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Strength Properties of Self-Compacting Concrete (SCC) Produced With Opepe Saw Dust Ash (SDA) Addictive

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ABSTRACT: Concrete is one of the widely used materials in the construction world. It is primarily made up of cement, fine aggregates, coarse aggregates and water, pozolanic materials and super plasticizer can be added based on demand. For over 150 years, concrete as proven to be a very good construction material. As the demand for concrete increases, the demand for cement also increases. Thus there is a linear relationship between the demand for concrete and volume of cement needed. Self-compacting concrete mix was designed by using the same constituent materials as those for conventional concrete mix, but their relative proportions were different. The mix design was done by considering past projects and EFNARC guidelines. The Pozolanic reactivity test was carried out for different samples of opepe sawdust ash at different temperatures of 400^{0}C, 500^{0}C, 600^{0}C, 700^{0}C, 800^{0}C, 850^{0}C, 870^{0}C and 900^{0}C. The Pozolanic reactivity of the sawdust ash was determined by Chappelle test in accordance to NF P 18-513. The test is necessary to check the optimum calcined temperature of Sawdust. For this test, two samples which include the blank and the pozolanic mixture were used. The blank sample contained 2g of calcium oxide (CaO) mixed with 1g of Sawdust ash for different temperatures of 400-800^{o}C at intervals of 100^{o}C, other temperatures were 850^{o}C, 870^{o}C and 900 ^{o}C. The compressive and tensile strength test was carried out for the samples and it was deducted that samples at 10% are more efficient. As regards the other mixes, the strength of Self Compacting Concrete mixture containing opepe Saw Dust Ash dosages beyond 10% were lower in strength than mixture without opepe Saw Dust Ash irrespective of curing age.

KEYWORDS: Saw dust ash, Pozolanic materials, Chapelle test, Self-compacting concrete, concrete strength.

I. INTRODUCTION

Concrete is one of the widely used material in the construction world. It is one of the main construction material used in fulfilling the ever increasing infrastructural need of the society. It is primarily made up of cement, fine aggregates, coarse aggregates and water, pozolanic materials and super plasticizer can be added based on demand.

According to Vazinram and Khodaparast (2009), about 125liters of fossil fuel and 118KWH of electricity is needed in the production of 1ton of cement. Patricija et al (2013), noted that apart from the huge energy required cement also contributes substantially to the emission of CO_2 which leads to global warming. Srinivasan et al (2010) observed that for 1 ton of cement to be produced, about 1 to 1⅓ ton of earth resources like lime stone is used up and an equivalent amount of CO_2 is released into the atmosphere. According to Jindal and Kamal (2015), the global production of cement is over 2.6 billion tons per year with a production growth rate of 5% per annum. The production of cement, generates nearly 7% of atmospheric carbon-dioxide (CO_2). Jindal and Partheeban (2013), stated that CO_2 emission is responsible for up to 65% of global warming. According to Malik et al (2015), the environmental and economic concern is the biggest challenge concrete industry is facing.

Due to this, researchers are making frantic effort to reduce the problem. One of the ways of achieving this is by substituting pozolanic materials such as fly ash, ground granulated blast furnace slag, rice husk ash, metakaolin, saw dust ash, etc, for cement in the production of concrete. Over the years, interest in self-compacting concrete has grown due to the challenges experienced with vibrated concrete. Some of this challenges include; poor compacting, high permeability and porosity, low passing ability, etc. Self-Compacting Concrete (SCC) is a special concrete that does not require

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external or internal vibration for consolidation rather, it gets consolidated under its own self weight. Some unique features of SCC in construction are resistance to segregations, flow ability, deformability, filling capacity, unrestrained shrinkage and permeability. The involvement of SCC promotes new ideology of concrete in construction industry. The production of self-compacting concrete requires large volume of cement compared to normal vibrated concrete.

In this research, saw dust ash shall be used to achieve the reduction of cement in the production of self-compacting concrete. Saw dust ash is a by-product of cutting, drilling or otherwise resulting from the mechanical milling or processing of timber into various sizes and shapes. It is also called wood dust. It is the waste material of timber industry. The dust is often used as a domestic fuel. (Batt and Batt, (2017) classified this material as a renewable resource of energy and an environmentally friendly material.

In Nigeria this material is radically available in large quantity at saw mill markets. This material constitutes environmental challenge at the market. The chemical composition of this material is a function of the type of timber it is gotten from (Olanders and Steenari, 1994).

Several studies have been conducted aim at replacing cement with saw dust ash SDA in vibrated concrete production, but little or nothing has been done in inculcating SDA into self-compacting concrete, hence this study. This study has lots of advantages amongst them are; reduction in the use of natural resources, cutting down environmental risk, reduction of construction cost and discovery of new material for concrete production.

In this research, Opepe sawdust ash shall be evaluated in terms of reactivity.

II. MATERIALS AND METHOD

The experimental program of self-compacting concrete involves identification and selection of materials, batching and mixing of self-compacting concrete, determination of rhetorical properties of the concrete, curing of specimens as well as testing of hardened concrete for physical and mechanical properties.

Locally available materials such as Portland cement (PC), Natural sand, granite, sawdust (Opepe wood) and water were used. Super plasticizer was also added to enhance the flow. In this research study, Portland cement of grade 42.5 which was free of lumps and conforms to the standard requirement set out by BS EN 197-1 2011, was used as a binder for the concrete mix. It was obtained from an open market in Ibadan.

The sawdust was obtained from Sango Sawmill in Ibadan. The dusts were of Opepe wood. opepe has its botanical name as Naucleadiderrichii, the sample is shown in figure 3.1 below. The dust was calccined at varying temperature ranging from 400-900^{O}C in an electric furnace at Segun Labiran and Associates Laboratory as shown in figure 3.2. The burning was done at intervals of 100^{O}C from 400-800 ^{O}C. The other temperatures were 850 ^{O}C, 870 ^{O}C and 900^{O}C

Figure 1: Sawdust from Opepe Wood

Figure 2: Calcination of Sawdust

Sand with maximum size of 4.75mm conforming to the requirement of BS 882(1992) was obtained within Ibadan metropolis. The fineness modulus of the sand was within the range of 2.4 and 2.6 based on recommendation stated by and Domoneet al (1999).

Granite was obtained from Takol quarry site at Shokuro village, off Lagos-Ibadan expressway in Ibadan. The granite size of 20mm down size having satisfied the requirement of BS 882: (1992) was used as coarse aggregate.

Water that contains organic material might affect the properties of fresh and hardened concrete. So, water which was free of impurities, salts and chloride was avoided in all cases.

2.1: Test on Aggregates

Various test on aggregates were carried on this project work in order to have a satisfactory result which will be discussed below

2.1.1: Particle size distribution of fine aggregates

The test was carried out to obtain the gradation of the fine aggregate. The test was carried out in accordance with BS812: PART 103.1:1985.

2.1.2: Pozollanic Reactivity Test by Chappelle Test on Saw dust Ash

The Pozollanic reactivity of the saw dust was determined by Chappelle test in accordance to NF P 18-513. The test is necessary to check the optimum calcined temperature of Sawdust

Reagents: calcium oxide, distilled water, saccharose, Hydrochloric acid, phenolphthalein (indicator solution)

Mix Proportions

Self-compacting laterized concrete mix was designed by using the same constituent materials as those for conventional concrete mix, but their relative proportions were different. The mix design was done by considering past projects and EFNARC guidelines. Table 3.1 shows the mix composition adopted.

Batching and mixing

Several batches in accordance with the below mix designs were prepared in this research work. The predetermined amount of fine and coarse aggregate was then added and mixed together manually as shown in table 3.2 Then, half of the required water was added and mixed thoroughly for some times. Predetermined quantities of cement, sawdust and super plasticizer minutes. Sawdust was added to each set of the concrete produced at 0%, 5%, 10% and 15% by weight of cement with the self-compacting concrete containing sand serving as a control.

Table 1: Trial Mix Composition

S/No	Materials	Proportion in Kg/m^3
1	Cement	450
2	Fine Aggregates	993
3	Coarse Aggregates	845
4	Water	171
5	Super Platisticizer	5.4

Source: EFNARC 2005

Table 2: Mix composition for 1m^3

Mixes	Cement Kg	SDA Kg	Coarse Agg Kg	Fine Agg Kg	Water Kg	SP Kg
SDA 0 %	450	0.0	845	993	171	5.4
SDA 5 %	422.5	22.5	845	993	171	5.4
SDA 10%	400	45.0	845	993	171	5.4
SDA 15%	382.5	67.5	845	993	171	5.4

2.2: Casting and Curing of Self Compacting Concrete

The concrete mould was oiled before use for easy removal of the concrete specimens after which the mixture is filled into the cube mould of size 150 x 150 x 150mm and cylindrical mould of size 150mm in diameter with 300mm long. Then, the specimens were demoulded after 24 hours of casting and immersed inside water for curing ages of 7,14,21,28 and 56 days.

2.2.1: Compressive strength test

Compressive Strength was carried out on all the cube specimens of size 150 x 150 x 150mm after attaining the ages of 7,14, 21, 28 and 56 days. Three specimens were tested for each of the curing days and the average of three values is then taken to determine the compressive strength of concrete. The test was carried out as described in BS EN 12390-3 (2009).

2.2.2: Splitting tensile test

Upon the attainment of specific ages of 28 and 56 days of curing, the sample was tested for split tensile strength.

This test was conducted on the specimens with at least three specimens being used for selected ages and proportion. The test was carried out in accordance to BS EN 123909-6

III: RESULTS AND DISCUSSION

3.0: PARTICLE SIZE ANALYSIS

The result of particle size analysis of fine and coarse aggregates is presented in Tables 3 while the particle size distribution curves is displayed in figures 3. From the results obtained, the fineness modulus of sand was 2.60. The fineness modulus of fine aggregates falls within the range used in producing the self-compacting concrete in accordance with recommendation stated by Domone et al (1999). Hence, they are suitable for self-compacting concrete.

Table 3: Measured parameters from the grade curve

Parameters	Sand	Granite
D_{10}	2.30	6.10
D_{30}	0.37	7.00
D_{60}	0.90	7.30
C_U	1.45	1.20
C_C	0.96	1.20

3.1: Pozollanic Reactivity Test

The Pozollanic reactivity test was carried out for different samples of opepe sawdust at different temperatures of 400^0C, 500^0C, 600^0C, 700^0C, 800^0C, 850^0C, 870^0C and 900^0C. At the end of the test, it was observed that opepe sample that was calcined at 870^0C had the highest reactivity of 1358Mg/g (the mg $Ca(OH_2)$ fixed by the opepe). The figure 4 below shows the chart of the opepepozolanic test

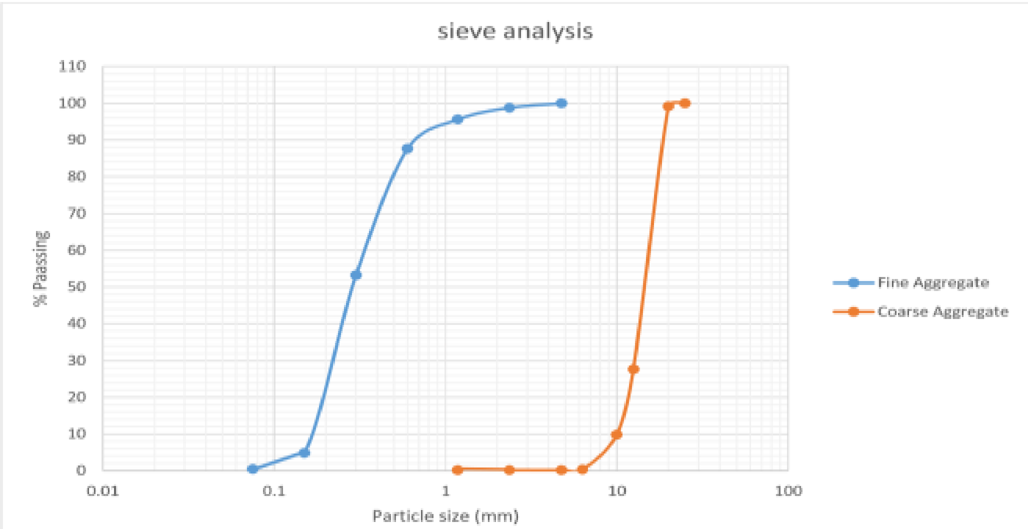

Figure3: Particle size Distribution Curve for Aggregates.

3.2: Slump Test Result of OPEPE SAW DUST ASH (OSDA)

The results of the slump flow at varying proportion of Opepe Saw Dust Ash for self-compacting concrete (SCC) are presented in Table 4. From this table, it was observed that as the percentage of Opepe Saw Dust Ash increases, there was a reduction in slump flow diameter with an increase in flow time. Thus, the flow ability reduced with increasing dosage of Opepe Saw Dust Ash. However, the results of slump flow diameters were within the range of 652-680mm. This showed that the SCC conformed to the range of specification (660-750mm for class SLF2) given by BS EN 206-9 (2010) and EFNARC (2002).

V-Funnel test: The result of V-Funnel test shows that all the normal SCC had values lesser than 9.0 as shown in Table 5 Hence, the SCC can be classified as VF1 according to BS EN 206-9 (2010).

Table 4: Slump flow test for Self-Compacting Concrete

Mixes	Slump Flow for SCC Dia(mm)	T_{50}(Sec)
OSDA 0 %	680	3.50
OSDA 5%	677	3.69
OSDA 10%	661	4.80
OSDA 15%	657	4.94

Table 5: V funnel test for Self -Compacting Concrete

Mixes	V-Funnel SCC (Sec)
OSDA 0 %	7.41
OSDA 5%	7.69
OSDA 10%	8.47
OSDA 15%	8.98

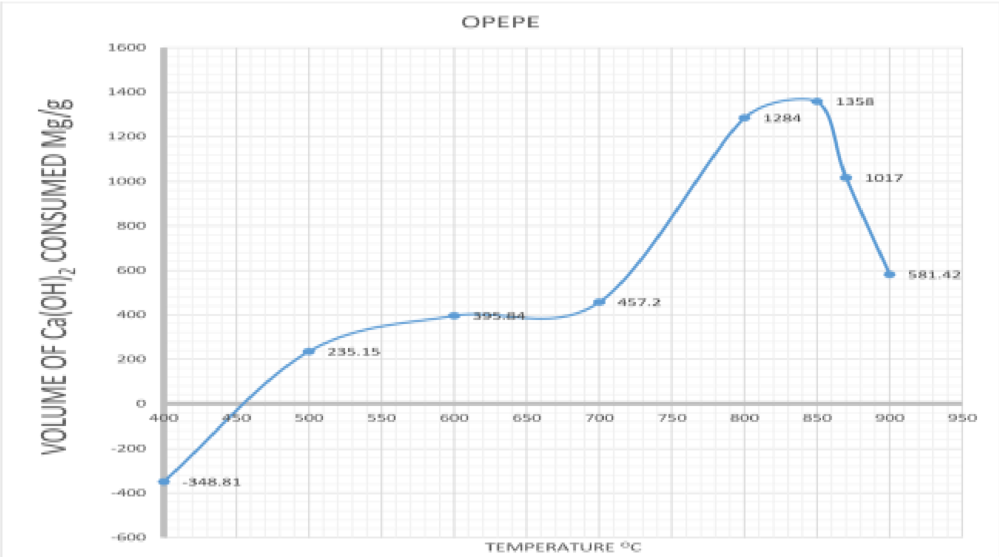

Figure 4:Pozzolanic Reactivity (Chappelle's test) for Opepe

3.3. Compressive strength

The result of the compressive strength conducted on the concrete are presented in Tables 6 to 9. From the results obtained (Figure 5), the compressive strength of SCC ranged from 12.04-12.67N/mm^2, 16.59-18.07N/mm,^{2} 21.04-22.07N/mm^{2}and 24.24-25.0N/mm^2 at 7, 21, 28 and 56days respectively. Generally, the strength increases with the curing age for all the prepared mixes. The compressive strength of SCC at 7 days, 21 days, 28 days and 56days were 12.04N/mm^2, 16.59N/mm^2, 21.48N/mm^{2}and 24.44N/mm^{2}for 0% OSDA; 12.47N/mm^2, 17.03N/mm^2, 21.33N/mm^{2}24.56N/mm^{2}for 5%OSDA; 12.67N/mm^2, 18.07N/mm^2 , 22.07N/mm^{2}and 25,03N/mm^{2}for 10%OSDA; 12.46 N/mm^2, 17.63 N/mm^2 , 21.04N/mm^{2}and 24.24N/mm^{2}for 15%OSDA respectively. The percentage variation in compressive strength of SCC dosed with 5%, 10% and 15% OSDA as expressed in terms of their control sample (0% OSDA) were +3.6%, +5.2% and 3.5% respectively at 7 days; +2.7%, + 8.9%, and 6.3% 21days; -0.7%, 2.7%, and -2.0% at 28 days respectively. These results shows that 10% dosage of SCC with OSDA produce better strength than mixes with other dosages (5% and 15% OSDA) at all ages.

As regards the other mixes, the strength of SCC mixture containing OSDA dosages beyond 10% were lower in strength than mixture without OSDA irrespective of curing age. This work contravenes the works of some researchers (Pranav and Sagar, 2018; Spurthi, 2018; Mohammad et al, 2015: Orime et al, 2020), which reported that the strength properties of concrete containing saw dust decreased with increased percentage replacement of saw dust ash when compared with the control.

The disagreement in result is due to the non-calcination of the saw dust and subsequent conducting of reactivity test to determine the optimum calcination temperature before utilizing the material for concrete production. However, this

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work agrees with the findings of Elinwa and Ahmed (2014) that at 10% replacement of cement wit saw dust ash strength properties improved.

Table 6: 7 Days Compressive Strength

Mix ID	Sample	Weight (Kg)	Density kg/ m^3	Crushing load KN	Compressive strength N/ mm^2
OSDA0%	1	7.0	2074	265.0	11.80
	2	7.2	2133	275.4	12.24
	3	7.7	2281	271.8	12.08
Average			**2162**		**12.04**
OSDA5%	1	8.1	2400	285.5	12.69
	2	7.2	2133	279.0	12.40
	3	8.0	2370	277.0	12.31
Average			**2301**		**12.47**
OSDA10%	1	8.0	2370	280.2	12.45
	2	7.7	2281	289.6	12.87
	3	7.6	2251	285.5	12.69
Average			**2300**		**12.67**
OSDA15%	1	7.9	2340	281.9	12.53
	2	8.0	2370	281.1	12.49
	3	7.5	2222	278.1	12.36
Average			**2301**		**12.46**

Table 7:21 Days Compressive Strength

Mix ID	Sample	Weight (Kg)	Density kg/ m^3	Crushing load KN	Compressive strength N/ mm^2
OSDA0%	1	7.6	2252	380	16.89
	2	7.9	2340	370	16.44
	3	7.8	2311	370	16.44
Average			**2301**		**16.59**
OSDA5%	1	7.6	2252	390	17.33
	2	7.9	2340	380	16.44
	3	8.1	2400	390	17.33
Average			**2331**		**17.03**
OSDA10%	1	7.8	2311	410	18.22
	2	8.1	2400	410	18.22
	3	7.8	2311	400	17.78
Average			**2340**		**18.07**
OSDA15%	1	8.3	2459	390	17..33
	2	7.7	2281	400	17.78
	3	7.9	2341	400	17.78
Average			**2360**		**17.63**

Table 8: 28 Days Compressive Strength

Mix ID	Sample	Weight (Kg)	Density kg/ m^3	Crushing load KN	Compressive strength N/ mm^2
OSDA0%	1	8.2	2430	490	21.78
	2	7.6	2311	490	21.78
	3	8.1	2400	470	20.89
Average			**2380**		**21.48**
OSDA5%	1	8.2	2430	470	20.89
	2	7.9	2341	480	21.33

	3	8.3	2459	490	21.78
Average			**2410**		**21.33**
OSDA10%	1	8.1	2400	500	21.78
	2	7.9	2341	490	21.33
	3	8.1	2400	500	22.22
Average			**2380**		**22.07**
OSDA15%	1	8.2	2430	480	21.33
	2	8.0	2370	470	20.89
	3	7.9	2380	470	20.89
Average			**2393**		**21.04**

Table 9: 56 Days Compressive Strength

Mix ID	**Sample**	**Weight (Kg)**	**Density kg/ m^3**	**Crushing load KN**	**Compressive strength N/ mm^2**
OSDA0%	1	8.1	2400	551	24.48
	2	8.0	2370	546	24.26
	3	8.0	2370	553	24.59
Average			**2380**		**24.44**
OSDA5%	1	8.2	2429	547	24.32
	2	7.9	2340	551	24.48
	3	8.2	2429	560	24.88
Average			**2399**		**24.56**
OSDA10%	1	8.2	2433	565	25.22
	2	8.2	2421	553	24.82
	3	8.0	2370	570	25.05
Average			**2408**		**25.03**
OSDA15%	1	8.2	2418	551	24.48
	2	8.0	2385	538	23.93
	3	8.2	2415	547	24.32
Average			**2406**		**24.24**

Figure 5:Split tensile strength

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The results of split tensile test obtained at 7, 28 and 56 days are displayed in Tables 7 to 11 respectively while the graphical illustration of result are presented in Figures 6. The split tensile strength dosed with 0%OSDA, 5%OSDA, 10%OSDA and 15%OSDA were 1.05N/mm^2, 1.20N/mm^2, 1.22N/mm^2, 1.08 N/mm^2 at 7days; 2.15N/mm^2, 1.9N/mm^2, 2.21N/mm^2, 2.0N/mm^2 at 28 days and 2.13N/mm^2, 1.92N/mm^2, 2.21N/mm^{2}and 2.02 N/mm^{2}at 56 days respectively. It can be deduced that the tensile strength of the concrete increased as the dosage of OSDA increased from 5% up to 15%. The strength of all the mixes containing OSDA were better in strength than the control at 7days but at 56days, only 10%OSDA was better than the control. From these results, the improvement in strength of SCC incorporating 10%OSDA was 1.6% and 2.7% at 7days and 56 days respectively. However, the split tensile result of SCC obtained from this present study corroborates with the deduction made by Elinwa and Ahmed (2014) 10%OSDA addition is required to produce better split tensile strength.

Table 9:7 Days Split Tensile Strength

Mix ID	**Sample**	**Weight (Kg)**	**Density kg/ m^3**	**Crushing load KN**	**Split strength N/ mm^2**
OSDA0%	1	12.7	2396	73.0	1.03
	2	12.3	2300	73.2	1.04
	3	12.5	2358	76.4	1.08
Average			**2351**		**1.05**
OSDA5%	1	12.9	2433	75.6	1.07
	2	12.7	2396	72.1	1.02
	3	12.4	2340	77.1	1.09
Average			**2390**		**1.06**
OSDA10%	1	12.6	2377	76.4	1.08
	2	12.8	2415	75.6	1.07
	3	12.9	2433	74.9	1.06
Average			**2318**		**1.07**
OSDA15%	1	12.4	2340	73.0	1.03
	2	12.6	2377	73.2	1.04
	3	12.9	2433	73.4	1.05
Average			**2383**		**1.04**

Table 10: 28 Days Split Tensile Strength

Mix ID	**Sample**	**Weight (Kg)**	**Density kg/ m^3**	**Crushing load KN**	**Split strength N/ mm^2**
OSDA0%	1	13.0	2452	152.0	2.15
	2	12.6	2377	150.0	2.12
	3	12.4	2341	154.0	2.18
Average			**2390**		**2.15**
OSDA5%	1	12.8	2415	132.6	1.88
	2	12.5	2358	134.3	1.90
	3	12.3	2300	136.0	1.92
Average			**2375**		**1.90**
OSDA10%	1	12.8	2415	154.2	2.18
	2	12.7	2396	154.4	2.18
	3	12.5	2358	160.0	2.26
Average			**2390**		**2.21**
OSDA15%	1	12.7	2396	141.4	2.00
	2	12.8	2415	142.2	2.01
	3	12.6	2433	140.6	1.99
Average			**2402**		**2.00**

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Table 11: 56 Days Split Tensile Strength

Mix ID	Sample	Weight (Kg)	Density kg/ m^3	Crushing load KN	Split strength N/ mm^2
OSDA0%	1	13.1	2420	156.0	2.20
	2	12.9	2412	154.0	2.18
	3	12.7	2390	146.3	2.07
Average			**2407**		**2.15**
OSDA5%	1	12.9	2385	137.1	1.94
	2	12.7	2340	135.0	1.91
	3	12.7	2320	134.0	1.90
Average			**2348**		**1.92**
OSDA10%	1	12.6	2425	157.0	2.22
	2	12.8	2420	158.4	2.24
	3	12.9	2405	156.0	2.20
Average			**2318**		**2.22**
OSDA15%	1	12.6	2370	145.0	2.05
	2	12.7	2360	142.0	2.01
	3	12.6	2343	141.5	2.00
Average			**2358**		**2.02**

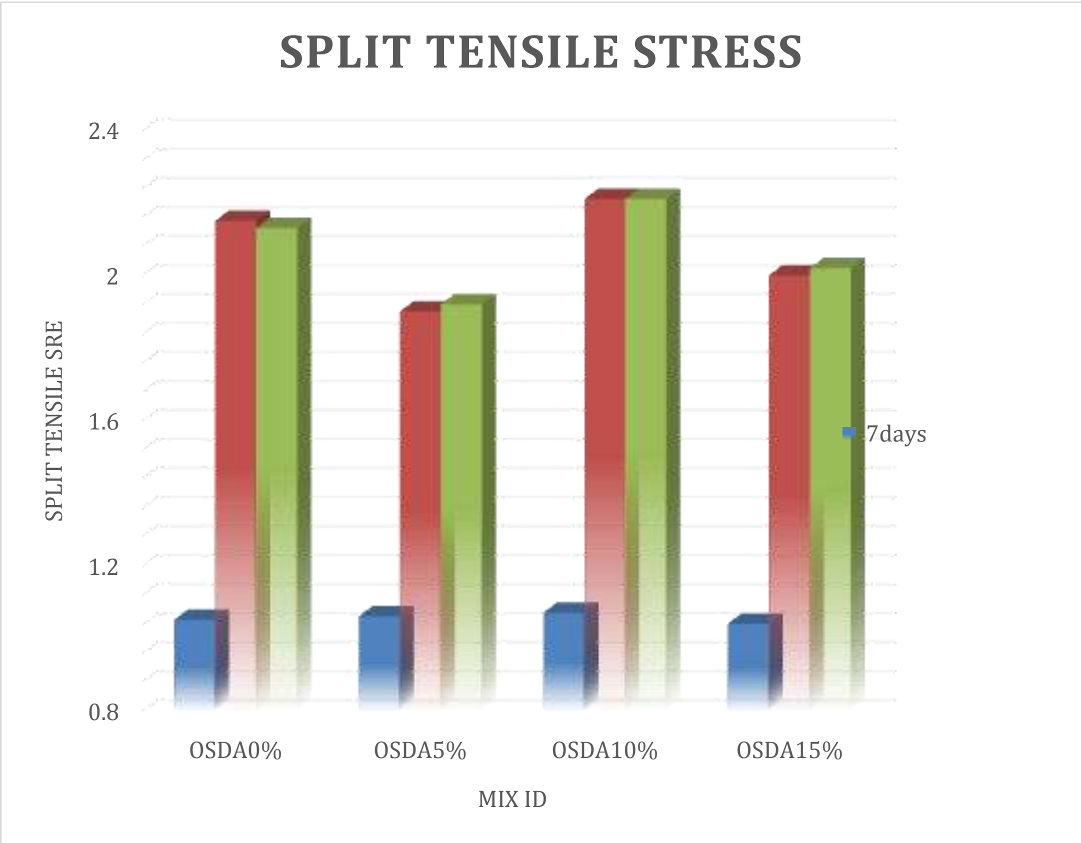

Figure 6:Split Tensile Stress Results

IV: CONCLUSION

1. Based on the results of the laboratory work conducted, the following conclusions can be drawn: The optimum reactive temperature is 850^{O}C for Opepe saw dust ash. The Opepe ash was reactive. However, at 400^{O}C, the ashes were unreactive.
2. At all level of replacement, the requirements for fresh concrete were met based on the test conducted. However, as the percentage of replacement increased, the rheological

properties were negatively in filling ability and passing ability as evident in the slump flow, V-funnel and L-box test conducted
3. The densities of the concrete produced increased with age and were within the range for normal density of concrete. The densities however increased with increase in replacement of cement with OSDA.
4. At 10% replacement of cement with OSDA, the compressive strength was maximum for all ages with +5.2%, + 8.9%, + 2.7%, and +2.23% increase in compressive strength at 7, 21, 28 and 56 days respectively. The tensile strength also improved with 1.6%, 2.7% and 0,01% at 7days,28days and 56days respectively.

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