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Original Research Article

Evaluating the Compressive Strength of Wood Shavings - Cassava Starch - Sodium Chloride Hybridized Concrete

Ikoko, O[1*], Bratte, A. G[2], Akpokodje, O. I[3]

[1]Department of Agricultural and Bio-Environmental Engineering Technology, Delta State Polytechnic, Ogwashi-Uku, Nigeria
[2]Department of Agricultural Engineering, Delta State University of Science and Technology, Ozoro, Nigeria
[3]Department of Civil and Water Resources Engineering, Delta State University of Science and Technology, Ozoro, Nigeria

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***Corresponding author:** Ikoko, O

Abstract

There is a quest and a sustained interest in environmentally friendly and sustainable building materials for farm structures, as well as general building construction, due to availability of suitable industrial materials, by-products and wastes, to which additional value can be provided in their utility and management. The suitability of using wood shavings as partial replacement for fine aggregate in concrete production, using cassava starch and sodium chloride (NaCl) as admixture was investigated in this study. The concrete was produced with a mix ratio of 1:2:4, and partial replacement of the fine aggregate with wood shavings, at the rate of 0%, 1.25%, 2.5%, 3.75%, 5%, 6.25%, and 7.5% (wt. of fine aggregate). Furthermore, cassava starch (2% by weight of the cement) and NaCl (1% by weight of the cement) were used as admixture. Results obtained from the slump and compression tests depicted that, the slump of the fresh concrete and the compressive strength of the harden concrete decreased non-linearly as the wood shaving volume increased from 0% to 7.5%. The findings of this study revealed that both the cassava starch and NaCl increased the slump properties of the fresh concrete, and compressive strength of the harden concrete, irrespective of the volume of wood shavings incorporated. Additionally, the results depicted that the hybridized concrete produced with wood shavings, cassava starch and NaCl had higher compressive strength, when compared to the hybridized concrete produced with only wood shavings and cassava starch. Results obtained from this study had affirmed that low volume of wood shavings, cassava starch and NaCl can be used for the production of plain concrete for farm structures, mostly in areas where metallic reinforcement materials are not required.

Keywords: Cassava starch, compressive strength, hybridized concrete, sodium chloride, wood shavings.

INTRODUCTION

Many farm structures used for various farm operations are constructed with concrete, mostly their foundations, beams, floors, columns, etc. Concretes are widely used in the construction of structures because of their ability to be moulded into different integrate shapes and their sizes, and relatively high compressive strength. It is important that concretes that are used for farm structures to have appreciable compressive strength, low density and good flexural strength, in order to avoid structural failures in these structures (Alengaram *et al*., 2011; FAO, 2011; Agbi *et al*., 2020). According to the Food Agricultural Organization (FAO), any material that is be used for the construction of farm structures must have appreciable compressive strength and stability; water, thermal and fire resistance abilities; sound insulation properties, etc. (FAO, 1988). Concrete compressive strength is influenced by the water-cement ratio, cement-sand mix ratio, the physical characteristics of the fine and coarse aggregates used, volume of fine and coarse aggregates used, curing method, admixture added, etc. The utilization of very low cement-sand-gravel mix ratio (≥ 1:8:16) in concrete production, will generally lead to poor bonding between the cement, sand and the gravel, due to poor densification of the tobermorite gel formed. Conversely, the addition of suitable admixture can help to enhance the mechanical properties of concrete produced from it (Akpokodje and Uguru, 2019; Akpokodje *et al.*, 2020; Akpokodje *et al.*, 2021a).

The need to enhance the mechanical properties of concrete with suitable agricultural (or organic) materials can hardly be overstressed, because these agricultural materials are environmental friendly, cost effective and readily available (Waziri *et al*, 2011; Uguru and Uyeri, 2018; Akpokodje *et al*., 2021b). According to Akpokodje *et al*. (2021b) cassava starch solution helped to increase the compressive and flexural strengths of concrete produced from it. Furthermore, the authors (Akpokodje *et al*., 2021b) reported that a low volume (2% of the coarse aggregate) of wood shavings can be used for concrete production, provided that the structures where the concretes are used are not subjected to harsh environmental conditions, such as high moisture and thermal levels. According to Nagesh (2012) concrete's durability and stability are affected by physical, chemical and biological conditions, such as: weather conditions (temperature and moisture levels), attack by natural or industrial effluents/gases or biological agents, abrasion, etc.

Tiwari *et al*. (2014) reported that concrete casted and cured with sodium chloride solution (38 g/L) developed higher compressive strength after 28 curing days, compared to the compressive strength of the concrete produced and cured with fresh water. According to Akpokodje *et al*. (2020), the compressive strength of concrete produced with fresh cassava root effluent had higher compressive strength, compared to the compressive strength of the concrete made from fresh water at 56 curing days; which was attributed to the high starch content and low organic acid (hydrocyanic acid) content of the fresh cassava root effluent. According to Akindahunsi and Uzoegbo (2015), cassava starch was able to reduce the rate of water absorption in concretes, as concretes made with cassava starch had lower water absorption rates, compared to the concretes made without cassava starch. Purnomo *et al*. (2019) reported that concrete produced with 0.15% citric acid developed a higher compressive strength, compared to concrete produced with fresh water at 28 curing days; but as the citric acid concentration increased from 0.15% to 0.45%, the compressive strength of the concrete declined from 48.46 MPa to 29.70 MPa.

According to Agbi and Uguru (2021), the introduction of 1% (wt. of cement) in cassava starch powder was able to enhance the compressive strength of paper pulp reinforced sandcrete blocks. At 28 curing days, sandcrete blocks produced with 10% and 20% (wt. of the fine aggregate "sharp sand") in paper pulp and cassava starch, recorded compressive strengths of 2.65 MPa and 2.32 MPa, respectively. In contrast, the sandcrete blocks produced with 10% and 20% paper pulp and no cassava starch powder, recorded lower compressive strengths of 1.81 MPa and 1.52 MPa, respectively, at 28 curing days. Agbi and Uguru (2021) further reported that the sandcrete blocks produced with cassava starch powder recorded lower water abortion rates and density, when compared to results obtained from sandcrete block produced without cassava starch power. According to Akpokodje *et al*. (2018) cassava root starch dissolves in soil moisture to forms a solution, which decreases the soil's porosity. This invariably increases the impermeability of the soil (and particulate materials generally); hence, decreasing the ability of the concrete made from such materials from absorbing moisture from the environment.

Several literatures (Mohammed *et al.*, 2014; Oyedepo *et al*., 2014; Sotiropoulou *et al*., 2017; Nurul *et al*., 2019; Akpokodje *et al*., 2021b) have reported on the suitability of using wood products as partial or total replacement for fine or coarse aggregates in concrete production. However, literature search on the application of both cassava starch and sodium chloride (NaCl) as admixtures in concrete production yielded no result. Therefore, the main aim of this work is to evaluate the suitability of using wood shavings as partial replacement for fine aggregate in concrete production, and employing cassava starch and NaCl as admixtures.

MATERIALS AND METHODS

Materials

Fine aggregate (River bed sand "Sharp sand")

The river bed sand was obtained from of River Ase, one of the tributaries of River Niger in Delta State, Southern Nigeria.

Coarse aggregate

Coarse aggregate employed was conventional crushed granite (20 mm gauge size).

Portland limestone cement

Dangote cement brand, with standard cement grade strength of 42.5 MPa.

Wood shavings

These were obtained from a local sawmill in Oleh, Delta State, Nigeria.

Cassava starch and sodium chloride

The cassava starch and sodium chloride (NaCl) were procured from a local market at Ozoro, Delta State of Nigeria.

METHODS

Mix ratio

For the purpose of this study, a mix ratio of 1:2:4 (C15) and volumetric batching method was used. A water-cement ratio of 0.6 was also adopted. The high water-cement ratio was taken, due to the high water absorptive nature of the dried wood shavings. Research works of previous authors (Sotiropoulou *et al.*, 2017; Akpokodje *et al.*, 2021b) indicated that concrete produced with wood materials as partial replacements (for aggregates) and low water-cement ratios had a very poor workability (slump).

Concrete Production

The concrete was produced by partial replacement of the sharp sand with wood shavings, at the rate of 0%, 1.25%, 2.5%, 3.75%, 5%, 6.25%, and 7.5% (wt. of the sand). The weight of wood shavings and fine aggregates in the concrete produced are shown in Table 1.

Table 1: Weight of sand replacement

Wood shavings		Weight of sand (kg)
Wt. (kg)	**% of sand replacement**	
0	0	40
0.5	1.25	39.5
1.0	2.5	39.0
1.5	3.75	38.5
2.0	5	28.0
2.5	6.25	37.5
3.0	7.5	37.0

To actualize the aim of this study, three sets of concrete was produced.

i. The first set of concrete was produced with only wood shavings, and was coded "CS";
ii. The second set of concrete was produced with wood shavings and cassava starch (2% by weight of the cement), and was coded "CSS";
iii. The third set of concrete was produced with wood shavings, cassava starch (2% by weight of the cement) and NaCl (1% by weight of the cement), and was coded "CST".

All the sets of concretes were cast in standard moulds (size: 150 mm x150 mm x 150 mm). During the concrete production, the constituents were mixed thoroughly and poured into the prepared moulds, rammed for 75 times, leveled with a hand trowel. These were covered and left under a shaded environment for 24 hours, after which they were removed from the moulds and cured by total immersion in water, as described by Akpokodje *et al.* (2021).

Laboratory test

Slump test of the fresh concrete was carried out in accordance with procedures recommended by ASTM C143 (2020). The compressive strength of the concrete cubes was determined in accordance with ASTM C109/C109M (2020), recommended procedures. Compressive strength of each concrete cube was calculated by using the expression shown in Equation 1 (Esegbuyota *et al.*, 2020).

$$Compressive\ strength = \frac{F}{A} \qquad \ldots\ldots\ldots\ldots\ldots 1$$

Where:
F = Crushing force (N)
A = Net area of concrete cube (mm^2)

RESULTS AND DISCUSSION

Concrete slump

The result of the slump of the fresh concrete is presented in Table 2. As given in Table 2, the slump decreased continuously, in the three sets of concrete, as the quantity of wood shavings increased from 0 kg to 3 kg. This is similar to results of the study carried out by Sotiropoulou *et al.*, (2017). Sotiropoulou *et al.*, (2017) reported that the slump obtained from mortar produced with wood shavings as partial replacements, decreased non-linearly as the volume of wood shaving volume increased from 30% to 70%. Likewise, Akpokodje *et al.*, (2021) observed that the slump of fresh concrete produced with wood shavings as admixture, decreased monotonically as the volume of wood shavings increased from 0 kg to 4 kg.

Test results further revealed that both the cassava starch and NaCl had appreciable effects on the slump of the fresh concrete. The slumps of the CSS and CST concretes were higher, when compared to the slump of the CS concrete, irrespective of the volume of wood shavings incorporated into the concrete. This depicted that both the cassava starch and NaCl combined, acted as concrete workability enhancers, by increasing the slump of the fresh concrete. Similar results were obtained by Abalaka and Babalaga (2011), in which NaCl solution enhanced the slump of concrete produced with rice husk ash (RHA), and the value of the slump declined from 25 mm to 5 mm, as the RHA content increased from 0% to 30%. The poor concrete slump value obtained at high organic material content could be attributed to the hygroscopic nature of such materials. As such, these organic materials will absorb water from the fresh concrete, consequently lowering the quantity of water made available for initial lubrication between particles and subsequent hydration of the cement in the concrete (Mohammed *et al.*, 2014; Akpokodje *et al.*, 2021).

Table 2: The fresh concrete slump

Wood shavings (kg)	CS (mm)	CSS (mm)	CST (mm)
0	27.34	33.17	34.83
0.5	21.15	25.09	27.45
1	14.15	18.68	20.03
1.5	9.42	13.18	14.85
2	5.04	7.21	9.08
2.5	0.82	3.52	4.24
3	0	1.03	1.22

Compressive strength

The compressive strength of the concrete produced from the different volumes of wood shavings is presented Figure 1. As presented in the plot in Figure 1, the CS concrete had the lowest compressive strength, regardless of the volume of wood shavings, at curing day 28; while the CST concrete had highest compressive strength, regardless of the wood shavings volume, at curing day 28. It was observed from the results that the CSS concrete developed a compressive strength that was higher than the CS concrete, but relatively lower than the CST concrete, at curing day 28. The findings of this study portrayed that both cassava starch and NaCl, enhanced the compressive strength of concrete produced from them. According to Akindahunsi and Uzoegbo (2015) and Akpokodje *et al*., (2021b), cassava starch has the ability of increasing the compressive strength of concrete; hence it can be adjudged as a green admixture. Similar results trend were obtained by Agbi and Uguru (2021) and Abalaka (2011), in which concrete produced with cassava starch had better (higher) compressive strength, when compared to the concrete produced without cassava starch, after 28 curing days. In a related development, Tiwari *et al*., (2014) stated that low concentration of NaCl can be used to improve the compressive strength of concrete, provided there is no metallic reinforcement material(s). This is because in that related research the compressive strength (41.34 MPa) of concrete produced with low concentration of NaCl was slightly higher, when compared with the compressive strength (39.12 MPa) of concrete produced fresh water, after 28 curing days. Abalaka and Babalaga (2011) reported that NaCl had adverse effect on concrete during aging, by lowering its compressive strength. This could be attributed to the high concentration of NaCl solution (5% - 10%) used by Abalaka and Babalaga (2011), which is in contrast to the low NaCl solution (1%) used in this study and 2% - 6% NaCl solution used by Tiwari *et al*., (2014) and Oladapo and Ekanem (2014)

Furthermore, the results portrayed that the concrete compressive strength declined non-linearly, with an increase in the volume of the wood shavings, regardless of the quantum of admixtures introduced into it. This phenomenon could be ascribed to the poor mechanical properties of the wood shavings. According to Stasiak *et al*., (2015), the modulus of elasticity of wood shaving ranged between 0.25 MPa and 0.33 MPa, and it is influenced by the moisture content of the wood shavings. As shown in Figure 1 and Table 1; the compressive strength of the CS concrete decreased from 29.13 MPa to 13.27 MPa, as the volume of wood shavings increased from 0% to 7.5% (by the weight of the fine aggregate); while the compressive strength of the CSS concrete decreased from 31.74 MPa to 14.05 MPa, as the wood shavings volume increased from 0% to 7.5%; and the compressive strength of the CST concrete decreased from 34.89 MPa to 15.54 MPa, as the wood shavings volume increased from 0% to 7.5%. Mohammed *et al*., (2014) observed a similar decline in the compressive strength of concrete produced from wood chippings, as the volume of the wood chipping increased from 0% to 30%; irrespective of the water-cement ratio adopted.

The results of this study affirmed that concrete can be produced with wood shavings, as a substitute for fine aggregate, and its strength enhanced with suitable admixtures. The study depicted that hybridization of green admixture was be used to enhance the compressive strength of concrete. As portrayed by the study's findings, concrete produced with up to 6.25% wood shavings as partial replacement for fine aggregates, in the presence of cassava starch and NaCl, developed compressive strength that fell within the range recommended (17 MPa) by the Standard Organisation of Nigeria (SON) for concrete to be used for residential building construction and related farm structures. Although NaCl which is one of the major constitutes used for this study is reactive to metallic reinforcement, the concrete produced can be useful in structures where metallic reinforcements are not required.

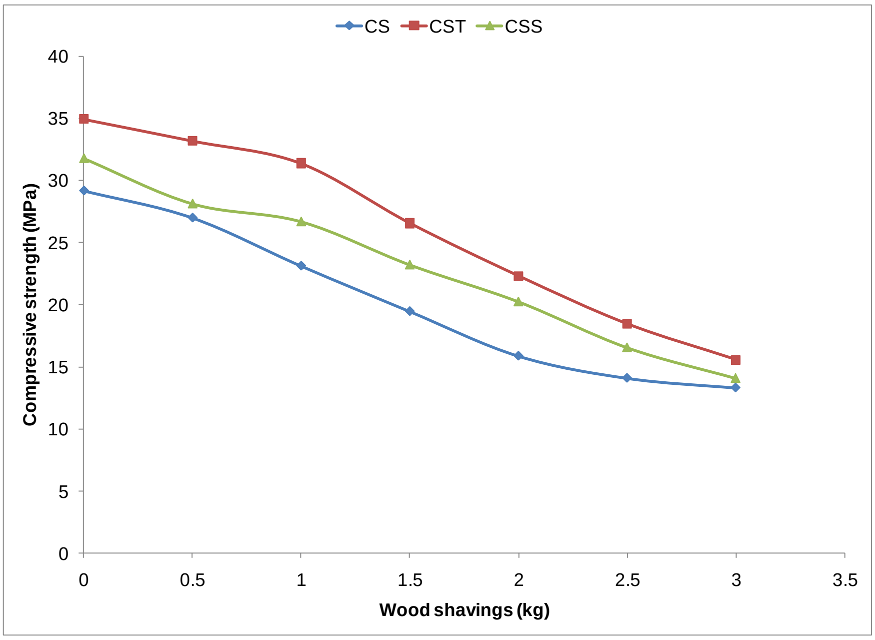

Figure 1: The compressive strength of the harden concrete at curing day 28

CONCLUSION

Series of laboratory research tests were conducted to evaluate the possibility of using wood shavings, as a sustainable material for the production of concrete mainly for the construction of farm structures and other related structures. The concrete was casted with wood shavings as partial replacement for fine aggregate, using cassava starch and NaCl as additional admixtures. The mechanical properties of the concrete produced were tested in accordance to ASTM International approved procedures. Based on the result obtained from the laboratory tests, the following conclusions can be drawn:

i. The concrete slump declined non-linearly as the quantity of wood shavings increased, irrespective of the admixtures added.
ii. The cassava starch and NaCl increased the workability of the fresh concrete, and the compressive strength of the harden concrete.
iii. The concrete compressive strength decreased monotonically as the wood shavings quantity increased, irrespective of the admixture added.
iv. Fine aggregate can be substituted with wood shavings for concrete production in farm structures and residential buildings.
v. Low concentrations of cassava starch and NaCl can be used as admixtures in plain concrete production.

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