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Investigation of Properties of Concrete Using Sawdust as Partial Replacement for Sand

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Abstract

The concrete mix ratio of 1:2:4. was prepared using water/cement of 0.65 with 0%, 25%, 50%, 75% and 100% sawdust as partial replacement for fine sand. The coefficient of uniformity C_u and coefficient of curvature C_c of the sand used in this study was 1.049 and 1.324 respectively which shows that the sand is a well graded sand as it does not exceed the range of 1 and 3 for C_u; and maximum of 6 for C_u specified by the British standard. The aggregate crushing value (ACV) obtained is 43.75 which is within the specified value of 45 as specified by the British standard (BS 812-110 1992). However, values of 40mm, 9mm and 5mm respectively was obtained for workability at 0%, 25% and 50% addition of sawdust as partial replacement for sand, while 14.15 N/mm^2, 12.96 N/mm^2 and 11.93 N/mm^2, were obtained for compressive strength with 25%, 75% and 100% sawdust as partial replacement. The Compressive strength values obtained were found not to conform to the minimum requirement of 17N/mm^2 for light weight concrete. Using sawdust in a proportion greater than 25% replacement of sand is however detrimental to strength and density properties of concrete.

Keywords: Sawdust, Concrete, Workability, Aggregate Crushing value, Compressive strength,

1. Introduction

The overall relevance of concrete in virtually all civil engineering practice and building construction works cannot be overemphasized (Adewuyi and Adegoke, 2008). Concrete is a combination of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to get a particular strength. The cement and water react together chemically to form a paste, which binds the aggregate particles together. The mixture sets into a rock-like solid mass, which has considerable compressive strength but little resistance in tension (Agbede and Menessh, 2009). However, the construction industry relies heavily on conventional materials such as cement, granite and sand for the production of concrete. The high and increasing cost of these materials has greatly hindered the development of shelter and other infrastructural facilities in developing countries (Olutoge, 2010). As the infrastructure of the entire world is kept developing, the construction industry is in need of large amount of raw materials. As the consumption of raw materials increases the demand increases material (Murali and Ramkumar, 2012). The growing concern of resource depletion and global pollution has challenged many researchers and engineers to seek and develop new materials relying on renewable resources. These include the use of by-products and waste materials in building construction. Many of these by-products are used as aggregate for the production of lightweight concrete (Adewuyi and Adegoke, 2008). The most widely used fine aggregate for the making of concrete is the natural sand mined from the riverbeds. However, the availability of river sand for the preparation of concrete is becoming scarce due to the excessive nonscientific methods of mining from the riverbeds, lowering of water table and sinking of the bridge piers among others, are becoming common treats (Mageswari and Vidivelli, 2010). The worldwide consumption of sand as fine aggregate in concrete production is very high, and several developing countries have encountered some strain in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years (Divakar et al, 2012). Nonetheless, accumulation of unmanaged wastes especially in developing countries has resulted in an increasing environmental concern. However, the increase in the popularity of using environmental friendly, lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting environment as well as maintaining the material requirements affirmed in the standards. Since a large demand has been placed on building material industry especially in the last decade owing to the increasing population that causes a chronic shortage of building materials, the civil engineers have been challenged to convert the industrial wastes to useful building and construction materials (Turgut, 2007). Sawdust is an industrial waste in the timber industry constitute a nuisance to both the health and environment when not properly managed (Elinwa and Abdulkadir, 2011). Wood sawdust wastes are accumulated from the countries all over the world and cause certain serious environmental problems and health hazards. It is one of the major underutilized by products from sawmilling operations. Generation of wood wastes in sawmill is an unavoidable hence a great efforts are made in the utilization of such waste (Zziwa1 et al, 2006).Thus, this research investigates the potential use of wood sawdust wastes to produce a low-cost and lightweight composite for construction and engineering purpose.

2. Materials and Methods

Materials used in this study are; ordinary Portland cement, aggregate (fine of 4.75 mm size and coarse aggregate of size 20mm), sawdust generated from the mechanical processing of raw wood from saw mill industries in Akure, Nigeria which sieved with sieve aperture 425 μm without pretreatment. It was sun dried, sieved and then kept in waterproof bags. However, portable water that was free from organic materials and dirt was used.
Concrete used for this study was prepared using mix ratio of 1: 2: 4 and a water to cement (W/C) of 0.65; while batching of materials was done by volume due to the remarkable differences in the specific gravities of cement, sand and sawdust. The percentage replacements of fine aggregates by sawdust were varied from 0%, 25%, 50%, 75% and 100% .This was done to determine the optimum percentage that would give the most favorable result. 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 × 50 mm metal moulds; the concrete de-moulded after 24 hour and cured, while compressive strength was performed after 7 days, 14 days, 21 days and 28 days.

2.1 Estimation for Mix Design

Estimation for mix design was done by mass using mix ratio of 1:2:4 and water cement ratio of 0.65% for concrete production. However, the saw dust introduced into concrete was varied from 0% to 100% (at 25% increase) as a fraction (replacement) of sand weight. The calculation for materials used in concreting is as shown below while; Table 1 shows the estimated quantity of sawdust introduced into the concrete cubes.

Table 1: Quantity of Sawdust Introduced into the Concrete

Sawdust Mass Fraction (%)	Sawdust Mass Fraction (kg)	Sawdust Mass Fraction (g)
0	0	0
25	0.491	49.1
50	0.982	98.2
75	1.473	147.3
100	1.964	196.4

Three representative samples of cubes with various proportion of sawdust as partial replacement of sand were produced for different age of curing.

2.2 Test Methods

Test carried out in these research and the respective standards used are;

i. Particle size distribution (BS 103-103.1 1983)
ii. Aggregate Crushing Value Test BS 812-110 (1992).
iii. Slump Test (BS1881 Part 102).
iv. Air Entrainment Test (BS 1881: part 106; 1983).
v. Density Test
vi. Compressive strength

3. Results and Discussion

Particle Size Distribution: The result of the particle size distributions of the sand used as fine aggregates is as shown in Figure 1 with particle larger than 0.075mm sizes.

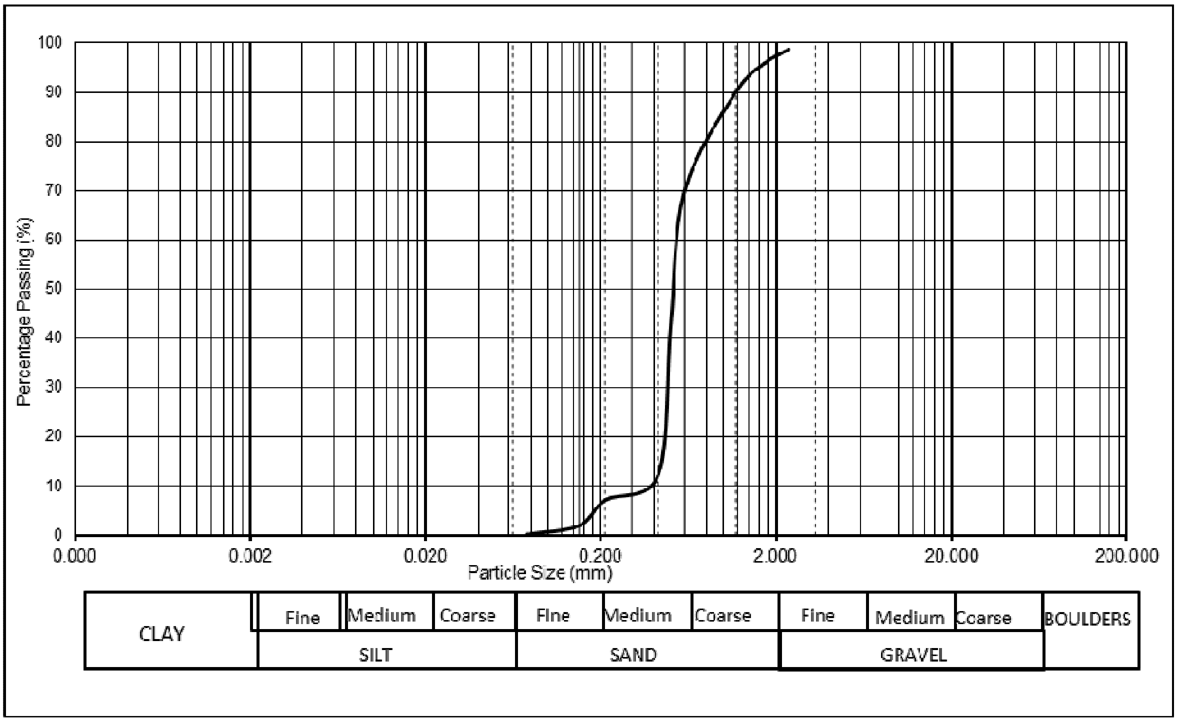

Figure 1: Particle Size Distribution of Sand Used as Fine Aggregates

This was evident by the fact that 50% of the total material by mass used as fine aggregate could not pass through 0.075 micron sieve. Also, the coefficient of uniformity C_u and coefficient of curvature $C_c$of the sand used in this study was 1.049 and 1.324 respectively which shows that the sand is a well graded sand as it does not exceed the range of 1 and 3 for C_u; and maximum of 6 for C_u specified by the British standard.

*Aggregate Crushing Value***:** The aggregate crushing value on 20mm coarse aggregate used was determined using indirect tensile strength test. Table 1 show the weight of the three representative samples.

Table 3.1: Aggregate Crushing Values (ACV) of Coarse Aggregates used in the Test

Aggregate Crushing Value Test	**1**	**2**	**3**
Weight (W1)	204	200	208
Weight (W2)	463	460	470
(W1/W2) X 100	44	43	44.26

$$\text{Aggregate Crushing Value (ACV) of Granite Aggregate used} = \frac{44.0 + 43.0 + 44.26}{3}$$

$$= 43.75$$

Remark: The aggregate crushing value (ACV) obtained is 43.75 which is within the specified value of 45 as specified by the British standard (BS 812-110 1992.

Slump Test: The result of the slump test carried out to determine the workability of concrete with different sawdust fraction as partial replacement of sand at 0.65 water cement ratio is as reported in Figure 2. Workability of concrete was observed to be decreasing as the percentage sawdust replacement of sand in the mix increases. Values of 40mm, 9mm and 5mm respectively was obtained for workability at 0%, 25% and 50% addition of sawdust as partial replacement for sand; however, at 75% replacement of sand with sawdust, the workability of the cement mix increases to 6mm and then to 15 mm at 100% replacement of sand with sawdust.

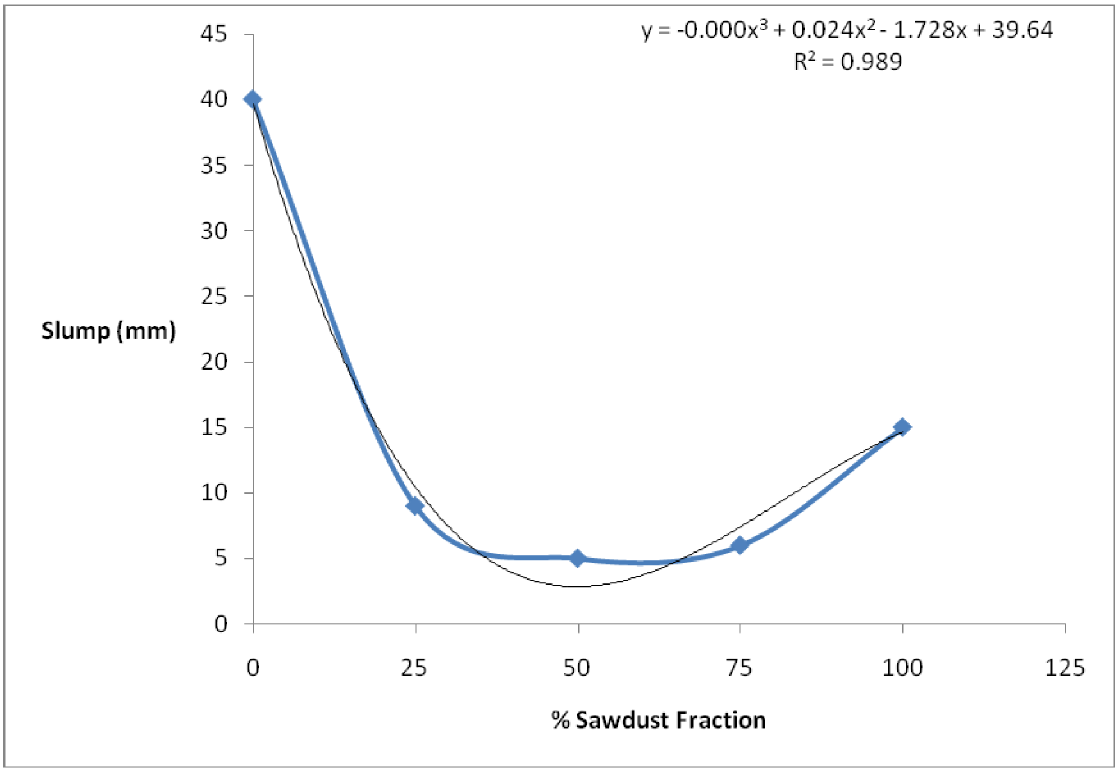

Figure 2: Slump against Sawdust Fraction at 0.65 Water/Cement Ratio

The decrease in the workability of the concrete up to 50% sawdust replacement of sand can be attributed to the difficulties encountered in achieving a uniform mix at 0.65 water cement ratio due to increase in surface area as well as high water absorption of sawdust introduced into the concrete cubes. The rise in the slump value of the concrete mix at 75% and 100% sawdust replacement of sand is attributed to the fact that there a larger proportion of sawdust in the mix which tends to adhere together to form almost a uniform mix.

Air Entrainment: The result of the Air entrained in the concrete cubes with different proportions of sawdust as replacement of sand at 0.65 water cement ratio is reported in Figure 3.

Figure 3: Air Entrained against Sawdust Fraction

Air Entrained in the concrete cubes was observed to increase linearly with increase in sawdust fraction used as replacement for sand. Values of 3.5%, 4.5%, 5.6%, 6.5% and 8% respectively were obtained at 0%, 25%, 50%, 75 % and 100% sawdust replacement. The increase in the air entrainment of the fresh concrete can be attributed to the difficulties encounter to produce a uniform matrix as sawdust and sand varies in their physical properties.

Compressive Strength: The results of the compressive strength obtained are shown in Figure 4. The compressive strength reduces with increase in sawdust fraction from 25% to 100% and with curing and concrete age.

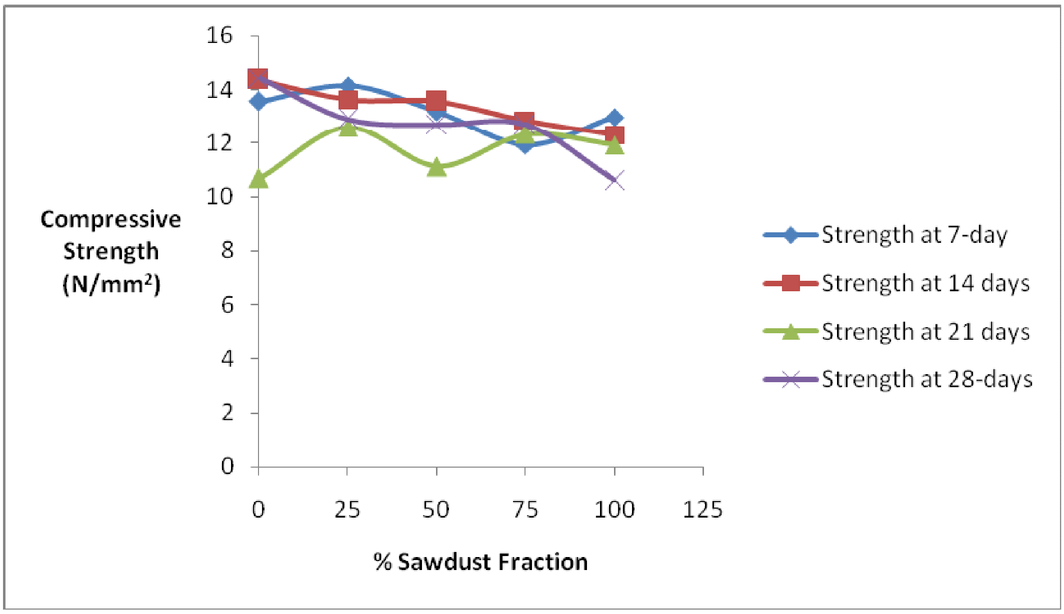

Figure 4: Average Compressive Strengths against Percentage Sawdust Fraction

Values of 14.15 N/mm^2, 12.96 N/mm^2 and 11.93 N/mm^2, were obtained for compressive strength with 25%, 75% and 100% sawdust as partial replacement.

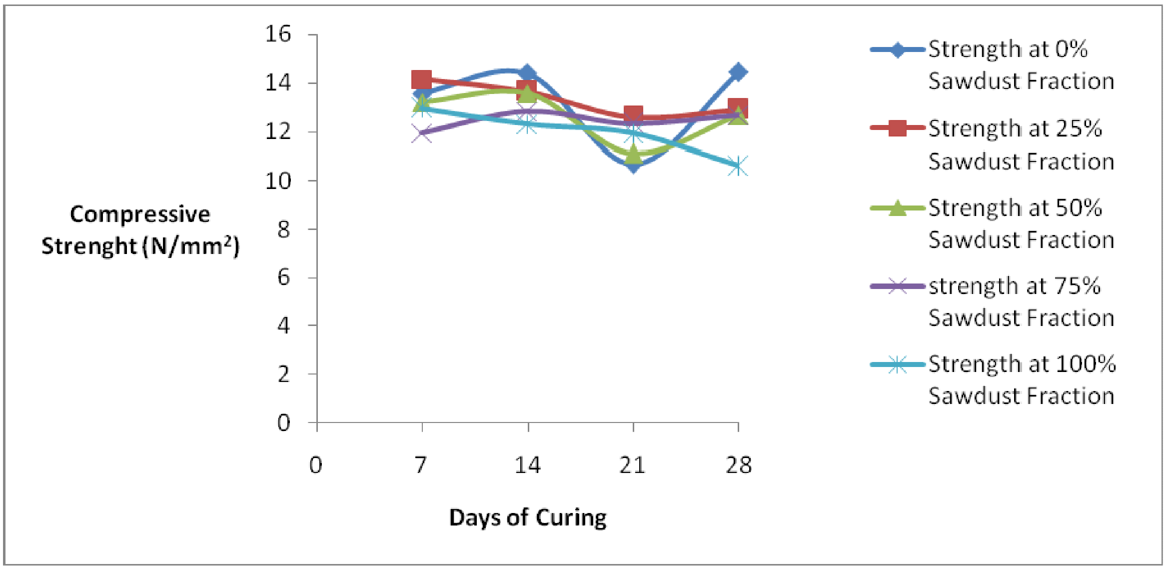

Figure 5: Average Compressive strengths of Concretes at Curing Ages

At 14 days of curing, similar trend (decrease in the compressive strength was observed) with 25% and 50% sawdust replacement of sand exhibiting approximately the same values of compressive strengths of 13.56 N/mm^2 (almost equivalent to the compressive strength value of 14.37N/mm^2 obtained for 0% sawdust inclusion).

At 21 days and 28 days, the compressive strength of the concrete cubes exhibited a trend different from those obtained at 7 and 14 days curing. At 21 days of curing the compressive strength of the concrete was found to increase from 10.67 N/mm^2 at 0% to 12.59 N/mm^2 at 25% sawdust inclusion. This was followed by a drop in the compressive strength at 50% sand replacement with sawdust (i.e. 11.11 N/mm^2) then an increase to 12.33N/mm^2 at 75% and then by a drop at 100% sand replacement with sawdust. Also at 28 days of curing the compressive strength of the concrete at different percentage sawdust replacement decreased from 14.44N/mm^2 and exhibited a constant trend of approximately 13N/mm^2 till 75% sawdust replacement then a drop to 10.57 at 100% sawdust replacement of sand. The general reduction in the strength of the concrete can be linked to the fact that the cement which serves as the bonding agent could not react properly at 0.65% water cement ratio because of the difference in absorption properties of sawdust.

The anomalous variation exhibited by the concrete cubes with 25% to 100% sawdust replacement of sand at 21 and 28 days of curing can be attributed to the fact that sawdust is a lignocellulolistic material that decomposes in the presence of water. When sawdust absorb water the lignocellulolistic components such as carbohydrate, lignin, cellulose decomposes into the cement (bounding material). This component that decomposes affects the overall strength of the concrete. Also sawdust differs in it physical properties from sand and the way sand will easily mix with cement will be different from the way sawdust mix. This might as well contributed to the variation exhibited by cubes containing 25% to 100% sawdust replacement of sand at 21 and 28 days of curing. Hence these suggest that the properties of sawdust should be investigated before use in concrete and it should be treated before use in concrete so as to reduce the proportion of the cellulolistic content of the sawdust. Also alternative curing method should be sought for when sawdust is to be used in concrete. However the strengths obtained at various sawdust inclusions does not meet the minimum specified requirement of 17N/mm^2 for light weight concrete.

Density: The result of the densities of the concrete cubes with sawdust as partial replacement of sand is as shown on Figure 6. The result showed that there was a decrease in the density of the cube with increasing sawdust replacement of sand in the concrete cubes when compared with each other (see Figure 6).

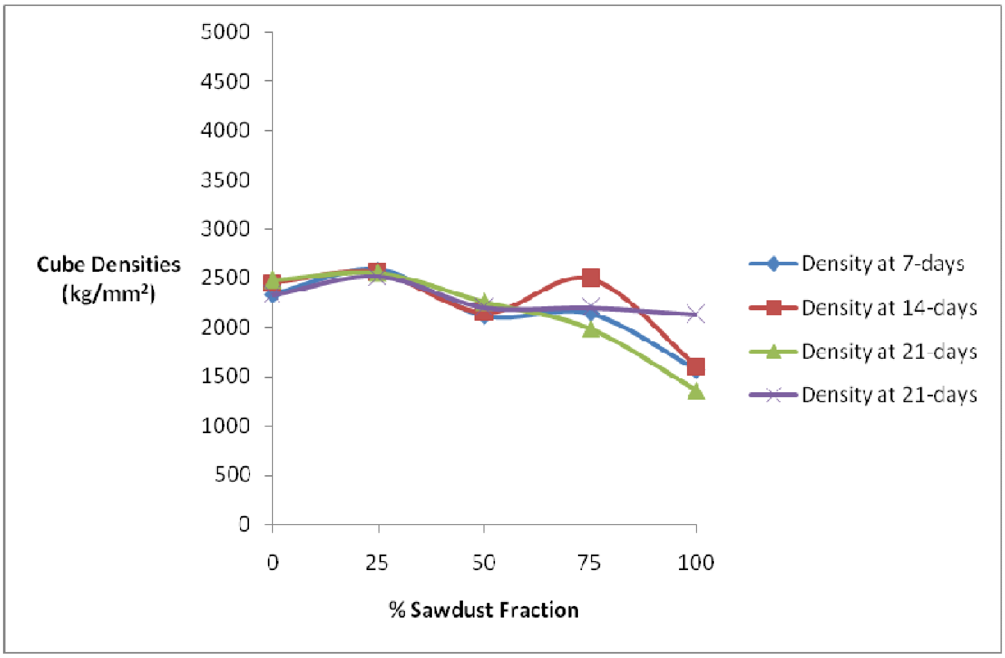

Figure 6: Average Densities of Cubes against Sawdust Fraction

Similarly, variation in the densities of the concrete cube with different sawdust content was observed (see Figure 7)

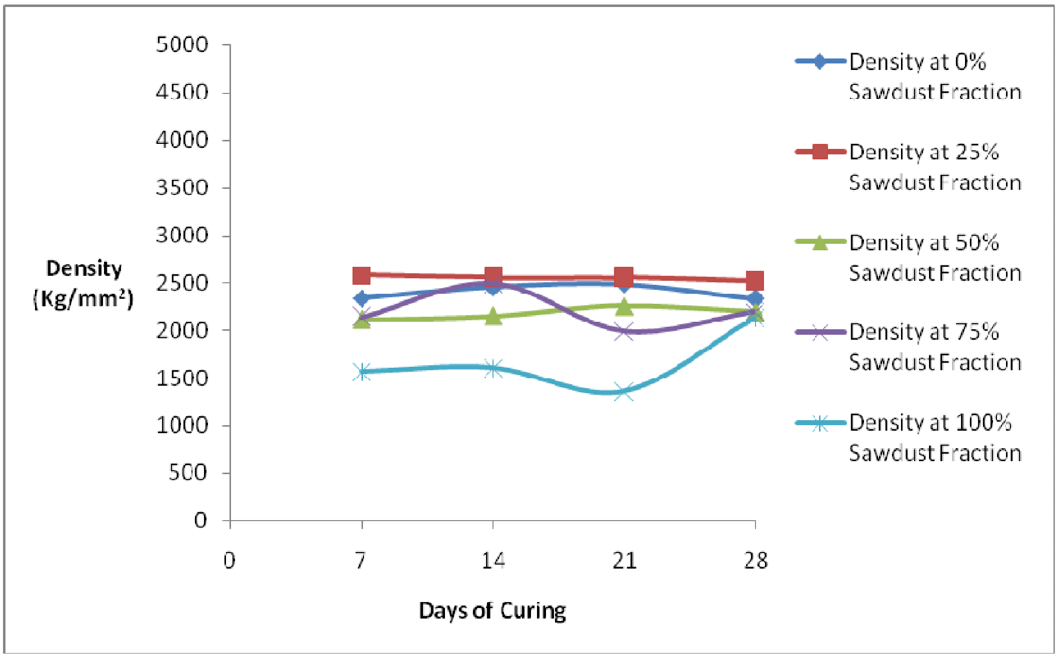

Figure 7: Average Densities against Days of Curing

For cube with 0% sawdust replacement the density of the cube was observed to increase with the days of curing with maximum value of 2485.21 kg/m^3 obtained at 21days of curing. However, cubes with 25 % sawdust replacement exhibited almost a constant trend with the densities of 2582.84kg/m^3, 2553.25kg/m3 and 2553.25kg/m^3 and 2514.79 kg/m^3 obtained for 7, 14, 21 and 28 days respectively.

At 50% sawdust replacement of sand, there were variations (a rise to 2150.89kg/m3 and 2257.40kg/m3 at 14 and 21 days of curing respectively) in the densities of the concrete cubes followed by a drop in the densities.

Similar behavior in in density strength was obtained for 75% and 100% sawdust replacement of sand as there were rise and fall in the density value obtained. This variation could be attributed to the hygroscopic behavior of sawdust in concrete cubes. However, none of the cube densities exceeded the minimum densities specified for light weight concrete i.e. 1480 to 1840 kg/m^3. Further research on the behavior of concrete with higher replacement of sand with sawdust under curing action of water is however suggested.

4. Concluding Remark

Concrete produced using sawdust as partial replacement of sand has influence on the properties of the concrete. The result of the analysis carried out shows that the workability of concrete with partial replacement of sand with sawdust reduces at constant water-cement ratio; while the use of sawdust in concrete at high percentage of sawdust replacement of sand affected the strength of the concrete as there was a decrease in the strength value, and the density requirement of 1480 to 1840 kg/m^3 was not meet. However, use of sawdust as partial replacement of sand at 25 percent by weight gives the same strength requirement when sawdust was not used. Thus, the use of sawdust as partial replacement of sand between 0 to 25% will contributes to reduction in sawdust waste generated in the society without adversely affecting concrete strength.

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