ISSN: 2754-4982

Journal of Civil Engineering Research & Technology

Scientific Research and Community

Research Article

Open Access

Properties of Laterized Concrete Incorporating Sawdust Ash as A Partial Replacement for Cement

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ABSTRACT

Ordinary Portland cement (OPC), the main binder in concrete, is the most expensive component and the major contributor to the embodied carbon of the composite. This necessitates alternative eco-friendly materials such as waste, with comparative binding properties as a part replacement for OPC to have economic and sustainable concrete production with minimal hazardous impact on the environment. This study uses Sawdust Ash (SDA) which is a waste product of the wood milling industry, to replace some proportion of OPC in concrete. To further reduce the cost and negative environmental impact of concrete, laterite was used to replace river sand, and fresh and hardened properties were investigated. The fresh property evaluated in this study is the slump, while the hardened properties investigated are the density and compressive strength. This study showed the viability of successfully incorporating SDA as a partial replacement of OPC and laterite soil to replace the conventional fine aggregate. An acceptable slump and compressive strength can be achieved using 10% SDA and 45% laterite as partial replacement of OPC and river sand, respectively.

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Received: May 06, 2022; **Accepted:** May 12, 2022; **Published:** May 19, 2022

Keywords: Compressive Strength, Laterized Concrete, Sawdust Ash, Sustainability

Introduction

The production of concrete in large quantities for different applications worldwide is a major sustainability concern [1]. This detrimental effect on the environment results from the high emission produced during the production of the major binder (i.e., ordinary Portland cement) in concrete. An equivalent amount of carbon dioxide is emitted into the environment just o produces 1 tonne of ordinary Portland cement (OPC). In addition, OPC is the most expensive and energy-intensive component in concrete. As more rapid development will ensue in the coming years in rural areas and developing countries, more production of OPC and corresponding emission is anticipated. Therefore, to ensure that future constructions in these areas are economical, resilient, and sustainable, it is paramount to find alternative locally available materials that can be used to replace OPC and other materials in concrete.

Several studies have explored using different materials as partial replacement of OPC. However, most of these materials are industrial by-products such as slag, silica fume, fly ash, rice husk ash [2-4]. However, some of these materials are not locally available in rural areas of developing countries. For constructions in these areas to be sustainable conscious, alternative readily available waste materials from the agricultural industry can be utilized [5-8]. This study explored possible locally available materials that can be used to produce eco-friendly concrete in rural areas of Nigeria. One of the materials that can replace OPC, readily available in these areas, is sawdust ash (SDA). SDA is obtained by burning at a specific high temperature the sawdust, which is a solid waste product of timber milling. The use of SDA as a partial replacement for OPC not only proffers an alternative binder but also helps to manage the detrimental waste that is a major environmental threat in these areas and as well mitigate greenhouse emissions caused by the production of cement [8].

The emergence of Laterized concrete can be traced back to the 1970s, when the pioneering researcher, published many researches works on laterized concrete and currently still gaining expanding interest from many researchers because of its strength characteristics and sustainable prospects [9-13]. Some studies have explored the use of SDA as a partial replacement of OPC in concrete, and even some studies utilized SDA and laterite as aggregate in concrete [8,14-17]. However, to the best of the authors' knowledge, there is a limited to no study on using SDA to replace OPC in laterized concrete partially. Therefore, the study explored the major engineering properties of laterized concrete incorporating SDA alongside determining the optimum mix for the components. SDA normal-weight as a partial replacement of OPC, and laterite is used to replace the conventional fine aggregate partially. This research is innovative as it investigates the viability of using locally available materials as components in concrete. It is anticipated that this study will open more pathways for research and the application of sustainable building materials. It is also hoped that this research will propel more economical and sustainable development in rural areas and developing countries.

Methodology

Type 1 OPC was used as the main binder, and it complies with ASTM C150. The chemical compound of the cement is shown in Table 1 as obtained from the manufacturer. SDA was used as a partial replacement of OPC in the range of 0 to 15% at increments of 5%. The OPC is obtained from a local building supplier, and the sawdust was obtained from Itamaga and Ijebu ode sawmill plants. After retrieving the sawdust from the local sawmill plant, it was burnt in the open air for 48 hours to obtain the ash (i.e., SDA). The SDA was sieved to obtain particles passing through the 75µm sieve, and the observed color of the SDA was greyish.

Granite was used as the only coarse aggregate in all mixtures while laterite is used as a partial replacement of river sand as fine aggregate in the range of 0 to 45 % at increments of 15%. All aggregates used in this study are obtained from the ground's laterites and fine aggregate from Ikorodu and coarse aggregate from quarry in Ijebu ode. The sieve analysis of the aggregates used in this study is presented in Figure 1, and their specific gravity and bulk density are presented in Table 2. It will be observed from Figure 1 that the laterite soil is finer than the conventional fine aggregate, but the gradation is similar. The water used for this study is potable, and it conforms with for concrete mixtures [18].

Table 1: Chemical Composition of Opc

Constituent	Weight (%)
Lime (CaO)	64.64
Silica (SiO_2)	21.28
Alumina (Al_2O_3)	5.60
Iron Oxide (Fe_22O_3)	3.36
Magnesia (MgO)	2.06
Sulphur Trioxide (SO_3)	2.14
Total Alkalis	0.05
Insoluble Residue	0.22
Loss of Ignition	0.92
Lime Sarturated Factor	0.92
Silica Modulus	2.38

Table 2: Specific Gravity and Bulk Density of Materials

Material	OPC	River sand	Laterite	Granite
Specific gravity	3.05	2.40	2.40	2.85
Bulk density (Kg/m^3)	1440	1437	1436	1437

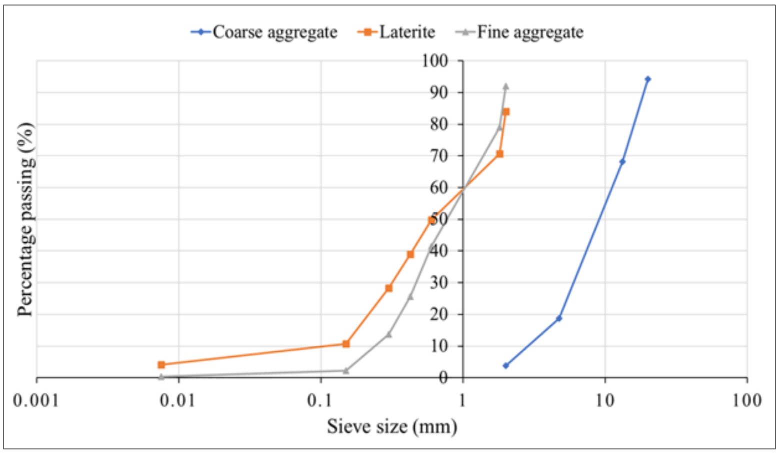

Figure 1: Sieve Analysis of Aggregates

The mixtures proportions evaluated in this study are classified in terms of percentage and presented in Table 2. The w/cm indicates the water to the cementitious ratio where the cementitious component is composed of the mass of all the binder used (i.e., OPC and/or SDA)

Table 2: Mixture Proportions (%)

Mixture notation	Mixture ID	Binder		Fine aggregate		w/cm
		OPC	SDA	River sand	Laterite	
M1	100OPC	100	-	100	-	0.63
M2	100OPC15LTR	100	-	85	15	0.63
M3	100OPC30LTR	100	-	70	30	0.63
M4	100OPC45LTR	100	-	55	45	0.63
M5	5SDA15LTR	95	5	85	15	0.63
M6	5SDA30LTR	95	5	70	30	0.63
M7	5SDA45LTR	95	5	55	45	0.63
M8	10SDA15LTR	90	10	85	15	0.63
M9	10SDA30LTR	90	10	70	30	0.63
M10	10SDA45LTR	90	10	55	45	0.63
M11	15SDA15LTR	85	15	85	15	0.63
M12	15SDA30LTR	85	15	70	30	0.63
M13	15SDA45LTR	85	15	55	45	0.63

Like the conventional mixing method, the aggregates and binders were first dry-mixed by a mixing machine (Figure 2a) for 3 mins, followed by the addition of water gradually to the mix. The mixture was further mixed for 2 mins after the addition of water. After mixing, the slump test was carried out following (Figure 2b), and the pre-prepared mold was filled with the concrete mixture (Figure 2c) [19]. All specimens are prepared and tested according to several British standards. The compressive test was carried out following [20]. Four 150 x 150 x 150mm cubes were cast for each mixture for the compressive strength testing (Figure 2d). The slump test was measured immediately after mixing. All samples are cured underwater after de-molding until the required tests are due (i.e., 7, 14, and 28 days). The density and compressive tests were carried out at 7, 14 and 28 days after curing.

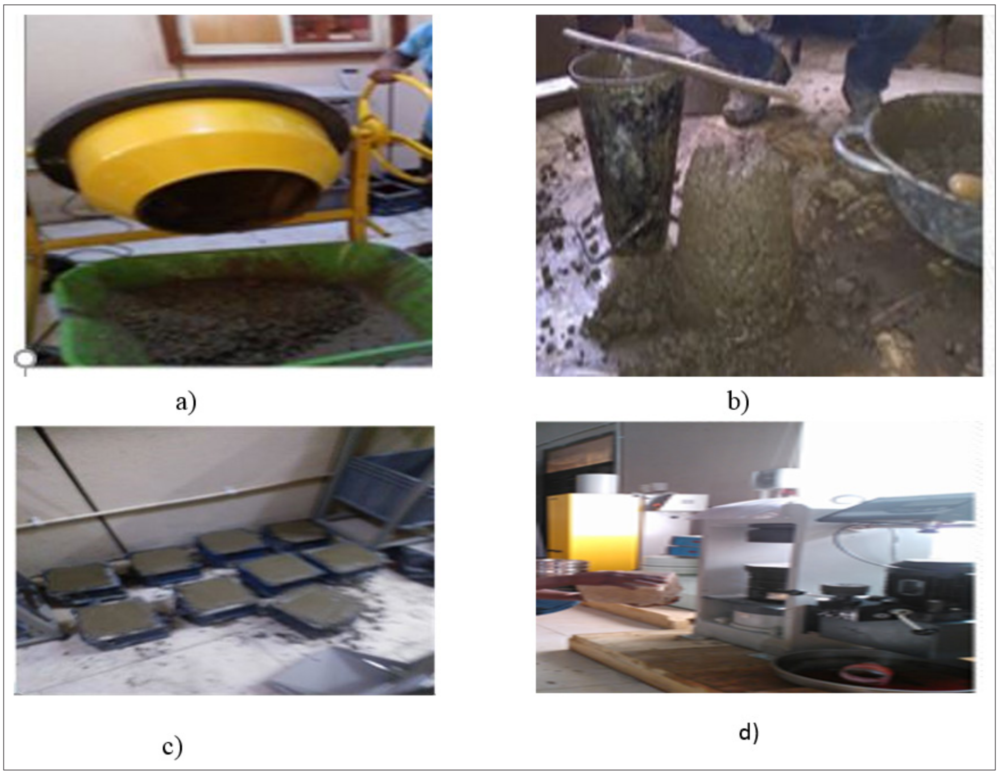

Figure 2: Experimental Method a) Machine Mixing of Concrete b) Slump Test c) Casting of Cubes For Compressive Strength d) Crushing Testing

Results and Discussion

Fresh Properties

Slump

The slump of concrete is one of its main fresh properties. The slump of concrete indicates its consistency and how workable the mixture is. The effect of partial replacement of OPC with SDA and river sand with laterite is presented in Figure 3 a-d. It will be observed that in all proportions of OPC, increasing the amount of laterite sand reduces the slump of the mixture. The reduction in the slump with the incorporation of laterite soil might result from its higher absorption rate, which reduces the amount of free water available in the mixture. When 100% OPC is used, the slump is reduced by approximately 50% when the river sand is replaced with 45% laterite soil. A similar trend was observed when OPC was replaced with SDA for 15%.

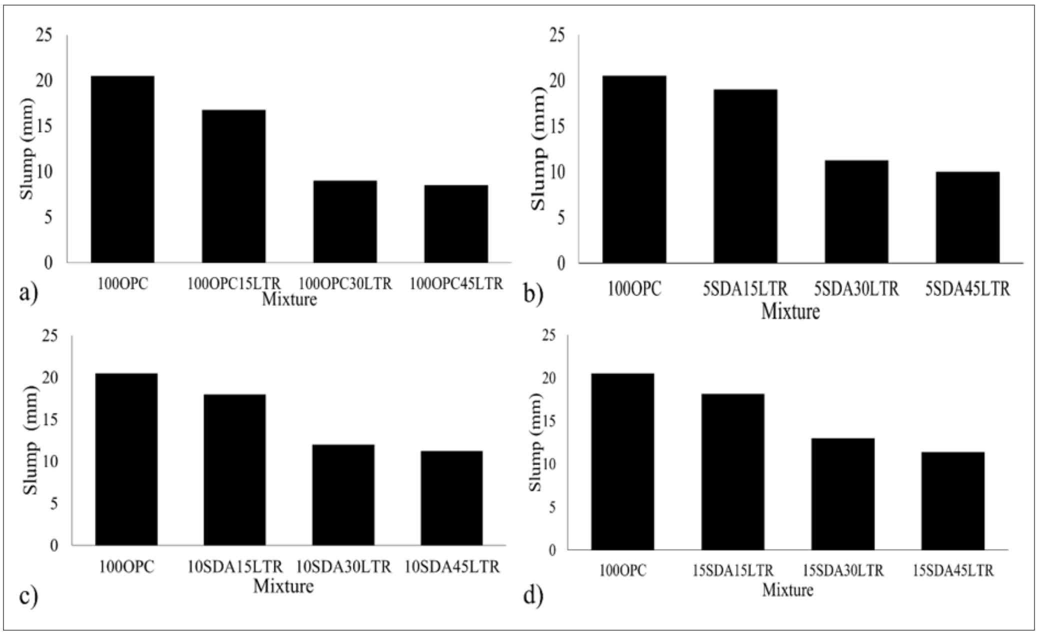

Figure 3: Effect of Replacement of River Sand at Different Levels When Opc Used Was a) 100% OPC b) 95% c) 90% d) 85%

Hardened Properties

Density

The results presented in Figure 4 show the hardened density of the mixtures measured at 7, 14 and 28 days. It will be observed from the figure that all mixtures have approximately the same density of about 2400Kg/m^3 except for M11 and M12. As all the densities measured are within the range of 2400Kg/m^3, this showed that all the concrete mixtures considered in this study could be classified as normal-weight concrete.

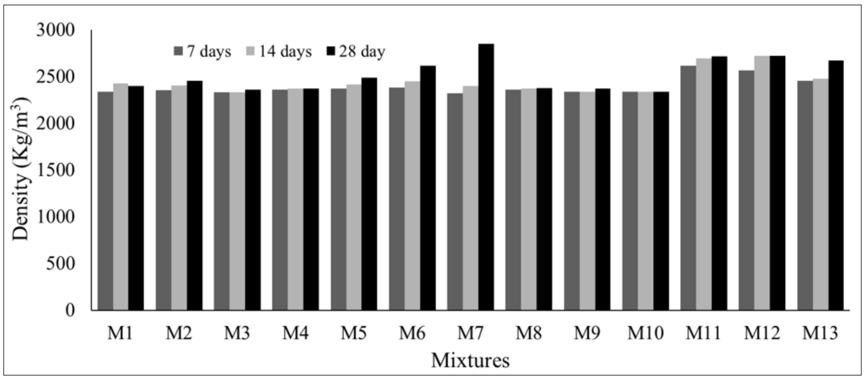

Figure 4: Effect of Sda and Laterite on The Density of Concrete

Compressive strength

The compressive strength of concrete indicates its ability to withstand a load in compression and can be correlated to other mechanical properties of concrete. For this experimental study, 52 cubes samples with a dimension of 150mm were tested for compressive strength. The compressive strength results presented in Figure 5 is an average of 4 cube samples for each mixture. It will be observed for all mixtures that the compressive strength increases with age. This increasing compressive strength shows the progression of hydration reaction with time. For all mixtures incorporating only OPC as a binder (i.e., M1 to M4), it will be observed that the compressive strength at seven days is about 65% of that at 28 days and 14 days' strength is about 83% of the 28 days compressive strength. The incorporation of SDA as partial replacement of OPC resulted in a significant decrease in the compressive strength of the concrete samples at all ages. This observation can result from a possible low pozzolanic reaction of the SDA. However, increasing the content of SDA from 5% to 10% resulted in compressive strength similar to that of the control without SDA. This observation is similar to other studies in which silica fume and metakaolin are used to replace OPC and the optimum was found to be 10% [21- 22]. In contrast to the effect of partial replacement of OPC with SDA, it will be observed from Figure 4 that increasing the replacement level of river sand with laterite sand increases the compressive strength significantly. Based on these results, the optimum replacement of OPC and river sand respectively is 10% SDA and 45% laterite sand (i.e., M10) [23-25].

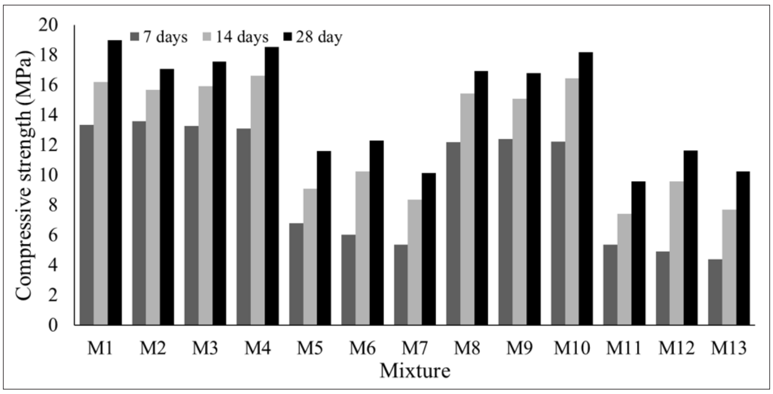

Figure 5: Effect or Sda And Laterite on The Compressive Strength of Concrete

Conclusion

This study explored the major properties of concrete incorporating SDA and laterite as partial replacement of OPC and fine aggregates, respectively. Based on this experimental study, the following conclusion could be drawn;

1. Replacement of OPC with SDA in the range of 5 to 15% and river sand with laterite sand in the range of 15 to 45% have no significant impact on the workability of concrete mixtures.
2. Laterized concrete incorporating SDA as a partial replacement of OPC can be classified as a normal weight concrete as all the densities measured are about 2400Kg/m^3.
3. The optimum amount of SDA is 10%, and that of laterite is 45% in terms of compressive strength
4. More research should be explored in this area to observe how incorporating different amounts of SDA and laterite affects other mechanical and durability properties of concrete.

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