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MECHANICAL PROPERTIES OF CONCRETE WITH OKRA AS A VISCOSITY MODIFYING ADMIXTURE IN FLY ASH SELF COMPACTING CONCRETE

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Abstract
Self-Compacting Concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction especially in congested reinforced concrete section. The unstable rheological properties and consistency have been the bane of SCC concretes however, the use of viscosity modifying admixtures (VMAs) have been proved to be effective in remedying the deficiencies. Although, most of the VMAs in the market are chemical admixtures and sometimes costly. In thi study, the possibility of producing self-compacting concrete using locally type VMA (Okra) along with super plasticizer at varying dosages. Rheological parameters such as slump flow, flow time, V-funnel and L-box of the fresh concrete were established. Also, hardened properties such as compressive, split tensile and flexural strengths and hardened properties such as compressive, split tensile and flexural strengths of different mixes with various dosages of Okra along with super plasticizer and partially replacing cement with fly ash. The performance of various SCC mixtures with VMA and super plasticizer partially replacing cement with fly ash was compared with normal SCC mix and found that both fresh and hardened properties were improved at maximum of 4% okra addition at the mechanical strength of 35.8N/mm^2 compressive, 5.86N/mm^2 flexural and 4.10N/mm^2 tensile. Therefore, Okra can be used to enhance the rheological properties of self-compacting concrete

Keywords:
Self-Compacting Concrete (SCC), Super Plasticizer (SP), Viscosity Modifying Admixture (VMA), Fly Ash (FA) Stability, Rheology.

INTRODUCTION

Different forms of concrete exist which are different from conventional concrete, which termed high strength or high-performance concrete. High strength concrete became a familiar phase in concrete technology in the late 1980s, and few years later were widened to high performance concrete. It has been the subject of many articles, books and conference papers, but it may have been preferable to use the term high performance concrete, since it is essentially an extension and enhancement of existing conventional concrete practice. High performance concrete is not a single type of concrete, but includes any concrete whose properties significantly exceed or extend the range of concrete currently being used. High performance concrete must be capable of being mixed, handle and placed with the same equipment and procedure as conventional concrete, albeit with higher standards of quality control and more careful selection of materials and mix design. The superior properties can thus be readily exploited in concrete practice (Illstone & Domone, 2001).

Sustainability and ecological demands on concrete, adoption and development of workable construction methods have remained a persistent challenge to researchers and developers of concrete admixtures. Therefore, the development of an ecological concrete is the only way to meet these challenges. An “ecological concrete” is a concrete which according to

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ecological criteria has an optimized composition of the individual components (fine/coarse aggregate, cement, water, concrete admixture/additives) as well as high technical specifications (Haner, Galli, Schluep, Madar & German, 2005). Today's concrete has to fulfill a wide range of requirements in both the fresh and hardened state. In most cases the properties of fresh concrete also affect the quality of the hardened concrete and ultimately its durability. This means that concrete has to be correctly proportioned and must remain homogeneous during placing and after compaction in order to avoid effects such as bleeding, segregation, honey combing, laitance, settlement and plastic cracking over the top bar. These effects would all lead to reduced quality and durability of the hardened concrete (EFNARC, 2002).

Self-consolidating Concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as conventional vibrated concrete (The Engineering Guideline for Self-Compacting Concrete, 2005). Rodriguez (2017) views it as a highly flow able type of concrete that spreads into the form without the need for mechanical vibration.

Several different approaches have been used to develop SCC. One method to achieve self-compacting property is to increase significantly the amount of fine materials (e.g., fly ash or limestone filler) without changing the water content compared with conventional concrete. One alternative approach consists of incorporating a viscosity modifying admixture (VMA) to enhance stability. The use of VMA along with adequate concentration of superplasticizer (SP) can ensure high deformability and adequate workability, leading to a good resistance to segregation. Mixture containing VMA exhibits shear-thinning behavior where by apparent viscosity decreases with the increase in shear rate. Such concrete is typically thixotropic where the viscosity builds up is promoted due to the viscous properties of the VMA at a low shear rate that can further inhibit flow and increase viscosity. The thixotropic property increases the stability of the concrete and reduces the risk of segregation after casting (Rodriguez 2017)

Okra is being used in this research due to its property of being viscous. Viscosity, which is the desired parameter, is one of the fundamental qualities that characterize flow behavior. It is, indeed, a measure of a fluid's ability to resist motion when a shearing stress is applied. Experiment shows that viscosity, generally, increased with increase in mixing ratio for both dried and fresh Okra (Burubai & Amber 2013). The viscosity of aqueous Okra suspension and the gum-like consistency which is desirable in soup is as a result of the presence of a chemical substance called Glycan (Owoye cited in Burubai & Amber 2013).

In this study, Okra as VMA was tested in the production of SCCs along with super plasticizer. The fresh concrete properties (slump flow, flow time, V-funnel and L-box) and mechanical properties (compressive strength, split tensile strength and flexural strength) of mixtures were evaluated and compared with normal SCC mix.

Self-compacting concrete with similar binder ratio will usually have a slightly higher strength compared with traditional vibrated concrete, due to lack of vibration which give an improve interface between the aggregate and hardened paste. The strength development will be similar on maturity, testing will be an effective way to control the strength development whether accelerated heating is used or not. A number of concrete properties may be related to the concrete compressive strength, the only concrete engineering properties that is routinely specified and tested (The European Guideline for Self-Compacting Concrete, 2005).

MATERIALS AND METHODS

Materials

The materials used in this research are: Dangote Ordinary Portland cement which conforms to type I Portland cement as specified by ASTM 150 (2004). The Fly Ash (FA) used for the study was sourced from Oji River Local Government area of Enugu state. The fly ash was then grounded by an electric powered machine at Katako market Jos to powdering form and

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sieved with a 125µm British Standard sieve in the Soil laboratory of the department of Building University of Jos. The chemical analysis of fly ash was done at the National Metallurgical Development Centre (NMDC) in Jos, Plateau State. This was done in a bid to ascertain the chemical composition of the fly Ash (FA) used for the study. The result is presented in Table 1. The okra used was dried okra sourced from Farin Gada Market in Jos North Local Government area of Plateau state, grounded by an electric powered machine at Katako market Jos to powdering form and sieved with a 125µm British Standard sieve in the Soil laboratory of the department of Building University of Jos as conform to EFNARC, (2006). The chemical analysis of okra was done at the National Metallurgical Development Centre (NMDC) Jos, Plateau State. This was done in a bid to ascertain the chemical composition of the okra used for the study and presented in Table 2. The super plasticizer used in this work was commercially available brand Sulphonated Naphthalene (SAMPLAST 300)-based super plasticizer. Fine aggregates (Sharp sand) used for the study were quartzite river sand, sourced from a river in Jos metropolis. The sand was sieved with 4.75mm sieve size and the grains that pass the sieve were used for the study. Coarse aggregate used for the study was obtained from PW quarry in Riyom Local Government Area of Plateau state which conforms to the requirement of BS-EN-1097 (2008). The water used was portable water fit for drinking supply to laboratory of the department of Building University of Jos and also conforms to the requirement of BS-EN-1008 (2002) which was used throughout the research work. The physical properties of the materials are presented in Table 3.

Materials batching

The assumption in batch computation is that the volume of the compacted concrete equals the absolute volume of the constituent's materials that make up the concrete, hence batching by weight was adopted for this study. For the purpose of this study, the trial mix was carried out to establish the control mix while the rest containing fly ash and okra adopts the control trial mix. The mix ratio adopted for this research is as shown in Table 4. For each percentage of powder content, 1.5% super plasticizer, 0.0%, 0.2%, 0.4% and 0.6% okra were added for the SCC and the Material required for the production of $1m^3$ of the concrete is given in Table 5.

Testing Procedure

The test method adopted was in accordance with the European Guidelines for Self-Compacting Concrete (2005) and Specification Guidelines for Self-Compacting Concrete (EFNARC, 2005) in accordance to the provisions of BS-EN 12350-1 and BS-EN-12350-2. The methods are:

- Slump flow test and T50cm test: the test method was based on the test for determining the slump in which the diameter of the circle is a measure for the filling ability of the concrete conforming to EN 12350-8.
- V funnel test and V funnel test at T 5minutes: the V-funnel test was used to determine the filling ability (flowability) of the concrete with the maximum aggregate size of 20mm. the funnel was fill with about 12 liters of concrete and the time taken for it to flow through the apparatus measured conforming to EN 12350-9.
- L-box test method: the test accessed the flow of the concrete, and also the extent to which it was subject to blocking by reinforcement. The apparatus consists of a rectangular-section box in the shape of an "L", with a vertical and horizontal section, separated by a movable gate, in front of which vertical length of reinforcement bars are fitted conforming to EN 12350-10.
- The Compressive strength tests were conducted on 100x100x100mm cubic specimens, after standard curing. Three specimens were prepared and tested for each sample. The curing period was 3, 7, 28, 56 and 90 days as shown in equation 1.

$$f_c = \frac{F}{A_c} \ldots\ldots\ldots\ldots 1$$

Where: f_c = compressive strength (N/mm^2), F = the max load at failure (N), A_c = cross sectional area (mm^2).

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- The Flexural strength tests were conducted on 100x100x500 mm cubic specimens, after standard curing. Three specimens were prepared and tested for each sample. The curing period was 3, 7, 28, 56 and 90 days as shown in equation 2.

$M_{max} = \frac{PL}{6}$.........2

$Z = \frac{bd^2}{6}$..............3

$f_{bl} = \frac{M}{Z} = \frac{PL}{bd^2}$.......2

Where: P = max total load in kN, L = length of the specimen, b = breath of the specimen, d = depth of the specimen, M_{max} = max moment and Z = section modulus.

- The split tensile strength tests were conducted on cylinder specimens with a diameter of 100mm and a height of 300mm, after standard curing. Three specimens were prepared and tested for each sample. The curing period was 3, 7, 28, 56 and 90 days as shown in equation 5.

$T = \frac{2P}{\pi LD}$.........5

Where: T = split tensile strength in MPa, P = max applied load in N, L = length of the specimen in mm, D = diameter of the specimen in mm.

Table 1: Chemical composition of FA

Elemental Oxide	SiO_2	Al_2O_3	K_2O	MnO	Fe_2O_3	SO_3	
% Composition	34.740	15.570	0.030	0.020	0.120	0.040	
Elemental Oxide	CuO	CrO_3	CaO	TiO_2	BaO	SrO	ZrO_2
% Composition	0.030	0.007	37.540	0.010	0.020	0.190	0.002

Table 2: Chemical composition of Okra

Elemental	Crude Protein	Crude Fat	Crude Ash	Fibre	Carbohydrates	Viscosity
% Composition	21.93	2.56	9.33	8.05	45.46	13.0Cp

Table 3: Physical properties of materials

Materials properties	Cement	FA	Okra	Fine Aggregate	Coarse Aggregate
Grain size	75µm	125µm	125µm	4.75mm	10mm
Specific Gravity	3.15	2.40	2.40	2.60	2.56
Loose bulk density	1.44kg/l	0.952	0.892	1.42kg/l	1.32kg/l
Compacted bulk density	1.52kg/l	1.060	1.020	1.66kg/l	1.46kg/l
Free moisture content	-	-	-	0.26%	0.15%
% Void ratio	-	-	-	44.96%	49.43%
Silt content	-	-	-	2.76%	-
AIV/ACI	-	-	-	11.09%	16.58%
Appearance	V.Fine powder	Fine powder	Fine powder	-	-
Colour	Grey	Dark Grey	Pale green	-	-

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Table 4: Mix Ratios of Materials Used.

Materials	Cement/FA	Fine Aggregate	Coarse Aggregate
SCC mix	1	2.5	2

Table 5: Summary of Materials Needed for One Cubic Meter of Concrete in Kilogram

Percentage Replacement (%)	Cement Content (kg)	Fly Ash Content (kg)	Fine Aggregate Content (kg)	Coarse Aggregate Content (kg)	Okra Content (kg)	SP Content (kg)	Water Content (kg)
0	385	0	1070	749	0	6	173
10	347	38	1070	749	1.4/3.0/4.6	6	167
15	327	58	1070	749	1.4/3.0/4.6	6	190
20	308	77	1070	749	1.4/3.0/4.6	6	190

TEST RESULTS AND DISCUSSION

Fresh Concrete Properties

A detailed study conducted on Okra as a viscosity modifying admixture in SCC (Mixing proportions are given in Tables 4 & 5) the fresh concrete testing results are presented in Table 6 with respect to w/c ratio of 0.45 and 1.5% SP addition. The addition of Okra (0.0%, 0.2%, 0.4% and 0.6%) slump-flow decreased, flow time increased and L-box value also decreased.

Table 6: Results for Self-Compacting Properties of Fresh Concrete.

Materials						Results		
Mix	OPC	FA	SP	Okra	Slump flow(mm)	T_{50} (s)	V-funnel (s)	L-box
C2	100%	0%	1.5%	0%	765	3.66	10	0.95
Mix 3a	90%	10%	1.5%	0%	751	3.69	9.0	0.92
b	90%	10%	1.5%	0.2%	743	3.70	8.5	0.90
c	90%	10%	1.5%	0.4%	738	3.72	8.0	0.87
d	90%	10%	1.5%	0.6%	710	3.73	7.5	0.83
Mix 4a	85%	15%	1.5%	0.0%	745	3.74	8.0	0.91
b	85%	15%	1.5%	0.2%	736	3.76	7.5	0.89
c	85%	15%	1.5%	0.4%	721	3.77	7.0	0.86
d	85%	15%	1.5%	0.6%	700	3.79	6.5	0.82
Mix 5a	80%	20%	1.5%	0.0%	740	3.80	7.0	0.88
b	80%	20%	1.5%	0.2%	732	3.82	6.5	0.86
c	80%	20%	1.5%	0.4%	712	3.86	6.0	0.81
d	80%	20%	1.5%	0.6%	692	3.95	5.5	0.79

Compressive Strength of Concrete

Table 1 revealed that compressive strength increases with curing age and decreased with an increase in FA content especially during the early age. It also revealed slightly increase in compressive strength across percentage increase in dosages of okra up to 4%, as okra dosages increases to 6%, compressive strength decreases, which may be attributed to the viscosity of aqueous Okra suspension and the gum-like consistency which in turn increase the homogeneity and cohesion of the concrete properties.

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Table X: Variation of compressive strength with Okra and age of Curing in N/mm^2

% Okra / Age of curing	3 (days)	7 (days)	28 (days)	56 (days)	90 (days)
	0% Fly Ash				
0.0					
0.20					
0.4					
0.6					
C2					
	10% Fly Ash				
0.0					
0.20					

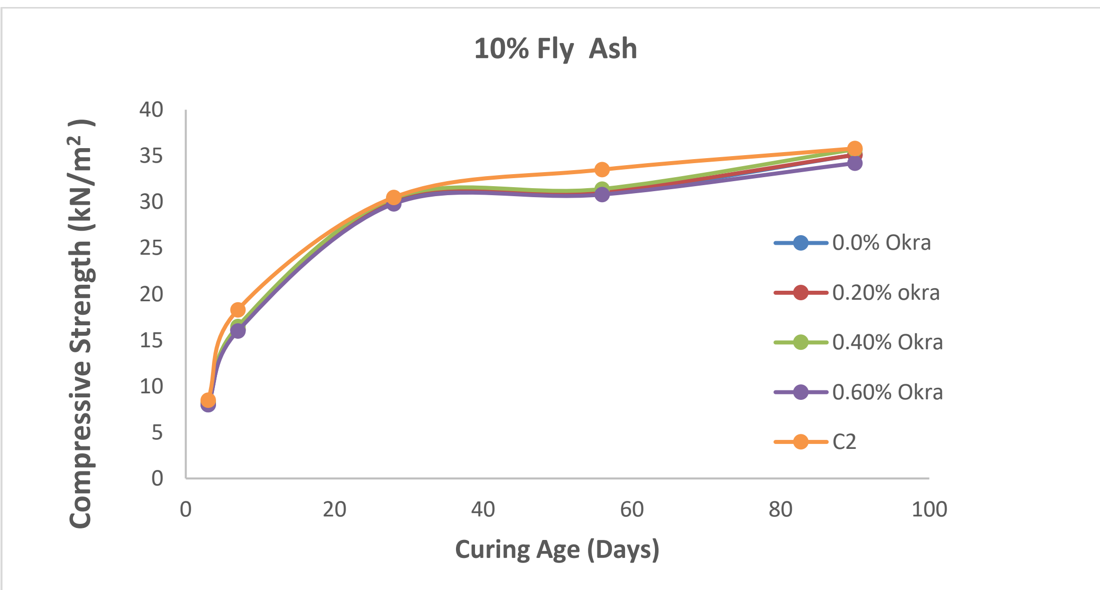

Figure 1:

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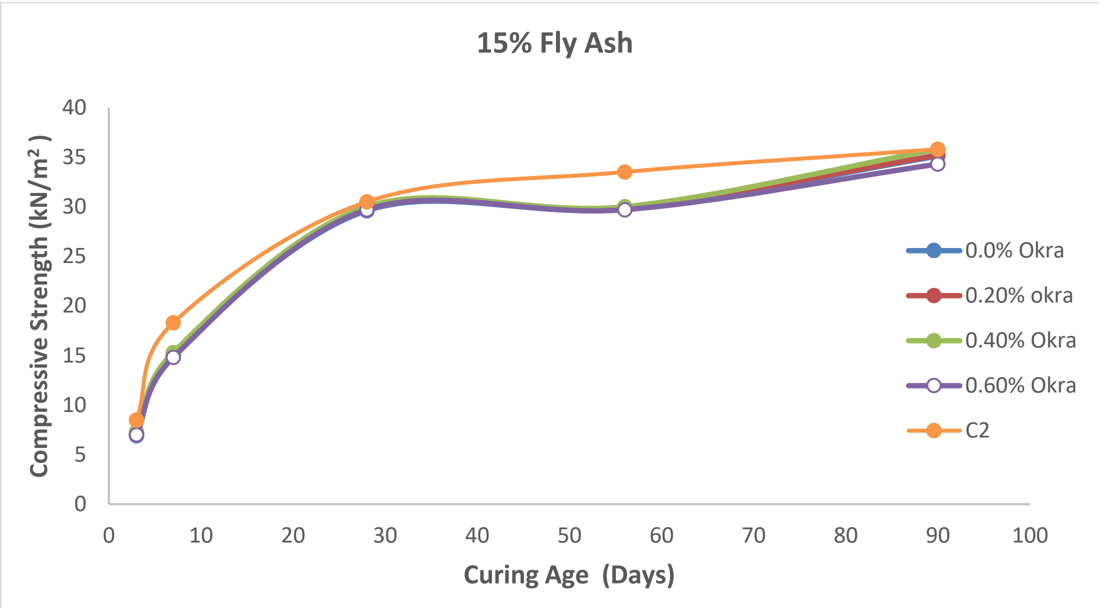

Figure 2:

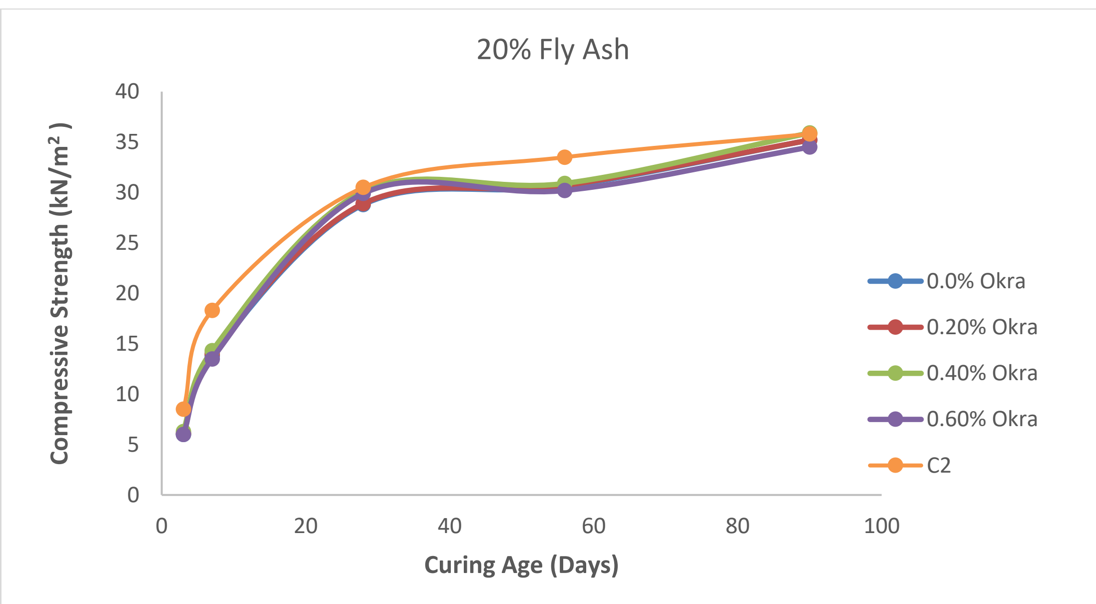

Figure 3:

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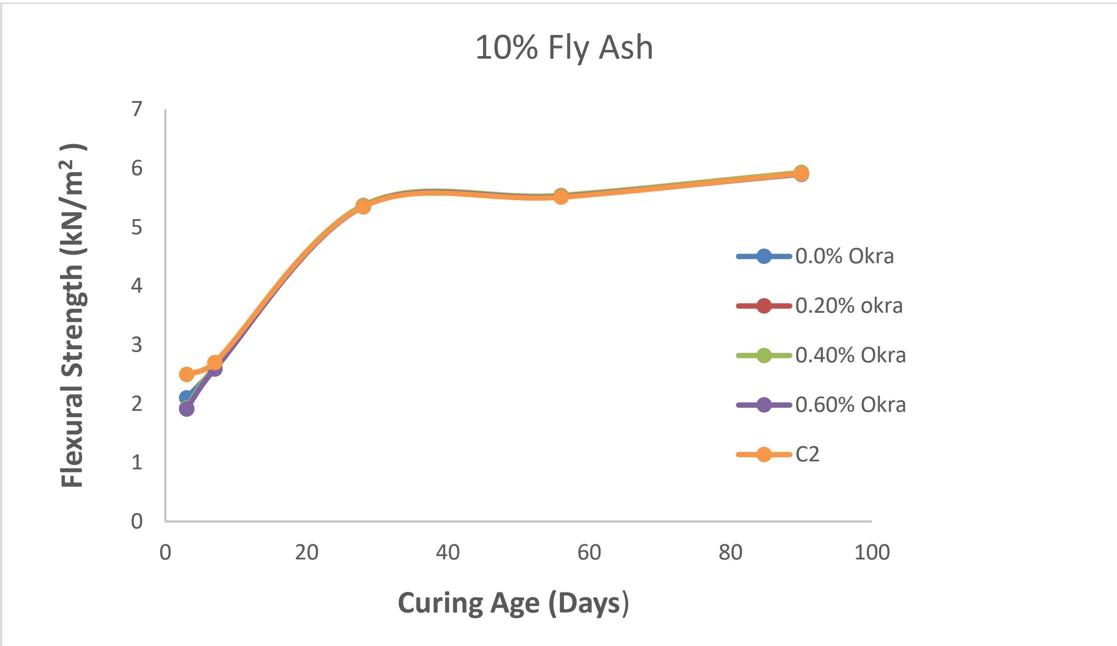
Flexural Strength of Concrete

Figure 2 revealed that flexural strength increases with curing age and decreased with an increase in FA content especially during the early age, it also shows increase in flexural strength across percentage increase in dosages of okra up to 4%, as okra dosages increases to 6%, flexural strength tends to slightly decreases.

Figure 2



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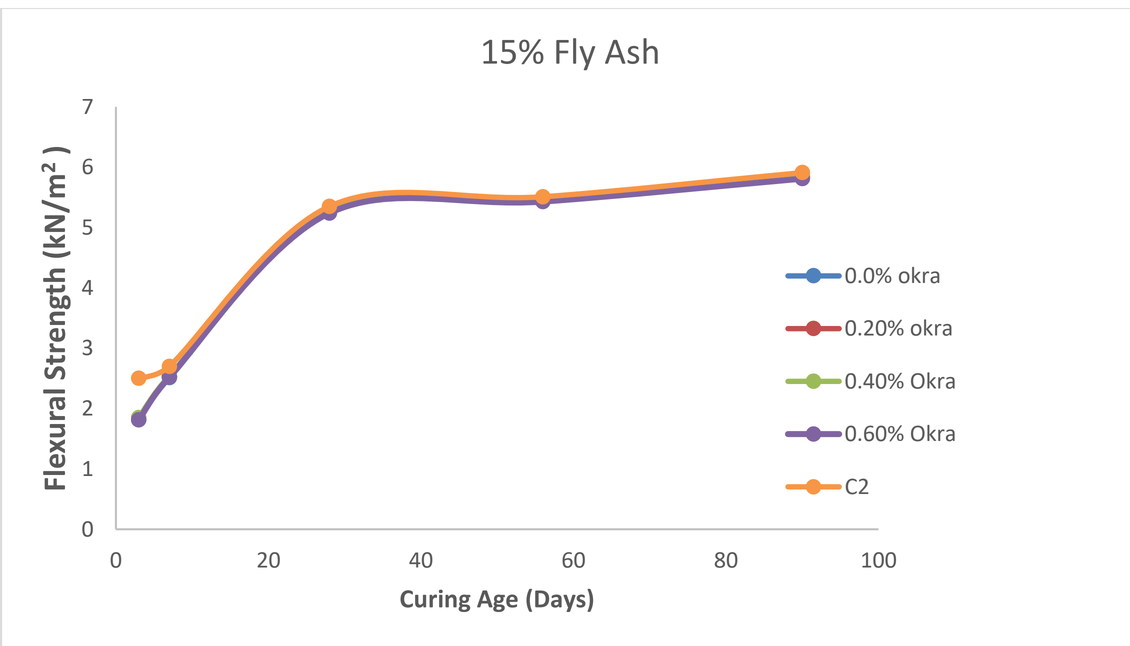

(b)

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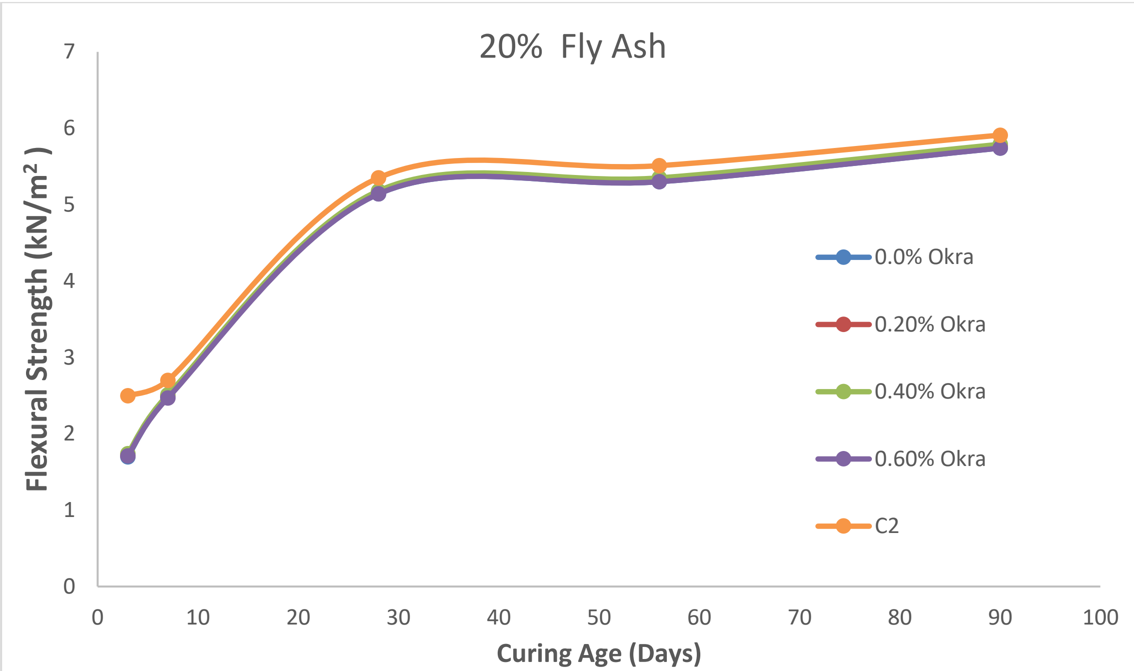

(c)

Split Tensile Strength of Concrete

Figure 3 revealed that split tensile strength increases with curing age and decreased with an increase in FA content especially during the early age, it also shows increase in split tensile strength across percentage increase in dosages of okra up to 6% unlike compressive and flexural strength which decreases when the dosages of okra increases to 6%,

Figure 3

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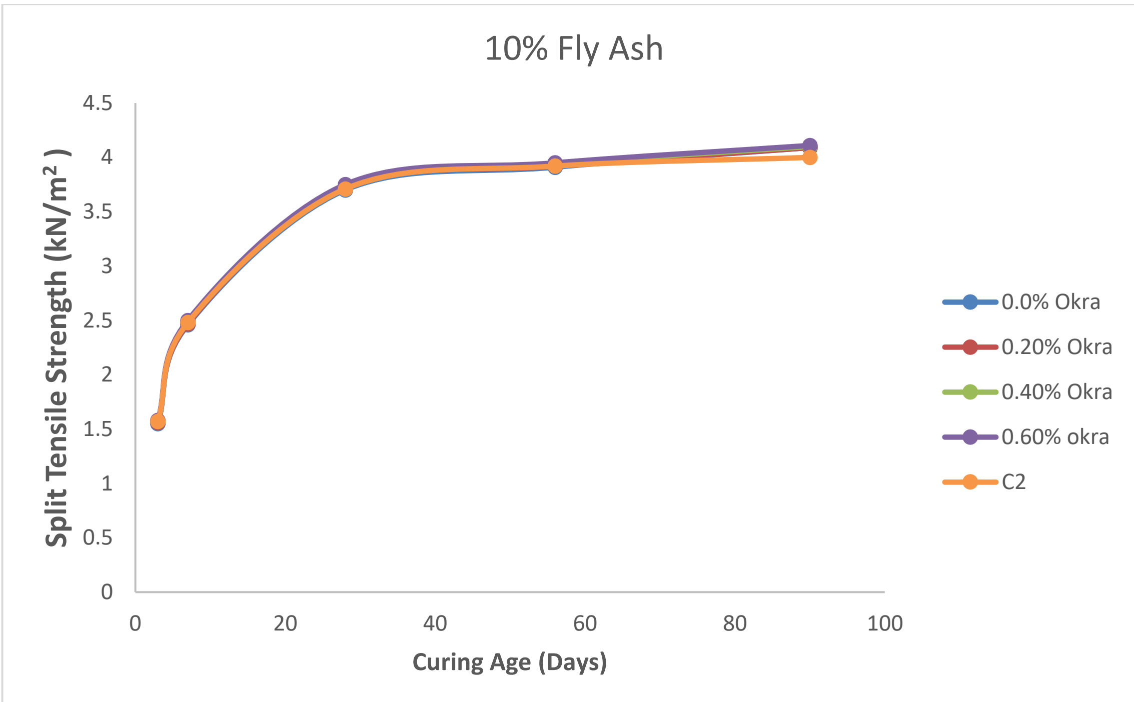

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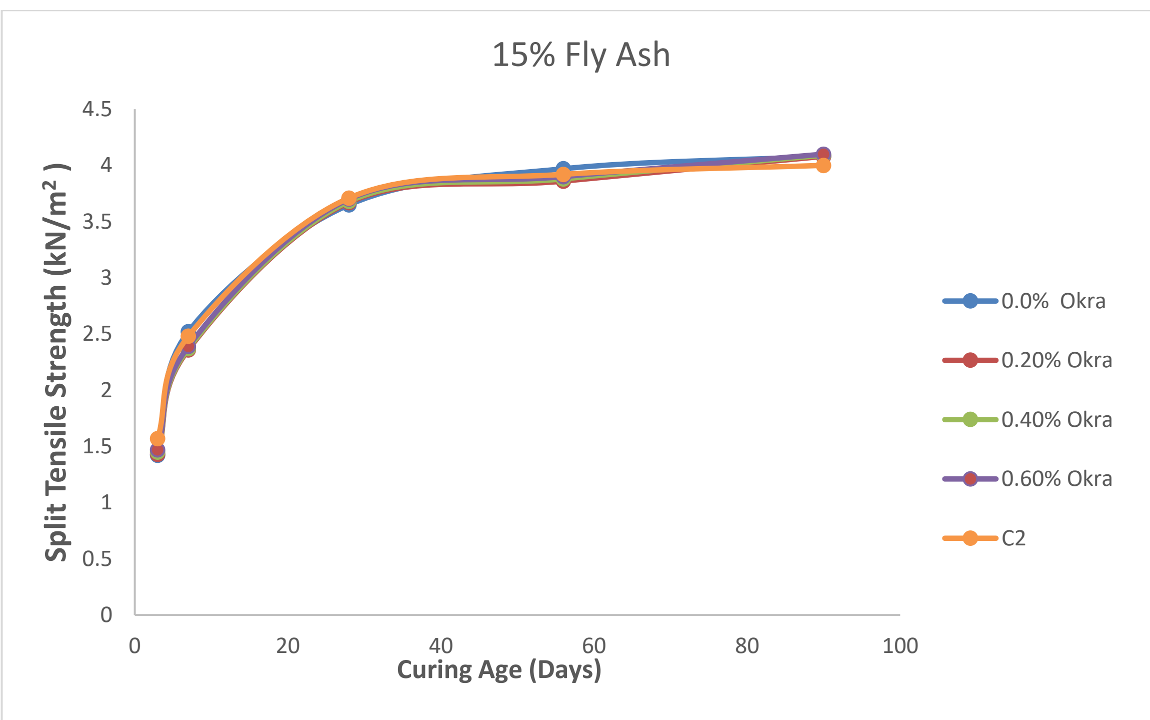

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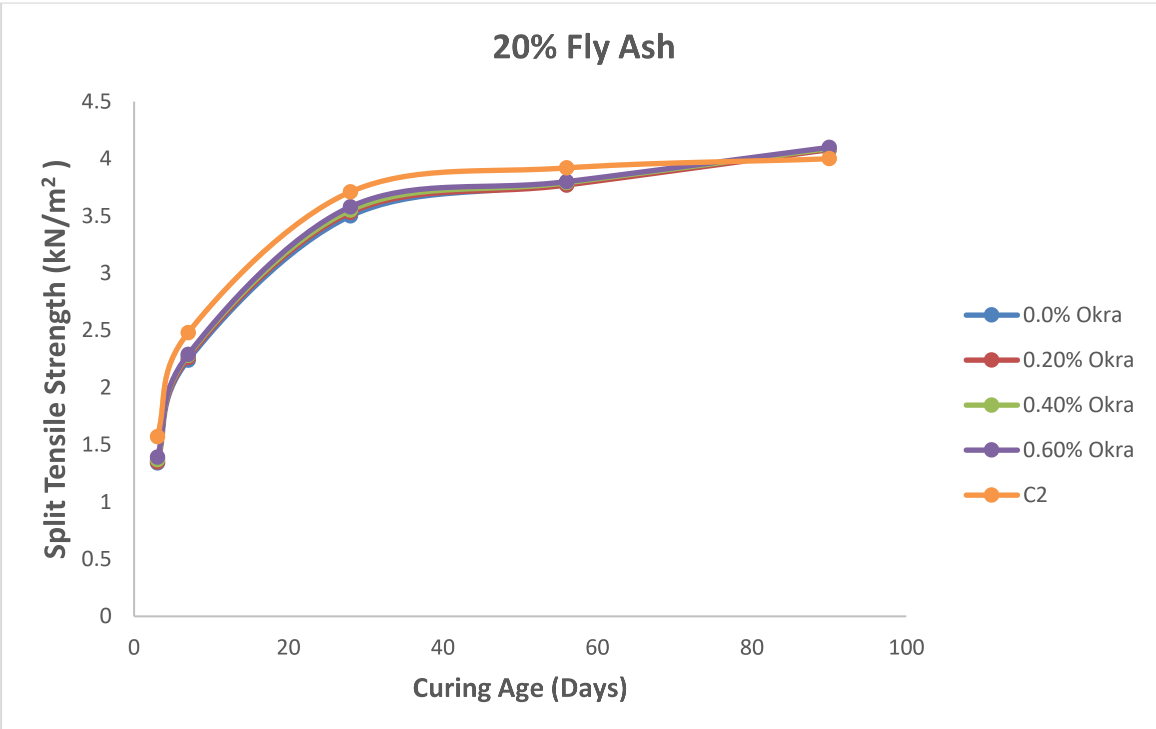

(c)

CONCLUSION

This experimental investigation on the performance of okra as a viscosity enhancing admixture in self-compacting concrete has led to the following conclusions; The optimum replacement level of okra for both fresh and hardened concrete was found to be 4% of the designed cement content, since concrete samples containing 4% of okra content has a good flow and the highest strength compare to other percentage replacements. It was observed that the incorporation of FA in self-compacting concrete results to a decrease in compressive, flexural and split tensile strength especially at the early age of 3days, 7days and 14days but increased at later age of 28days strength and above.

RECOMMENDATION

The following recommendations are based on the findings of the study:

1. Okra can be used to enhance the rheological properties of self-compacting concrete; it shows a reduction in the rate of segregation of fresh material constituents and improve its homogeneity and performance of hardened product.
2. A 4% addition of okra was found to be the optimum replacement level for both fresh and hardened concrete that produced acceptable self-compacting concrete.

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