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Properties of eco-friendly concrete produced by partial replacement of sand with sawdust with emphasis on water-cement ratio

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Abstract

There is environmental nuisance and degradation occasioned by indiscriminate disposal of sawdust. There is also growing concerns about the depletion of non-renewable natural resources like sand. In response to these problems, researches have been carried out on the usage of sawdust to supplement sand as fine aggregate in concrete. This research examines the effects of water-cement ratio on the engineering properties of concrete produced using sawdust as partial replacement for sand. Standard mixes were prepared without sawdust to serve as control and then sawdust mixes were prepared using 20% replacement of sand with sawdust. The mixes were prepared for varying water cement ratios of 0.4, 0.45, 0.5, 0.55 and 0.6 with the corresponding mix ratios of 1:1.1:2.6; 1:1.3:3; 1:1.5:3.4; 1:1.6:3.8 and 1:1.8:4.2 respectively. A total of 120 cubes of concrete were cast in triplicates for each water-cement ratio and each curing period for both 0 % and 20 % replacement. The results revealed that the slump values increased as the water-cement ratio increased. The results indicate that for a water cement ratio of 0.4 and 0.5, the sawdust concrete attains good properties with compressive strength values of 22.82 N/mm^2 and 21.56 N/mm^2 respectively at 28 days. However, by increasing the water cement ratio to 0.6, the sawdust concrete recorded a low value for the various properties of concrete with compressive strength value of 14.15 N/mm^2 at 28 days. This is due to the decomposition of lignocellulolytic components such as carbohydrates, lignin, cellulose, etc. Therefore, at 20% replacement of sand with sawdust, it is recommended to use water-cement ratio not exceeding 0.5 due to the water absorption rate of the sawdust concrete.

Keywords: Concrete, aggregates, compressive strength, water-cement ratio, sawdust, sand

1.0 INTRODUCTION

The worldwide consumption of sand as fine aggregate in concrete production is very high, and several developing countries have encountered some strains in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years [1]. There arises the need for engineering consideration of the use of cheaper and locally available materials to meet desired need, enhance self-efficiency, and lead to an overall reduction in construction cost for sustainable development [2]. In addition, pollution of our environment with wastes and the associated harm to our ecosystem and health is of great concern globally [3]. In engineering practice, the strength of concrete at a given age cured in water at a prescribed temperature is assumed to depend primarily on two factors; the water-cement ratio and the degree of compaction. Thus, for a fully compacted concrete, the strength is taken to be inversely proportional to the water-cement ratio [4]. However, the increase in popularity of using environmentally friendly, light weight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting environment as well as maintain the materials requirements affirmed in the standards [5]. Sawdust is a typical example of such materials. Globally, demand for timber is increasing annually at the rate of 1.7 percent [6]. Hence, sawdust is readily available and affordable. The physical and chemical properties of sawdust vary significantly depending on several factors, especially the species of wood [7].

Sawdust can be used as a partial replacement for fine aggregate in concrete production [8]. 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 [9].

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According to Olugbenga *et al* [10], the presence of tannin in sawdust acts as retarder, adversely affecting cube strength. Though, as the percentage sawdust content increases in the mix, the compressive strength decreases.

Concrete develops its strength by hydration of the cement and additives to form a complex series of hydrates. The initial hydration fixes the cement particles into a weak structure surrounded by a water-filled space, where the initial water-cement ratio is high, the resulting pore structure within the hydrates is interconnected and the resulting concrete has low strength, high penetrability and low durability [11]. Concrete gradually changes from a workable mixture into an artificial stone as a result of hydration process. This hydration process has a lot to do with the quantity of water and cement in the concrete [12]. Some researchers have reported on the effect of water-cement ratio on properties of concrete. [13] reported that reduction in water-cement ratio increased the compressive strength of concrete by 34.4%, while [14] posited that the higher the water-cement ratio, the greater the compressive strength of concrete. [15] optimised the compressive strength of cement-oyster shell powder concrete by varying the water-cement ratio, among other constituents of concrete and arrived at water-cement ratio of 0.54 as the optimum for cement-oyster shell powder concrete. However, the near absence of literature on the influence of water-cement ratio in sand-sawdust concrete composite has necessitated the research.

The objective of this study is to investigate the effects of water-cement ratio on the fresh and hardened properties of concrete produced using sawdust as partial replacement of sand, and ascertain the water-cement ratio at which the sawdust concrete attains its optimal properties.

2.0 MATERIALS AND METHODS

The Dangote brand of Ordinary Portland Cement that conformed to the requirements of [16] was used. The sand was sourced from Imo River, Imo State of Nigeria. It was sieved through 10mm British Standard test sieve to remove cobbles to conform to the requirements of [17].

Sawdust used for this work was generated from the mechanical processing of raw wood from Saw Mill. Then sieved through 2 mm British Standard test sieve to remove logs and then soaked in water and stirred continuously to remove air and enhance adequate absorption of water into its matrix and the set up left for 12 hours and then dried off its water in air to remove surface water. The percentages of replacements of fine aggregates by sawdust were 0% and 20%. The granite was sourced from the quarry site at Ishiagu, Ebonyi State, Nigeria. The maximum size of aggregate used for this work is 20mm diameter. It conformed to the requirements of [17]. The water used was obtained from borehole. The water was clean and free from any visible impurities. it conformed to the requirements of [18]. The water does not contain harmful constituents in such quantities as may be detrimental to the setting, hardening and durability of the concrete. The concrete used for this study was prepared using mix ratio 1:1.1:2.6, 1:1.3:3, 1:1.44:3.4, 1:1.6:3.8, 1:1.8:4.2 for different water-cement ratios of 0.4, 0.45, 0.5, 0.55, and 0.6 respectively for target strength of 31.56 N/mm^2 while batching of materials was done by mass and volume using 20 % replacement of sand with sawdust. A replicate of 3 (150 mm × 150 mm × 150 mm) cubes were cast for each water-cement ratio, and for each curing period for both 0% and 20% replacement making a total of 120 cubes.

However, dry mix method was used for concrete constituent before the addition of water. The homogenized mixture was then introduced into 150 mm ×150 mm × 150 mm metal moulds; in three layers and compacted with the tamping rod 25 stroke per layer and the top finish with the trowel and label accurately conforming to [19]. The concrete was de-moulded after 24 hours and immersed in a curing tank, while compressive strength was performed after 3, 7,14 and 28 days.

3.0 RESULTS AND DISCUSSIONS

3.1 Sieve analysis

The results of the comparative sieve analyses of sand and sawdust are shown in *Table 1.*

Table 1: Comparative results of sieve analyses of sand and sawdust

Sieve size (mm)	Mass retained (gm)		Percentage retained		Cumulative percentage retained		Percentage passing	
	Sand	SD	Sand	SD	Sand	SD	Sand	SD
4.75	-	-	-	-	-	-	100	100
2.00	10.5	3.90	2.10	5.57	2.10	5.57	97.90	94.43
1.18	21.80	11.40	4.36	16.29	6.46	21.86	93.54	78.14

Sieve size (mm)	Mass retained (gm)		Percentage retained		Cumulative percentage retained		Percentage passing	
0.6	85.20	22.90	17.04	32.71	23.50	54.57	76.50	45.43
0.425	105.00	16.30	21.00	23.29	44.50	77.86	55.50	22.14
0 .15	260.5	13.10	52.10	18.71	96.60	96.57	3.40	3.43
0.075	12.20	1.80	2.44	2.57	99.04	99.14	0.96	0.86
Pan	4.80	0.0	0.96	0.86	100	100	0	0

From the particle size distribution *Table 1*, the sawdust will act as sand and even as mineral fillers by virtue of the distribution. The coefficient of curvature, *Cc* of sand and sawdust used in this study were 2.23 and 2.88 respectively. This shows that both sand and sawdust were well graded sand as they fell within the range of 1 and 3 specified by [20]. The grading curves are shown in Figure 1.

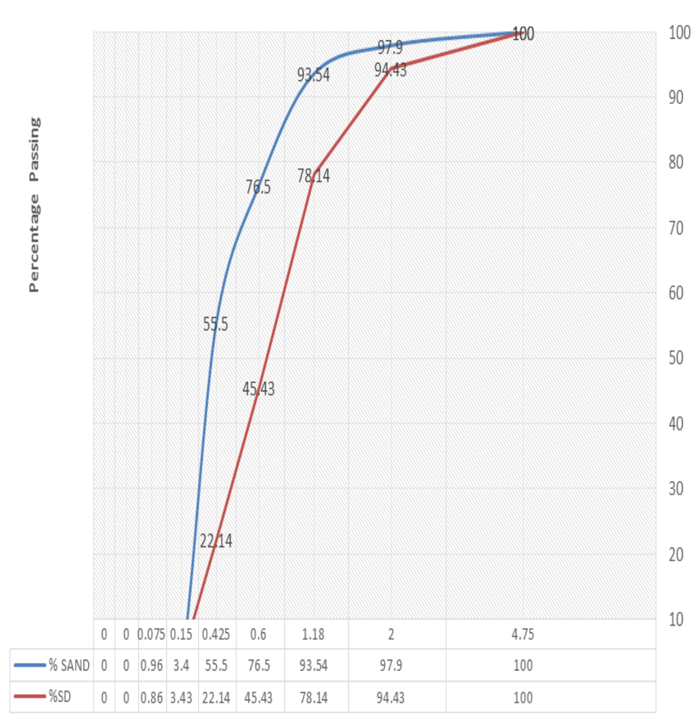

Figure 1: Grading Curves for Sand and Sawdust

3.2 Slump of fresh concrete

The values obtained from the slump test correspond to the designed slump range of 10 – 30mm. It can be seen from *Figure 2*, that the slump increases as the water cement ratio increase for both 0 % and 20 % replacement of sand with sawdust. The slump of 0 % replacement is approximately 1.04 times higher than 20 % replacement showing that workability is reduced in sand-sawdust concrete. This is attributable to increase in surface area, as well as high water absorption of sawdust introduced into the concrete.

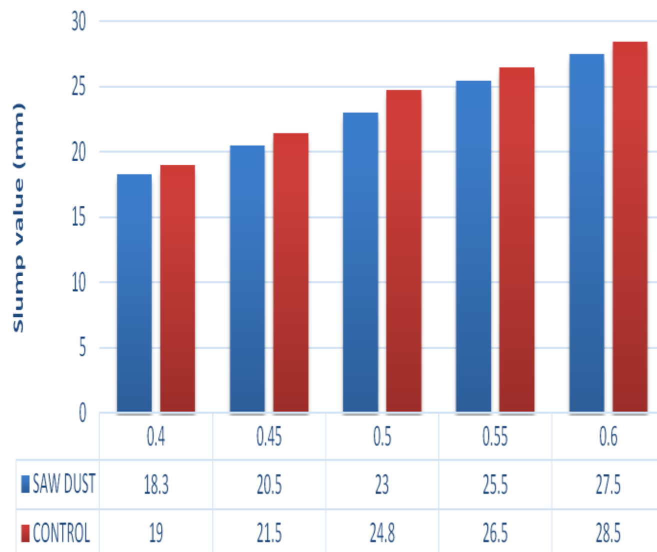

Figure 2: Comparative Variation of slump of concrete with water-cement ratio

3.3 Water absorption of concrete

The variation in water absorption as the water-cement ratio and curing age vary is shown in *Table 2*. It is observed from *Table 2* that the water absorption capacity of both standard and sawdust concrete decreases as the curing period increases from 3 to 28 days. This is attributable to more water being absorbed at greater rate in the early days of hydration than at later days, when the specimens are somewhat saturated. In addition, water absorption of sawdust concrete is significantly more than those of normal concrete. On the average, the comparative water absorption of sawdust concrete is from 1.5 – 2.3 times (150 – 230%) those of normal concrete. However, water absorption increases as water-cement ratio increases from 0.4 to 0.6 due to more quantity of cement which requires more water for hydration. It can be observed that sawdust concrete has higher water absorption capacity than the standard concrete.

Table 2: Comparative water absorption by standard and sand-sawdust concrete

Water-cement ratio	Water absorbed for standard concrete (kg)				Water absorbed for sawdust concrete (kg)			
Age	3 days	7 days	14 days	28 days	3 days	7 days	14 days	28 days
0.4	0.072	0.07	0.068	0.066	0.18	0.16	0.13	0.10
0.45	0.078	0.074	0.072	0.07	0.20	0.18	0.15	0.14
0.5	0.08	0.078	0.073	0.071	0.23	0.21	0.18	0.16
0.55	0.085	0.08	0.077	0.075	0.26	0.24	0.20	0.18
0.6	0.09	0.088	0.083	0.08	0.30	0.28	0.25	0.22

3.4 Compressive strength of standard and sand-sawdust concretes

The compressive strength of standard concrete for various water-cement ratio and curing age are given in *Figure 3.*

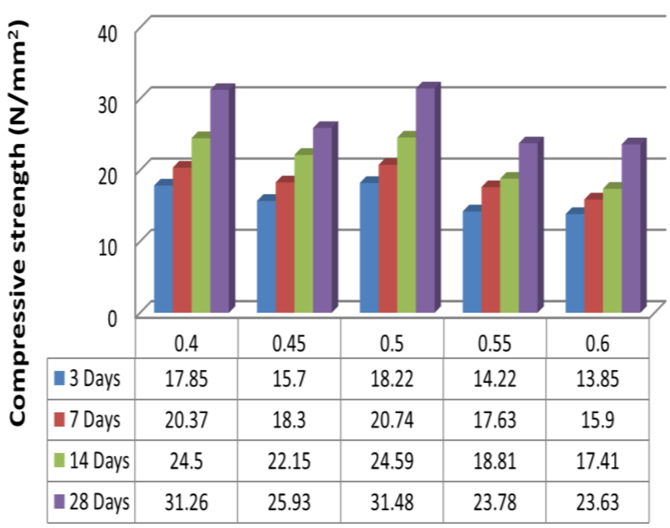

Figure 3: Compressive strength of standard concrete versus water-cement ratio

The compressive strength of concrete increases with increase in age. 0.4 and 0.5 water-cement ratio have the values of 31.26 N/mm^2 and 31.48 N/mm^2 which are above the target mean strength which makes them the optimum water cement ratio. The compressive strength of concrete reduces as the water cement ratio increases above 0.5. There is approximately 6.4% decrease in strength as the water-cement ratio is increased from 0.4 to 0.45.

Comparing the compressive strength of sawdust concrete from *Figure 4*, the water-cement ratio of 0.4 and 0.5 have the values of 22.82 N/mm^2 and 21.56 N/mm^2 which are approximately the same and the highest value making them also the optimum water cement ratio. However, the strength of 0.4 water cement ratio increased by 16.2 % within 14 – 28 days curing. Nevertheless, for 0.6 and 0.55 water cement ratio the strength of the concrete reduced by 10.8 % after 14 days curing. Water cement ratio of 0.5 showed a continuous, progressive and approximately uniform increase in the strength as the curing period increases.

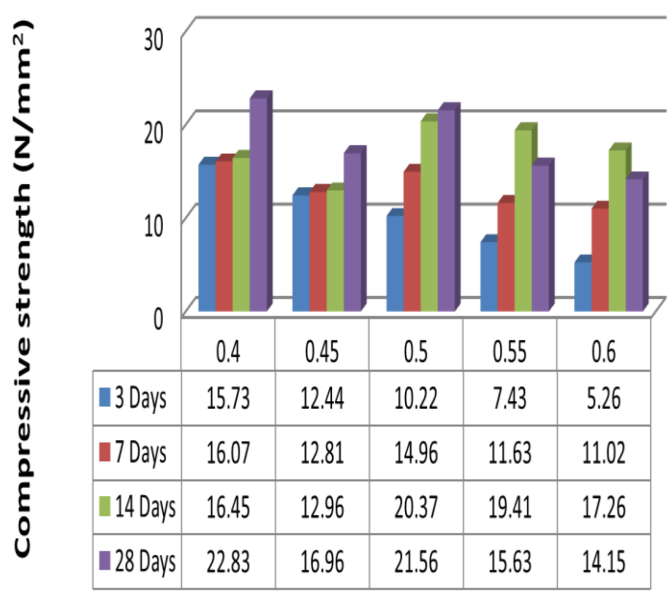

Figure 4: Compressive strength of sand-sawdust concrete versus water-cement ratio

However, the highest value of sawdust concrete is 22.83 N/mm^2 at 0.4 water-cement ratio while that of standard concrete is 31.48 N/mm^2 at 0.5 water/cement ratio which shows that the strength decreased by 16 %. There is an anomalous variation in the compressive strength of the sawdust concrete at 14 and 28 days curing period for 0.55 and 0.6 water/cement ratio, this can be attributed to the fact that sawdust is a lignocellulolistic material that decomposes in the presence of water. This component that decomposes affects the overall strength of the concrete. Also, sawdust differs in its physical properties from sand and the way sand will easily mix with cement is different from the way sawdust mix. This also infers that sawdust content which increased the water

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absorption of concrete. Hence, leaving very little for hydration, thereby caused corresponding decrease in compressive strength.

4.0 CONCLUSION

The following conclusion can be drawn from the foregoing results and discussions:

(a) Concrete with 20% sawdust and 0% sawdust replacement yielded the optimal result at water cement ratio of 0.4 and 0.5 respectively, which implies that water-cement ratio above 0.5 is not recommended.

(b) The slump value increased as the water cement ratio increased from 0.4 to 0.6 for both 0% and 20% which entails that workability increases. Hence, ease of compaction is enhanced.

(c) The sand-sawdust concrete has higher capacity to absorb water than the standard concrete; hence, should be used in the superstructure, lightweight and ecofriendly structures preferably.

(d) The compressive strengths of both standard and sand-sawdust concrete were appreciably high above the designed strength for 0.4 and 0.5 water-cement ratios.

(e) The utilization of this wood material for construction work will in turn reduce its effect as environmental pollutant and emission of gases which causes global warming when they are being burned or allowed to decay thereby facilitating a healthy environment.

RECOMMENDATION

Owing to the lignocellulolistic nature of sawdust and its higher water absorption rate, sand-sawdust concrete should be used for superstructure in addition to its usage for lightweight and eco-friendly structures. Its usage in substructure is not encouraged.

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