Original Research Article

Effect of Sawdust and Coconut Shell on the Mechanical Properties of Concrete

ABSTRACT

The increased demand for infrastructure due to global population growth has resulted in the depletion of natural aggregate sources and the escalation in the cost of building materials. There is also the problem of environmental pollution as a result of wastes generated from agricultural activities. This has led to various studies aimed at investigating the use of waste materials as substitutes for natural aggregates in concrete. In this research, sawdust (SD) And coconut shell (CS) were used as partial replacements for fine and coarse aggregates respectively in concrete. Concrete cubes, cylinders and prisms were cast and tested for compressive, split-tensile and flexural strengths at 0% (control), 10%, 20%, 30% and 40% replacement of sand and granite by weight with SD and CS respectively, after curing in water for 7, 14 and 28 days. The results showed that as SD and CS increased in the matrix, the concrete's compressive, split-tensile and flexural strengths decreased. The modified mixes can however be used as economic alternatives for lightweight concrete production.

Keywords: sawdust, coconut shell, concrete, strength

1. INTRODUCTION

Concrete typically made up of cement, sand, crushed rock (granite) and water, is the most widely used construction material globally owing to its ability to withstand large compressive stresses [1]. The increasing demand for infrastructure due to global population increase has escalated the demand for aggregates resulting in the rapid depletion of natural aggregate sources [2]. As the construction industry relies heavily on conventional materials such as cement, granite and sand for the production of concrete, the costs of these materials have escalated, hindering the development of shelter and other infrastructural facilities in developing countries. The disposal of wastes generated from agricultural and industrial waste in the environment has been brought to the fore in the last few decades due to the environmental impact arising from these activities. In the last decade, there has been increased global agitation on the need for green construction [3].

There arises the need for the engineering consideration of the use of cheaper and locally available materials, as well as agricultural and industrial wastes to meet desired needs, enhance self-efficiency, and lead to an overall reduction in construction cost for sustainable development, improved environmental waste management and profitable utilization of wastes [4].

Sawdust (SD) and coconut shells (CS) are waste materials generated mainly from furniture-making and agricultural industries. Disposing of and burning these wastes in the environment results in environmental pollution. Researchers have carried out separate investigations to ascertain the suitability of using SD as a substitute for fine aggregates and CS as a substitute for coarse aggregates in the production of concrete. The use of SD as a substitute for fine aggregates in concrete has been reported to result in a decrease in density, compressive and split-tensile strengths, increase in capillary water absorption, water penetration, chloride permeability, and improved workability and resistance to sulphate attacks [2, 5-9]. The use of CS as a substitute for coarse aggregates in concrete is also reported to result in a decrease in workability, density, compressive and split-tensile strengths [10-12].

The current study evaluated the effect of simultaneously substituting fine and coarse aggregates with SD and CS respectively on the mechanical properties of concrete.

2. MATERIALS AND METHODS

2.1 Materials

The following materials were sourced and used in the study:

2.1.1 Cement

Portland-Limestone Cement, CEM II/B-L, Grade 42.5, manufactured in conformity to Nigerian Industrial Standard (NIS) 444-1 [13], was used for this research. The cement was purchased in Ibadan, Nigeria.

2.1.2 Sand

Sharp river sand (purchased in Ibadan, Nigeria) that is free of clay, loam, dirt and any organic or chemical matter and a maximum size of 4.75mm was used for this research. The properties of the sand are presented in Table 1.

Table 1. Properties of Aggregates Used

Property	Sand	Sawdust	Granite	Coconut Shell
Specific gravity	2.65	0.91	2.75	1.35
Fineness modulus	2.41	2.11	-	-
Water absorption (%)	0.9	39.35	0.47	15.52
Density (Kg/m^3)	1460	625	1590	780
Shell thickness (mm)	-	-	-	2-7

2.1.3 Sawdust

The SD used for this research was sourced from furniture workshops in Ibadan environs. It was sieved and a maximum size of 4.75mm was used for this research (see Figure 1). The SD was put in sacks and thoroughly flushed with water to remove dirt and impurities, after which they were sun-dried. Table 1 presents the properties of the sawdust.

Fig 1. Sieving of sawdust

2.1.4 Coarse Aggregates

Crushed granite coarse aggregates of 19 mm maximum size, free from impurities such as dust, clay particles organic matter, etc., purchased in Ibadan, Nigeria, was used for this research. The properties of the granite are presented in Table 1.

2.1.5 Coconut Shell

Coconut shells collected from Bodija market, Ibadan, Nigeria were used for this research. It was sieved and a maximum size of 19mm was used for this research (see Figure 2). The CS were put in baskets and thoroughly flushed with water to remove dirt and impurities. They were sun-dried and broken into smaller sizes manually. The surface texture of the shell was fairly smooth on concave and rough on convex faces. Table 1 presents the properties of the coconut shells.

Fig 2. Sieving of coconut shells

2.1.6 Water

Potable water supply at the Civil Engineering Department, University of was used for this research.

2.2 Experimental Investigation

Experimental investigations were carried out to evaluate the strength properties of concrete mixes in which fine aggregates (sand) and coarse aggregates (granite) were partially replaced with SD and CS respectively. The compressive, split-tensile and flexural strength of the specimens after replacing the sand and granite with SD and CS at 0% (control), 10%, 20%, 30% and 40% by weight were investigated after 7, 14 and 28 days of curing. Concrete cubes (100 mm X 100 mm X 100 mm), concrete cylinders (Φ100 mm X 200 mm) and concrete prisms (100 mm X 100 mm X 500 mm) were cast for the conventional mix as well as other mixes.

2.2.1 Mix proportioning

The concrete mix design was proposed to achieve the compressive strength of 30N/mm^2 after curing for 28 days in the case of cubes, cylinders for split-tensile strength and prisms for flexural strength. The concrete mix proportion was 1:2:4 (i.e., cement: fine aggregates: coarse aggregates) with a water/cement ratio of 0.55. Table 2 shows the proportions of materials used for the various concrete mixes.

Table 2. Concrete Mix Proportions Used

Mix ID	% SD & CS	Cement (Kg/m^3)	Sand (Kg/m^3)	Sawdust (Kg/m^3)	Granite (Kg/m^3)	Coconut Shell (Kg/m^3)	Water/Cement Ratio
C1	0	15	30	0	60	0	0.55
R10	10	15	27	3	54	6	0.55
R20	20	15	24	6	48	12	0.55
R30	30	15	21	9	42	18	0.55
R40	40	15	18	12	36	24	0.55

2.2.2 Casting and Testing of Specimens

A total of 135 specimens were cast, 9 specimens each for the control mix and modified concrete mixes were cast for compressive, split-tensile and flexural strength tests respectively, and cured in water. Casting, compaction and curing of the specimens were conducted in conformity with B.S. EN 12390 [14-15]. Testing of the specimens for density was carried out according to BS 812-2 [16] specifications while compressive, split-tensile and flexural strength tests was carried out in conformity with B.S. EN 12390 [17-19] at the Material Testing Laboratories of the Civil Engineering Department and the Agricultural and Environmental Engineering Department, University of Ibadan, Ibadan, Nigeria. The compressive, split-tensile and flexural strengths were recorded at 7, 14 and 28 days of curing. Figure 3 shows a prism specimen been tested for flexural strength.

Fig 3. Prism specimen undergoing flexural test

3. RESULTS AND DISCUSSION

3.1 Density

The results of the density test are shown in Figure 4. The results reveal that the density of the various concrete mixes increased as the number of days of curing increased. However, it was observed that as the percentage of replacement of sand and granite with SD and CS in the matrix increased, the density of concrete reduced. On the 28th day, the control mix had the highest density (2805 kg/m^3) while the mix having 40% replacement recorded the lowest density (2120 kg/m^3), which is a 24.42% decrease. The decrease in density can be attributed to the lesser specific gravity and bulk density of SD and CS when compared with sand and granite respectively. When SD and CS displace sand and granite respectively in the matrix, the density of concrete will be reduced.

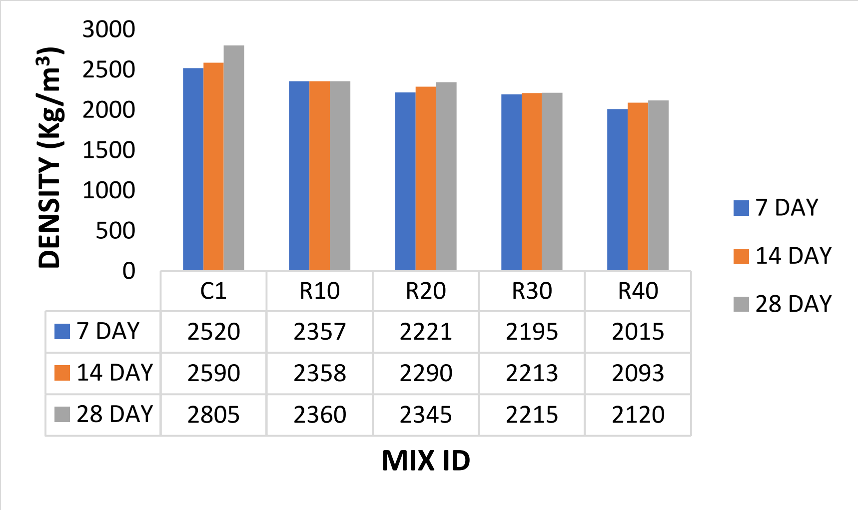


Fig 4. Average density of specimens

3.2 Compressive Strength

The results of the compressive strength test are shown in Figure 5. From the results obtained, the compressive strength of the various mixes increased as the curing duration increased. The compressive strength, however, reduced as the percentage of SD and CS in the matrix increased. The highest compressive strength obtained after 28 days of curing was 31.20N/mm^2 (control) while the lowest was 19.07 N/mm^2 (40% replacement), which is a 38.88% decrease. The reduction in compressive strength may be attributed to the reduction in the density of the mixes, as density is a major factor that influences the compressive strength of materials. SD and CS have high water absorption rates compared to sand and granite; hence, they will consume much of the water needed for the hydration of cement leading to reduced compressive strength. Also, the fibrous nature and surface texture of SD and CS would affect proper bonding and cohesion of the mix as the volume of voids will increase leading to reduced compressive strength. This aligns with the findings of Deraman *et al.* [8] and Azunna *et al.* [11].

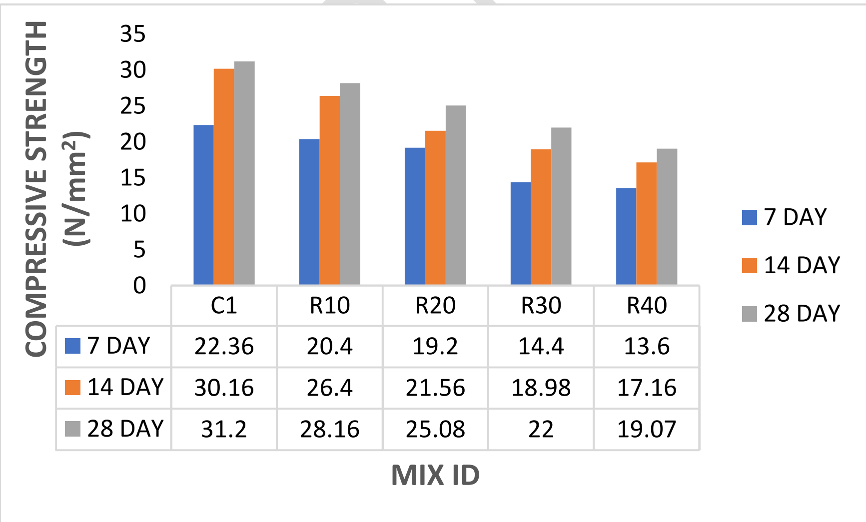
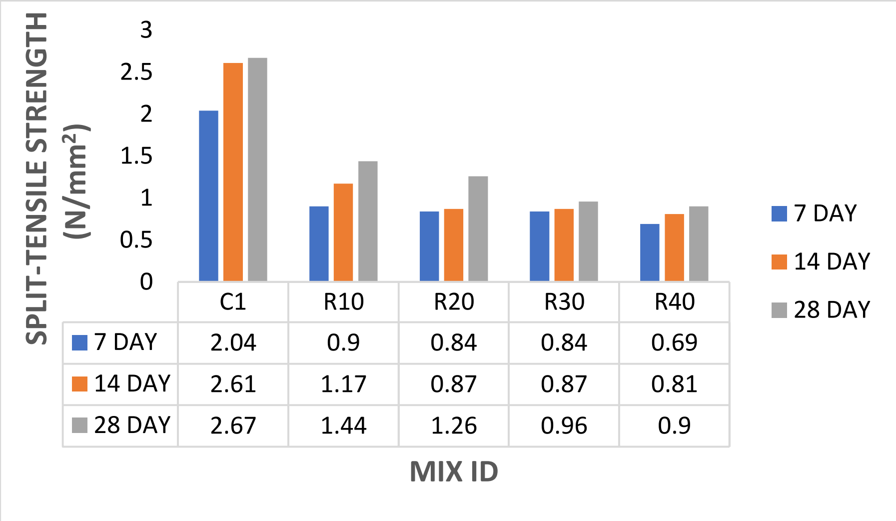


Fig 5. Average compressive strength of specimens

3.3 Split-tensile Strength

The results of the spilt-tensile strength test are shown in Figure 6. Just like the compressive strength test results, a similar trend is observed for the split-tensile strength. As the proportion of SD and CS increases in the matrix, the split-tensile strength decreases. There was however a very sharp decrease in the split-tensile strength when the control specimen is compared to that 10% replacement. The highest spilt-tensile strength obtained after 28 days of curing was 2.67N/mm^2 (control) while the lowest was 0.90 N/mm^2 (40% replacement), which is a 66.29% decrease. This may also be attributed to the surface texture of SD and CS which affects proper bonding and cohesion of the mix.

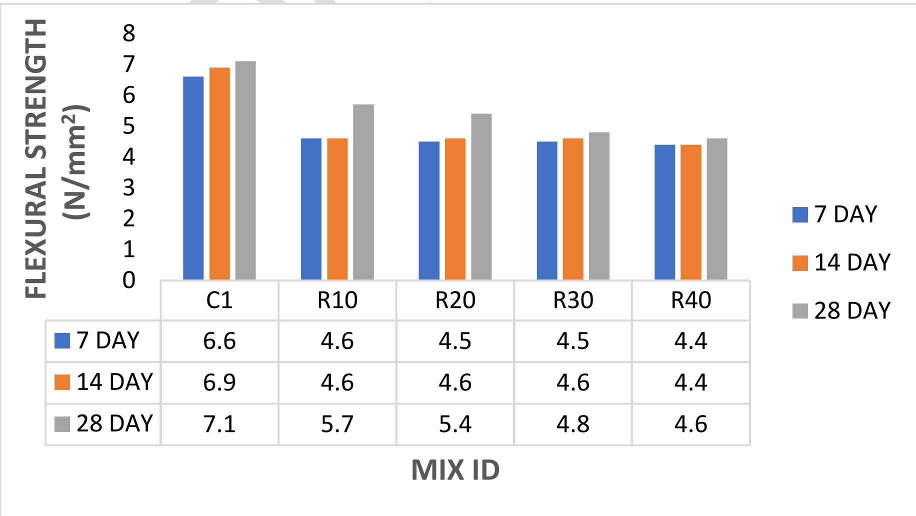


	C1	R10	R20	R30	R40
7 DAY	2.04	0.9	0.84	0.84	0.69
14 DAY	2.61	1.17	0.87	0.87	0.81
28 DAY	2.67	1.44	1.26	0.96	0.9

Fig 6. Average split-tensile strength of specimens

3.4 Flexural Strength

The results of the flexural strength test are shown in Figure 7. Just like the compressive strength test results, a similar trend is observed for flexural strength. As the proportion of SD and CS increases in the matrix, the flexural strength decreases. It was observed that for all the mixes there was marginal increase in the flexural strength between the 7th and 14th day of curing. The highest flexural strength obtained after 28 days of curing was 7.10N/mm^2 (control) while the lowest was 4.60 N/mm^2 (40% replacement), which is a 35.21% decrease. This may also be attributed to the surface texture of SD and CS which affects proper bonding and cohesion of the mix.



	C1	R10	R20	R30	R40
7 DAY	6.6	4.6	4.5	4.5	4.4
14 DAY	6.9	4.6	4.6	4.6	4.4
28 DAY	7.1	5.7	5.4	4.8	4.6

Fig 7. Average flexural strength of specimens

3.5 Cost Analysis

The cost of 1m^3 of concrete for the various mixes is presented in Table 3. The cost analysis shows that as the proportion of SD and CS in the matrix increased, the cost per cubic metre of concrete reduced. This is because SD and CS are readily available at no cost. Therefore, the use of SD and CS in concrete production will be more affordable and cost-effective, especially for lightweight concrete.

Table 3. Cost of Concrete Mixes

Mix ID	% SD & CS	Cement (₦)	Sand (₦)	SD (₦)	Granite (₦)	CS (₦)	Cost of 1m^3 Concrete (₦)	% Cost Reduction
C1	0	9900	2700	0	9000	0	21600	-
R10	10	9900	2430	0	8100	0	20430	5.42
R20	20	9900	2160	0	7200	0	19260	10.83
R30	30	9900	1890	0	6300	0	18090	16.25
R40	40	9900	1620	0	5400	0	16920	21.67

4. CONCLUSION

In this research, sawdust (SD) and coconut shell (CS) were used as partial replacements for fine and coarse aggregates respectively in concrete. The following conclusions can be drawn from the results obtained from this experimental investigation:

1. The use of sawdust and coconut shells in concrete will reduce environmental pollution, and improve waste management and profitable use of wastes.
2. Sawdust and coconut shells can be incorporated into concrete matrices for lightweight concrete production.
3. When compared with conventional concrete, the concrete produced incorporating sawdust and coconut shells is more economical for lightweight concrete production.

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