Manganese Oxide (Mno), which have constituent related to ordinary Portland cement. ASTM C618-05 (2006) specifies that for a pozzolana to be used as a cement blend in concrete it requires a minimum 70% amount combined of silica, alumina and ferric oxides. Hence, rice husk ash is suitable and can be used as a pozzolana. The total combined content of silica, alumina and ferric-oxides was 84.42%.

Table 1: Chemical properties of RHA

Oxide Composition of RHA by mass	% Composition
Aluminum Oxide (Al_2O_3)	1.61
Silicon Oxide (SiO_2)	81.47
Iron Oxide (Fe_2O_3)	1.34
Calcium Oxide (CaO)	1.22
Manganese Oxide (MnO)	0.03
Magnesium Oxide (MgO)	1.46
Potassium Oxide (K_2O)	0.32
Sodium Oxide (Na_2O_2)	0.08
Loss on Ignition (LOI)	4.92

Source: Laboratory Research Work (2021)

Specific Gravity

The specific gravity of rice husk ash, coarse aggregate and fine aggregate is presented in Table 2, 3 and 4 respectively. The result shows that specific gravity of rice husk ash is 2.06, the specific gravity for coarse aggregate is 2.68, while that of fine aggregate is 2.63. According to Shetty (2005), the specific gravity for coarse aggregate should fall within 2.60 to 2.80, while that of fine aggregate should fall within 2.4 to 2.9 according to BS 882, (1992). According to ACI E1-99 the specific range for normal weight aggregate is between 2.30 to 2.90. However, the specific gravity of the aggregates falls within the limit as specified by the standards.

Table 2: Specific Gravity Test on Rice Husk Ash

Trial	Trial 1	Trial 2	Trial 3
Weight of empty cylinder (M_1) g	13.6	13.6	13.6
Weight of cylinder + sample (M_2) g	57.4	57.1	56.8
Weight of cylinder + water + sample (M_3) g	95.2	95.1	95.6
Weight of cylinder + water (M4) g	73.2	72.3	72.9
Specific Gravity = $\frac{M2-M1}{(M4-M1)-(M3-M2)}$	2.01	2.10	2.06
Average Specific Gravity		2.06	

Source: Laboratory Research Work (2021)

Table 3: Specific Gravity Test on Coarse Aggregate

Trial	Trial 1	Trial 2	Trial 3
Weight of empty cylinder (M1) g	117.6	117.6	117.6
Weight of cylinder + sample (M_2) g	233.4	246.1	232.6
Weight of cylinder + water + sample (M_3) g	520.6	505.6	521.1
Weight of cylinder + water (M4) g	447.5	425.6	449.2
Specific Gravity = $\frac{M2-M1}{(M4-M1)-(M3-M2)}$	2.71	2.65	2.67

Average Specific Gravity	2.68

Source: Laboratory Research Work (2021)

Table 4: Specific Gravity Test on Fine Aggregate

Trial	Trial 1	Trial 2	Trial 3
Weight of empty cylinder (M_1) g	13.6	13.6	13.6
Weight of cylinder + sample (M_2) g	85.6	83.8	81.4
Weight of cylinder + water + sample (M_3) g	628.9	648.2	647.7
Weight of cylinder + water (M_4) g	584.4	604.7	605.7
Specific Gravity = $\frac{M2-M1}{(M4-M1)-(M3-M2)}$	2.62	2.63	2.63
Average Specific Gravity		2.63	

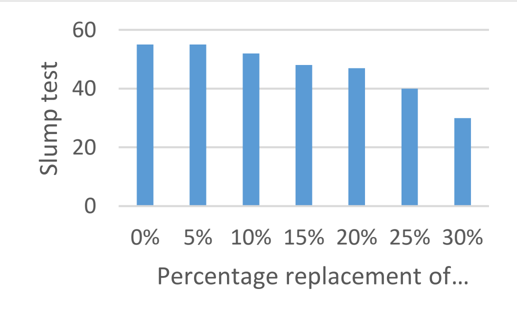
Source: Laboratory Research Work (2021)

Workability Test

Figure 6 and 7 shows the slump and compacting values for concrete containing 5% to 30% replacement of cement with rice husk ash. Result from the experiment shows that control concrete had slump value of 55mm, 5% has a slump value of 55mm, 10% has a slump value of 52mm, 15% has a slump value of 48mm, 20% has a slump value of 47mm, 25% has a slump value of 40mm, while 30% replacement of cement with RHA in concrete has slump value of 30mm. 15%, 20%, 25% and 30% cement replacement was in the S1 classification (10mm – 40mm) as classified by BS ENV-206, (1992), while the remaining of 0%, 5% and 10% replacement were in the S2 classification (50mm-90mm) as classified by (BS ENV-206, 1992).

Result for compacting factor test shows that control concrete has value of 0.92, 5% has a value of 0.92, 10% has a value of 0.92, 15% has a value of 0.91, 20% has a value of 0.89, 25% has a value of 0.88, while 30% replacement of cement with RHA in concrete has value of 0.87. Compacting factor values can be categorized as very low (0.78), low (0.85), medium (0.92) and high (0.95) in accordance with Building research establishment and specified by (Neville & Brooks, 2010).

The test result indicated that the concrete is of medium degree workability. There was increase in the slump value for 5% and 10% cement replacement with rice husk ash which is same as that of control concrete. The result shows that the concrete is of good quality.



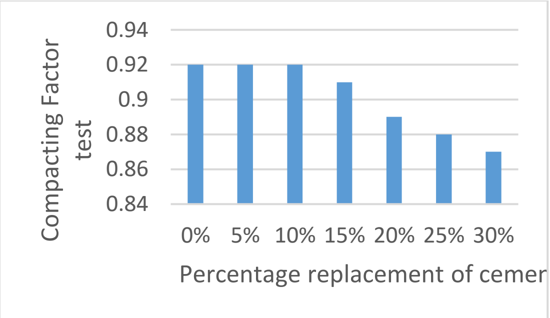


Figure 5: Slump Test

Figure 6: Compacting Factor Test

Density of Concrete

Figure 7, 8 and 9 present result on the density of concrete. Density values of concrete increase with increase in hydration period. Concrete cube, cylinder and beams produced with 0% control concrete, 5% and 10% cement replacement with rice husk ash produced higher density. In addition, from the figures presented, an analysis can be drawn that the concrete specimens produced conform to the density of normal-weight concrete, and favor higher durability, reason that the concrete value recorded higher than 2400 kg/m³ for concrete sample, except for samples produced at 30% replacement of cement with RHA.

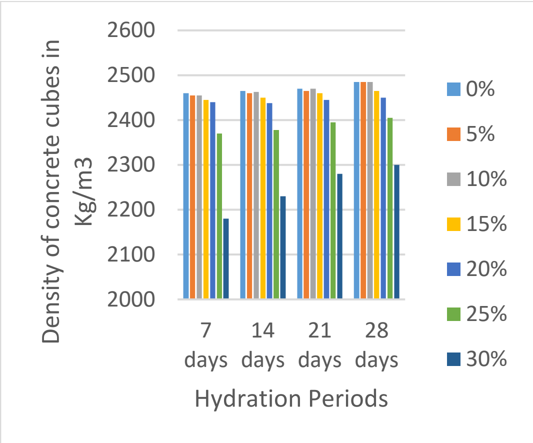


Figure 7: Density of Concrete Cubes

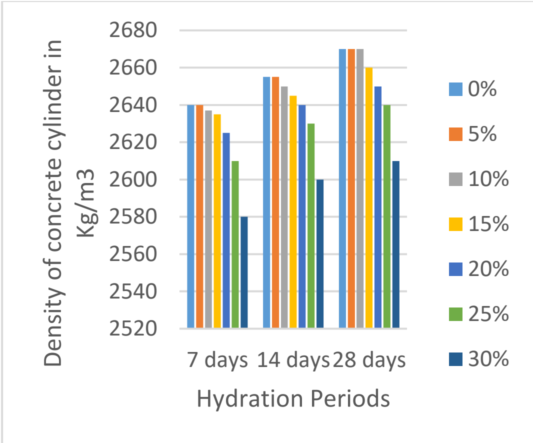


Figure 8: Density of Concrete Cylinder

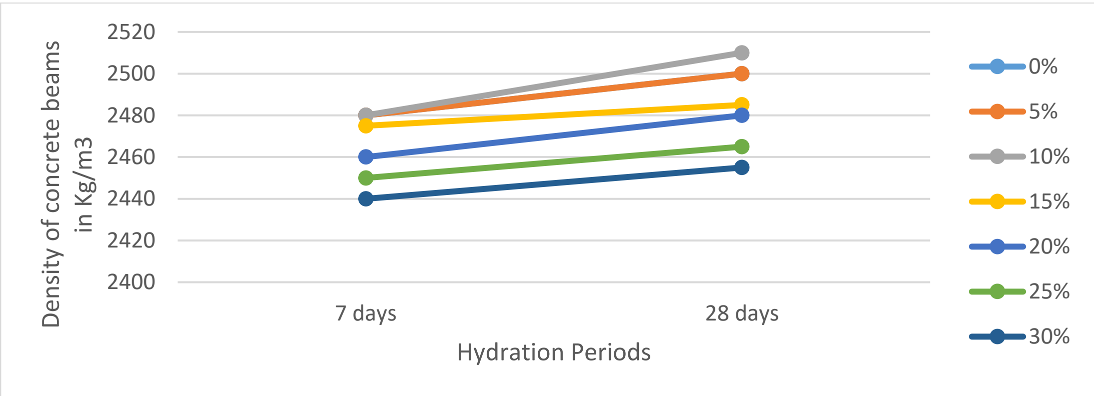


Figure 9: Density of Concrete Beams

Compressive Strength of Concrete

Figure 10 shows the compressive strength of concrete produced with rice husk ash as partial replacement of cement in concrete, the maximum strength was at 0% control concrete which attained 13.7 N/mm² as compared to 5% and 10% replacement of cement with RHA in concrete which attained 13.5 N/mm² and 13.6 N/mm² respectively at 7 days' hydration period. The results obtained for control concrete and for all other cement replacement levels except 30%, meet the 10N/mm² provision of BS ENV-206 (1992) for use as mass concrete and floors. At 14 days' hydration period, 0% control concrete attained 16.4 N/mm² as compared to 5% and 10% replacement of cement with rice husk ash in concrete which attained 16.2 N/mm² and 16.4 N/mm² respectively, the control concrete shows same strength as 10% partial replacement of OPC with RHA. Also, 0% control concrete attained 22.7 N/mm² as compared to 5% and 10% replacement of cement with rice husk ash in concrete which attained 22.4 N/mm² and 22.7 N/mm² respectively at 21 days' hydration period, the control concrete shows same strength as 10% partial replacement.

In addition, 0% control concrete attained 26.9 N/mm² as compared to 5% and 10% replacement of cement with RHA in concrete which attained 26.6 N/mm² and 26.8 N/mm² respectively at 28 days' hydration period. At 28 days' hydration period, control concrete shows better strength as compared to concrete specimen with partial replacement. To produce concrete with strength class C20/25 which is the minimum concrete strength class recommended for the construction of the load-bearing structural member of a building, a minimum of 1:2:4 mix ratio and Portland-limestone cement grade 42.5 is required BS ENV-206 (1992). Concrete mix is expected to attain 25N/mm² at hydration period of 28 days for general purpose structural works and 21N/mm² for light reinforced concrete works, however concrete produced with 0% control, 5% up-to 10% meet the requirement for general structural works.

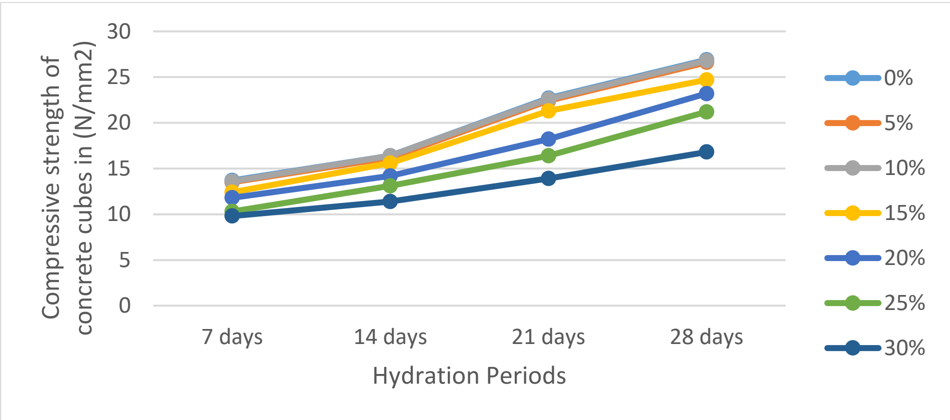


Figure 10: Compressive Strength of Concrete versus Hydration Periods

Split tensile strength

Figure 11 shows the tensile strength of concrete produced with rice husk ash as partial replacement of cement in concrete, with maximum strength achieved at 10% cement replacement with RHA which attained 2.63 N/mm² as compared to 0% control concrete and 5% replacement of cement with rice husk ash in concrete which both attained 2.61 N/mm² at 7 days. While 15%, 20%, 25% and 30% attained 2.58 N/mm², 2.53 N/mm², 2.45 N/mm², and 2.38 N/mm², respectively.

At 14 days', maximum strength was achieved at 10% cement replacement with RHA, which attained 2.86 N/mm² as compared to 5% replacement of OPC with RHA in concrete and 0% control concrete, which attained 2.85 N/mm² and 2.83 N/mm² respectively, concrete with 10% cement replacement shows enhanced strength.

At 28 days' hydration period, maximum strength was achieved at 10% OPC replacement with RHA, which attained 3.54 N/mm² as compared to 5% replacement and 0% control concrete, which attained 3.52 N/mm² and 3.51 N/mm² respectively, concrete with 10% cement replacement shows improved strength.

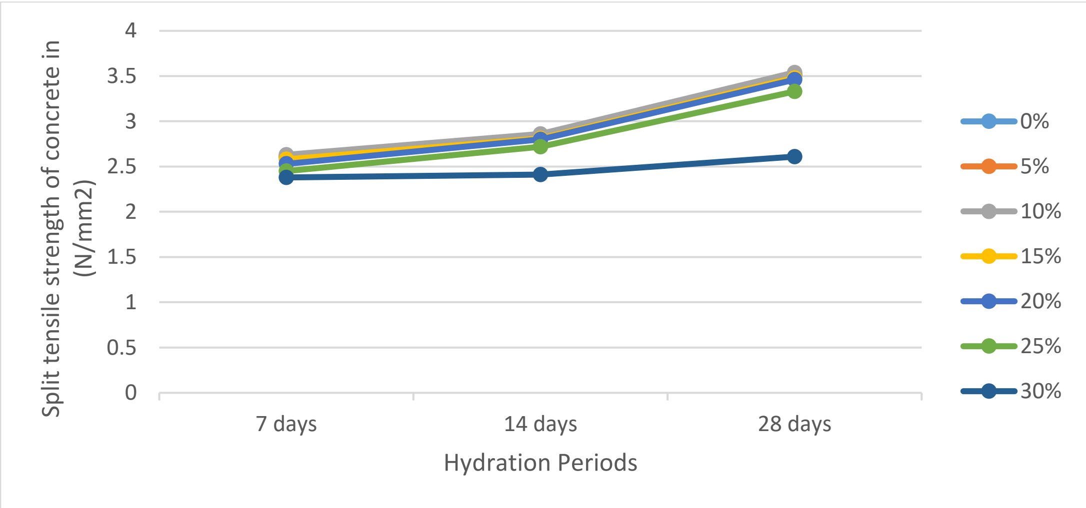


Figure 11: Split Tensile Strength of Concrete versus Hydration Periods

Beam Test

From the results of the flexural strength test shown in figure 12. The values of flexural strength were 4.35 N/mm², 4.34 N/mm², 4.37 N/mm², 4.21 N/mm², 4.12 N/mm², 3.56 N/mm², and 3.23 N/mm² form 0%, 5%, 10%, 15%, 20% 25% and 30% respectively for concrete produced with rice husk ash as partial replacement of cement at 7 days. The control concrete shows higher strength as compared to other replacement levels. While, at 28 days' hydration period, concrete strength achieved 4.47 N/mm², 4.49 N/mm², 4.49 N/mm², 4.33 N/mm², 4.26 N/mm², 3.73 N/mm², and 3.51 N/mm², for concrete produced with 0%, 5%, 10%, 15%, 20%, 25% and 30% cement replacement with RHA respectively. The 5% and 10% cement replacement shows better strength as compared to the control concrete. It was observed that as compressive strength increases, it results in a corresponding increase in flexural strength. In essence as compressive strength increase with increase hydration period, flexural strength increase with increase in hydration period. This conforms to the relationship of Linear proportionality between flexural and compressive strength described by (Neville & Brooks, 2010).

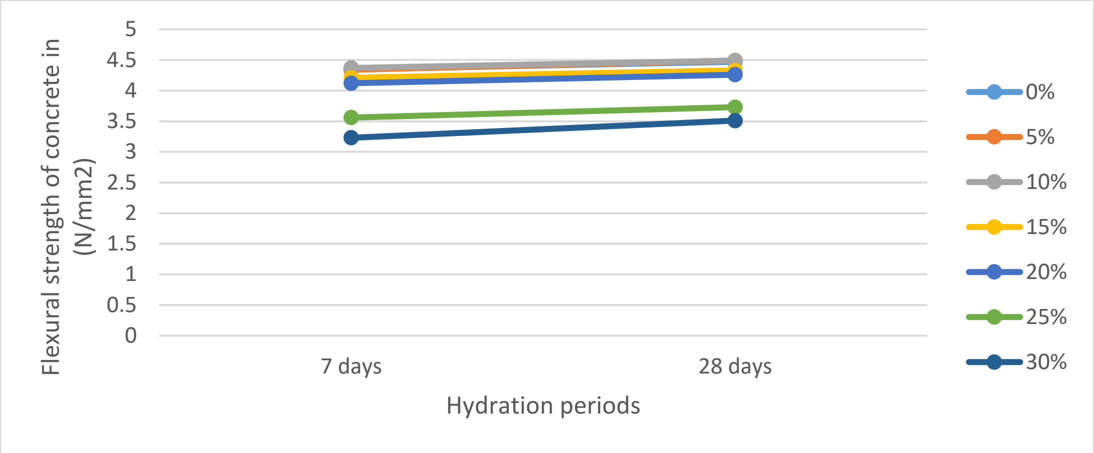


Figure 12: Flexural Strength of Concrete versus Hydration Periods

Conclusion

The rice husk ash used in this study is efficient as a pozollanic material, it is rich in amorphous silica (81.47). RHA is a suitable pozzolana because the summation of aluminum, silicon and ferric oxides was 84.42% which is more than 70% specified by ASTM C618-05. The specific gravity all fall within specified limit standard. The workability of the fresh mix concrete produced with 0%-10% cement replacement with RHA fell within medium classifications. The density related values of concrete produced shows similar result to that of control concrete especially at 5% and 10% cement replacement with RHA at 28 days. The compressive strength of the blended concrete with 10% rice husk ash increased significantly, and for up-to 15% replacement could valuably replace cement without adversely affecting the strength. 10% cement replacement with RHA has higher strength as compared to the control concrete in tensile strength at 28 days. In addition, at 28 days the flexural strength of concrete produced with 0%-20% cement replacement with RHA surpassed and or meet up the requirement of 4 N/mm^2. The study suggests that RHA can replace cement up-to 15% and comfortably meet strength requirement, with a water cement ratio of 0.5. The research concluded that rice husk ash is a good material for replacing cement in concrete production and can produce a very strong concrete.

Recommendations

1. The research recommends the use of rice husk ash to replace OPC in concrete production to save environment and improve the properties of concrete.
2. Rice husk ash can be used as an admixture to alter initial and final setting time of OPC-RHA concrete is recommended.
3. The use of 10% rice husk ash is the optimum OPC/RHA replacement level that can be used to produce concrete with the required strength for construction purposes.

Recommendations for Further Studies

1. Further studies recommended on other properties such as shrinkage resistance and other durability properties of concrete such as fire resistance, permeability, concrete subject in aggressive chemical environment, also using a different mix ratio and altering water cement ratio is also recommended.
2. The effect of RHA properties on the fresh and hardened properties of OPC concrete should be investigated for different types and sizes of coarse aggregate.
3. It is recommended that evaluating properties of concrete produced with 5% to 30% rice husk ash as partial replacement of cement be extended to 180 and 360 days to further determine the pozzolanic ability of the concrete.

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