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Mechanical Properties of Guarea Thompsonii Sawdust Modified Concrete

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Abstract

Timber waste has continued to be generated in large quantities contributing to environmental depletion. The work investigated the feasibility of the use of sawdust from Guarea Thompsonii as an admixture in concrete. It finds its importance in showing the effect of using sawdust of a hard wood of known properties, on some mechanical properties of concrete. It applied the laboratory investigative technique. The content of the sawdust in a standard 1:2:4:0.55 concrete mix representing; cement; fine aggregate, coarse aggregate and water respectively was varied in the order; 0%, 2%, 4%, 6% 8% and 10%. Guarea Thompsonii sawdust gave a specific density of 1.29. The addition of the sawdust increased the setting time of ordinary Portland cement from 4.33hrs to 5.07hrs for 2%, 6.00hrs for 4%, 6.15hrs for 6%, 7.06hrs for 8%, and 7.17hrs for 10%. It produced a decrease in the compressive strength and density of the concrete increasing its plasticity. It showed best performance of compressive strength and density at 6% addition with 28.83 N/mm^2 -a decrease of 14.75% and 2.53 x $10^{-3}kg/m^3$ respectively with a slump of 10mm. The work concludes that Guarea Thompsonii sawdust is an ideal filler material to produce light weight concrete which can be used for permanent form work floor panels, wall panels, paving blocks, noise barriers and load/Non-load bearing walls. The reuse of otherwise waste materials in the construction industry will no doubt contribute to efforts at conserving the Earth's available energy.

Keywords: Timber, waste, Admixtures, Concrete and Compressive Strength.

INTRODUCTION

The promotion of environmental management and the mission of sustainable development have exerted pressure which demands the adsorption of proper methods to protect the environment from the hazards of waste, across industries the construction industry inclusive. Timber waste is the by product of human and industrial activity on the product of trees and sometimes other fibrous plant used for construction purpose that has no residual value. Timber is a product of trees used for construction purpose. The reuse of waste generated from the timber industry will no doubt help to achieve this. Much waste is generated into the environment from the timber industry which may become useful in concrete design.

Timber has been used with concrete to produce civil engineering artifact (Dragoslav and Toma, 2007, Jolio et al., 2010). Concrete is composed mainly of three materials, namely cement, water and aggregate and an additional material known as an admixture, is sometimes added to modify properties of concrete (Orie and Osadebe, 2009). In the present work, the waste produced from Guarea Thompsonii in the form of sawdust is used as an additive in concrete and the effects on some concrete mechanical properties determined.

Guarea Thompsonii called Obobonekwhi in some parts of Nigeria and black Guarea in the United Kingdom, is pinkish in colour, like a fine textured Mahogany. The wood has a typical cedar scent and important commercial specie of timber. It darkens in colour during seasoning, but not to the same extent as true mahoganies. The grain tends to be straighter, and the appearance plainer. It is common in southern state high forest. Its density at 18% moisture content is $656kg/m^3$. According to the Nigerian standard code of practice (1973), it belongs to the strength group N_3, when the moisture content of this group N_3 is greater than 18 percent, it's bending and tension parallel to grain is 18.0, compression parallel to grain is 14.0, shear parallel to grain 2.24, compression perpendicular to grain 3.15 and mean value modulus of elasticity 9.500. The stress applicable to N_3 with a moisture content of 18 percent or less include; bending and tension parallel to grain 22.4 N/mm^2, compression parallel to grain 18.0N/mm^2 shear parallel to grain 2.80; compression perpendicular to grain 4.00N/mm^2 and mean value modulus of elasticity 10,600N/mm^2. Guarea Thompsonii naturally is durable, resistant to impregnation, has small movement and medium shrinkage. It is selected for use in the present work to see if it can add its strength to that of concrete.

Jackson and Dhir (1996) reported that timber as a construction material has a long history probably tying with stone as the oldest structural material still in common use and easily first in terms of annual world consumption. Timber's versality is part of its continuing attraction as it is amenable to factory mass production yet is equally easily worked using simple hand tools. Timber is light but strong and tough. It has excellent thermal insulation properties and is more fire resistant than steel or concrete and it has a warm and attractive appearance. Wood is readily available in most parts of the world in variety of species. It has the ability to resist both tensile and compressive stress and the ratio of the strength to weight is relatively high. It can absorb considerable energy before it fractures. It is quite resistant to deterioration and will withstand intense temperatures. National Academy of science (1980) reported that the principal course of deterioration of wood in service as distinct from the deterioration during seasoning are mechanical failure in fire, fungus infection, termite and other insect or marine-bore attack.

Baldwin (1973) stated that using timber efficiently in manufacturing/production of items like furniture, cabinet work shop's fitting or in the area of construction hinges upon two important criteria. These are selection of the most suitable timber and choice of the best and most appropriate method of joining the timber. Concrete on the other hand is a composite which incorporates other material amongst which could be timber either as admixture or filler (Orie, 2008, Orie and Orojo, 2014).

Kenzie (2004) reported that concrete is a widely used structural material with applications ranging from simple elements such as fence posts and railway sleepers to major structures such as bridges, offshore oil production platform and high rise building. The material is a conglomerate of chemically inert aggregates (i.e. natural sands, crushed rock etc) bonded together by a matrix of mineral cement. The aggregate and cement are mixed together with water to create an amorphous plastic mass. Concrete may sometimes be mixed with other components called admixtures (Orie and Osadebe, 2009) and these mixes require optimization.

Jackson and Dhir (1996) defined admixtures as substances introduced into a batch of concrete, during or immediately before its mixing, in order to alter or improve the properties of fresh or hardened concrete or both. The materials used by the cement manufactures to modify the properties of cement are normally described as additives. These effects are brought about through the influence of the admixture on hydration, liberation of heat, formation of pores and the development of the gel structure. Since admixtures may also have detrimental effect, their suitability for a particular concrete should be carefully evaluated before use. Their use must based on knowledge of their main active ingredients on available performance data and on trail mixes. This also formed the bases for the present work. It is important to note that admixtures are not intended to replace good concreting practice and should not be used indiscriminately.

British Standard Institution (1957) stated that most mechanical properties such as compressive strength of seasoned timber vary with changes in moisture content. These properties of timbers may cause them to affect concrete differently.

An important area or research is making cost effective concrete without compromising the structural integrity and durability of the material as it has been known to last for a life time (David and Galliford, 2000). The effect of several industrial and domestic wastes on concrete in this respect has been examined. For example, Yumping et al. (2004) showed that recycled plastics can be used as partial replacement of aggregate in concrete. Research has shown that sawdust does not significantly enhance the compressive strength of sandcrete blocks and it slows down the setting and early stiffening of the mortar mix (Oyekan, 2008). It reduced dry density of finished burnt brick product from 1755 kg/m^3 for 0%, to 1512 kg/m^3 for mix with 10% sawdust content (Emmanuel, 2008). Wood ash has been found to have compressive and flexural strength of between 62 and 91% and 65 and 98% respectively when compared with plain concrete. The concrete also absorbed higher water with higher additive levels (Felix, et al, 2006). An increase in percentage sawdust in concrete slabs led to a corresponding reduction in both flexural and compressive strength values with a weight reduction of 14.5% (Olutoge, 2010). Elinwa and Ejeh (2011) studied the effect of sawdust-ash (SDA) on some mechanical properties of mortar in aggressive chemical environments. The results obtained further confirmed SDA as a pozzolanic material with optimum at 10% replacement. It has been confirmed that the ash has a pozzolanic index value of 75.9% and that 10% of the sawdust ash gave desired workability and strength (Elinwa and Mahmood, 2002). The use of waste materials as supplementary materials in concrete has contributed immensely sustainable developments (Karim et al., 2011).

Literature revealed that wood sawdust had some reducing effects on concrete. The present work examined specifically, Guarea Thompsonii –a hard wood. Hardness is a desired property in the compressive advantage of concrete as a structural material.

METHODOLOGY

The work applied the laboratory investigation technique. The sawdust was randomly sourced from a local wood processing factory in Benin City while the fine aggregate was sourced from Okhuahe River near Benin. The coarse aggregate which had a maximum particle size of 20mm was sourced from Ifon in Ondo State Nigeria. Potable water was used. The particle size distribution of the fine aggregate and sawdust were determined. Workability based on slump test and the determination of the quantity of water necessary to produce a paste of normal consistency and setting time were also carried out. The apparent specific gravity of the materials were determined using the water displacement method and in accordance with BS812 part 2 of 1975. A standard concrete mix of 1:2:4 was prepared and 0%, 2%, 4%, 6% 8% and 10% of the mass of cement were consecutively substituted with Guarea Thompsonii sawdust sourced from a local wood processing factory. These were filled into British Standard cube moulds measuring 100 x 100 x100mm, vibrated, compacted and the tops troweled. The samples were demoulded after 24 hours and stored in a curing tank controlled at 24^0C. Compressive strength test conforming to BS 1881, 1970 was carried out on the samples at 7, 14, 21 and 28 days.

RESULTS AND DISCUSSION

The results obtained are presented in tables and figures. The particle size distribution of sawdust is shown in Table 1 while that of the fine aggregate (sand) is in Table 2.

Table 3 gives the specific gravity of sawdust while Table 4 gives that of the fine aggregate. The slump test and setting time results are shown in Table 5 and 6 respectively. The results of the compressive strength are shown in Table 8.

Table 1 showed that the sawdust was not uniformly graded, it had coarse lump and more of fine particle from 600mm – 75mm. this necessitated its being sieved with a 425µm sieve. Table 2 showed that the sand was well graded with sizes ranging from 75µm to 2.36mm. The specific gravity results of Tables 3 and 4 showed that the sawdust had specific gravity value of 1.29 while that of sand was 2.40 kg/m^3 respectively. Lydon (1972) classified sawdust as light weight aggregate since normal weight aggregate have specific gravity between 2.6 to 2.8 kg/m^3.

Table 1. Sieve analysis of sawdust

Approx. Imperial Equivalent	British Standard Sieve sizes	Retained in gm	Passing in gm	Passing in %
7	2.36	3.61	96.39	96.39
10	2.00	1.45	94.94	94.94
14	1.18	37.79	57.15	57.15
25	600µm	48.93	8.22	8.22
36	425µm	3.33	4.87	4.87
52	300µm	0.68	4.21	4.21
72	212µm	0.23	3.98	3.98
100	150µm	0.03	3.95	3.95
200	75µm	0.15	3.80	3.80

The setting time results on Table showed that the sawdust acts as a set retarder in concrete.

The slump test results of Table 5 showed that increases in the percentage of sawdust in the concrete led to decreased workability effect on the water to cement ratio which made the mix drier and difficult to work as the sawdust absorbed the water. This is synonymous with the literature (Felix et al., 2006). The plot of Figure 1 showed that at 8% and 10% addition of the sawdust, the mix had a zero slump and was almost unworkable. The workability of the resulting concrete therefore was used to determine where the addition of sawdust and hence the experiment terminated.

The materials for the compressive strength are presented in Table 7 and the test results in Table 8. The relationship between the compressive strength, age an addition of the sawdust is shown in Figure 2. The figure showed that there was a progressive increase in the compressive strength of the Guarea Thompsonii modified concrete. In other words, the sawdust did not inhibit the natural process of compressive strength growth of concrete. At 28 days, the compressive strength decreased from 30.50 at 0% to 21.50 at 4%. Beyond which it rose to 28.83 N/mm^2 at 6% after which a continuous decline was observed.

Table 2. Sieve analysis of fine aggregate (sharp sand)

Approx. Imperial Equivalent	British Standard Sieve sizes	Retained in gm	Passing in gm	Passing in %
7	2.36	1.88	98.12	98.12
10	2.00	1.00	97.12	97.12
14	1.18	6.76	90.36	90.36
25	600µm	19.62	70.74	70.74
36	425µm	20.59	50.15	50.15
52	300µm	18.90	31.25	31.25
72	212µm	18.57	12.65	12.65
100	150µm	5.62	7.06	7.06
200	75µm	3.13	3.93	3.93

Table 3. Specific gravity of sawdust

Samples	W_1	W_2	W_3	W_4	W	Specific gravity
1	16.03	20.49	69.78	69.03	3.31	1.23
2	26.15	30.63	76.05	75.00	3.34	1.3
					Average	1.285

Table 4. Specific gravity of fine aggregate

Samples	W_1	W_2	W_3	W_4	W	Specific gravity
1	25.80	37.05	82.40	75.40	4.70	2.489
2	26.53	37.60	82.67	76.40	4.80	2.306
					Average	2.397

Table 5. Slump test of Guarea Thompsonii Modified Concrete

Variation of sawdust (%)	Mix	Water ratio	Mass of Sawdust (kg)	Slump (mm)
0	1:2:4	0;55	0.0	25
2	1:2:4	0.55	0.1	30
4	1:2:4	0.55	0.2	30
6	1:2:4	0.55	0.3	10
8	1:2:4	0.60	0.4	05
10	1:2:4	0.60	0.5	00

Table 6. Setting time result of Guarea Thompsonii **Modified Mortar**

Sawdust (%)	Cement Mass (g)	Water (ml)	Penetration	Final setting time (hrs)
0	8	144	5mm	4.33
2	8	148	5mm	5.07
4	16	154	5mm	6.00
6	24	160	5mm	6.15
8	32	170	5mm	6.06
10	40	180	5mm	7.17

Table 7. Materials for Compressive strength tests: Mix 1:2:4:0:55

Sawdust (%)	Sawdust (kg)	Cement (kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)
0	0	5	10	20
2%	0.1	5	10	20
4%	0.2	5	10	20
6%	0.3	5	10	20
8%	0.4	5	10	20
10%	0.5	5	10	20

Table 8: Compressive Strength of Guarea Thompsonii Modified Concrete

Addition of Sawdust (%)	7 Days		14 Days		21 Days		28 Days		
	Mass (kg)	Strength (N/mm^2)	Mass (kg)	Strength (N/mm^2)	Mass (kg)	Strength (N/mm^2)	Mass (kg)	Strength (N/mm^2)	Density ($x10^{-3}$ kg/m^3)
0	2.46	25.67	2.62	25.67	2.63	34.40	2.60	30.50	2.60
2	2.55	23.67	2.57	32.00	2.61	26.00	2.47	26.50	2.47
4	2.45	18.33	2.49	27.17	2.48	21.75	2.50	21.50	2.50
6	2.48	23.17	2.47	26.33	2.43	20.00	2.53	28.83	2.53
8	2.43	19.33	2.46	26.33	2.41	19.00	2.50	26.00	2.50
10	2.37	16.67	2.38	16.83	2.40	19.25	2.36	20.50	2.36

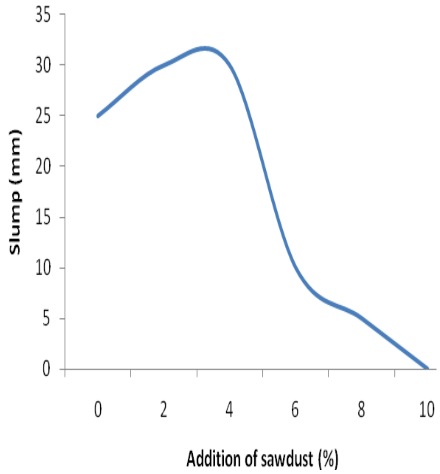

Fig. 1. Relationship between Slump and Sawdust Content

The figure also showed that, for all the ages, there was a decrease in compressive strength with increasing percentage sawdust addition. At 7 days, the compressive strength decreased from 25.67 at 0% of sawdust to 18.33N/mm^2 at 4% of sawdust. This rose to 23.17 N/mm^2 at 6% beyond which a continuous decline was observed. Figure 2 showed that this phenomena break in the declination process of the compressive strength of the concrete with increasing sawdust content was also observed in all the ages of the concrete.

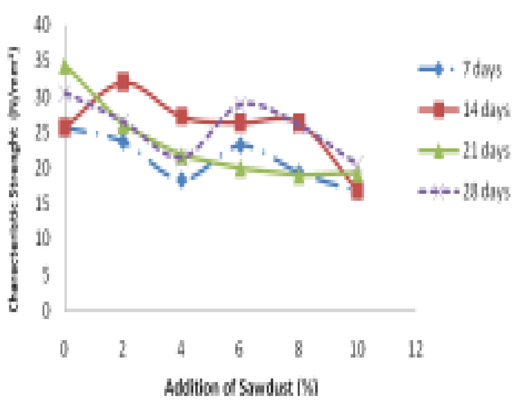

Fig. 2. Relationship between Compressive Strength and sawdust

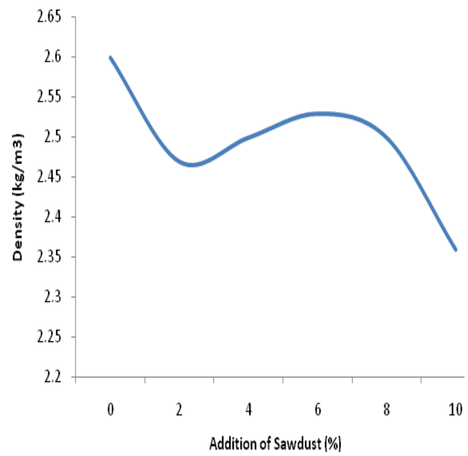

Fig. 3. Relationship between Density and Sawdust Content

This compressive strength however meets the requirement for a 1:2:4 concrete mix by BS 8110: Part 2; 1990, which stipulates that a grade 25 concrete should have acquired 16.5 N/mm^2 within the first 7 days and 25N/mm^2 within 28 days. Table 8 also showed the results of the 28 days density of the modified concrete and the relationship is described in Figure 3. Within the range of sawdust addition investigated, the figure showed a slight improvement in the density of the concrete at 6% addition of the dust. The figure showed that the density of the concrete reduced from 2.60 x 10^{-3}kg/m^3 at 0% to 2.50 x 10^{-3}kg/m^3 at 4% of the sawdust. The density improved slightly to 2.53 x 10^{-3}kg/m^3 at 6% after which a further decline was observed. The apparent improvement in the density at 6% of the sawdust addition may be due to an optimal combination of the dust and the aggregates, with the dust acting as adequate fillers to the voids in the concrete. Guarea Thompsonii sawdust is therefore an ideal filler material to produce light weight concrete which can be used for permanent form work floor panels, wall panels, paving blocks, noise barriers and load/Non-load bearing blocks.

CONCLUSION

The addition of sawdust in large quantities affects the water to cement ratio and increases the plasticity of the concrete. At 8 and 10% of cement addition of sawdust, the concrete mix was almost unworkable. That addition of sawdust increased the setting time from 4.33 hours at 05 to 7.17 hours at 10%. The use of Guarea Thompsonii sawdust in concrete should not exceed 6% of the cement content. An increase in the percentage addition of the saw dust beyond 6% caused a reduction of 14.75% in the compressive strength of the concrete. Guarea Thompsonii sawdust will be an ideal filler material to produce light weight concrete when 2 – 6% cement content of the sawdust additions are made.

LIMITATION

A large mass of timber was required to produce a hand full of sawdust. The low density of the wood dust, a very high sensitive weighing instrument was required and these are usually very expensive. There could also be health hazards in working with Guarea Thompsonii dust which has not been considered in the study.

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