Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.11, 2016

Effect of Sawdust on the Compressive Strength of Concrete

Anthony Woode, Isaac Agyei-Boakye, Bright Aforla*, David Kwame Amoah, Samuel Osei, Akanbi Abu-dil Karimu and Albert Kwadwo Abakah

Civil Engineering Department, Accra Technical University, P. O. Box GP 561, Accra.

Abstract

This study was undertaken to investigate the properties of concrete produced by partial replacement by weight of sand with sawdust generated from different species of wood. The sawdust used in this investigation consist of the wood species, *Piptadeniastrum africanum* (leguminosae family), *Triplochiton scleroxylon* (sterculiaceae family) and *Celtis mildbraedii***,** locally known as Dahoma, Wawa and Essa respectively. The addition of sawdust to the concrete was done by 5% increment up to 25% by weight of the fine aggregate. Concrete cubes of size 150mm x150mm x 150mm were prepared after batching and mechanical mixing for the compressive strength tests. The compressive strength tests were carried out after 28 day curing of the concrete cubes in accordance with BS EN12390-3:2009 series. Sawdust blend concrete from wawa - a lightwood species gave the best result of 5.3 N/mm^2 at 28 days. The optimum replacement of sand with sawdust has been found to be 5% for lightwood species.

Keywords: Batching, Mechanical mixing, Sawdust, Compressive strength.

1. Introduction

Concrete products are of great importance as far as the building and construction industry is concerned in Ghana. Different concrete products are useful for different purposes based on the constituent materials. Concrete is a combination of cement, course and fine aggregates and water, which are mixed in specified proportion to meet the specified strength. Sometimes additional materials known as admixture are added to modify its properties. The cement and water reacts together chemically to form a paste which binds the aggregate particles together. The mixture when compacted and well cured, is capable of attaining the required strength at 28 days. Concretes are classified into two main groups; dense and lightweight concretes. The dense ones are those with densities above 2000kg/m^3; those with densities less than that, are the lightweight ones. Broadly speaking, for any given type of aggregate, high density in concrete is associated with high strength, hardness, durability, imperviousness, frost resistance and thermal conductivity, (Everett, 1986). Lightweight types are obtained by aerating the mix (cellular concrete), by using lightweight aggregates, or by omitting the fine aggregate in the concrete. The latter are made in densities down to about 1600kg/m^3. The common examples such as foamed slag, expanded clay, expanded slate and sintered pulverized fuel ash concretes are suitable for reinforced concrete structures with strengths in compression up to 62 N/mm^2, and with densities 30-40 per cent, and thermal conductivities of 50 per cent or more, less than those of aggregate concretes, (Marthong, 2012)

The high demand for shelter due to rapid population growth has forced the construction industry to rely heavily on conventional materials such as sand and aggregates and cement for the production of concrete. The high and increasing cost of these materials has greatly hindered the development of housing and other infrastructural facilities in developing countries (Olutoge, 2010). The global concern of resource depletion and environmental pollution has challenged many researchers to seek for other sources of cheaper materials, (Murali et al, 2012). This has called for the use of industrial by-products and waste materials in the construction industry.

The efficient use of forest resources and their residues play a vital role in forest sustainability and preservation of the environment. Sawdust is one of the commonest wood residues which is encountered mostly in the saw mills, trade mills and in the furniture workshops and are often indiscriminately disposed of, (Zziwal et al, 2006). Ofosu-Asiedu et al, (1993), in their study of product-yield and wood residues from seven selected indigenous species established that the residues amount to about 54%. The easiest means of its disposal hitherto is by burning, which poses severe environmental problems. The uses to which a particular timber can be put depend greatly on the physical properties which include the density. The density of a material is the mass per unit volume of that material. The density may be measured as basic, air-dry and green densities. The basic density refers to the mass of the bone-dry piece of wood divided by its volume. The air-dry density is the density at 12%

moisture content, the condition that most wood is in after thorough air-drying. The green density is the density of freshly-felled wood and varies depending upon the season in which the felling occurs. Very dense woods tend to be impermeable as there is little space into which liquids can penetrate. The density of softwoods is estimated to be about 513 kg/m^3 whilst that of hardwoods is about 769 kg/m^3. Timber species such as Dahoma (*Piptadeniastrum africanum*), Essa (*Celtis mildbraedii*), and Wawa (*Triplochiton scleroxylon*) are all broad-leaved and tropical in origin, with Dahoma and Essa as typical dense hardwoods and Wawa as lightwood. Of these three species, Dahoma is the densest, followed by Essa (600 - 785 Kg/m^3) with Wawa being the least dense (below 400 Kg/m^3) .The thermal conductivity is a measure of the rate of heat transfer through a unit thickness and an area of a material from face to face. The conductivity of materials is known to vary with density, temperature, porosity and moisture content. With a moisture content of 20%, by volume, most building materials transmit between two to three times as much heat as they do when they are dry. Hygroscopic materials such as wood vary in moisture content with the relative humidity of the atmosphere.

Ghana as a developing nation is embarking on her extensive infrastructural investment and as a result, natural sand is greatly used in concrete production. This has promoted extensive sand winning with its attendant effect on the environment (Wood et al, 2015). On the other hand, sawdust, mostly a waste product of the wood processing and furniture manufacturing factories abound posing serious environmental threat. In addition to the sawdust generated by sawmills, carpentry works on construction project sites also generate significant amount of sawdust which often gets into contact with fresh concrete during placement especially when concreting and carpentry works go on concurrently. The extent to which sawdust affects the strength of concrete in such circumstances needs to be investigated.

Raheem et al, (2012) in their research established that sawdust ash (SDA) is a suitable material to be used as a pozzolan. Mageswari & Vidivelli, (2009) investigated the use of SDA as replacement for fine aggregate in concrete by replacing sand with 5 to 30% of SDA in making concrete cubes and cylinders and testing for compressive, tensile, and flexural strengths up to 180 days of curing. Their results showed a similarity in properties of concrete with 100% sand as fine aggregate and those obtained by replacing sand with SDA at 10 to 20%. Studies conducted by Elinwa et al, (2011) also confirmed that SDA is a pozzolanic material with optimum SDA replacement at 10%. They further established that the material has the ability to reduce porosity and hence effective in reducing corrosion of reinforcements in concrete. Marthong, (2012) investigated the strength of mortar cubes, concrete cubes, and beam specimen made with OPC-SDA blended cement and concluded that the inclusion of SDA caused some expansion due to low calcium content but early strength development was about 50 to 60% of their 28-day strength. The study further suggested the use of SDA as partial replacement of cement up to 10% by volume in all grades of cement.

Literature is replete with research on the use of sawdust blend from mixed wood species as a partial replacement for sand. This research however, investigates the properties of concrete produced from the blend of sand with sawdust generated from different wood species and their effect on the compressive strength of concrete.

2.0 Materials and Methods

2.1 Materials

2.1.1 Sawdust

The sawdust was sourced from sawmill and furniture markets in Accra. It consists of the following wood species: *P. africanum (Leguminosae family), C. mildbraedii and T. scleroxylon (Sterculiaceae family) and* locally known as Dahoma, Essa and Wawa respectively. These species are locally available and are extensively used in the construction industry.

2.1.2 Coarse aggregate

The coarse aggregate used for the study was commercially crushed gneissic rocks of maximum size 14mm obtained from a quarry in the Greater Accra region of Ghana.

2.1.3 Fine aggregate

The fine aggregate is river sand, which was free from any visible impurities and passing through 2mm size mechanical sieve was used for the tests after it had been oven dried.

2.1.4 Cement

The cement used was the commercially available Ordinary Portland limestone cement of 32.5 Grade and conforming to Ghana Standard 914:2007.

2.1.5 Water

Portable water free from any visible impurities was used for the experiments (BS3148 (1980).

2.2 Drying of sawdust

The various wood species in the form of saw dusts were oven dried to expel all moisture. The dried sawdusts were kept in waterproof bags to avoid contamination and absorption of water present in the air. The saw dusts which passed through 2mm size mechanical sieve were used for the experiments because it is comparable to the nominal size of sawdusts generated on site.

2.3 Batching

Batching of materials for the concrete was done by weight in the ratio of 1:2:4 with water/cement ratio of 0.45 for Dahoma and Essa replacement. When Wawa was added to the concrete mix it was realized that the concrete was not workable at water/cement ratio of 0.45. The water/cement ratio was, therefore, increased to 0.8 to make it workable. The addition of sawdust to the concrete was done by 5% increment up to 25% by weight of the fine aggregate.

In all eighteen (18) concrete cubes (150mm x150mm x 150mm) were made after batching and mechanical mixing for the compressive strength tests.

2.4 Compressive strength tests

Compressive strength tests were carried out on the 28 day concrete cubes in accordance with EN12390-3:2009 series after curing.

3.0 Results and Discussion

The results obtained from the compressive strength tests for concrete/ Wawa mix, concrete/ Dahoma mix, concrete/ Essa mix are given in Tables 1 to 3.

Table 1. Compressive Strength values for Wawa sample

Wawa Sawdust Replacement (%)	Weight (kg)	Density (kg/m^3)	Maximum Load (kN)	Average Stress (N/mm^2)
0	7.87	2.33	365.43	16.42
5	6.78	2.01	118.98	5.29
10	6.77	2.01	85.15	3.79
15	6.19	1.83	54.47	2.42
20	5.23	1.64	37.28	1.66
25	5.58	1.66	25.91	1.15

Table 2. Compressive Strength values for Dahoma sample

Dahoma Sawdust Replacement (%)	Weight (kg)	Density (kg/m^3)	Maximum Load (kN)	Average Stress (N/mm^2)
0	7.87	2.33	365.43	16.42
5	7.20	2.14	100.78	4.48
10	7.10	2.10	70.79	3.15
15	6.44	1.91	68.68	1.59
20	6.14	1.82	35.76	1.48
25	6.17	1.83	33.33	3.05

Table 3. Compressive Strength values for Essa sample

Essa Sawdust Replacement (%)	Weight (kg)	Density (kg/m^3)	Maximum Load (kN)	Average Stress (N/mm^2)
0	7.87	2.33	365.43	16.42
5	6.82	2.02	60.98	2.71
10	6.98	2.07	58.32	2.59
15	7.05	2.09	56.31	2.50
20	6.50	1.93	34.02	1.51
25	6.13	1.83	30.58	1.36

Graphical Representation of Results

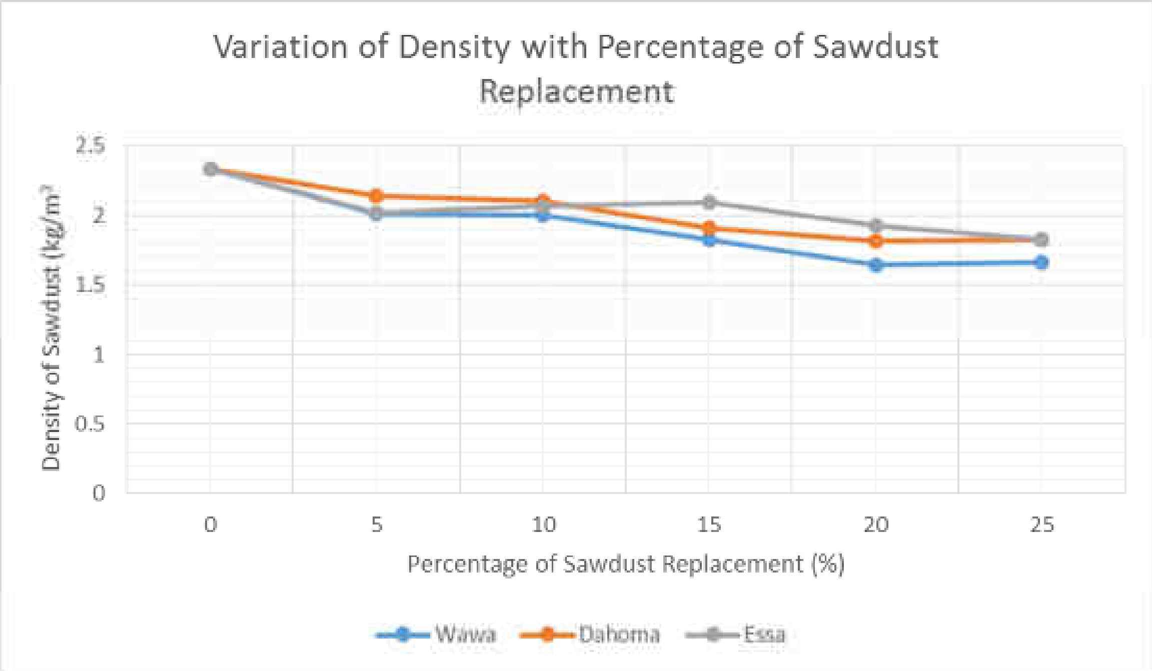

Figure 1. Variation of density with percentage of sawdust

Density: Figure 1 shows the results of the density tests conducted on the concrete cubes prepared using sawdust as partial replacement of sand from all the three species of wood, namely Wawa, Dahoma and Essa. The results show a general decrease in the density of concrete with increasing sawdust replacement of sand in the proportions of 5 to 25%. However, the density of essa sawdust blended concrete increased slightly from 2.02 kg/m^3 to 2.09kg/m^3 at 5% and 15% sawdust replacement respectively before dropping finally to 1.83kg/m^3. The Dahoma sawdust blended concrete recorded the highest density of 2.14kg/m^3 at 5% sawdust replacement followed by Essa with a density of 2.09kg/m^3 at 15% sawdust replacement. Wawa sawdust blended concrete recorded the lowest densities at all the sawdust replacement percentages of 5 - 25% with the least density of 1.66 kg/m^3 at 25% sawdust replacement. The results confirm that Dahoma is the densest wood followed by Essa, and Wawa being the least dense. It can then be concluded that Dahoma and Essa are dense hardwood species while Wawa is a lightwood.

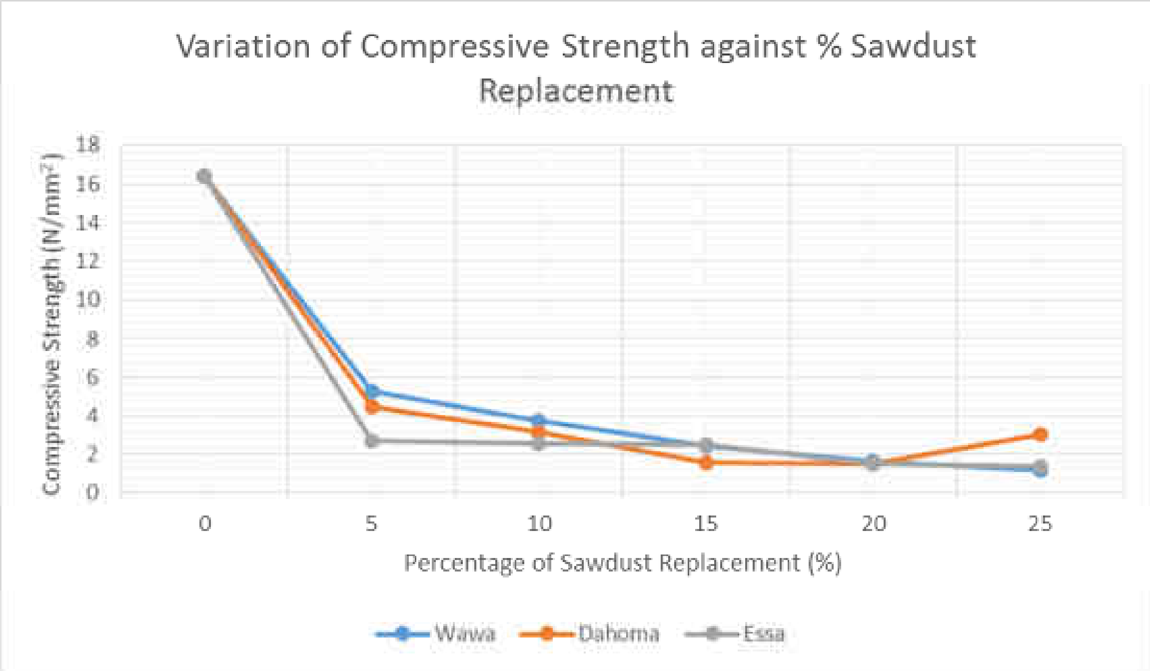

Figure 2. Compressive Strength of concrete against percentage of saw dust.

Compressive strength: The properties of the sawdust-blend concrete were compared with that of normal concrete. Figure 2 (above) shows the effect of sawdust replacement on the compressive strength of concrete. The results indicate a general decrease in the compressive strengths of all the concrete produced from the blend with sawdust generated from each of the three wood species used in this investigation, namely, *P. africanum* (leguminosae family), *T. scleroxylon* (sterculiaceae family) and *C. mildbraedii***,** locally known as dahoma, wawa and essa respectively. As the percentage of sawdust content increased from 5 to 25% by weight in the mix, the compressive strengths decreased. At 5% sawdust replacement, the compressive strengths of all the sawdust blend concrete produced from all the three wood species dropped sharply from 16.42 N/mm^2 for control concrete to as low as 2.71 N/mm^2 for essa, 5.29 N/mm^2 for wawa, and 4.48 N/mm^2 for dahoma. Sawdust blend concrete produced from all the three wood species showed further decrease in compressive strengths as the percentage of sawdust increased from 10 to 25%.

The low values of compressive strengths of concrete recorded in this investigation could be attributed to the air entrapped in the mix which is known to cause reduction in strength. The low compressive strength values could also be due to the fact that sawdust contains some substances that inhibit the hydration of cement and hence the development of the required strength. Furthermore, certain chemical substances found in wood, especially those of acidic nature, sugars, starches and tannins, such as are found in hardwood have been found to interfere adversely with the chemistry of cement setting. Due to the presence of these substances, hardwood sawdust in general is inferior for making sawdust cement concrete. The results obtained from this investigation show that, Wawa which is a type of lightwood makes better quality concrete than denser hardwood species because they either lack such chemical substances or contain them in minute quantities. Poor quality sawdust concrete can be improved to some extent by adding hydrated lime.

4.0 Conclusion

From the results of the tests conducted, the following conclusions can be drawn:

As the proportion of sawdust increases, concrete becomes less workable meaning that water cement ratio needs to be increased to make mixes more workable. Based on the strength behaviour of sawdust blend concrete carried out, a possibility exists for the partial replacement of sand for the production of lightweight concrete. The optimum replacement of sand with sawdust has been found to be 5% for the lightwood species. Beyond this limit, concrete produced did not meet the minimum strength requirement of 6 N/mm^2 at 28 days according to BS 8110 (1997). Lightwood species make better quality concrete than denser hardwood species. Generally, denser hardwood sawdust is inferior for making sawdust cement concrete materials because they contain large amount of sugars, starches, and tannins. Tannin is common in hardwoods such as cedar, pine, and redwood. In general, lightwoods such as Wawa have a low tannin content. It is recommended that only sawdust that has been allowed to stand in the open for about a year for conditioning in order to leach out the harmful extractives be used. Poor quality sawdust can be offset to some extent by adding hydrated lime. A lightweight concrete is achieved with low thermal conductivity and better insulating qualities than normal concrete and can be used as a light-weight construction material in many civil engineering works. If used in the production of ground floor slabs and wall panels, there is the possibility of seasonal shrinkage and swelling because of the hygroscopic nature of sawdust with resulting effect of cracking and lifting of floor surfaces on wetting and drying. Use of bituminous coating or other suitable sealants is suggested to prevent seasonal changes in moisture content and resulting dimensional change.

With the use of sawdust concrete, advantage can be taken of the apparent availability of free and low cost sawdust in many parts of the world thereby mitigating against pollution of the environment through the indiscriminate dumping and burning of sawdust.

A lot of sawdust is generated on construction sites through carpentry works which often come in contact with fresh concrete during placement. Construction workers are hereby cautioned to practice strict quality control in their concrete works to avoid the contact of sawdust with fresh concrete, most especially when structural concrete is required.

5.0 References

Elinwa A.U & Abdulkadir S.,(2011). *"Characterizing Saw Dust Ash for Use as an Inhibitor for Reinforcement Corrosion"*. New Clues in Sciences, 1, 1 -10.

Everett A. (1986). "*Materials"*. (Mitchell's Building Series). Reprinted by Longman Scientific and Technical 1992, 1993. Printed by Bookcraft (Bath) Ltd. Pg 74,184 -188.
Mageswari M. & Vidivelli B., (2009). *"The Use of Sawdust Ash as Fine Aggregate Replacement in Concrete"*. Journal of Environment Research and Development, 3 (3), 720 - 726.

Marthong C. (2012). *"Size Effect Study of Saw Dust Ash- Concrete under Compressive Load"*. IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), 2(5), 27 -32.

Murali G. & Ramkumar V.R.(2012). *"Properties of Concrete with Partial Replacement of Coarse Aggregate"*.International Journal of Emerging Trends in Engineering and Development, 4(2), 585 - 589.

Ofosu-Asiedu, et al, (1993). "*Better Utilisation of Tropical Timber Resources in order to Improve Sustainability and Reduce Negative Ecological Impacts"*. FORIG, Kumasi, Ghana.
Olutoge F.A, (2010). *"Investigations on Sawdust and Palm Kernel Shells as AggregateReplacement"*.ARPN Journal of Engineering and Applied Sciences, 5(4), 8- 12.

Raheem et al, (2012). *"Sawdust Ash as Partial Replacement in Concrete"*. Organization, Technology and Management in Construction, 4(2), 474 - 480.

Wood et al, (2015), *"An Experiment to Determine the Effect of Partial Replacement of Natural Sand with Manufactured Sand on the Strength of Concrete"*. Civil and Environmental Research, Vol. 7 No. 11, 48-53

Zziwa1, A. et al, (2006). *"Production of Composite Bricks from Sawdust Using Portland Cement as a Binder"*. Uganda Journal of Agricultural Sciences, 12(1), 38-44.