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Mechanical Properties of Wood Dust-Palm Kernel Shell Concrete Blend

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Abstract:- This research presents the Mechanical properties of wooddust(sawdust)-Palm Kernel shell concrete blend. It provides the panacea to the limitation of Mechanical properties of Sawdust-Palm Kernel shell concrete blend, which is a concrete composite blend of cement, sawdust and palm kernel shell (PKS). The component materials utilized in this study are: Ordinary Portland Cement, wood dust dust, PKS and water. The physical index properties were carried out on the aggregates utilized in this study. Sawdust gave values of 564.28kg/m^3, 0.494, 34.68%, 2.72, 1.0 and 2.79 for the mean unit weight, mean specific gravity, mean percentage water absorption, finess modulus, mean coefficient of curvature(Cc) and mean uniformity(Cu) respectively. PKS gave relative values of 730.1kg/m^3, 1.67, 12.09%, 5.98, 1.38 and 2.69. Batching of materials was carried out volumetrically by virtue of the low bulk density and light-weightness of the component material. The blending of the aggregate materials and binder were manually done. A total of six(6) cubes measuring 150mm, six(6) numbers of cylinders measuring 150mm × 300mm and six(6) samples of solid beams of measuring 150mm × 150mm × 600mm were produced from blend ratios of 0.9:1:3:3 and 0.9:1:3:4 which corresponds with (water : cement : fine aggregate : coarse aggregate) to obtain the compression strength, split tensile strength and bending(flexural) strength respectively. The above blend ratio and water-cement ratio were adopted due to the high rate of water absorption of the constituent materials and to attain the required slump level and strength for light weight concrete blend. For the blend ratio of 0.9:1:3:3, the mean compressive strength, mean flexural strength, mean split tensile strength and mean static modulus of elasticity were 7.73MPa, 2.76MPa, 1.57MPa and 4.41GPa. The contemporary values for the blend ratio of 0.9:1:3:4 are 3.84MPa, 2.51MPa, 1.42MPa and 4.06GPa. The mean Poisson's ratio ranges from 0.2 - 0.37. The shear modulus ranged from 1.48MPa – 1.84MPa. The mean flexural strength of wooddust-PKS blend beams ranged from 2.5MPa to 2.76MPa.

Keywords:- *Wood Dust, PKS, Cement, Plywood, Laminate, Composite.*

I. INTRODUCTION

The incessant skyrocketing demand in the utilization of common concrete elements which include fine sand, cement and granite has degenerated to ecological degradation especially land degradation in the process of producing the aforementioned concrete elements [1]. This has brought the utilization of agro-industrial end products such as wood dust and PKS to limelight owing to their being affordable, lesser dead weight, and exhumes little or no ecological degradation. Contrary to the above, common civil engineering materials such as river sand and granites, is known for its a high dead load generated more stress to the foundation thereby giving room for an expensive foundation. In line with the above, the skyrocketed demand and price of the regular concrete elements stone, has made building unaffordable to low earners in the society [3]. Similarly the adoption of these agro-industrial end products will encourage the 3R mantra of waste management which is Reduce, Recycle and Reuse of the agro-industrial end products and also generation of revenue to timber millers.

Concrete blend made from Saw dust & palm kernel is a blend of cement concrete binder, water, sawdust and palm kernel shell (coarse aggregate). Usman et al. [4] studied the the replacement of concrete aggregates with agro-industrial end products with objective of making the entire mix less expensive. In the above research, three(3) categories of concrete were blend at 1:3: 5 and 1:4:8 reprectively. First category was replacement sand with sawdust, second category is replacement of granite with PKS and the last is replacement of both aggregates.

Several tests were conducted on the specimens and the observation showed that the decrease in compressive strength of the specmen made with PKS(second category) were as a result of porousness of the PKS, the irregular shape and size of the PKS, hindering adequate binding strength within the particles of the blend.

The mechanical characteristics of PKS as a non-total substitute of coarse material for asphaltic mix was studied by Ndoke[5]. From his study, Ndoke drew an inference that PKS can serve as a non-total substutute for coarse material with maximum of 12% substitution rate for trunk A roads and 45% substitution rate for trunk C roads.

The utilization of palm kernel shells and wood dust as an alternative replacement for concrete constituent material was studied by Olutoge [6]. He drew an inference that partially replacing 30% of the agro-industrial end products produced a light self-weight element with good strength, lessening the self-weight by 19.41%.

The structural behaviour of wood-dust composite was studied by Fakhrul et al.[7]. They drew an inference that the lesser the quantity of wood dust and wheat flour, the lower the mean strength of the composite in the tension zone. Till this moment of publication, there is or no investigative work on the mechanical properties of sawdust PKS concrete blend, thus, this gives more relevance to this study piece.

II. MATERIALS AND METHODS

A. Sawdust(Wood-dust):

Wood dust (Sawdust) can become the future aggregates replacement in concrete industry. Wood-dust is defined as the fine grainy timber milling end products obtained in timber saw-mills of wood by Maharani et al. [8]. Wood dust is required to be boiled and cleaned prior to its usage in order to get rid of gums, rubbers and resins. This could affect the its time of set and workability with the binder if not eradicated. which can affect setting and hydration of cement. Concrete obtained from sawdust concrete blend is a blend of wood dust, gravel and water inorder to attain the required slump and a proper adequate bond strength between the cement and the wood dust. Sawdust concrete is is a light weight mix with moderate heat and fire resistance. Steel and screws can be drive and be held tenaciously in sawdust concrete blend when compared with its contemporaries of other low deadweight concrete blends [9].

With respect to this work, the wood dust was gotten from from the Timber milling market in Naze, Imo State, Nigeria. Firstly, Wood dust is required to be boiled and cleaned prior to its usage in order to get rid of gums, rubbers and resins. The wood dust was heated under water for about 120 minutes and sundried. The physical characteristics of the wood dust was utilized to classify the wood dust accordingly, using the results obtained from laboratory analysis. The physical and structural properties tests were carried out on the sawdust. Sawdust gave values of 0.61, 36.12%, 512.3kg/m^3, 2.58, 2.71 and 1.0 for mean specific gravity, mean water absorption, mean bulk density , coefficient of curvature (Cc) , uniformity (Cu) and finess modulus respectively.

B. Palm Kernel shell (PKS)

They are defined as the crushed exterior portion of palm nut, obtained from squashing of palm oil from the nut. Palm kernel shell (PKS) is simply the rocky endocarp of palm fruit which embodies the seed. It is derived as broken crucibles through the breaking process to obtain seed [10].

PSK being known as the rocky shell inhabiting the palm kernel seed is gotten from the oil palm tree, with botanical name of elaeis guineensis. It is a typical cash crop and predominant in tropical region of Africa [5].

PKS are predominantly found in quantum in oil palm regions of south east region of Nigeria such as Elele town, Omorku in Rivers state, and Ohaji Egbema, Ikeduru in Imo State. They are also predominantly found in Ode-aye farm settlement, Araromi obu rubber and oil plantations, Irele oil plantations in Ondo State, NIFOR and Okomu farms in Benin City, and also found largely in the other southern part of Nigeria. The Palm kernel shell utilized in this study was gotten from the PKS milling plant in Umukene Village, Umuagwo town, Ohaji LGA, Imo State. First, the palm kernel shells were boiled and rinsed to get rid of resin, wax and fat. After heating for 120minutes, the PKS were sundried for weeks. The sun dried PKS was categorised according to the results of the physical characteristisation. Palm kernel shell gave relative values of 1.59, 12.02%, 698.11kg/m3, 5.93, 1.41 and 2.76 for mean specific gravity, mean water absorption, mean bulk density, finess modulus, coefficient of curvature (Cc) and coefficient of uniformity (Cu) respectively.

C. Ordinary Portland Cement(OPC)

OPC is the conventional type of cement used in tropical Africa and also other parts of the world. Ordinary Portland cement is the elementary component of mortar and concrete(both light and heavy). Portland cement is a powdery fine calcium carbonate material which compose mainly of components of lime, silica, alumina and iron. OPC forms a paste like mortar when it is blend with water and hardens after its setting time by binding concrete components such as sand, granite etc to form a solid rocky element called concrete [11]. OPC is also known as an well powdery calcium carbonate product obtained by heating limestone at very high temperature with measured amounts of calcareous and argillaceous raw materials, with addition gypsum in small quantum [12]. OP cement which is in accordance to the standards of [13] was purchased from cement depot in Imo state, Nigeria.

D. Water

Water was gotten from a groundwater well within the vicinity of FUTO, Owerri, Imo State. The water is potable and in line with to the conformation of [14]. The water met the conformation of drinking, it is therefore good for making concrete production.

E. Compressive Strength Test for Sawdust-PKS blend

Compression strength tests of the Sawdust- PKS blend was carried out using a cube specimen in cube forms, by mixing manually in a square mould of 150mm. The moulds were oiled to prevent the specimen from sticking on its surface. The sawdust-PKS sample was poured into the mould in four layered compacted stages by the use of a compaction rammer. A gross of six (6) cubes were cast using the mix ratios 0.9:1:3:3 and 0.9:1:3: 4 respectively. The Sawdust-PKS blend cubes were cured for 28days by water spraying. After 28days curing, compression test were implemented on the cubes using Okhard Universal testing machine and in comformity to [15]. The compressive loads at failure point were recorded and corresponding strengths were determined using Eq (1).

$$\textbf{Compressive strength} = \frac{\textbf{Fc (N)}}{\textbf{A (mm}^2\textbf{)}} \qquad (1)$$

$\textbf{where}$; $\textbf{Fc} =$ $\textbf{Compressive load at failure}(\textbf{N})$,
A =$\textbf{Cross sectional area}(\ \textbf{mm}^2)$

The dry density or unit weight of the blend after the 28-day curing was determined as it is a determinant parameter for some other mechanical properties such as shear modulus, poisson ratio and static modulus of elasticity. The cubic specimen for the compression strength test were weighed using a weight scale of 50kg max. and the dry density of the specimen were estimated using Equation (2).

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Dry density, $\rho = \frac{M}{V}$ (2)

Where; M = Mass of specimen, V= Vol. of specimen

F. Split tensile Strength Test for wooddust-PKS blend

Split tensile strength tests of the sawdust-PKS blend were carried out using cylindrical specimen measuring 150mm x 300mm geometrically in line with the specification of [15] and [16]. A gross of six (6) cylinders with geometric size of 150mm x 300mm were cast from the two(2) blend ratios; 0.9 : 1 : 3 : 3 and 0.9 : 1 : 3 : 4 respectively. The Sawdust-PKS cylindrical specimen were cured by sprinkling method for 28 days, and tested in Universal Testing Machine (UTM. The cylindrical specimens were positioned laterally in-between the plates rods of the machine and the loading force was exerted until the specimen failed completely occur by cutting along the tranverse midline of the cylindrical specimen.

The compression load at deformation were recorded and eq. (3) was utilised to obtain the split tensile values of the wooddust-PKS blend.

Split tensile Strength, $\delta_c = \frac{2F(N)}{\pi Ld\ (mm^2)}$ (3)

F is the max. force in Newton; L is the longitudinal length of the specimen in mm; d is the diameter in mm of the specimen. The test was done in line with [15] and [16].

G. Flexural Strength Test of Sawdust-PKS blend

A gross number of Six (6) beams specimen with geometric size of (150mm × 150mm × 600)millimetre were produced from the blend ratios of 0.9 : 1 : 3 : 3 and 0.9 : 1 : 2 : 4 respectively. Manual blending was adopted to produce the of the beams. The beams were compacted in 3 layers to ensure appropriate compaction of the mix was achieved. The beam specimens were tested in Universal Testing Machine (UTM); after 28 days curing in line with [17]. The Flexural strength was determined using Equation (4) .

Flexural Strength, $f_{cf} = \frac{F \times L}{b \times d_2^{\ 2}}$ (4)

P is the fail load (N);
b is the breadth and *d* is the depth of beam (mm);
For beam b = 150mm, d = 150mm;
L is the distance between the support base(in mm); for beam L = 300mm.

H. Static Modulus of Elasticity of Sawdust-PKS composite blend

A mathematical correlation of the compressive strength and unit weight (density) was utilized to determine the static modulus of elasticity of sawdust-PKS blend in line with [18]. Equation (5) was used to determine the elastic modulus of the concrete blend:

$$E_S = 1.7\rho^2 [\![f_c]\!] \text{\^{}}(0.33) \times 10^{-6} \quad (5)$$

Where *ES* =Static modulus of Elasticity
ρ = dry density
f_c = compressive strength

I. Poisson Ratio of Sawdust-PKS blend

A mathematical correlation of the tensile crack-stress for flexural elements and compression crack-stress for compressive element was utilized to determine the poisson ratio of sawdust-PKS blend in line with[18] using equation (6). The Poisson μ is given as:

Poisson ratio, $\mu = \frac{\delta_f}{\delta_c}$ (6)

$$\delta_f = tensile\ stress\ at\ flexural\ crack$$
$$\delta_c = compressive\ stress\ at\ crack$$

J. Shear Modulus of Sawdust-PKS concrete blend

A equation of elasticity modulus, E over the linear range of the failure and Poisson's ratio was utilized to determine the shear modulus of sawdust-PKS composite in line with [18], using the the equation (7) below:

Shear Modulus, $G = \frac{E_C}{2(\mu - 1)}$ (7)

μ = Poisson's ratio
E_c = Elasticity modulus of concrete over the linear range of the failure.

K. Shear Strength of Sawdust-PKS concrete blend

The distortion loading due to shear and slide was derived from the bending strength and the shear strength using eq. (8) below:

Shear Strength, $f_s = \frac{F}{A}$ (8)

Where f_s = shear strength

F = distortion load due to shear
A= area of section

III. RESULTS

A. 28th day Compressive Strength values of Sawdust–Sawdust-PKS concrete blend:

The values of the 28th day compressive strength of Sawdust- Sawdust-PKS concrete blend are presented in Table 1:

IV. DISCUSSION

The mean compression strength of 1:3:3 and 1:3:4 are 7.73MPa and 3.84MPa respectively. The derived strengths are less than the minimal allowable compressive strength of light weight concrete for 28th day strength which shouldn't be below the allowable of 18.2 MPa for structural purposes. The mean density(unit weight) of sawdust-PKS for 1:3:3 and 1:3:4 are 1150.6Kg/m3 and 1238.5Kg/m3 respectively; from literature, the unit weight of lightweight concrete is expected not beyond 1920kg/m3.

The split tensile strength of sawdust-PKS concrete composite varies from 1.43MPa to 1.57MPa. The tensile strength of lightweight concrete in line with literature varies from 1.92 to 2.93MPa. This is an indication that the split tensile strength of the Sawdust-PKS did not agree to that standard for light weight concrete in line with literature.

The mean flexural(bending) strength of sawdust-PKS concrete composite blend beams varies from 2.5Mpa to 2.76Mpa. The static modulus of elasticity of sawdust-PKS concrete composite blend varies from 4.06MPa to 4.42MPa; but the static modulus of elasticity of conventional concrete varies from 23.46GPa to 47.3GPa which implies the results obtained from sawdust-PKS is far below that conventional concrete.

The Poisson Ratio of sawdust-PKS concrete blend varies from 0.2 to 0.37 while that of regular concrete varies from 0.2 to 0.4.The shear modulus of sawdust-PKS concrete composite blend varies from 1.48 Gpa to 1.83Gpa while the shear modulus of sawdust-PKS concrete composite blend varies from 2.91 to 5.15 in line with literature.

V. CONCLUSION

Observation from the test values indicates that the mean compression strength for the two(2) blend ratios derived aare far below the minimum allowable compressive value of light-weight concrete for 28th day strength which shouldn't be below 18.2 Mpa for civil works. This downside can be balanced up by the utilisation of an additive. The average unit weight(density) of sawdust-palm kernel shellcrete for 1:3:3 and 1:3:4 are 1150.6Kg/m3 and 1238.5Kg/m3 respectively; in line with literature, the unit weight(density) of light-weight concrete blend should not be beyond 1920kg/m3. Therefore, sawdust-PKS concrete composite blend is a light- weight concrete with respect to unit weight. From the values derived from the split tensile strength of sawdust-PKS concrete blend conforms within the allowable specification for split tensile strength of light weight concrete, which varies from 1.87 to 2.75Mpa in line with literature. Thus, the values of split tensile strength is practically okay for a lightweight concrete. The Poisson Ratio of sawdust-PKS concrete blend composite varies from 0.2 to 0.37 while that of regular concrete varies from 0.2 to 0.4. These values are adequately and suitably in line with the specification for a light weight concrete.

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