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Compressive Strength of Concrete Using Sawdust as Aggregate

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Abstract—This paper reports on experimental investigations on the effect of replacing sand with sawdust on the properties of concrete. A concrete mix of 1:2:4 was used as control while sawdust was used to replace 25%, 50%, 75% and 100% of sand by volume. The percentage reduction in density are 5.96%, 12.44%,13.56% and 17.93% respectively while the corresponding percentage reduction in compressive strength were 57.5%, 68.1%, 83.7%,and 87.3% respectively. The results of the study indicate that both the density and compressive strength of concrete decreased as the percentage replacement increased but replacement of sand by sawdust produced a higher percentage reduction in compressive strength than in density. Sawdust can potentially be used as aggregate in the production of both non-structural lightweight concrete and structural concrete. However, further research should be conducted to establish its suitability as aggregate in concrete

Keywords— compressive strength, concrete, sawdust, sawdust concrete

1 INTRODUCTION

Increasing population has created an urgent need for accelerated housing and infrastructural development in developing countries like Ghana. However, the rising costs of construction materials, dwindling material sources and environmental considerations have seriously affected the ability of both public and private organizations to meet this challenge. It has therefore become necessary to investigate non-traditional sources of materials for use in civil engineering construction. The use of wastes such as palm kernel shells, coconut shells, and sawdust in construction would help to reduce over reliance on traditional materials such as cement, sand and crushed rock aggregates whose exploitation has resulted in negative environmental consequences.

According to Turgut and Algin (2007), accumulation of unmanaged waste especially in developing countries has resulted in increasing environmental concerns whilst recycling of such waste as building materials appears to be a viable solution not only to such pollution problem but also to economic design of buildings.

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The use of waste materials in construction contributes to the natural resources conservation and environmental protection (Ramezanianpour et al, 2009). The main advantages of waste materials include preservation of virgin raw materials; re-use of waste and energy as well the development of sustainable concrete and construction of eco-friendly buildings (Bechio et. al., 2009).

The production of timber generates a lot of waste such as sawdust, wood shavings etc. most of which are not recycled but dumped or burnt in the open, thus impacting the environment negatively without any economic benefits.

Sawdust refers to the tiny sized and powdery waste produced by the sawing of wood (Maharani et al, 2010) .Sawdust is a highly variable material with differing particle size, chemical composition, density and colour (Ravidrajajah et al, 2001). It is principally composed of cellulose, hemicelluloses, lignin and extractives. Sawdust is used in the production of particle boards, charcoal briquettes, and also as fuel for cooking.

In an investigation on the use of sawdust as sand replacement to produce a low-cost and lightweight material for use in construction, Adebaku et al (2012) found out that at 10% sawdust replacement, production costs and weight reduced by 3% and 10% respectively. Usman et al (2012) found out that the strength of concrete reduced with sawdust as fine aggregate due to its higher rate of water absorption and the optimum replacement was 25%. Olutoge (2010) investigated the suitability of palm kernel shells and sawdust as replacements of crushed granite and sand respectively in the production of concrete.

Bechio et al. (2009) observed that increase in wood aggregate content reduces the weight of concrete by distinctly decreasing its density while compressive strength test indicates mechanical properties drop with decrease in density.

This study investigated the properties of concrete with sawdust as replacement of sand with a view to assess the use of sawdust concrete as a sustainable material.

2 M ATERIALS AND METHODS

Rapid hardening cement produced by Ghana Cement Factory at Takoradi in the Western Region of Ghana was used as the binder in this study. It conformed to the requirements of GS 22(2004).Water produced by Ghana Water Company was used in mixing materials for concrete production. It looked clean and free from any visible impurities, conforming to BS 1348(1980).Crushed granite used as coarse aggregate was obtained from a local quarry works. Sand was sourced from a local supplier in Cape Coast while sawdust was obtained from a local sawmill.
A concrete mix of ratio 1:2:4 by volume was used as control; to which the properties of the other mixes were compared. Sawdust was used to replace sand at percentages of 25%, 50%, 75% and 100% by volume. A water cement ratio of 0.55 was adopted. Concrete was produced by mixing the constituent raw materials in an electric concrete mixer. Twelve specimens of each mix were produced .Concrete was cast in cast iron moulds measuring 150mm150mm150mm internally. A total of sixty (60) specimens were produced in accordance with BS 1881(1996). After casting the moulds were covered with polythene sheets to prevent loss of water. Twenty four hours after casting, the specimens were demoulded and placed in a curing tank until the day of testing. The compressive strengths of the specimens were determined at 7, 14, 21 and 28 days of curing using a 1500kN Matest compression tester. On the day of crushing, the specimens were removed from the curing tank, wiped clean with a soft towel and placed on the floor of the laboratory for about two hours prior to crushing. The densities of the specimens were determined by weighing and calculation of volume. The results presented are the average value of three specimens of the same mix. All tests were conducted at the materials laboratory in the Department of Civil Engineering of Cape Coast Polytechnic.

3 RESULTS AND DISCUSSION

3.1 Compressive Strength

The results obtained from compressive strength testing are presented in Table 1.

Table 1 Compressive Strength (Nmm^{-2})

Percentage replacement	Age(days)			
	7	14	21	28
0	23.36	25.12	26.87	28.64
25	9.54	9.61	10.40	12.13
50	5.85	7.78	8.33	9.15
75	2.92	3.44	4.00	4.66
100	2.47	2.87	3.22	3.37

It is seen from Table 1 that for the control mix, the compressive strength of concrete increased from 23.36Nmm-2 at 7days to 28.64 Nmm^{-2} at 28days.The compressive strength at 25% replacement increased from 9.54 Nmm^{-2} at 7days to 12.13 Nmm^{-2} at 28days, while it increased from 5.85 Nmm^{-2} at 7days to 9.15 Nmm-2 at 28days.Similarly, at 75% replacement the compressive strength increased from 2.92 Nmm^{-2} at 7days to 4.66 Nmm^{-2} at 28days. At complete replacement the compressive strength increased from 2.47Nmm^{-2} at 7days to 3.37 Nmm^{-2} at 28 days.

Fig. 1 shows the variation of compressive strength with percentage replacement. It can be seen that at any percentage replacement of sand by saw dust the compressive strength of concrete increased with age. As the curing time increases, the reaction between cement and water continues thereby forming more C-S-H gel which improves the bond between the cement paste and the aggregates, thereby increasing the compressive strength. It is also seen that the compressive strength of concrete reduced as the saw dust content increased.

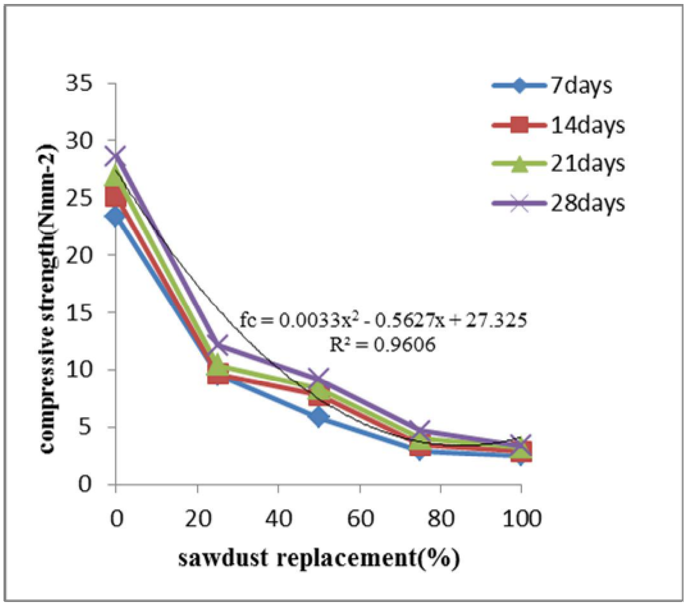

Fig. 1 Variation of compressive strength with percentage replacement of sand by sawdust

According to Vaidkelionis and Vaickelionene (2006), wood extractives slow down the hydration of cement. As the quantity of sawdust increases, the amount of wood extractives increases, thereby leading to further reduction in the rate of hydration of cement. Therefore, increasing the quantity of sawdust considerably decreased the compressive strength of cement stone. A percentage replacement of approximately fourteen percent (14%) can be used to produce grade 20 concrete, the minimum required for construction of structures whilst a replacement of 16% corresponds to the compressive strength of grade 17 concrete, the minimum required for production of structural lightweight concrete according to BS 8110(1997).

An equation of f_c=0.0033x^2-0.5627x+27.325 with an R^2 value of 0.960 may be used to represent the variation of the 28-day compressive strength of concrete (f_c) with sawdust replacement percentage (x) .A strong relationship therefore exists between the compressive strength and percentage replacement.

3.2 Density

Table 2 shows the results of average density of concrete specimens obtained from the tests. The density of concrete reduces as the sawdust content increases.

Table 2 Density (kgm^{-3})

Percentage replacement	Age(days)			
	7	14	21	28
0	2293	2297	2316	2331
25	2128	2145	2151	2192
50	1989	2004	2018	2041
75	1966	1973	1997	2005
100	1871	1889	1907	1913

The density of the control mix concrete increased from 2293kgm^{-3} at 7days to 2331kgm^{-3} at 28days.The density at 25% replacement increased from 2128kgm^{-3} at 7days to 2192kgm^{-3} at 28days, while it increased from 1989kgm^{-3} at 7days to 2041kgm^{-3} at 28days.Similarly, at 75% replacement the density increased from 1966 kgm^{-3} at 7days to 2038kgm^{-3} at 28days.At complete replacement, the density increased from 1871kgm^{-3} at 7days to 1913kgm^{-3} at 28 days. The density of concrete increased with age. The variation of the density with sawdust content at various ages is presented in Figure 2.

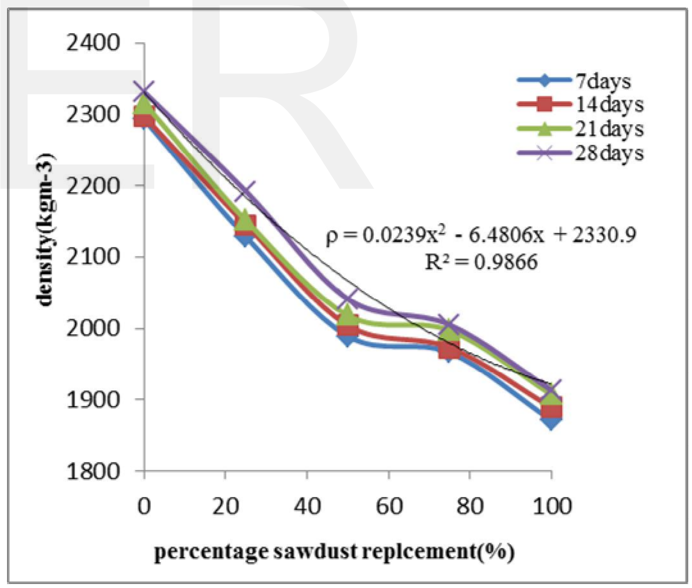

Fig. 2 Variation of density with percentage replacement of sand by sawdust

At all ages, the density of concrete decreased as the percentage replacement of sand by sawdust increased. The density of sand is higher than the density of sawdust, therefore as sand is replaced by an equal volume of sawdust the mass of the mixture reduced, leading to a decrease in density. An equation of ρ=0.0239x^2-0.6.4806x+2330.9 with an R^2 value of 0.9866 may be used to represent the variation of the 28-day density of concrete (ρ) with sawdust replacement percentage (x). This shows that a strong relationship exists between the compressive strength and percentage replacement

3.3 Compressive strength and density reduction

The percentage reduction in compressive strength and density is shown in Table 3.

Table 3 Percentage reduction in compressive strength and density

Percentage replacement	Density	Compressive strength
0	0	0
25	5.96	57.47
50	12.44	68.05
75	13.56	83.73
100	17.93	87.30

The percentage reduction in compressive strength at 25%, 50%, 75% and 100% replacements of sand by sawdust are 57.47%, 68.05%, 87.37% and 87.30% respectively. Similarly, the percentage reduction in density at 0%, 25%, 50%,75% and 100% replacements of sand by sawdust are 0%, 5.96%, 12.44%, 13.56% 17.93% respectively. The percentage reduction in 28-day compressive strength and density as a function of percentage replacement of sand by sawdust is shown in Figure 3.

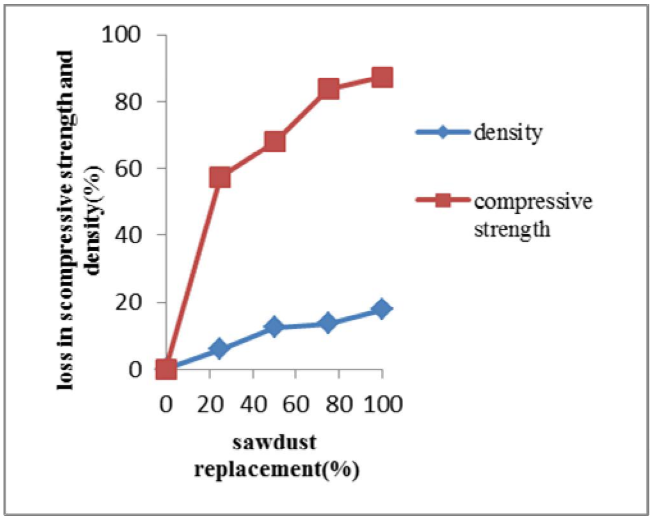

Figure 3 Percentage reduction in compressive strength and density

It is seen that the percentage loss of both compressive strength and density increased as the percentage replacement of sand by sawdust increased.

Replacement of sand by sawdust produced a higher percentage reduction in compressive strength than in density. Sand therefore be replaced by sand in situation where strength is not a major requirement.

4 CONCLUSION AND RECOMMENDATIONS

In this study the effects of the replacement of sand with sawdust on the strength and density were investigated. Based on the results obtained, the following conclusions are drawn:

- The compressive strength and density of concrete reduced as the percentage replacement of sand by sawdust increased.
- The effect of sawdust on the strength of concrete was more pronounced than the effect on the density of concrete.
- Sawdust concrete can potentially be used in situations where compressive strength is not a major requirement.
- A percentage replacement of at least 14% can potentially be used in producing structural concrete.
- Sawdust can potentially replace 16% of sand in the production of structural lightweight concrete.
- Since sawdust may be obtained at virtually no cost, the cost of concrete can potentially be reduced by replacing sand with sawdust in concrete.

Further studies should be conducted on the potential of sawdust as replacement of sand in the production of structural concrete.

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