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EXPERIMENTAL STUDY ON THE PROPERTIES OF SAWDUST CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT WITH SAWDUST ASH

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ABSTRACT :This experimental study considered the use of sawdust ash (SDA) as a partial replacement for cement and sawdust as a partial replacement for sand as fine aggregate in the production of concrete. The sawdust replacement percentage was kept constant at 2.5% while that of SDA varied from 0 to 10%. A total of 60 concrete cubes of 150 mm x 150 mm x 150 mm for testing in the laboratory were produced. Two sets of samples were produced; one set with 0% sawdust and the other with 2.5% sawdust. Sieve analysis was carried out on the sawdust specimen while pozzolanicity test was carried out on SDA. Slump test was carried out on fresh concrete while compressive strength and Bulk density were tested at 7 and 28 days of curing. Results showed that pozzolanicity of SDA were greater at room temperature and increased with reaction time. Increased SDA proportions resulted in increased workability. Bulk Density had its greatest value at 5% SDA replacement while that of compressive strength was at 7.5%. The control mix with 0% sawdust had greater values than that with 2.5% sawdust replacement for both compressive strength and bulk density.

KEYWORDS:*Sawdust ash, sawdust, concrete, compressive strength, bulk density*

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I. INTRODUCTION

In the construction industry Concrete has appeared to be the most widely used construction material all over the world with innovations in science and technology, the scope of concrete as a structural material has widened. Concrete is stable in compression and has unstable strength in tension and flexure. The utilization of concrete is increasing at a higher rate due to development in infrastructure and construction activities all around the world. The River sand which is most commonly used fine aggregate in the production of concrete;possess the problem of acute shortage in many areas, whose continued use has started posing serious problems with respect to its availability, cost and environmental impact. Attempts have also been made to reduce the total construction cost by investigating and ascertaining the usefulness of sawdust, thereby using locally available materials or waste materials to replace the rivers and to produce low cost concrete. Generation of wood wastes in sawmill is an unavoidable environmental pollution and hence great efforts are made in the utilization of such waste. Thus, this research investigates the potential use of wood sawdust wastes to produce a low-cost and lightweight composite for construction and engineering purpose.

Many researchers have particularly found sawdust ash a suitable agricultural by-product for use in formulating binary blended cements with OPC (Elinwa, Ejeh, and Mamuda, 2008).

Wood sawdust wastes are accumulated from countries all over the world and cause certain serious environmental problems and health hazards. The fine aggregate used in the production of concrete is mostly obtained from borrow pits which are most times situated farther away from our immediate environment. The reason for this research is that for a practical average housing unit, the white cement powder is the most costly material, occurring in walls (mortar and plaster, sandcrete block), floors and foundation. Cement being the mostly used binder in the country makes it have a monotonous control in building materials. The high costs of construction material, labour and equipment have collectively become the very reason that has made building houses and consequently renting expensive to come by. To this effect, an alternative measure has been investigated to cushion the proliferated cost of materials in building houses.

Sawdust can be used as alternative substitute for fine aggregate in concrete production (Ganiron, 2013). The usage of sawdust in production of lightweight concrete enables a safe means of sawdust disposal as a waste material. The sawdust concrete also enables us to achieve certain desirable properties in concrete such as improved ability to hold nails, internal curing and reduced weight among others (Himanshu *et al.* 2018, Awal *et al.* 2016).

Certain predictions state that if sawdust is mixed with cement and gravel, it might simulate a synthetic wood fibre bond found in trees. Since trees exhibit great strength and feats that manmade concrete structures cannot do without steel reinforcements, wood fibre bonding that could be more flexible and intricate in its own way might be adapted by most concrete structures allowing them to be shaped in more complicated forms. Also, presumptions indicate that if each sawdust particle took up enough water during hydration, they could aid

the hydration process especially in the centre parts of concrete that is impossible to cure with water thus eliminating the need of curing because water deposited in sawdust particles are being harvested by cement particles. The most important aspect and main target of the experiment are proving that sawdust-cement-gravel mixtures can prove to be more lightweight and cost efficient (Ganiron, 2013). According to the study carried out by Ezeagu and Agbo-Anike (2020), the optimum percentage replacement of sand for sawdust concrete batched by weight was gotten to be about 2.38% to achieve allowable value ranges of compressive strength, water absorption and slump.

According to ACI (2021), a pozzolan is a siliceous or silico-aluminous material 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 (there are both natural and artificial pozzolans). Malinowski (1993) reports that the oldest example of hydraulic binder, dating from 5000-4000B.C, was a mixture of lime and natural pozzolan, a diatomaceous earth from the Persian Gulf. The next oldest reported use was in the

Mediterranean region. The pozzolan was volcanic ash produced from two volcanic eruptions.

Sometime between 1600 and 1500B.C on the Aegeon Island of Thera, now called Santorin, Greece, the other in 79 A.D at Mt. Versuvius on the bay of Naples, Italy. Both are volcanic ashes or pumicites consisting of almost 80% volcanic glass (pumice and obsidian). According to Elinwa and Mahmoodb, (2002), sawdust is an organic waste resulting from the mechanical milling or processing of timber into various shapes and sizes. The dust is usually used as domestic fuel. The resulting ash known as saw dust ash (SDA) is a form of pozzolana. According to Swamy (1986), natural pozzolans have been in use for many centuries. When mixed with lime they provide cement with long lasting strength. The relationship between the lime-pozzolana reaction and the mechanical properties of the cement has not been defined other than qualitative terms. Nevertheless, it is recognized that the reaction is influenced by the chemical and mineralogical composition of pozzolana and the cement, their relative fineness, conditions of ambience, curing time and the effect of admixtures.

According to Cheah and Ramli (2011), the beneficial effects of pozzolans addition in terms of higher compressive strength performance and greater durability are mostly attributed to the pozzolanic reaction in which calcium hydroxide is consumed to produce additional C-S-H and C-A-H reaction products. These pozzolanic reaction products fill in pores and result in a refining of the pore size distribution or pore structure. This results in a lowered permeability of the binder. The increased chemical resistance to the ingress and harmful action of aggressive solutions constitutes one of the main advantages of pozzolan blended cements.

The improved durability of the pozzolan-blended binders enables to lengthen the service life of structure and reduces the costly and inconvenient need to replace damaged constructions.

One of the principal reasons for the increased durability is the lowered calcium hydroxide content available to take part in deleterious expansive reactions induced by e.g. sulfate attack. Ettu et al. (2013) investigated the variation of strength of OPC–RHA-SDA cement composites with mix proportion and found that for all percentage replacement of OPC with RHA-SDA at 28 and 50 days of curing and a given water cement ratio, the compressive strength increased with leanness of mix up to some level of leanness after which the strength reduced.

In order to maximise the use of sawdust waste as a construction material, this study will leverage on the variations in concrete properties provided by sawdust as a partial replacement for fine aggregate as shown in previous studies and the variations in concrete properties resulting from sawdust ash, a pozzolana, as a partial replacement of cement. Making these two replacements in a single mix will provide data and information on the resulting property variations in concrete as a result of the combined effect of both sawdust and sawdust ash as against their individual effects obtained from previous studies.

This Research work studies the model properties in sawdust concrete with sawdust ash used as a pozzolan for replacement of cement. The objectives include the following:

i. Formulation of lightweight sawdust concrete composite

ii. Experimental work on concrete-sawdust mixture by placing concrete in cubes where cement is replaced with sawdust ash at 0%, 2.5%, 5%, 7.5% and10% and fine aggregate (sand) with sawdust at 2.5%.

iii. To evaluate the physical and strength properties of the mixture samples.4

The scope of this study includes:

i. To determine the physical and chemical characteristics of the derived sawdust ash.

ii. To formulate light weight concrete as a mixture of cement, sand, water, sawdust and sawdust ash using sawdust ash and sawdust as partial replacement for cement and sand respectively.

iii.To validate the models generated by experiments and through existing knowledge.

iv.To compare the workability, water absorption, density and strength properties of the wood sawdust generics.

This study will suggest ways to further research improvements on the use of local raw materials as construction materials. This research will equally aid in the overall reduction cost of producing concrete, which implies housing and other forms of concrete construction works will have affordable rates. The effect of sawdust on concrete properties will be evaluated.

II METHODOLOGY

The following materials/equipment was used to achieve the aims and objectives of this study:

i. Cement - Ordinary Portland cement (BUA).

ii. Fine aggregates (River Sand) carefully collected from the river bank of River Niger in Onitsha, Anambra state.

iii. Water which was obtained and stored in a 500litre plastic tank situated at the Engineering Concrete workshop, NAU.

iv. Sawdust sourced from Amansea saw mill market at Awka North, Anambra state.

v. Saw dust Ash (pozzolan) the sawdust was burnt with open air method of calcination after some days of drying. After burning they were sieved and those that passed through 150um were stored in air tight containers.

Particle size distribution was carried out on the sawdust specimen while Pozzolanicity Reactivity Test was carried out on the sawdust ash (SDA) before they were used for concrete casting. The Slump Test was carried out to determine the workability of the fresh concrete before cube casting

A total of 30 cubes were cast at a water/cement ratio of 0.5 for the control mix and 0.55 for

the sawdust concrete sample mix. The following tests were carried out at 7 and 28 days curing: Density Test, Compressive strength Test.

III RESULTS AND DISCUSSION

Particle Size Distribution

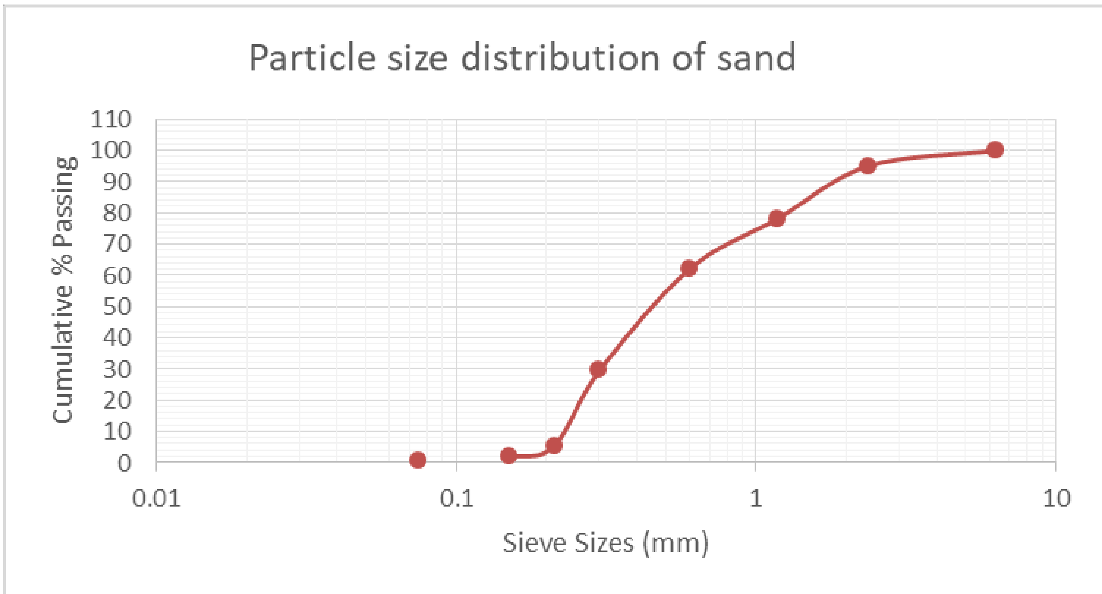

Fig.1: Graph of percentage passing against sieve sizes for sawdust

From Fig.1, Uniformity Coefficient for sand,

$$C_u = \frac{D60}{D10} = \frac{0.58}{0.23} = 2.52$$

This value of Cu indicates that the sawdust specimen is a well graded specimen and is suitable for replacement of fine aggregate.

Pozzolanicity

Table 1: Pozzolanicity of sawdust Ash (SDA)

Time (mins)	5	20	40	60	90
At Room Temperature	0.78	0.88	0.89	0.94	1.00
At 75^{o}C		0.76	0.81	0.83	0.83

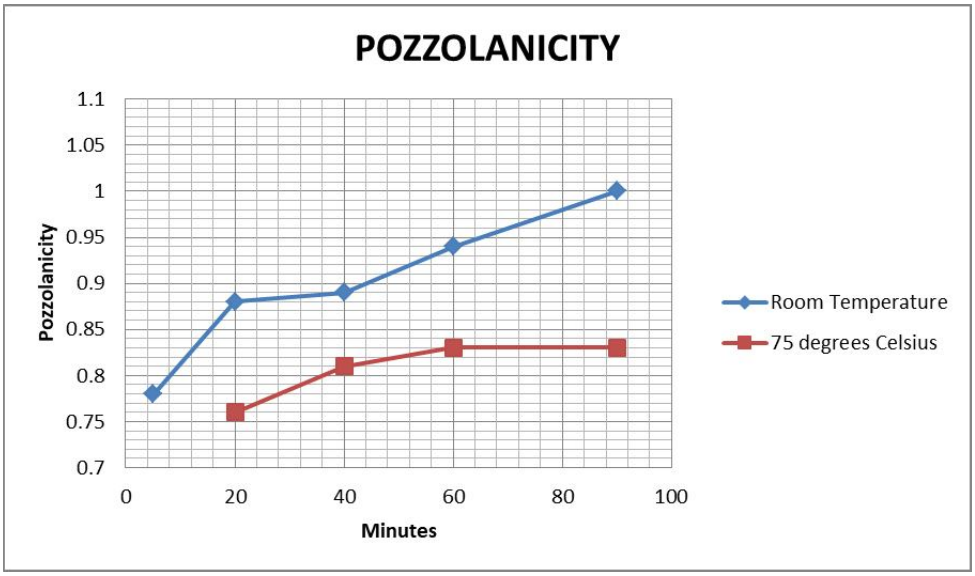

Fig.2: Graph of pozzolanicity against time

From Fig.2, it can be observed that the pozzolanicity of Sawdust ash is higher at room temperature than at 75oC. It also indicates that the pozzolanicity increases with increase in time from 5 minutes to 90 minutes.

Slump Test

Table 2: Slump Test

Sample No	Replacement Level (%) SDA	SAWDUST	Height of Subsidence (mm)	Slump (mm)
A0	0	0	296	4
A1		2.5	289	11
B0	2.5	0	288	12
B1		2.5	283	17
C0	5.0	0	282	18
C1		2.5	275	25
D0	7.5	0	279	21
D1		2.5	254	46
E0	10	0	264	36
E1		2.5	255	45

From Table 2, the various average slumps of the different concrete mixes can be obtained. It is observed that the value of slump increases with increase in the percentage of cement replacement with SDA. This is evident from samples E0 and E1 which have 10% of cement 7 replaced with SDA having the greatest slump values. It is also observed that the control mixes, A0 to E0 each have lesser slump values than their corresponding mixes with 2.5% fine aggregate replacement with sawdust. This might be a result of the higher Water/Cement ratio of the sawdust concrete (0.55) over that of the control mix (0.5).

Bulk Density Test

Table 3: Bulk Density of Concrete Cubes

Sample No	Mass of Cube (kg)		Density of Cube (kg/m^3)		Average Density of Cube(kg/m^3)	
	Day 7	**Day 28**	**Day 7**	**Day 28**	**Day 7**	**Day 28**
A0	8.77	6.82	2598.52	2020.74	2545.19	2154.07
	8.46	7.74	2506.67	2293.33		
	8.54	7.25	2530.37	2148.15		
A1	8.17	7.67	2420.74	2272.59	2438.52	2168.89
	7.95	7.44	2355.56	2204.44		
	8.57	6.85	2539.26	2029.63		

B0	8.54	8.0	2530.37	2370.37	2450.37	2438.52
	8.11	8.75	2402.96	2592.59		
	8.16	7.94	2417.78	2352.59		
B1	8.32	7.67	2465.19	2272.59	2397.04	2385.19
	7.88	8.26	2334.81	2447.41		
	8.09	8.22	2397.04	2435.56		
C0	8.48	8.55	2512.59	2533.33	2586.67	2586.67
	8.92	8.71	2642.96	2580.74		
	8.79	8.93	2604.44	2645.93		
C1	7.41	7.77	2195.56	2302.22	2397.04	2385.19
	7.88	8.32	2334.81	2465.19		
	8.98	8.06	2660.74	2388.15		
D0	8.43	7.76	2497.78	2299.26	2444.44	2438.52
	7.45	8.48	2207.41	2512.59		
	8.87	8.45	2628.15	2503.70		
D1	7.46	8.27	2210.37	2450.37	2317.04	2317.04
	8.09	7.83	2397.04	2320.00		
	7.91	7.36	2343.70	2180.74		
E0	7.85	7.48	2325.93	2216.30	2429.63	2423.70
	8.64	8.34	2560.00	2471.11		
	8.29	8.72	2456.30	2583.70		
E1	7.89	8.31	2337.78	2462.22	2400.00	2370.37
	7.73	7.74	2290.37	2293.33		
	8.68	7.95	2571.85	2355.56		

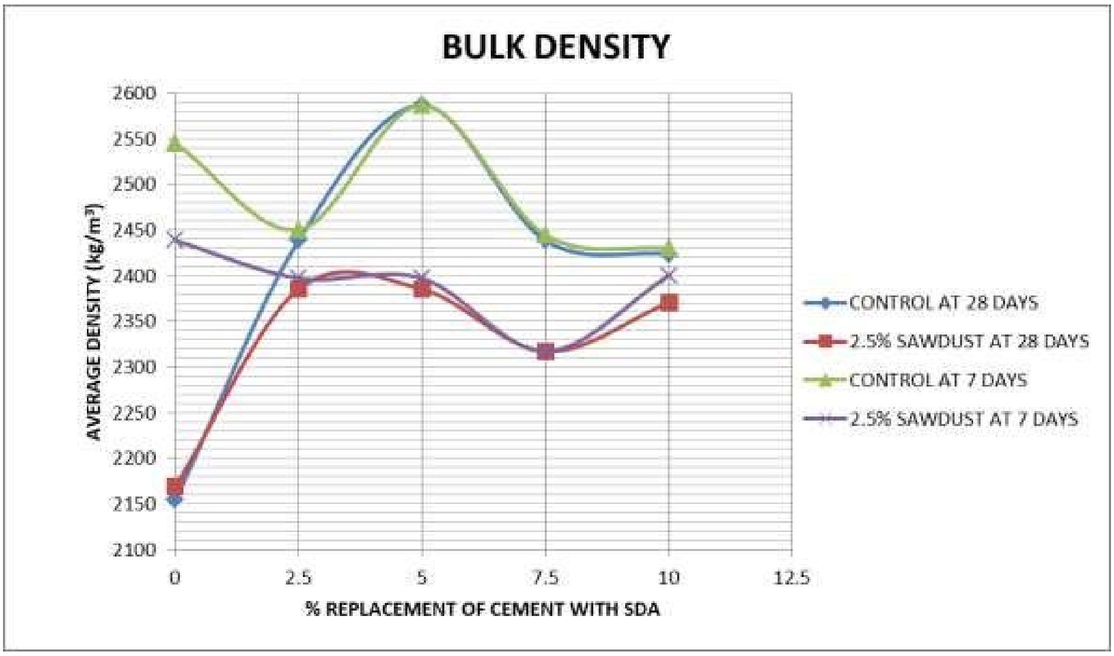

Fig.3: Graph of Bulk Density against % replacement of Cement with SDA

Table 3 indicates the results from the Bulk Density test of the samples. For most samples, there was a reduction in density of the concrete between 7 days and 28 days of curing. For sample A0 and A1, there was a reduction in mass and density for all six samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its mass per unit volume was decreasing. At 28 days curing, the Average density of the control mix sample A0 was less than that of the sawdust concrete mix sample A1 at 0% SDA replacement.

For sample B0 and B1, there were cases of reduction in mass and density and also increase in mass and density for samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its mass per unit volume was either increasing or decreasing. At 28 days curing, the Average density of the control mix sample B0 was greater than that of the sawdust concrete mix sample B1 at 2.5% SDA replacement.

For sample C0 and C1, there were cases of reduction in mass and density and also increase in mass and density for samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its mass per unit volume was either increasing or decreasing. At 28 days curing, the Average density of the control mix sample C0 was greater than that of the sawdust concrete mix sample C1 at 5.0% SDA replacement.

For sample D0 and D1, there were cases of reduction in mass and density and also increase in mass and density for samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its mass per unit volume was either increasing or decreasing. At 28 days curing, the Average density of the control mix sample D0 was greater than that of the sawdust concrete mix sample D1 at 7.5% SDA replacement.

For sample E0 and E1, there were cases of reduction in mass and density and also increase in mass and density for samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its mass per unit volume was either increasing or decreasing. At 28 days curing, the Average density of the control mix sample E0 was greater than that of the sawdust concrete mix sample E1 at 10% SDA replacement.

From Fig.3, it is observed that samples B to E had Bulk density values that were generally within the same range at both 7 and 28 days. However, samples A had a relatively lower density value. This suggests that samples where cement was partially replaced with SDA had generally higher densities than samples with 0% SDA replacement. It can also be observed that mixes with 2.5% sawdust replacement with fine aggregate had generally less density values than the control samples. This is in line with the study carried out by Ezeagu and

Agbo-Anike (2020) which concluded that sawdust replacement of fine aggregate results in less dense lightweight concrete.

Compressive Strength Test

Table 4: Compressive Strength of Concrete Cubes

Sample No	**Force at Failure (KN)**		**Compressive Strength (KN/m^3)**		**Average Compressive Strength (KN/m^3)**	
	Day7	**Day 28**	**Day 7**	**Day 28**	**Day 7**	**Day 28**
A0	240.20	369.54	10.68	16.42		
	232.98	358.43	10.35	15.93	11.70	18.00
	316.83	487.43	14.08	21.66		
A1	321.04	501.62	14.27	22.29		
	271.83	424.73	12.08	18.88	13.07	20.43
	289.54	452.40	12.87	20.11		
B0	309.97	476.87	13.78	21.19		

	358.90	552.15	15.95	24.54		
	306.66	471.79	13.63	20.97		
B1	288.85	451.32	12.84	20.06	14.13	22.08
	328.03	512.54	14.58	22.78		
	336.91	526.42	14.97	23.40		
C0	399.48	614.59	17.75	27.32	17.24	26.53
	369.05	567.77	16.40	25.23		
	395.49	608.45	17.58	27.04		
C1	247.39	386.54	11.00	17.18	12.33	19.27
	308.29	481.71	13.70	21.41		
	276.56	432.13	12.29	19.21		
D0	385.50	593.07	17.13	26.36	19.22	29.57
	450.77	693.49	20.03	30.82		
	461.31	709.70	20.50	31.54		
D1	423.88	662.32	18.84	29.44	16.83	26.29
	313.32	489.57	13.93	21.76		
	398.51	622.67	17.71	27.67		
E0	451.90	695.23	20.08	30.90	18.66	28.71
	465.33	715.89	20.68	31.82		
	342.59	527.06	15.23	23.42		
E1	234.57	366.52	10.43	16.29	9.13	14.27
	141.50	221.09	6.29	9.83		
	240.29	375.45	10.68	16.69		

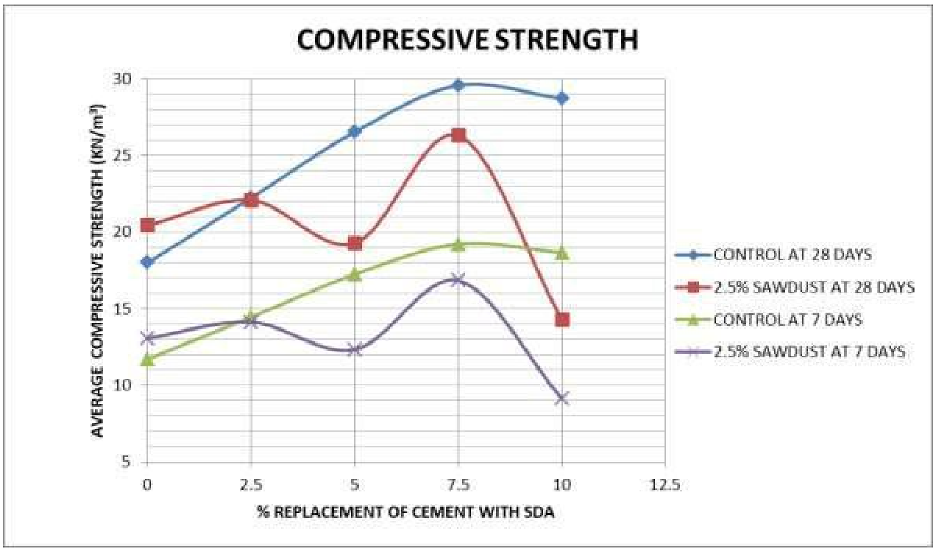

Fig.4: Graph of Compressive strength against % replacement of Cement with SDA

Table 4 indicates the results from the Compressive Strength test of the samples. For most samples, there was an increase in compressive strength of the concrete between 7 days and 28 days of curing.

For sample A0 and A1, there was an increase in compressive strength for all six samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its compressive strength was increasing. At 28 days curing, the Average compressive strength of the control mix sample A0 was less than that of the sawdust concrete mix sample A1 at 0% SDA replacement.

For sample B0 and B1, there was an increase in compressive strength for all six samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its compressive strength was increasing. At 28 days curing, the Average compressive strength of the control mix sample B0 was at close range to that of the sawdust concrete mix sample B1 at 2.5% SDA replacement.

For sample C0 and C1, there was an increase in compressive strength for all six samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its compressive strength was increasing. At 28 days curing, the Average compressive strength of the control mix sample C0 was greater than that of the sawdust concrete mix sample C1 at 5.0% SDA replacement.

For sample D0 and D1, there was an increase in compressive strength for all six samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its compressive strength was increasing. At 28 days curing, the Average compressive strength of the control mix sample D0 was greater than that of the sawdust concrete mix sample D1 at 7.5% SDA replacement.

For sample E0 and E1, there was an increase in compressive strength for all six samples between 7 days and 28 days curing. This indicates that while the concrete hardened during curing, its compressive strength was increasing. At 28 days curing, the Average compressive strength of the control mix sample E0 was greater than that of the sawdust concrete mix sample E1 at 10% SDA replacement.

From Fig.4, it can be observed that control samples B to E had compressive strength values that were generally above 20KN/m3 within the acceptable range. This strength generally increased with an increase in SDA replacement up till 7.5% replacement. However, samples A0 had a relatively lower compressive strength value. This suggests that samples in which cement was partially replaced with SDA had generally higher compressive strength thasn samples with 0% SDA replacement.

It can also be observed that concrete mixes with 2.5% sawdust replacement with fine aggregate had generally less compressive strength values than their control sample counterparts. This indicates that while partial replacement of cement with SDA results in increased compressive strength, partial replacement of fine aggregate with sawdust had the opposite effect on the compressive strength of concrete.

IV. CONCLUSION AND RECOMMENDATION

The sawdust was uniformly graded making it a suitable replacement for sand as fine aggregate.

Pozzolanicity of Sawdust Ash (SDA) is greater at room temperature that at 75^{o}C. The pozzolanicity also increases with increase in reaction time.

Concrete workability increases with increase in the percentage of replacement of cement with SDA. The workability also increases with increase in water cement ratio despite the partial replacement of fine aggregate with sawdust.

The Bulk Density of the control concrete samples increases with increase in the percentage of replacement of cement with SDA up till 5% replacement and then began to decrease. For the sawdust concrete samples, the bulk density varied in a non-uniform manner with increase in SDA replacement percentages. The highest values were obtained by the control samples. This can be attributed to the lightweight nature of sawdust when used as a replacement for sand. Bulk density values also decreased with increase in curing time for all samples.

The compressive strength of the control concrete samples increases with increase in the percentage of replacement of cement with SDA up till 7.5% replacement and then began to decrease. This is a similar occurrence for the sawdust concrete samples which also have their highest values at 7.5% replacement with SDA. The control concrete samples have a greater compressive strength than the sawdust concrete samples for the same percentage replacement with SDA. Compressive strength values also increased with increase in curing time for all samples.

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