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Experimental Study on Concrete Compressive Strength made by Sawdust as a Partial Replacement of Sand

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Abstract:- The main objective of this study was to experimentally investigate the effects of sawdust on workability, density and compressive strength of concrete. A lot of waste of sawdust which is produced from milling stations resulting in affecting the environment is a thoughtful issue not to leave behind. The conducted study intended to use sawdust as one of the sustainable solutions for low-cost housing especially for the lightweight concrete production. Concrete mix ratio of 1:1:2 was used, sand was replaced with sawdust at a percentage of 0, 5, 10, 15 and 20 by weight and the effects of replacement on concrete's properties were noted. Different tests such as slump and compressive strength tests were performed on concrete to see how concrete was affected by the introduction of sawdust. The results showed that when sawdust content increases in a concrete mix while maintaining water to cement ratio constant, concrete becomes stiff. Concrete's density and compressive strength decreased as sawdust content increased. Concrete's strength at the age of 28 days of curing where sawdust replaced sand by 5, 10, 15 and 20% reduced by 4.99, 21.76, 37.05 and 47.99% respectively. The density was also reduced by 3.5, 8.2, 13, and 15.8% respectively. Since sawdust is already seen as a waste, using it in construction will reduce the construction cost and also it will be a solution to environmental pollution. However much the compressive strength reduced as sawdust content increased, five per cent of sawdust in concrete will contribute a lot as far as waste management is concerned.

Keywords*:- Sawdust; Workability; Lightweight Concrete; Curing; Compression Strength.*

I. INTRODUCTION

Construction all over the world is progressing on a daily basis and different measures are under trial to see if the construction cost can be taken down by introducing local waste materials like sawdust, coconut shells in construction (Joy, A. M., Jolly, A. K., Raju, A. M. and Joseph, 2016). Due to the rise of construction cost especially aggregates and cement, researchers have to crop up with alternative materials that could be introduced in construction industry to assist the existing in order to cut down construction cost (David, A., Boobalan, E. and Devaraj, 2014). (Tomas U. G, 2014) described sawdust as a waste produced when cutting or drilling woods and this waste is normally made of wood's fine particles. Not only human kind can produce sawdust when cutting woods, there are also animals, insects and birds that produce sawdust. Normally, sawdust concrete is not heavy and it has the property of insulating heat and resist from fire (Cheah, 2011).

Sawdust's molecular is loose and this may cause at some stages cause a structure to fail and may retard the hydration procedure but there is an advantage in a way caused by the loose particles of sawdust, if each of these particles can store a certain amount of water in it, it will be helpful in curing concrete especially internally where it is impossible to cure in normal conditions (Kumar *et al*., 2014).

II. PROBLEM STATEMENT

Construction materials are becoming scarce nowadays and their cost as well is increasing, for this reason, measures of coming up or innovating new materials should be put into considerations by looking at waste materials which can be found locally such as agricultural like sawdust, fly ash or industrial waste.

Due to the lack of proper scientific methods that can be employed to mine river sand from riverbeds, the way of extracting such sand is currently done in improper manner and this leads to different problems like lowering water table and causing the bridges piers to sink and other environmental issues.

But besides the above issues, there is also a lot of waste that is formed from the milling stations and such wastes are just generated in the environment resulting in affecting it, however in this hard time it can be a solution when coming up with low-cost houses that are built using lightweight concrete. The purpose of this current study is to get basic data that can be helpful when introducing sawdust in concrete as a new construction material simultaneously by protecting our environment.

III. METHODOLOGY OF THE STUDY

In this section, different laboratory tests including but not limited to sand equivalent, bulk density, workability, compressive strength tests and so on which have been done are discussed here and the procedures followed as well as the used standards.

A. Aggregates Properties Determination

Different properties of aggregates were determined from the laboratory by carrying out different laboratory tests including gradation and sand equivalent tests for fine aggregates, Los Angeles and aggregates crushing value tests for coarse aggregates and bulk density test for sawdust and sand.

➢ *Gradation Test*

One of the basic concrete's constituents is aggregate and its quality is very important because ¾ of the whole volume of concrete is made by aggregates. Gradation of such aggregates is a key physical property that affects concrete's properties(Price, 1951). (Mamlouk, M. S. and Zaniewski, 2011) defined gradation which is again termed as sieve analysis a distribution of particle sizes which is expressed as a percentage of total dry weight of material.

• *Testing Procedure*

Samples to be tested were taken into an oven which was set at 105^0C for drying them. A certain amount of sample was drawn from the original one and weighed, its weight was recorded. Different sieves were taken and arranged starting from the one with small openings to that of big openings as follow; 10, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15 and 0.075mm as per Indian Standard (383-1970). The sample which has been weighed was then poured on the top sieve. Sieves were then allowed to shake by the usage of an instrument called a sieve shaker for about fifteen minutes. When all the materials supposed to fall into trays were done, whatever has been retained on every sieve was taken separately and weighed. The % age of total sample was now taken and the cumulative mass of the sample passing each sieve was tabulated and the logarithmic chart was plotted as a grading curve.

➢ *Sand Equivalent Test*

This is a test which is performed for the purpose of checking if sand has got much dust or fines which can cause a mixture to be unstable when manufacturing mixtures.

• *Procedures of Testing*

When conducting sand equivalent test, aggregate's sample that passes through a 4.75 mm sieve together with a certain amount of flocculating solution were poured into a graduated cylinder and it was agitated. After a certain sedimentation time, different heights; those are the height of sand and that of flocculated clay were recorded. Sand equivalent was now computed as the ratio of those two heights, that's height of sand over that of clay.

➢ *Los Angeles Abrasion Test*

According to (Mamlouk, M. S. and Zaniewski 2011), for aggregates to resist from damaging loads, they need that ability which has a relationship with how hard or though those aggregates are, this ability is revealed after carrying out a test called Los Angeles abrasion test. The % age of aggregate weight which has passed through a sieve of 1.7mm is what normally called abrasion value.

• *Testing Procedure*

A special graded mixture of coarse aggregates of 10 and 14mm weighing in total 5000 grams, that is (W1) was taken and put into a Los Angeles cylinder with addition of 11 steel bars. The cylinder was then closed and allowed to rotate for five hundred revolutions at a rate of thirty to thirty three revolutions per minute.

After the above stated revolutions, the machine stopped by itself and the whole content was taken out and poured on a tray. The eleven balls were now taken out of the content and the remaining was sieved on a sieve of two millimeter. Whatever retained on that sieve was weighed as (W_2). The percentage of passed material was now taken as the abrasion value as per Eq. (3.1) as follow;

$$Abrasion = \frac{W1-W2}{W1} \times 100 \tag{3.1}$$

➢ *Aggregate Crushing Value*

This is a test which is performed to know coarse aggregates' strength. This value (ACV) is what gives how aggregates can resist from loads that tend to crush them. This test is done on aggregates that pass through a sieve of 14mm and retained on that of 10mm.

• *Procedures of ACV Testing*

Following the procedures stated in British Standard, that's BS 812-110 of 1992, the apparatus was well placed on the base plate and the amount equating to a third of sample to be tested was introduced in this cylinder and allowed to be tamped twenty five times. Two layers were then added one at ago by also tamping them in a similar manner as the first and aggregate's surface was then leveled. Afterwards, a cylinder containing a sample for testing together with a plunger was taken and placed between the compressive testing machine's platen and then after, a uniform force was applied in ten minutes till a load of 400KN was reached.

After releasing the load, the crushed aggregates were then taken out of the cylinder and poured on a tray of known mass and both were weighed again so as to record aggregates' mass as m_1. These aggregates were then separated through a sieve of 2.36mm of openings' diameter and m_2 was recorded as the weight of whatever retained on that sieve. This procedure was repeated twice by sing the same quantity as the first sample, finally aggregate crushing value was computed as per Eq. (3.2) as follow;

$$ACV = \frac{m1-m2}{m1} \times 100 \tag{3.2}$$

➢ *Bulk Density Determination*

The ratio between weight and volume of a material whereby solids and pores of that material are taken into consideration is what termed as bulk density noted like BD as described in Eq. (3.3). Particle density and bulk density differ in a way that the former considers only mineral solids.

$$BD = \frac{Weight}{Vsolid + Vpores} \quad (3.3)$$

Where the Bulk Density-BD can be either Bulk Density at Saturated Surface Dry moisture condition (BD_{SSD}) or Bulk Density at Air Dry moisture condition (BD_{AD})

- *Testing Procedure*

An electronic balance was used to record the weight of an empty mold; the mold's volume also was computed and noted. A sample of sawdust or sand was freely poured in the mold until it gets full and its weight was recorded. The same procedure was done thrice in order to get the mean weight. The weight of sawdust or sand itself was then gotten by subtracting the mold's weight from the weight gotten when containing the sample. After all, the bulk density was then determined by taking the sample's weight divided by the mold's volume as per BS 1377.

B. Fresh Concrete Preparation

According to Indian Standard (456-2000), fresh concrete is a mixed concrete which has not yet lost its plasticity. Different procedures of batching and mixing have been followed to prepare the green concrete and after all, the fresh concrete testing also has been performed that is a slump test to determine how workable concrete was.

➢ *Batching of Ingredients*

(Day *et al*., 2013) described batching as weighing or measuring and introducing ingredients of concrete into a mixer. Batching method that has been adopted in this study was by weight which is more accurate than by volume. The advantages of the former method are that there is no negative effect caused by bulking of aggregates on the proportioning of materials.

- *Target Mean Strength*

The mix was designed for increased value which is known as target mean strength just to take care of possible deviation in strength and this target mean strength denoted by f'_{ck} is normally determined by Eq. (3.4) as described below;

$$f'_{ck} = f_{ck} + kS \quad (3.4)$$

Where; f_{ck}: Characteristic cube strength at the age of 28days.

k: Statistical coefficient depending on the accepted proportion of low results.
S: Standard deviation

The Indian Standard indicated the distinctive strength as the value below which is not more than 5 percent is accepted to decrease and the value of k is taken as 1.64. The value of the standard deviation depends on the concrete grade as presented in Table 1shown below.

Concrete's grade	M10 & M15	M20 & M25	M30 to M50
Standard deviation in N/mm²	3.5	4.0	5.0

Table 1:- Standard deviation values
Source: IS 456-2000

The mix ratio used was 1:1:2 confirming to a concrete grade of M25 where M stands for the term mix and 25 represents the characteristic strength in mega Pascal after 28days of curing. However, target mean strength was computed as follow; Target mean strength = 25+1.64*4= 31N/mm^2 and this is the compressive strength that has to be met in order to ensure that concrete produced will meet the requirements.

- *Batching Procedure*

Testing ages were; 7, 14 and 28 days
Sawdust replacement percentages; 0 %, 5 %, 10 %, 15 % and 20 %

The dimensions of one specimen were as follow;
Length = 150mm, Width = 150mm and Height = 150mm
Volume of one specimen (m^3) = Length*Width*Height= 0.15*0.15*0.15= 3.375x10^{-3} m^3

Number of specimens to be cast for one batch is six cubes as there would be two cubes to be tested for each percentage at each testing age; this led to a total of thirty cubes to be cast.

The density of concrete is normally 2400kg/m^3, and from here the mass of concrete required was gotten by multiplying the volume of one specimen with the total number of the specimen to be cast with the concrete density as described below;
Mass of concrete = 3.375x10^{-3}*30*2400= 243 kg

Taking into account 5% wastage, the total mass of concrete required was computed;
Total mass of concrete = $\frac{105}{100} * 243$= 255.15 kg

The quantities of materials used were then tabulated as indicated the below Table 2;

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Sawdust	Number of cubes	Cement (kg)	Gravel (kg)	Sand (kg)	Sawdust (kg)	Water (kg)
0%	6	12.7575	25.5150	12.7575	0.000	5.7409
5%	6	12.7575	25.5150	12.1196	0.6379	6.3788
10%	6	12.7575	25.5150	11.4818	1.2758	7.6545
15%	6	12.7575	25.5150	10.8439	1.9136	8.9303
20%	6	12.7575	25.5150	10.2060	2.5515	10.2060
Total	**30**	**63.787**	**127.575**	**57.4088**	**6.3788**	**38.9105**

Table 2:- Quantities of ingredients used

➢ *Concrete Mixing*

A uniform paste which is workable is gotten by carrying out a proper concrete mixing. Both coarse and fine aggregates as well as cement were poured on a well-prepared mixing area and were mixed dry until the mixture looks homogeneous and had the desired consistency.

➢ *Workability Determination*

(Li, 2011) said that the way of handling fresh concrete so much depends on its properties. Concrete's consolidation also depends on that and these may also later alone have an impact on hardened concrete's properties. It is in this way that workability is measured by carrying out slump test and when a cone is removed, that concrete's sag is what termed as slump. A workable concrete is then well-defined as the one appropriate for placing and tamping under the site conditions.

- *Testing Procedure*

As per Indian Standard (7320-1974), the inner surface of the slump cone was well prepared by cleaning it and applying oil on it in order to avoid adhesion of fresh concrete. Afterwards, a moist and rigid base of the plate was prepared and the cone was placed on it and held firmly by foot. Fresh concrete was therefore taken into the cone in 3-layers whereby each layer was compacted by using a rod for twenty-five strokes. Afterwards, overflows were leveled and the cone was removed carefully and the slump was measured and the findings were recorded.

C. Hardened Concrete

Price (1951) stated that concrete changes states from fluid finally to solid when the hydration process is taking place. External loads can be supported by concrete when it is only in a solid state which is again known as hardened state and this state is characterized by stability of dimensions, durability and strength. Different procedures such as cube casting, curing, density determination and finally testing of the compressive strength have been followed to compute the hardened concrete properties.

➢ *Specimens Casting*

As recommended by ASTM C131, concrete cubes of 150*150*150mm of size were cast by the use of iron molds which at first were cleaned and oiled to avoid adhesion. The 3-layers of fresh concrete were then added into the mold one at ago by compacting it with 25-strokes of rod and then after the excess were removed and the surface was leveled. After twenty four hours, molds were then removed and the cubes were kept in a curing place for 7, 14 and 28days.

➢ *Curing of Concrete Cubes*

A process of maintaining for a defined time enough temperature and moisture content in concrete is normally known as curing, and this process is responsible for hydration process as well as the gain in concrete strength. When curing stops, concrete will only gain fifty percent of the strength that it could have gained when cured on a continuous basis (Mamlouk, M. S. and Zaniewski, 2011).

The speed of hydration process normally depends on curing, this is because when concrete is cured properly, it gains strength and this strength is a result of cement hydration (Merritt, F. S. and Ricketts, 2000).

Specimens were carefully removed from the molds 24 hours after being casted and they were marked and cured by wet covering method as shown in Fig. 1for a period of prescribed ages such as at 7, 14 and 28 days with the purpose of keeping concrete as saturated as possible to facilitate the hydration process to take place.

Fig 1:- Curing of specimens

➢ *Density Calculation*

There are two types of aggregate's density, one excludes the volume of pores in aggregate and it is computed as shown in Eq. (3.5) which is the weight over volume of only solid material, another type of density includes the volume of pores (Li 2011).

$$Density = \frac{Mass}{Volume\ of\ solid} \qquad (3.5)$$

In the present study, the weight of a specimen was gotten using the balance and the volume was also computed by cubing the specimen side. The density (D) of different specimens containing different percentages of sawdust partially replaced sand has been computed using the formula described above and the results were tabulated.

The volume of each concrete cube was calculated as follow;
The length equals to 0.15m, Width is 0.15m and the height is equivalent to 0.15m
Volume (m^3) = Length*Width*Height= 0.15*0.15*0.15= $3.375\times10^{-3}\,m^3$

➢ *Determination of Concrete Compressive Strength*

Concrete compressive strength is described as its ability of resisting from compression or simply from the loads that tend to reduce it in size. A compressive strength test is conducted in order to reveal this capacity. In the current study, the test was done based on the IS 4031-1988. Two specimens were crushed at every testing age for each sawdust replacement percentage and the average compressive strength was computed for each percentage.

- *Testing Procedure*

After the cubes have attained the required age for testing, that's 7 days, 14 days & 28 days, they were taken out of the curing place and cleaned well to remove surface water to get ready for the test. Specimens were then weighted and their weight was recorded for the purpose of density computation. Then after, cubes were positioned in the machine one at a go by making sure that the cubes are well positioned in the machine as indicated in Fig. 2. The enter button was pressed followed by the start button for loading the load of 2000KN at a constant rate of 13.5KN/s. Once the readings started moving backward as the curve becomes constant, the stop button was pressed and the readings were recorded.

Fig 2:- Concrete Cube Testing

IV. DISCUSSIONS OF THE RESULTS

In this section, the results of this research are subjected to thorough scrutiny with the aim of achieving the target of the research. The results from different laboratory tests that have been performed like sieve analysis, Sand equivalent, slump, Los Angeles abrasion, bulk density and compressive strength are described, analyzed and discussed.

A. Gradation Results

Concrete compressive strength, especially in times when there is a partial replacement of sand with sawdust can be affected by how worse or well the fines aggregates used were graded, it is for this reason that fines aggregates were first sieved for the purpose of getting their particle size distribution and the results are presented in the below Table 3.

			Standard	IS 383 (1970)
			Initial weight (g)	1190
			Final weight (g)	1175.5
Sieve (mm)	***Partial retained***	***Cumulative retained***	***Percentage retained (%)***	***Percentage passing (%)***
10.00	0	0	0.0	100.0
4.75	0	0	0.0	100.0
2.36	135.5	135.5	11.4	88.6
1.18	220.5	356	29.9	70.1
0.60	363	719	60.4	39.6
0.30	342.5	1061.5	89.2	10.8
0.15	104	1165.5	97.9	2.1
0.075	10	1175.5	98.8	1.2

Table 3:- Results of sieve analysis test

According to the results as per Table 3, the fine aggregates used in the current study were well graded with conformity to grading zone II as per Indian Standard (383-1970) which tends to be coarse. Concrete's compressive strength with such sand's grade was expected not to be affected negatively.

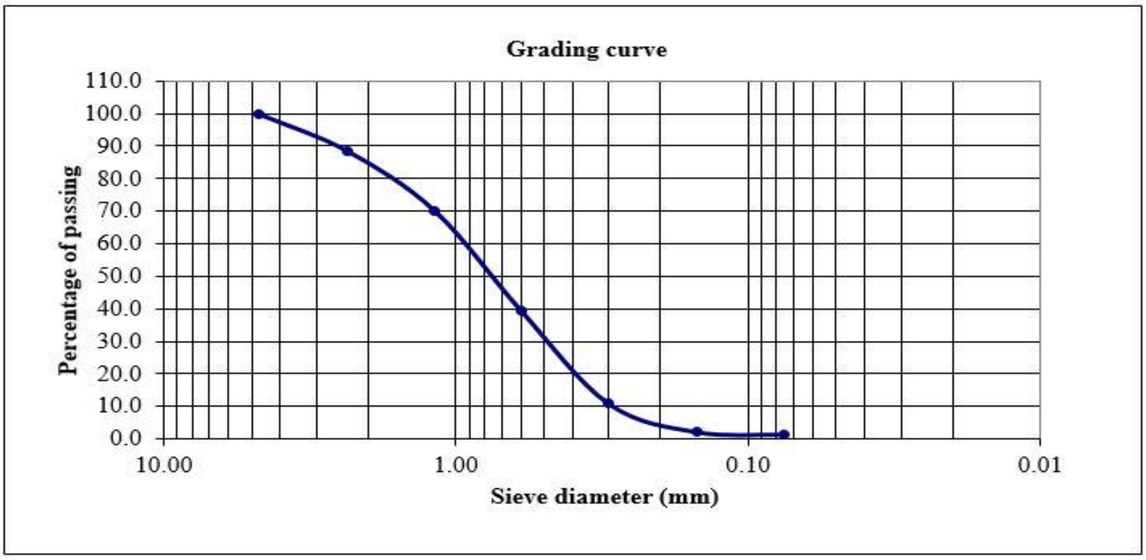

Fig 3:- Grading curve

Figure 3 is a logarithmic chart of sieve analysis' test results and it shows how well fine aggregates are graded.

B. Results of sand equivalent test

The obtained results presented below are findings obtained after carrying out sand equivalent test;

Tested samples	Sample Nº 1	Sample Nº 2
Sand reading after irrigation and sedimentation (H_1)	8.8	8.6
Clay reading after irrigation and sedimentation (H_2)	6.5	6.4
$Sand\ equivalent = \frac{H2}{H1} \times 100$	73.9	74.4
Sand equivalent (%)	**74.1**	

Table 4:- Findings of sand equivalent test

The results of sand equivalent test as indicated in Table 4 were found to be a height ratio of clay over that of sand after a 10 minutes soaking time. When sand equivalent is high, it implies that sand is clean which means it has less clay materials or simply less fines. Normally, sand equivalent value ranges between 30 and 90 percent. Sand of good quality usually goes above 60 percent as far as sand equivalent value is concerned. Since the results are greater than 60% as shown in Table 4, thus the sand used was of a good quality hence expected to give the best results for the compression strength.

C. Coarse aggregates Los Angeles value

After the 500 rotations, the surviving aggregate particles and the crushed debris were sieved on a 2mm sieve and the weight of the retained material was recorded as 3543.5g. The abrasion value or Los Angeles value was computed using Eq. (3.1) as described earlier.

$$Abrasion\ value = \frac{5000-3543.5}{5000} * 100 = 29.13\%$$

Accordingly, it was concluded that the aggregates were of a good quality because the abrasion value was less than 35% which is the maximum value of the abrasion for the aggregates to be allowed in concrete.

D. Aggregate crushing value test results

Aggregates crushing value results are presented below;

Test number	1	2
Mass of aggregates before test, passing 14mm and retained on 10mm sieves M_1(g)	2874	2746
Mass of aggregates after compression, retained on a sieve of 2.36mm M_2(g)	2198	2081
$ACV = \frac{m1 - m2}{m1} \times 100$	23.5	24.2
Aggregate crushing value (%)	**23.9**	

Table 5:- Findings of aggregate crushing value test

Aggregates crushing value was computed as the average between the two findings as shown in Table 5, aggregates crushing value for the coarse aggregates to be used in concrete preparation should not exceed 30%. Hence a value of 23.9% was gotten and as it was well below the maximum acceptable value of ACV, it was concluded that the aggregates were of a good quality.

E. Sawdust and sand bulk density

Mold dimensions; Diameter (d) = 15cm Height (h) = 15cm

Volume of the mold (V) = d^2*h* π /4 = 15^2*15*3.14/4 = 2651.79cm^3

The weight of the mold = 924g

Sawdust				***Sand***		
Sample N°	***Mold + sample (g)***	***Sample (g)***		***Sample N⁰***	***Mold + sample (g)***	***Sample (g)***
1	1365	441		1	4873.5	3949.5
2	1355	431		2	4824.5	3900.5
3	1338	414		3	4779	3855
Sample's average mass (g)		428.67		Sample's average mass (g)		3901.67
Bulk Density (g/cm³)		**0.16**		**Bulk Density (g/cm³)**		**1.47**

Table 6:- Fine aggregates bulk density

$$Bulk\ Density = \frac{Sample's\ average\ mass}{Volume\ of\ the\ mold} \quad (4.1)$$

According to the results found and presented in Table 6, sand has got the bulk density of 1.47g/cm^3 meaning 9 times denser than sawdust because the later got a bulk density of 0.16g/cm^3 as computed using Eq. (4.1) and this indicated that a light concrete was expected when sawdust partially replaced sand.

F. Results of Slump Test

While carrying out the slump test with a purpose of computing how workable the fresh concrete was, at a water to cement ratio of 0.45 with different percentages of sawdust, findings were presented in Fig. 4. There was a decrease in concrete's workability when sawdust content increases in the mix. Findings of 6, 4.5, 3, 2 and 1.5 cm were obtained as a slump at 0, 5, 10, 15 and 20% addition of sawdust partially replacing sand respectively.

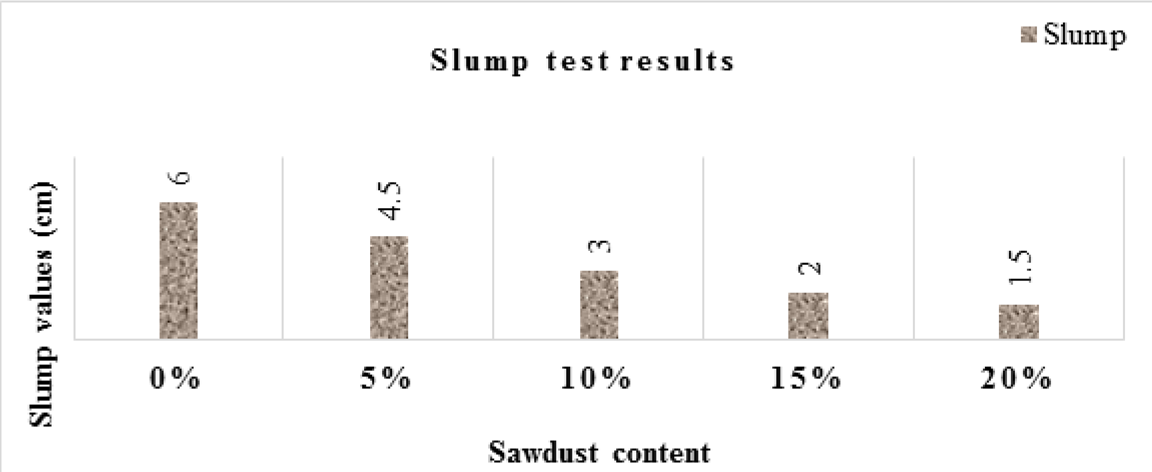

Fig 4:- Slump test results at a 0.45 water to cement ratio

Normally, for a reinforced concrete, the intersection of degree of workability for lightly and heavily reinforced is 5 cm to 7.5 cm, concrete with a slump which was below that range could not be cast; water had to be added in to increase the slump as well as the workability. Table 7 shows how water to cement ratio was modified in order to get a slump that falls within the acceptable range. Nevertheless, water could be modified so as to meet the required range of slump, by increasing the quantity of water to cement ratio in concrete, there was a high tendency of reducing the compressive strength of concrete because one of the factors which decrease concrete compressive strength is a high water to cement ratio.

Sawdust content	0%	5%	10%	15%	20%
Water to cement ratio	0.45	0.5	0.6	0.7	0.8
Slump values (cm)	6	6	5.5	6	5.5
Water content (Kg/m^3)	284	315	378	441	504

Table 7:- Slump test results when water to cement ratio was modified

The decrease in the workability of concrete with the introduction of sawdust partially replacing sand can be related to how it was difficult to come up with a uniform mix at a water to cement ratio of 0.45 because of the increase in surface area and of course a high sawdust's water absorption. Figure 5 shows the modified water to cement ratio that has been used in preparing the fresh concrete.

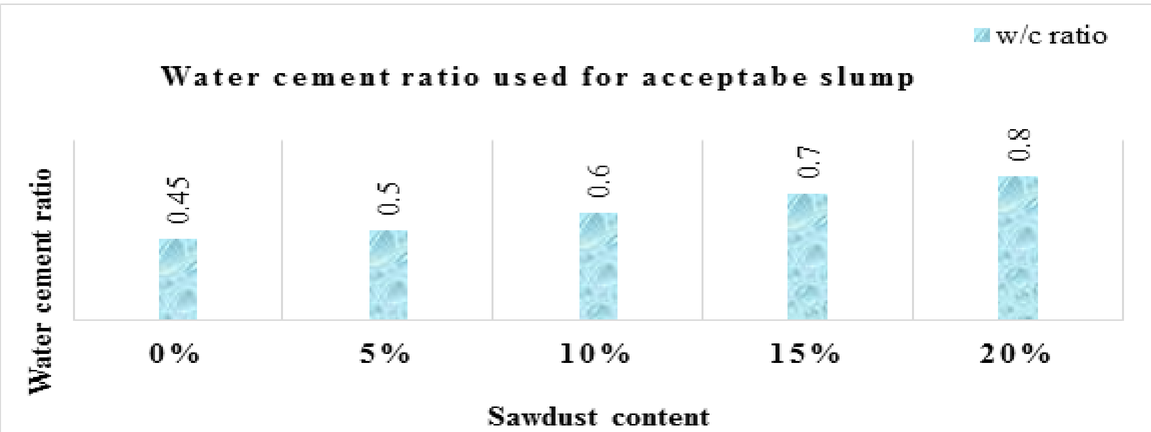

Fig 5:- Used water to cement ratio for acceptable slump

G. Density of concrete cubes

Concrete cubes made as a result of partial replacement of sand with sawdust were tested for density and the findings are presented and discussed in this section. It was discovered that the density kept on decreasing as sawdust content increased in the mix. in general, when curing days increased, the density did the reverse for each percentage of sawdust. The volume of each concrete cube was computed as 3.375×10^{-3} m^3 from the previous sections.

***Sawdust content** (%)*	***Concrete cubes density at different ages** (Kg/m^3)*		
	7days	***14days***	***28days***
0	2464.4	2444.9	2441.7
5	2367.2	2363.8	2356.2
10	2269.1	2250.6	2242.3
15	2146.5	2138.8	2125.1
20	2055.4	2038.8	2055.0

Table 8:- Concrete cubes density at different ages

Normally, the density of the material is proportional to its weight, as the weight increases so as the density and verse versa. As the curing age increased to 28days, the cubes weight kept on decreasing due to the loss of water from the concrete and the density also reduced. The overall and summarized results of the density are well presented in Table 8 above. In general, when the density goes high so as the compressive strength does, but for this case where sand has been partially replaced by sawdust it was different.

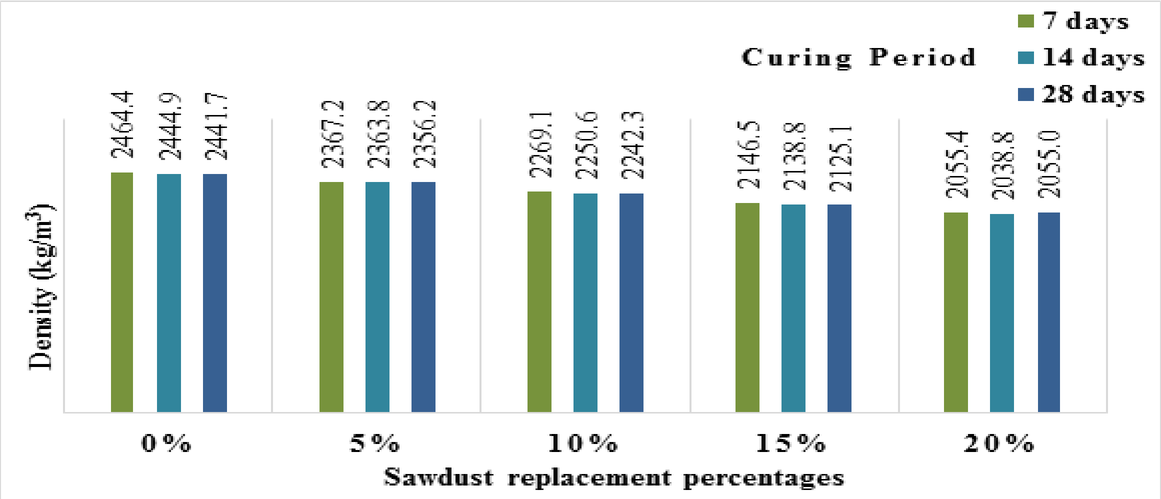

Fig 6:- Concrete cubes density versus sawdust content

Based on the results from Fig. 6, it is clear that after 28 days of concrete cubes curing, a decrease and increase were noted for the density and sawdust proportion respectively. This could be attributed to the low density of sawdust compared to sand and the hygroscopic nature of sawdust. However, all these densities exceeded 1840Kg/m^3, the maximum density of lightweight aggregate concrete; hence more variations should be done to come up with such concrete. Concrete compressive strength cannot be just measured in one day; there should be a period of testing and curing in the same time to see how the strength development is progressing.

H. Compressive strength results and discussions

In this study, it was revealed that when sawdust content in concrete increases, compressive strength goes down. Table 9 presents the summary of the results at different ages of curing and how the strength kept on changing as the curing ages increased from 7days to 28 days.

***Sawdust content** (%)*	***Compressive strength at different ages** (N/mm^2)*		
	7days	***14days***	***28days***
0	24.33	28.94	33.63
5	22.80	25.95	31.95
10	18.48	21.48	26.31
15	11.50	16.50	21.17
20	10.67	11.53	17.49

Table 9:- Overall compressive strength test results

Having in mind that the development of the strength of concrete depends on hydration process, the introduction of sawdust in this concrete might have disturbed this reaction negatively. Organic matters like cellulose, small amount of pectic substances, lignin and hemicellulose were decomposed when sawdust absorbed water and these lead to the disturbance of hydration reaction causing concrete not to get strength. This has been market especially where sawdust content in concrete exceeded ten percent.

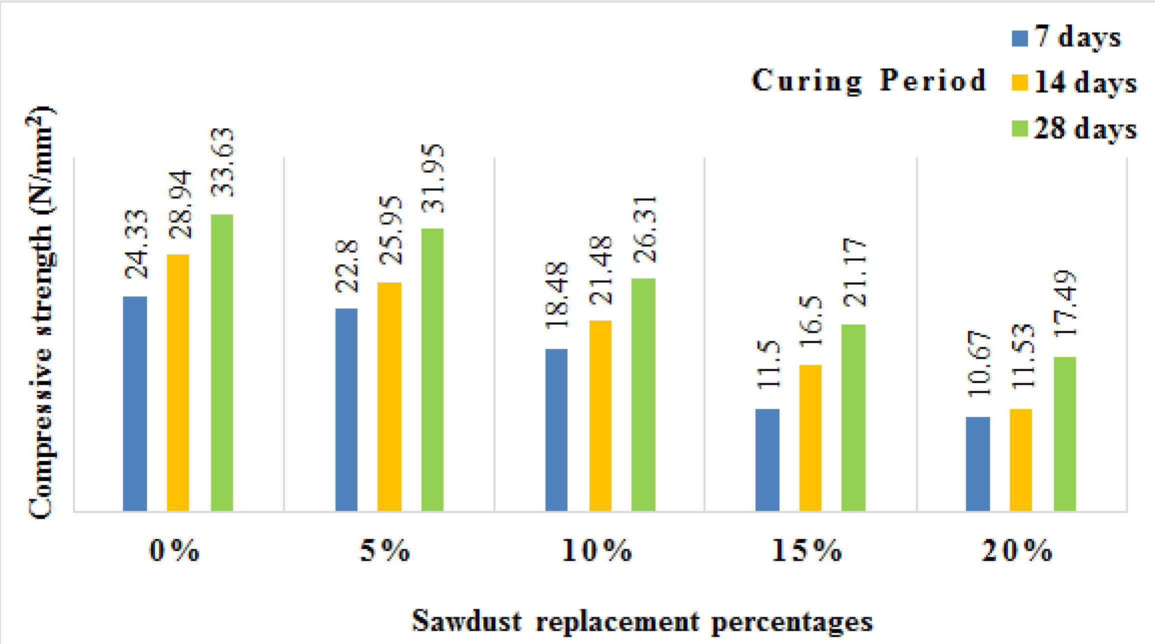

Fig 7:- Compressive strength versus sawdust percentage

Generally, Fig. 7 shows the reduction in concrete's compressive strength as sawdust content increases and this could be related to many reasons; one is that there was a high degree of voids in concrete cubes with a high percentage of sawdust and according to the literature, voids in concrete are among the key factors which affect concrete's compressive strength negatively. Two, sawdust absorbs water which means it is hygroscopic leading to a change in its volume and all these result into internal stresses within concrete mix. These might have been a result of poor bonding which occurred between cement paste and particles of sawdust. When sawdust content in concrete increased, concrete's compressive strength decreased as it is seen in Fig. 7.

V. CONCLUDING REMARKS

In the current study, effects caused by partial replacement of sand with sawdust on density, workability and strength were investigated. According to the findings, the following remarks were drawn;

At a constant water to cement ratio, when sawdust content increases, the workability decreases. Concrete's density decreased a bit as the content of sawdust increased, the required density of a lightweight aggregate concrete that ranges normally between 1480 and 1840 kg/m^3 was not achieved. However much the concrete's strength and density reduced when sawdust content increased, they didn't reduce at the same rate. The reduction in strength was higher than that of density. For this reason, concrete with sawdust might potentially be used where the concrete's compressive strength is not a key factor to consider.

With a content of five per cent of sawdust in concrete, there is no problem that can impede someone from using such concrete, because at this level concrete is not yet in a range of light weight aggregate one, some modifications can be performed on sawdust to increase its content in concrete but without compromising too much the strength just at least to maintain it above 17n/mm^2. Pre-treating sawdust like boiling it in lime water can be the best way of removing all the substances present in sawdust that could have been impeding the hydration process. Water proofing substances may also be added into sawdust in order to avoid its high rate of absorbing water. Optimum sawdust replacement with sand was discovered as five per cent for an M25 concrete's grade.

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