



INVESTIGATION OF THE PROPERTIES OF CONCRETE MADE WITH FLY-ASH AND DRY WASTE OKRA POWDER

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Concrete is the most utilized construction material globally, with the issues of global warming, overburden and over-dependence on cement leads to the research into alternative materials in the production of concrete, which would not only reduce the usage of cement but also improve the performance of concrete product. The research investigates the effect of fly ash (FA) and dry waste okra powder (DWOP) on the strength performance of concrete. Concrete mix of 1:2.43:2.85 with water cement ratio of 0.5 was used. 10% by weight of cement was replaced by fly-ash, and dry waste okra powder was added at 0.25% to 1% at 0.25% interval as admixture. The parameters investigated are, chemical composition, setting time, workability, chemical composition of fly-ash and dry waste okra powder, density, compressive strength, flexural strength and split tensile strength. The results showed that fly-ash is a good pozzolan with combined SiO_2 , Al_2O_3 and Fe_2O_3 to equal 89.04%. The use of dry waste okra powder increases the setting time of cement/FA-DWOP paste and also resulted in the increase in workability of the concrete as the percentage admixture increases. The result showed that fly-ash ash has a pozzolanic effect and DWOP has an admixture effect on concrete properties by considering the strength activity index, higher compressive strength, higher flexural and splitting strength than control concrete for fly-ash blended admixture concrete at 0.5% and 0.75% up-to 1% admixture content. From this result, it can be concluded that FA as partial replacement material is a good pozzolanic material and DWOP is suitable as admixture material in concrete production.

1.0 Introduction

Concrete is the most utilized and acceptable construction material in the world. The concrete industry, due to its complexity, nature and sheer size, has a considerable impact on the environment. Concrete itself is inherently environmentally friendly but materials used its production are not friendly due to process of sourcing and producing them, Portland cement (PC) which is a major component in concrete production is not environmentally friendly. According to Lappiatt and Ahmad (2004) in Agboola, (2020) that concrete industries throughout the world annually produces concrete around 12 billion tons and utilizes Portland cement estimate around 1.6 billion tons. Which means on an average, approximately 1 ton of concrete is produced each year for every human being in the world. There is a concern to the large usage of concrete and cement and there is need for more understanding on how to improve concrete properties. The amount of CO_2 produced from the usage of concrete is directly proportional to the amount of cement used in the concrete mix (Agboola, *et al.*, 2020). Of all the pollutants in the cement manufacturing industry, CO_2 gas emission is the most

prevalent. According to Mahasanan, et al. (2003) 900 kg of CO₂ is emitted for the manufacturing of every ton of cement. PC is under discussion currently, not only because it is cost intensive in application but also for its effect on environment during manufacturing.

The problems of pollution and other properties of concrete have led to research on cement alternative that will partially or completely replace cement in the construction industry (Agboola, et al., 2021). The current trend is to reduce the amount of Portland cement used in the production of concrete with Supplementary Cementitious Material (SCM) which is affordable and available to improve desirable properties of concrete.

One of the best strategies to make the construction industry more compatible with the requirements of sustainable development would be to utilize concrete as much as possible, but with the least amount of Portland cement in any way possible. One of such strategy is the usage of Byproducts of industrial process that are classified as pozzolan which possesses excellent cementitious properties such as, fly ash, ground granulated blast furnace slag, and condensed silica fume. The other strategy to improve the environmental friendliness of the concrete industry is the large-scale utilization of waste products which are classified as pozzolan or supplementary cementitious material such as waste glass powder (Agboola, et al., 2020); construction debris, waste papers, saw dust waste from wood, dredged material, recycled carpets, and tires. According to Mohammad (2010) cement is one of the essential ingredients of concrete that both contributes to the construction industries and environmental problem. However, the production of cement emits carbon dioxide to the surroundings which result to environmental pollutions. The American Society for Testing and Material (ASTM C125-06) defined pozzolan as a siliceous or siliceous-aluminous material, which in itself possesses little or no cementitious value but which will, in finely divided form and at normal temperature and in the presence of moisture chemically react with calcium hydroxide to form compounds that contain cementitious properties.

Pozzolan can be used to replace cement in concrete to improve strength and durability properties (Agboola, et al., 2019). Shetty (2009) Pozzolan can be classified into two namely, natural or artificial pozzolan. Natural pozzolans include clay and shales, opaline cherts, diatomaceous earth, volcanic ash and pumicites, Artificial pozzolans include fly ash, blast furnace slag, silica fume, rice husk ash, and metakaolin. Fly ash, as one of the classifications of artificial pozzolans, is not environmentally friendly, but economical and accessible. Fly ash is a fine powder which is an industrial waste which a product of burning of coal in electric generation power plants. Fly ash is a pozzolanic material that contains aluminous and siliceous materials that forms cement in the presence of water. Fly ash forms a compound similar to cement in the presence of lime and water. Fly ash can be classified as class F and class C according to ASTM C618 (Gourav and Reddy, 2014). According to Yazici and Sahan, (2012), fly ash is one of the potential materials in reducing the use of cement in construction as it possesses similar binding ability when blended with cement while containing little to no hazardous chemical substances, making it a more viable and environmentally friendly supplementary material. Also, with the utilization of fly ash in concrete and with the requirements to boost the pozzolanic activity of fly ash in an attempt to improve the performance in concrete, okra waste powder was introduced into concrete mix. However, okra powder is an admixture which has a potential for improving the properties in concrete.

As part of these efforts, Karandikar et al. (2014) researched on aqueous okra powder and the result showed that the aqueous okra possessed Ca₂⁺ ions of cement paste which aid hydration rate in concrete. However, this led to the consideration of okra powder as an alternative to synthetic admixture. Synthetic admixture contributes largely to the emission of toxic substance into the atmosphere, although can be used as additive to cement in concrete. Asif, et al. (2019) conducted a study on aqueous okra with silica fume on concrete and found out that pectin which is a major compound present in okra extract showed more calcium than silica fume in

concrete. It is on the premises that indigenous material such as okra plant, which is very cheap, it is abundant and readily available, it is encouraged not only for cooking purpose but also for other positive uses such as in concrete production. The okra plant is planted in many cities in Nigeria. Okra is a traditionally cultivated rain-fed crop which is sensitive to mild winters.

Little changes in weather affect the crops and this leads it to bioactive waste littered around, which is not utilize for any purpose but causes environment hazards. However, compared to the other parts of the world, the amount of fruitful works done on the use of bio-based admixtures in concrete productions in Nigeria is limited. Huge amounts of okra vegetable are wasted every year with little attention given to exploit its usage as a source of mineral admixture. This prompted the research to explore the locally available materials to improve on the performance of concrete in construction. Concrete strength is majorly deemed to be one of the most important properties that need to be satisfied for any concrete. Strength of concrete is the single property that is most valued by designers and quality control engineers which can be defined as the ability to resist stress without failure which manifest by the appearance of cracks. This study however, investigate the properties of concrete made with fly ash and dry waste okra powder.

2.0 Materials and Methods

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

2.1 Materials

The materials for the laboratory experiment included, coarse aggregate fine aggregate, Cement, fly ash, dried waste okra powder (*Abelmoschus esculentus* (L.)) and water. coarse aggregate was obtained from a quarry site within Bauchi metropolis. The fine aggregate was 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. The dried waste okra powder was obtained within Bayara in Bauchi local government area of Bauchi state from local farmers. The particle sizes of fine aggregate were those passing through sieve with aperture size of 2.36 mm but retained on sieves of 150 μ m. It was confirmed to be free from dust and free from deleterious substances. The coarse aggregates used in this study were granite with particle size range between 5 mm and 20 mm.

The dried waste okra powder (DWOP) was milled to fine powder, and was stored in a cool place. Portable water which was fresh, colorless, odorless and free of organic matter was used in these experiments. For the purpose of this investigation, a mix ratio of 1:2.43:2.85 by weight of cement, sand and gravel, and water cement ratio of 0.50 was used. The cement in the mix was partially replaced with fly ash at interval of 10%, and dried waste okra powder was added at 0.25%, 0.5%, 0.75% and 1%. The concrete with 0% pozzolanic replacement and admixture served as the control.

2.2 Methods

2.2 Chemical Test on Fly Ash

In order to determine the chemical constituents of fly-ash, samples were taken and subjected to analysis at Ashaka cement factory in Gombe State, Nigeria.

2.3 Setting Times Tests

Setting Times Tests The setting times (initial and final) were carried out in accordance with BS EN 196-3 (1995), using the Vicat probe and the Vicat needle apparatus. The cement content of the paste was tested of 100% cement, then partially replaced at 10% fly-ash without admixture, and percentage dosage of dry waste okra powder (DWOP) was added to 10%FA at 0.25%, 0.5%, 0.75%, 1%. The paste without pozzolana and DWOP served as the control.

2.3 Strength Activity Index of Cement

The strength activity indices of cement-Fly Ash were evaluated according to ASTM C311. The control mortars were prepared according to the recipe provided in ASTM C311. Cubes were prepared for compressive strength testing. For the mixture with the fly ash as partial cement replacement, test mixture was prepared with constant water and sand volume fraction, and a 20 % replacement by volume of cement with fly ash. The compressive strength test was carried out in accordance with ASTM C109. A 1:3 cement sand mix with water cement ratio of 0.5 was used to prepare 50 x 50 x 50mm prism specimens to determine the compressive strength of the cement mortar, cured at 7 and 28 days.

2.4 Workability Test

The slump test was carried out in accordance with the provisions of BS EN 12350: Part 2 (2000). The replacement was done at 10% with fly-ash, other concrete mix include percentage dosage of dry waste okra powder was at 0%, 0.25%, 0.5%, 0.75%, 1% at 10% fly ash as cement replacement. The slurry sample without FA serves as the control. Compacting factor test was conducted in accordance with (BS 1881-102, 1983).

2.5 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. Density is calculated as mass of concrete specimen in (kg) divided by volume of concrete cube (m^3) and expressed in kg/m^3 .

2.6 Compressive strength

Cubes of size 100mm x 100mm x 100mm were cast for each mix and left in room temperature for 24 hours before demolding and cured in water until testing at 7 days to 90 days. Compressive strength was determined in accordance with BS EN 12390-3 (2009), 100mm cubes have been used for the investigation and the nominal size of the coarse aggregate used in this study does not exceed 20mm.

2.7 Flexural strength

Flexural strength of pervious concrete specimens was determined by a point load test on beam specimens of size 100 mm x 100 mm x 500 mm, and in accordance with BS EN 12390-3 (2009), Three numbers of specimens for each set were tested at 28, 56 and 90 days of normal curing. The samples were tested in Universal Testing Machine (UTM) of capacity 1000kN. Flexural strength of the specimen is expressed as the modules of rupture. Flexural strength was computed using equation 1.

$$F_{ct} = \frac{2F}{\pi \times L \times d} \quad (1)$$

where

F is the maximum load in (KN)

L is the average measured length in (mm)

d is the average measured diameter in (mm)

The tensile splitting strength is expressed to the nearest 0.05 MPa.

2.8 Split Tensile Strength Test of Concrete

In the determination of tensile strength of concrete, the procedures as in accordance with BS EN 12390-3 (2009) was followed. The split tensile strength F_{ct} in N/mm^2 was computed using the equation 2.

$$F_{ct} = \frac{2F}{p \times L \times d} \quad (2)$$

Where:

F is the maximum load in (KN)

L is the average measured length in (mm)

d is the average measured diameter in (mm)

3. Result and Discussion

3.1 Chemical Composition of Fly-Ash

Table I shows the chemical composition of fly ash determined using a XRF technique. The result obtained in this study is in consistent and comparable with ASTM C618 requirement, which shows that $(SiO_2 + Al_2O_3 + Fe_2O_3)$ minimum requirement for a standard pozzolana is 70%. However, the findings of this shows that $(SiO_2 + Al_2O_3 + Fe_2O_3)$ is equal to 89.04% and this met the minimum requirement for a pozzolana. Therefore, fly-ash sample is expected to show pozzolanic behavior in cementitious system. Minor compounds such as TiO_2 , P_2O_5 , MgO , MnO , SO_3 , Na_2O , CaO , are also found in fly-ash sample under consideration in minute quantity.

Table I: Chemical Composition of Fly-Ash

Sample	FA	
Silicon oxide	SiO_2	58.56
Aluminium oxide	Al_2O_3	23.31
Iron trioxide	Fe_2O_3	7.17
Calcium oxide	CaO	3.36
Potassium oxide	K_2O	0.16
Sodium Oxide	Na_2O	0.14
Sulphur trioxide	SO_3	0.03
Phosphorus Pentoxide	P_2O_5	0.82
Magnesium Oxide	MgO	1.61
Manganese Oxide	MnO	0.03
Titanium oxide	TiO_2	0.08
Loss of Ignition	LOI	1.26

3.2 Setting Time Test

Figure I shows setting time and consistency of Portland cement/fly ash-dry waste okra powder paste. It was discovered that the higher the amount of okra powder in the paste, the higher the time required for the paste to set. The observed setting time and consistency behavior corresponds and in consistent with finding of Agboola et al. (2020) which observed that setting time increases with the addition of pozzolana.

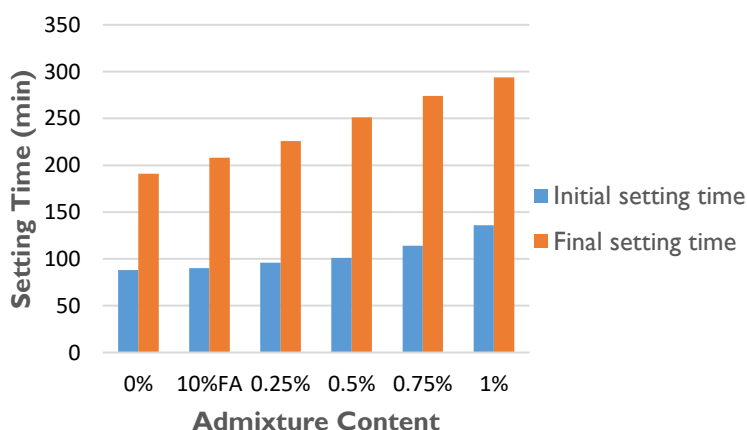


Figure I: Setting Time Test of FA-DWOP paste

3.3 Strength Activity Index

The result for the strength activity index of cement mortar is presented in Table 2. The result shows an increasing trend of strength at 7 days and 28 days respectively for both control mortar and mortar produced with fly ash as partial replacement of cement. The result also shows that, at both 7- and 28-days curing age, the strength activity index of 20% fly ash cement mortar meet the minimum requirement specified by ASTM C311, that the strength activity index of pozzolana must meet 75% of the control strength at 7 and 28 days. This indicates that fly ash is a good pozzolana and can be used to replace cement in concrete production.

Table 2: Strength Activity of Cement-Fly Ash

% RHA	Compressive Strength (N/mm ²)		Strength Activity Index	
	7 days		7 days	28 days
0% Control	24.0	33.5	100	100
20% Fly Ash	19.6	29.3	81.7	87.5

3.4 Workability

The Slump test results are presented in Figure 2. The slump value increases with increase ratio of dry waste okra powder content. From the values for the six mixes, on the degree of workability for slump test, 0.25% to 1% addition with dry waste okra powder falls within high slump (50 -100) which is a category of high degree workability, while 0% control concrete and 10% fly-ash falls with medium slump (25–50) which is a low degree workability according to Neville and Brooks (2010). The workability increases with the addition of DWOP in concrete.

For the compacting factor test, the degree of workability ranges from low to medium, which falls within the range specified by BS 812 and Neville and Brooks (2010). Mixes with 0%, 10%FA, 0.25%, 0.50%, 0.75% DWOP, has compacting value of 0.93, 0.93, 0.93, 0.92, and 0.92 respectively, which shows higher workability while 1% DWOP admixture with 0.90 shows low workability as presented in Figure 3.

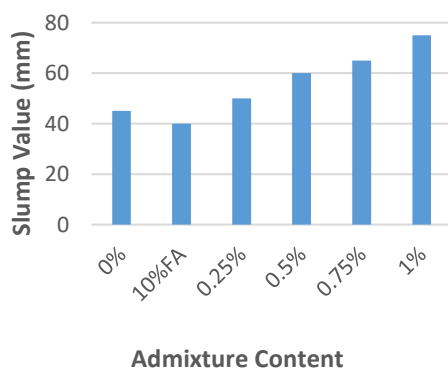


Figure 2: Slump Test of FA-DWOP paste

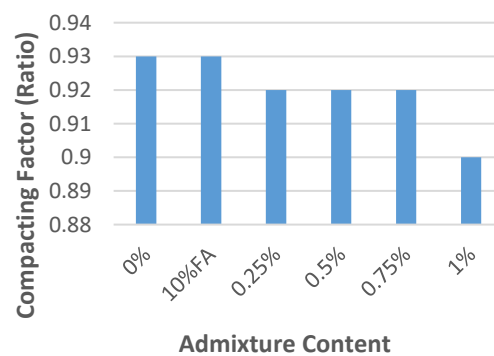


Figure 3: Compacting Factor Test of FA-DWOP paste

3.4 Density of Concrete

The results of the density test are shown in Figure 4, for OPC/FA-DWOP concrete samples cured in normal water and weighed at 7, 14, 28, 56 and 90 curing days. The density of concrete cube samples varies from 2450 kg/m³ to 2560 kg/m³ and it increase with increase curing periods. Concrete with 0.75% dried waste okra powder present higher density than all other percentage addition of admixture beyond 28days of curing. The density of concrete increase as the percentage admixture increases up-to 0.75%. Concrete samples with density higher than 2600kg/m² are called higher density concrete samples (Kazjonovs et al., 2010), Values obtained exceeded the 2400 kg/m³ at 28days hydration period expected for a normal weight concrete.

This indicates that concrete produced with fly ash and okra powder replacement shows dense concrete and possesses quality for greater durability of concrete.

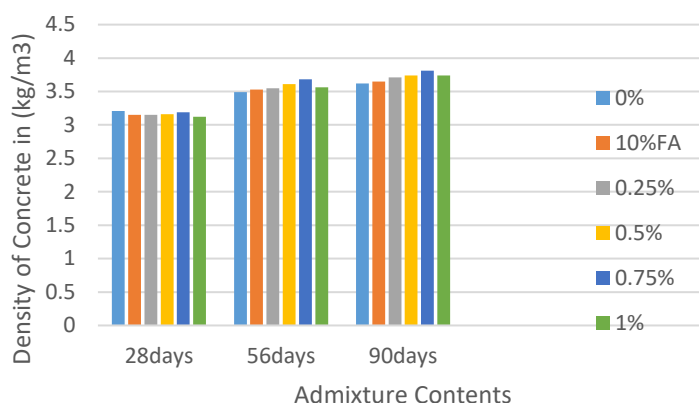


Figure 4: Density of FA-DWOP Concrete

3.5 Compressive Strength of concrete

Figure 5 presents compressive strength of OPC/FA-DWOP concrete specimens cured in water, and crushed at 7, 14, 28, 56 and 90days hydration periods. Concrete samples with 0% replacement has high strength index at early days of strength test at 7days to 28days but encountered loss in strength as compared to concrete with 10% fly-ash as cement replacement and other admixture addition percentage level. Concrete specimens with 0% admixture achieved 28.9 N/mm² while 10%FA achieved 28.4 N/mm² and 0.25%, 0.50%, 0.75%, and 1.0% FA-DWOP achieved 28.5 N/mm², 28.6 N/mm², and 28.9 N/mm², and 28.5 N/mm² at 28 days respectively. Control Concrete has high strength as compared to all other admixture content mix at 28days.

At 56-day curing age, concrete specimens with 0% control concrete achieved 29.5 N/mm² while 10%FA achieved 29.9 N/mm² and 0.25%, 0.50%, 0.75%, and 1.0% FA-DWOP achieved 30.5 N/mm², 30.8 N/mm², 31.6 N/mm², and 31.2 N/mm². This shows 6.65% strength increase of 0.75%FA-DWOP concrete as compared to control concrete. At 90day curing age, 0% control concrete specimens achieved 30.4 N/mm² while 10%FA achieved 31.2 N/mm² and 0.25%, 0.50%, 0.75%, and 1.0% FA-DWOP achieved 31.5 N/mm², 32.4 N/mm², 31.8 N/mm², and 31.2 N/mm². This shows 6.17% strength increase of 0.75%FA-DWOP concrete as compared to control concrete. The result is in line with the study of Agboola (2020) who stated that pozzolanic material influences strength and durability properties of concrete at later stages. The increase in strength might be as a result of admixture and pozzolanic material present in the concrete mix. Presence of pozzolanic materials enhance the strength of concrete (Duggal, (2008); ACI 201.2R (2001)). Pozzolanic material can be used as a partial replacement of cement in concrete due to the high silica present in it and its ability to react with calcium in cement in the presence of water to form a compound with calcium hydrate silicate (CSH). The result shows 0.75% admixture has high strength beyond all other percentage admixture and the control concrete at higher curing age.

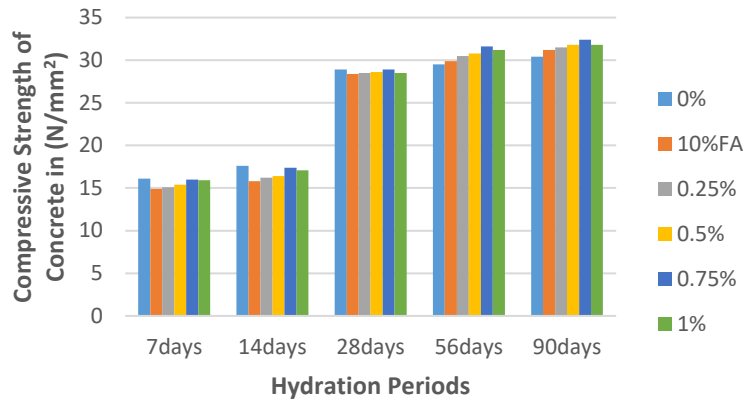


Figure 5: Compressive Strength Test of FA-DWOP Concrete

3.6 Flexural Strength of Concrete

Figure 6 shows the flexural strength of OPC/FA-DWOP specimen cured in water and tested at 28, 56- and 90-days curing ages. 0% control concrete specimens achieved 4.63 N/mm² while 10%FA achieved 4.43 N/mm² and 0.25%, 0.50%, 0.75% and 1.0% percentage admixture achieved is 4.43 N/mm², 4.51 N/mm², 4.61 N/mm² and 4.53 N/mm² at 28 days. At 56 days curing age, concrete specimens with 0% control concrete achieved 5.11 N/mm² while 10%FA achieved 4.97 N/mm² and 0.25%, 0.50%, 0.75% and 1.0% percentage admixture achieved 5.18 N/mm², 5.27 N/mm², 5.43 N/mm² and 5.11 N/mm². This represents 3.04% increase in flexural strength of 0.75% FA-DWOP concrete as compared to control concrete. At 90 days curing age, concrete specimens with 0% control concrete achieved 5.43 N/mm² while 10%FA achieved 5.51 N/mm² and 0.25%, 0.50%, 0.75% and 1.0% percentage admixture achieved 5.51 N/mm², 5.55 N/mm², 5.57 N/mm² and 5.54 N/mm². This represents 2.51% increase in flexural strength of 0.75% FA-DWOP concrete as compared to control concrete. The increase in strength of concrete produced could be as a result of the type of admixture and pozzolana used in the production of the concrete. However, the flexural strength increases with increase in curing days. Concrete produced with Fly ash and dry waste okra powder gives higher flexural strength as it creates good bond, excellent filler and admixture between the concrete constituents.

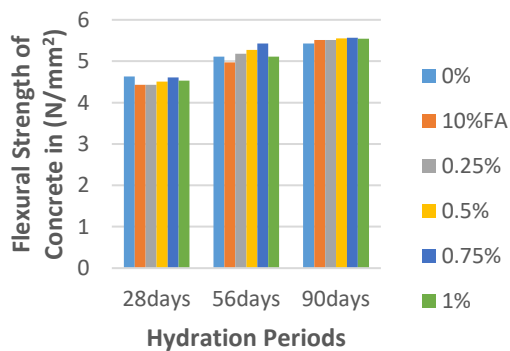


Figure 6: Flexural Strength Test of FA-DWOP Concrete

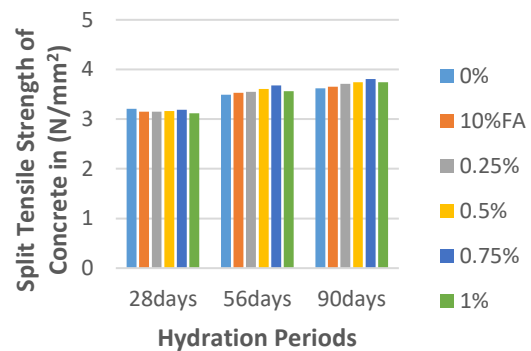


Figure 7: Split Tensile Strength of FA-DWOP Concrete

3.7 Split Tensile Strength of Concrete

Figure 7 shows the split tensile strength of OPC/FA-DWOP specimen cured in water and tested at 28, 56- and 90-days curing ages. 0% control concrete specimens achieved 3.21 N/mm² while 10%FA achieved 3.15 N/mm² and 0.25%, 0.50%, 0.75% and 1.0% percentage admixture achieved is 3.15 N/mm², 3.16 N/mm², 3.19 N/mm² and 3.12 N/mm² at 28 days, control concrete has highest strength at 28 days of curing. At 56 days curing age, concrete specimens with 0%

control concrete achieved 3.49 N/mm² while 10%FA achieved 3.53 N/mm² and 0.25%, 0.50%, 0.75% and 1.0% percentage admixture achieved 3.55 N/mm², 3.61 N/mm², 3.68 N/mm² and 3.56 N/mm². This represents 5.16% increase in flexural strength of 0.75% FA-DWOP concrete as compared to control concrete. At 90 days curing age, concrete specimens with 0% control concrete achieved 3.62 N/mm² while 10%FA achieved 3.65 N/mm² and 0.25%, 0.50%, 0.75% and 1.0% percentage admixture achieved 3.71 N/mm², 3.74 N/mm², 3.81 N/mm² and 3.74 N/mm². This represents 4.99% increase in split tensile strength of 0.75% FA-DWOP concrete as compared to control concrete. The increase in strength of concrete produced could be as a result of the type of admixture and pozzolana used in the production of the concrete. However, the split tensile strength increases with increase in curing days. Concrete produced with Fly ash and dry waste okra powder gives higher tensile strength as it creates good bond, excellent filler and admixture between the concrete constituents.

4. Conclusion and Recommendations

The results of pozzolanic property and the oxide composition of fly-ash showed that it is a good pozzolana with essential constituent which include 58.56% SiO₂, 23.31%, Al₂O₃ and 7.17% Fe₂O₃ content summing up-to to 89.04%. Concrete of structural and mass concrete purposes can be produced by incorporating two types of waste materials, namely dry waste okra powder and fly-ash as admixture and cement replacement respectively. The use of locally available material as building material will also solve the problem of environmental impact. In addition, production of every ton of fly-ash concrete results in the reduction of each ton of CO₂ emission from cement production, and save the environment significantly by reducing green-house gas and particulate production. The fly-ash-blended cements and paste with DWOP as admixture have higher setting time than 100% cement paste; hence, they are most applicable where low rate of heat development is required such as in mass concreting. This indicated that fly-ash-blended cement is good as low heat cement. Control concrete, 10% fly ash concrete and Pozzolanic concrete containing 0.25% DWOP have low workability as compared to concrete containing higher DWOP content. To improve workability, 0.5% up-to 1% DWOP should be used in the concrete mix. The compressive strength of concrete ranges from 28.4 to 28.9 MPa (at 28 days), and the strength of concrete increase as the curing days increases. Fly-ash can be used up to 10% to replace cement for structural concrete in order to improve its compressive strength. The optimum DWOP content is 0.75% considering concrete compressive strength at 90 days. DWOP up to 1% can be used for structural concrete purposes due to its high strength index. Dry waste okra powder as admixture is compatible with blended cement. Strength development of DWOP modified fly-ash blended concrete of 0.75% exceeded the control samples by 6.65% and 6.17% at 56days, 90days at respectively. It is recommended that further tests be conducted to determine the water absorption capacity, permeability, shrinkage resistance, fire resistance, durability on concrete and mortars made with dry waste okra powder and fly-ash blended cement, also using a different mix and altering water cement ratio is also recommended. Test should also be conducted to determine the effects of fly-ash blended cement and dry waste okra powder as admixture on the mechanical properties of concrete for longer curing duration beyond 90 days.

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