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Structural Characteristics of Sawdust-Sand-Cement Composite

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ABSTRACT

This research presents the structural characteristics of sawdust-sand-cement composite. It addresses the problem of absence of structural characteristics of sawdust-sand-cement composite which is a concrete mixture of sawdust, cement and sand. The materials used in the laboratory experiments include: Ordinary Portland Cement, river sand, sawdust, and water. The physical and mechanical characterization tests were performed on the aggregate and sawdust used in this experimental work of which Sawdust gave values of 733.92kg/m^3, 0.35, 14%, 1.0, 2.8 for average bulk density, average specific gravity, water absorption, coefficient of curvature (Cc) and uniformity (Cu) respectively; sand gave values of 1564kg/m^3, 2.65, 1.53, 2.0 for average bulk density, specific gravity, coefficient of curvature (Cc) and uniformity (Cu) respectively. Manual mixing operation was adopted and all sawdust-sand-cement composite ingredients where batched by weight. A total of nine (9) cubes of size 150mm x 150mm x 150mm, nine (9) cylinders of size 150mm x 300mm and nine (9) beams of size 150mm x 150mm x 600mm were produced from mix ratios 0.75:1:1:1, 0.75:1:2:2, and 0.75:1:3:3 for compressive strength test, split tensile strength test and flexural strength test respectively. The average compressive strength for the three (3) mix ratios used are 10.86Mpa, 9.126Mpa and 4.471Mpa respectively. The average flexural strength from beams samples for the three (3) mix ratios are 2.32Mpa, 2.09Mpa and 1.89Mpa. The average split tensile strength for three (3) mix ratios are 1.98Mpa, 1.71Mpa and 1.58Mpa. The average static modulus of elasticity for the three mix are 10.08Gpa, 9.84Gpa and 7.35Gpa. The average Poisson's ratio ranges from 0.18-0.35. The shear modulus ranges from 4.24Mpa – 2.72Mpa.

Keywords: Sawdust, sand, cement, composite, compressive strength, flexural strength, static modulus of elasticity, split tensile strength and Poisson's ratio.

1 INTRODUCTION

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The production of concrete involves the use of cement, water, fine and coarse aggregate at times admixture [1]. The chief material contributing much to weight of concrete member been coarse and fine aggregate of which using another material that has lightweight and reliable in strength as well as withstanding the applied load will be an advantage. The structural characteristics of materials do suggest where it can be used for efficiency purposes. Researchers have suggested the use of waste like sawdust for concrete production; to that effect there are needs to fully know the structural characteristics of a composite produced from sawdust, sand and cement.Zziwa et al. [2] carried out research on production of composite bricks from sawdust using Portland cement as a binder he was able to show that the mean compressive strength of the block was 1.61N/mm^2.

Del Menezzi et al. [3] studied the production and properties of a medium density wood cement boards produced with oriented strands and silica fume. Their study tried to solve the problem that can be associated with the use of wood cement board which is the inhibitory effects of wood on the setting time of cement and the high specific gravity of the final product.

Maharani[4] studied the physical properties of sawdust and effect of mills and sawdust particles; from his work, the physical properties of sawdust were developed. Olutoge et al. [5] carried out investigations on sawdust and palm kernel shells as aggregate replacement. The result shows that 25% replacement of both components produced a good lightweight material; also there was reduction in weight from 14.5% to 17.9%.

Fakhrul et al. [6] carried out studies on properties of wood sawdust and wheat flour reinforced polypropylene composite. His results show that the average tensile strength of the composite decreases with addition of sawdust and wheat flour. Kasim et al. [7] carried out research on the mechanical properties of wood shavings-cement lightweight composite; they proved that the compressive strength and tensile strength of the wood cement matrix have satisfactory values. In order to produce lightweight concrete, effect of sawdust as fine aggregate in concrete mixture was carried out by [8], from his research, he prove that sawdust can be used to replace sand. His investigation was centered on concrete of grade 15-22. He also studied the effect of partial replacement of sand with sawdust, from these work he concluded that the best replacement is from 25-50%. From all the papers re-viewed there is no published work on the structural characteristics of sawdust-sand-cement composite, hence this paper.

2 Materials And Methods

2.1 Materials

2.1.1 Sawdust

Sawdust can be defined as loose particles or wood chippings obtained as by-products from sawing timber into standard useable sizes [5]. According to [4], Sawdust refers to the tiny-sized and powdery wood waste produced by the sawing of wood. The size of sawdust particles depends on the kinds of wood from which the sawdust is obtained and also on the size of the saw teeth [9]. About 10-13% of the total volume of the wood log is reduced to sawdust in milling operations; this sawdust generally depends largely on the average width of the saw kern and the thickness of the timber sawed [10].

Generally, utilization of the generated tropical commercial wood sawdust becomes an urgent problem since alternative to clean with by just employing the so-called conventional incineration may produce environmentally hazardous pollutants such as polychlorinated dibenzo-dioxins and dibenzo-furans [11]; [12]. In addition, sawdust being essentially a lignocellulosic material, is not easily deteriorated but rather stable on recalcitrant in the environment, and rarely produces odour during its long-term biodegradation process [11]; [13].

To carry out this work, sawdust was obtained from the Wood Processing market in Ogbo-Osisi, Owerri North, Imo State, Nigeria. First, the sawdust was washed and boiled to remove any resin. After boiling for about 3 hours the particles were dried completely. The particles were classified according to their granulometry, in sieves of different sizes. The particles had a moisture content of approximately less than 12. The physical and mechanical characterization tests was performed on the sawdust used in this experimental work of which Sawdust gave values of 733.92kg/m^3, 0.35, 14%, 1.0, 2.8 for average bulk density, average specific gravity, water absorption, coefficient of curvature (Cc) and uniformity (Cu) respectively;

2.1.2Aggregate The aggregates used in this research work was fine aggregate. It was obtained from a flowing river (Otamiri River) purchased from mining site inside Federal University Owerri, Imo State. It was sun-dried for seven days inside the laboratory before usage. The aggregates used were free from deleterious matters. The maximum diameter of sand used was 5mm. The physical and mechanical characterization tests were performed on the sand; the values of 1564kg/m^3, 2.65, 1.53, 2.0 for average bulk density, specific gravity, coefficient of curvature (Cc) and uniformity (Cu) were obtained respectively.

2.1.3 Water

Water used for this research work was obtained from a bore-hole within the premises of Federal University of Technology, Owerri, Imo State. The water is potable and conforming to the standard of [14]. Since it meets the standard for drinking, it is also good for making concrete and curing cocrete.

2.1.4 Cement

Cement can be defined as a product of calcareous (lime) and argillaceous (clay) materials which when mixed with water

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forms a paste and binds the inert materials like sand, gravel and crushed stones [15]. According to [16] "cement is a hydraulic binder that sets and hardens by chemical interaction with water and is capable of doing so under water".
Dangote brand of ordinary Portland cement which conforms to the requirements of [17]. was obtained from dealer in Owerri and use for all the work.

2.2 Methods

The following tests were carried out to determine the structural characteristic of Sawdust-sand-cement composite.

2.2.1 Compressive Strength Test for Sawdust-sand-cement composite

Compressive strength test was carried out in order to determine the compressive strength of the Sawdust-sand-cement composite. The Sawdust-sand-cement composite cubes were produced using manual mixing method in a mould measuring 150mm x 150mm x 150 mm in size. The moulds were first oiled for easy removal of the samples after setting. The Sawdust-sand-cement composite sample was introduced into the mould in three layers with proper vibration. A total of 9 cubes were produced from the 3 mix ratios used and the mix ratios are 0.75: 1:1:1, 0.75: 1:2:2, 0.75: 1:3:3, three cubes from each mix. The first set of 9 cubes made from the mix ratios, were used to obtain the 28-day compressive strength. The Sawdust-sand-cement composite cubes were cured by spraying water on it for 28 days, and tested in Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM) thereafter. The machine conforms to the requirement of [18]and has a testing range of 0-1000kN. The compression load at failure was recorded and used in Equation (1) to determine the compressive strength of the Sawdust-sand-cement composite

$$\text{Compressive strength} = \frac{compressive\ \ load\ of\ cube\ at\ failure\ \ (N)}{cross\ \ sectio\ nal\ area\ of\ mould\ \ (mm^2)} \quad (1)$$

The density of the 28-day compressive strength was obtained since some structural characteristic depends on it. The cubes for the compressive Strength Test were weighed in a digital weighing balance that has accurancy of 0.01g and recorded and the densities of the samples were computed using Equation 2.

$$Density = \frac{Mass\ of\ Sample}{Volume\ of\ the\ sample} \quad (2)$$

2.2.2 Split tensile Strength Test for Sawdust-sand-cement composite

Splitting tensile strength tests were carried out in order to determine the tensile strength of the Sawdust-sand-cement composite. The Sawdust-sand-cement composite sample, were cylinder measuring 150mm x 3000mm in size in accordance to the requirements of BS EN 12390-1 (2000) and BS EN 12390 – 6 (2009). A total of nine (9) cylinders were produced from the three mix ratios used and the mix ratios are 0.75: 1:1:1, 0.75: 1:2:2 and 0.75: 1:3:3, three cylinders from each mix. The Sawdust-sand-cement composite cylinders were cured by spraying water on it for 28 days, and tested in Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM) compression machine thereafter. The cylinder specimens were placed with its horizontal axis between the platens of the machine and the load gradually applied until failure by splitting along the centre line occurred. The compression load at failure were recorded and used in Equation (3) to determine the split tensile strength of the Sawdust-sand-cement composite.

$$\text{Splitting tensile strength } \sigma_c = \frac{2F\ (N)}{\pi Ld\ \ (mm^2)} \quad (3)$$

F is the maximum load (in N); L is the length of the specimen; d is the cross-sectional dimension of the specimen. The test will be in according to [19] ;[20];[21].

2.2.3 Static Modulus of Elasticity Sawdust-sand-cement composite

The static modulus of elasticity of the Sawdust-sand-cement composite were determined as a function of the compressive strength and density using Equation 4

$$E_S = 1.7p^2 {f_c}^{0.33} x10^{-6} \quad (4)$$

Where E_S =Static modulus of Elasticity
P= density
Fc= compressive strength

2.2.4 Poisson Ratio of Sawdust-sand-cement composite

The Poisson Ratio of the Sawdust-sand-cement composite were determined as a function of the tensile stress at cracking in flexure and compressive stress at cracking for compression members using equation 2.7 reproduced here as Equation 5. The value of Poisson μ is given as

$$\mu = \frac{\delta_f}{\delta_c} \quad (5)$$

2.2.5 Shear Strength of Sawdust-sand-cement composite

The failure load in shear was obtained from the flexural strength test and the shear strength calculated using Equation 6

$$f_S = \frac{F}{A} \quad (6)$$

Where Fs = shear strength
F = shear load at failure
A= cross- sectional area of the test specimen

2.2.6 Shear Modulus of Sawdust-sand-cement composite

The Shear Modulus of the Sawdust-sand-cement composite were determined as a function of the modulus of elasticity over the linear range of the deformation and Static Poisson's ratio using equation 2.8 reproduced here as Equation 7

$$G = \frac{E_c}{2(\mu + 1)} \quad (7)$$

μ = Static Poisson's ratio

Ec = modulus of elasticity of concrete over the linear range of the deformation.

2.2.7 Flexural Strength Test of Sawdust-sand-cement composite Beams

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Nine (9) beams of size 150mm x 150mm x 600mm were cast from the three mix ratio 0.75: 1:1:1, 0.75: 1:2:2 and 0.75: 1:3:3. Manual mixing method was used during casting of the beams; the beams were cast in layers to make sure that proper vibration of the composite was obtained. The beam samples were tested in Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM); after curing by spraying water on it for 28 days. The machine conforms to the requirement of [21] and has a testing range of 0-1000KN. The results obtained were used to determining flexural strength of the Sawdust-sand-cement composite.

The flexural strength fcf (in N/mm²) is given by the Equation 8

$$f_{cf} = \frac{F\ x\ L}{d_1 x {d_2}^2} \qquad (8)$$

Where.

F is the breaking load (in N);

d1 and d2 are the lateral dimensions of the cross-section (in mm); for beam d_1 = 150mm, d_2 = 150mm.

3.0 Results and Discussions

3.1 Results

3.1.1 Compressive Strength Result for Sawdust-sand-cement composite

The results of compressive results of sawdust-sand-cement composite is presented in Table 3.1

Table 3.1: 28th day Compressive Strength Result for Sawdust-sand-cement composite

Mix ratio	Sample No	Area of Sample in (mm²)	Weight of Sample in (Kg)	Crushing load in KN	Compressive Strength N/mm²	Average Compressive strength N/mm²
1:1:1	A	22500	5.55	230.7	10.253	10.861
1:1:1	B	22500	5.37	253.6	11.27	
1:1:1	C	22500	5.48	248.8	11.059	
1:2:2	A	22500	5.53	210.4	9.35	9.126
1:2:2	B	22500	5.58	216.4	9.619	
1:2:2	C	22500	5.30	189.2	8.41	
1:3:3	A	22500	5.62	97.76	4.345	4.471
1:3:3	B	22500	5.33	104.67	4.652	
1:3:3	C	22500	5.50	99.36	4.416	

3.1.2 Dried Density Results for Sawdust-sand-cement composite

The results of density were obtained from the 28-day weight of compressive strength test sample before they were crushed and the results are as presented in Table 3.2

Table 3.2: Density Result for Sawdust-sand-cement composite

Mix ratio	Sample No	Volume of Sample in (m³)	Weight of Sample in (Kg)	Density of the Sawdust-sand-cement in Kg/m³
1:1:1	A	0.003375	5.55	1643.30
1:1:1	B	0.003375	5.37	1590.88

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1:1:1	C	0.003375	5.48	1622.79
1:2:2	A	0.003375	5.53	1638.75
1:2:2	B	0.003375	5.58	1652.42
1:2:2	C	0.003375	5.30	1570.37
1:3:3	A	0.003375	5.62	1663.82
1:3:3	B	0.003375	5.33	1579.49
1:3:3	C	0.003375	5.50	1629.63

Average density of Sawdust-sand-cement composite is 1621.273Kg/m^3

3.1.3 Splitting Tensile Strength Test Results of Sawdust-sand-cement composite

The results of split Tensile strength of Sawdust-sand-cement composite are as presented in Table 3.3; the averages of the computed results were as well recorded in same table.

Table 3.3: 28th day Splitting Tensile Strength Result for Sawdust- sand- cement composite

Mix ratio	Sample No	πdL (mm^2)	Weight of Sample in (Kg)	Crushing load in KN	splitting Tensile N/mm^2	Average splitting Tensile strength N/mm^2
1:1:1	A	141371.67	10.49	277.09	1.96	1.98
1:1:1	B	141371.67	10.15	276.10	1.95	
1:1:1	C	141371.67	10.36	285.01	2.02	
1:2:2	A	141371.67	10.45	246.41	1.74	1.71
1:2:2	B	141371.67	10.55	243.44	1.72	
1:2:2	C	141371.67	10.02	234.54	1.66	
1:3:3	A	141371.67	10.62	222.66	1.58	1.58
1:3:3	B	141371.67	10.07	216.72	1.53	
1:3:3	C	141371.67	10.40	231.57	1.64	

3.1.4 Static modulus of elasticity Results

The static modulus of elasticity results of Sawdust-sand-cement composite is as presented in Table 3.4 alongside with the average static results for each mix ratio.

Table 3.4: Static modulus of elasticity Result for Sawdust-sand-cement composite

Mix ratio	Sample No	Density of Sample in (mm^2)	Weight of Sample in (Kg)	Crushing load in KN	Compressive Strength N/mm^2	Static modulus of elasticity Gpa	Average Static modulus of elasticity Gpa
1:1:1	A	1643.30	5.55	230.7	10.253	9.90	9.79
1:1:1	B	1590.88	5.37	253.6	11.27	9.57	
1:1:1	C	1622.79	5.48	248.8	11.059	9.89	
1:2:2	A	1638.75	5.53	210.4	9.35	9.55	9.27
1:2:2	B	1652.42	5.58	216.4	9.619	9.80	
1:2:2	C	1570.37	5.30	189.2	8.41	8.47	
1:3:3	A	1663.82	5.62	97.76	4.345	7.64	7.35
1:3:3	B	1579.49	5.33	104.67	4.652	7.04	
1:3:3	C	1629.63	5.50	99.36	4.416	7.37	

3.1.5 Poisson Ratio Results of Sawdust-sand-cement composite

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The results of Poisson ratio are as presented in Table 3.5 alongside with the average Poisson ratio for Sawdust-sand-cement composite.

Table 3.5: Poisson Ratio Result for Sawdust-crete

Mix ratio	Sample No	Density of Sample in (Mkg/m^3)	Crushing load in KN	Compressive Strength N/mm^2	Tensile Stress N/mm2	Poisson Ratio μ	Average Poisson ratio μ
1:1:1	A	1643.30	230.7	10.253	1.96	0.19	
1:1:1	B	1590.88	253.6	11.27	1.95	0.17	0.18
1:1:1	C	1622.79	248.8	11.059	2.02	0.18	
1:2:2	A	1638.75	210.4	9.35	1.74	0.19	
1:2:2	B	1652.42	216.4	9.619	1.72	0.18	0.19
1:2:2	C	1570.37	189.2	8.41	1.66	0.20	
1:3:3	A	1663.82	97.76	4.345	1.58	0.36	
1:3:3	B	1579.49	104.67	4.652	1.53	0.33	
1:3:3	C	1629.63	99.36	4.416	1.64	0.37	0.35

3.1.6 Shear Modulus Results of Sawdust-sand-cement composite

The results of shear modulus of Sawdust-sand-cement composite are as presented in Table 3.6 alongside with the average shear modulus.

Table 3.6: Shear Modulus Result for Sawdust-sand-cement composite

Mix ratio	Sample No	Density of Sample in (mm^2)	Tensile stress N/mm^2	Compressive Stress N/mm^2	Static modulus of elasticity	Poisson Ratio μ	Shear Modulus Gpa	Average Shear Modulus Gpa
1:1:1	A	1643.30	1.96	10.253	9.90	0.19	4.16	
1:1:1	B	1590.88	1.95	11.27	9.57	0.17	4.09	4.15
1:1:1	C	1622.79	2.02	11.059	9.89	0.18	4.19	
1:2:2	A	1638.75	1.74	9.35	9.55	0.19	4.01	
1:2:2	B	1652.42	1.72	9.619	9.80	0.18	4.15	3.90
1:2:2	C	1570.37	1.66	8.41	8.47	0.20	3.53	
1:3:3	A	1663.82	1.58	4.345	7.64	0.36	2.81	
1:3:3	B	1579.49	1.53	4.652	7.04	0.33	2.65	2.72
1:3:3	C	1629.63	1.64	4.416	7.37	0.37	2.69	

3.1.7 Shear Strength Results of Sawdust-sand-cement composite

The results of shear strength are as presented in Table 3.7.

Table 3.7: Shear Strength Result for Sawdust-sand-cement composite

Mix ratio	Sample No	Cross Sectional Area (mm^2)	Weight of Sample in (Kg)	Crushing load in KN	Flexural strength N/mm^2	Shear Strength N/mm^2
1:1:1	A	90000	16.64	24.86	2.21	0.28
1:1:1	B	90000	16.11	27.00	2.4	0.30
1:1:1	C	90000	16.43	26.33	2.34	0.29
1:2:2	A	90000	16.59	23.63	2.1	0.26
1:2:2	B	90000	16.73	24.75	2.2	0.28
1:2:2	C	90000	15.90	22.28	1.98	0.25
1:3:3	A	90000	16.85	21.15	1.88	0.24
1:3:3	B	90000	15.99	20.48	1.82	0.23

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1:3:3	C	90000	16.50	22.28	1.98	0.25

3.1.8 Flexural Strength Test Results on Sawdust-sand-cement composite Beams

The results of the flexural strength of Sawdust-sand-cement composite beam tested at 28-day is presented in Table 3.8, the average flexural strength were also computed and recorded in the same Table 3.8

Table 3.8: 28th day Flexural Strength Result for Sawdust-sand-cement composite Beams

Mix ratio	Sample No	Weight of Sample in (Kg)	Crushing load in KN	Flexural strength N/mm^2	Average Flexural strength N/mm^2
1:1:1	A	16.64	24.86	2.21	
1:1:1	B	16.11	27.00	2.4	2.32
1:1:1	C	16.43	26.33	2.34	
1:2:2	A	16.59	23.63	2.1	
1:2:2	B	16.73	24.75	2.2	2.09
1:2:2	C	15.90	22.28	1.98	
1:3:3	A	16.85	21.15	1.88	
1:3:3	B	15.99	20.48	1.82	1.89
1:3:3	C	16.50	22.28	1.98	

3.2 Discussion of Results

The average compressive strength of mix ratio of 1:1:1 is 10.861Mpa, the average compressive strength of 1:2:2 and 1:3:3 are 9.126Mpa and 4.471Mpa respectively. The values obtained are less than the minimum value of light weight concrete for 28-day strength which should not be less than 17.5Mpa for structural purposes.The average density of sawdust-crete composite is 1621.27Kg/m3; from literature, the density of light-weight concrete should not exceed 1840kg/m3. Therefore, sawdust-sand-cement composite is a light-weight concrete in terms of density.The split tensile strength of sawdust-crete composite ranges from 1.58Mpa to 1.98Mpa. The tensile strength of light weight concrete according to literature ranges from 1.87 to 2.75Mpa.The static modulus of elasticity of sawdust-sand-cement composite ranges from 7.35Mpa to 9.79Mpa; but the static modulus of elasticity of normal concrete ranges from 21.4Gpa to 46.4Gpa that means the values obtained from sawdust-sand-cement is less than those of normal weight concrete.The Poisson Ratio of sawdust-crete composite ranges from 0.18 to 0.35 while that of normal concrete ranges from 0.15 to 0.3.The shear modulus of sawdust-sand-cement ranges from 2.72 Gpa to 4.15Gpa while the shear strength of sawdust-sand-cement composite ranges from 2.72 to 4.15. The average flexural strength of sawdust-sand-cement composite slab ranges from 1.89Mpa to 2.32Mpa.

4.0 Recommendation

The following Recommendation are made: -

i. Sawdust-sand-cement composite should be used for light structural members that are not carrying much loads and the weight is much less compared with those of convectional concrete.

ii. Further studies should be carried out on how to improve the strength of Sawdust-sand-cement composite by the use of additives.

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