MECHANICAL PROPERTIES OF SUGARCANE STRAW WASTE ASH USED AS BINDER IN CONCRETE PRODUCTION

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Abstract: The utilization of industrial and agricultural waste produced during the manufacturing processes has been the emphasis of waste reduction research for economic, environmental and technical reasons. Sugar Cane Straw Waste Ash (SSWA) is a fibrous waste product of the sugar industry, along with ethanol vapor. This waste product is already causing serious environmental pollution, which calls for urgent ways of handling the waste. The SSWA is rich in SiO_2 + Al_2O_3 + Fe_2O_3 (83.13%). It has limited life span and after use, it is either stock piled or sent to landfills. This study focuses on experimental investigation on the use of SSWA as cement substitute in concrete production. Total number of 120 cubes of size 150 x 150 x 150 mm, 72 numbers of cylindrical size of 150 mm diameter and 300 mm height specimen were casted from a mix ratio of 1:2:4 by weight and water-cement ratio of 0.6. Concrete cubes were then cast and tested to examine various properties of concrete partially replaced in the ratio of 05, 10 15 20 and 25% by weight of cement. Slump test was conducted on the fresh concrete and it was discovered that the workability increase with increase in additional levels of SSWA which shows that the water absorption capacity of SSWA is low. The compressive strength and flexural strength were carried out on the hardened concrete at various ages of 7, 14, 21 and 28 days, respectively. Both the compressive strength and flexural strength of concrete decrease with increase in SSWA content, however, from the results we can conclude that optimum amount of sugarcane straw waste ash that can be replaced with cement is 10% by weight without any admixture.

Keywords: OPC, SSWA partial replacement, workability, compressive strength, flexural strength

Introduction

Concrete is a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate, usually a combination of fine aggregate and coarse aggregate. Concrete is made from some basic component such as aggregates (fine and coarse), cement, water and some time with addition of additive. The cement reacts chemically with the water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses. Often, additives (such as pozzolana) are included in the mixture to improve the physical properties of wet mix or the finished material (Kosmatka and Panarese, 2002).

The over dependent on the utilization of industrially manufactured binding materials (cement) have kept the cost of construction financially high. This has up till now prevented third world countries like Nigeria in providing good housing for its citizen, particularly rural dwellers that are mostly agriculturally dependent (Agbede and Joel, 2011). The use of waste materials in mortars and concrete can be an important step towards sustainability as the construction industry is significant and worldwide use cement as their main binder, (Krammart, 2004). The use of alternative binders that are less polluting and/or the use of residues could impact the construction industry towards the production of concrete with less environmental impact. In order to achieve this, concrete must have adequate characteristics, implying that certain mechanical characteristics and water behavior must be achieved.

Sugarcane straw waste (SSW) is the by-product of milling the sugarcane, which can also be produced by chewing the sugarcane by individuals. Since bagasse is a by-product of the sugar industry, the quantity of production in each year is in line with the quantity of sugar cane produced. About 33% of the (SSW) produced, supplies the fuel for the generation of steam (Bilba *et al.*, 2003). According to Jayminkumar and Raijiwala (2015), the SSW has been considered to be a waste which causes the problems of disposal at the power plant; and also the landfills of SSW ash are still the problem of power plants because the waste of ash is currently not useful for any works

With present alternative sources of fuel, sugar factories have an excess of bagasse, which together with locally generated bagasse, pose a serious environmental problem, which when inhaled in excess, causes respiratory disease known as bagassiosis (Laurianne, 2004). In Nigeria, the estimated land under sugar cane cultivation is 23 – 30 kha, while large scale cultivation is done at Bacita and Numan in Niger State of Nigeria, with an estimated annual output of 96, (Misari *et al.*, 1998). According to Ahmed and Shaikh (1992), the physical and chemical properties of sugarcane straw ash are found to be satisfactory and conform to the requirements for class N pozzolana (ASTM C618-78). Despite reports by Ola (1983) through Osinubi (2006) have shown that the use of phosphate waste and pulverized coal bottom ash and sugarcane straw ash as pozzolana does not receive considerable attention.

Materials and Methods

Materials

The materials used for this study are fine aggregate (correspond to zone 2 based on sieve analysis carried out in accordance to BS 882 code of practice), coarse aggregate, ordinary Portland cement, sugarcane straw waste ash, and water – cement ratio of 0.60 which was obtained from mix design. The method adopted in the preparation of sugarcane straw waste ash is as follows. The sugarcane straw waste samples used were obtained from Wuya in Gbako local government area of Niger State and then dried to remove moisture. After which the dried sample is then burnt using close burning at National Cereal Research Institute (NCRI) Baddegi, Niger State and sieved using BS sieve (75 microns), the portion passing through the sieve would have the degree of fineness of 0.63 mm and below for cement, while the residue was thrown away and the sieved SSWA was then stored in a cement bag ready for use. Casting and testing of concrete cubes; a total of 120 cubes of 150 x 150 x 150 mm dimensions were cast based on 28 days target compressive strength of 25 N/mm^2. The cubes were cast using 0, 5, 10, 15, 20 and 25% of SSWA as a partial replacement for cement and slump test was carried out during casting to check the workability of each concrete mix.

Methodology

This study involved the collection and preparation of sugarcane straw waste ash, and the mix design in accordance with BS 5328: Part2; 1991 was adopted, then followed by casting, curing and testing of concrete cubes. The total numbers of 120 cubes of 150 x 150 x 150 mm and 72 numbers of cylindrical size of 150 mm diameter and 300 mm height specimen were cast in which 20 cubes and 12 cylinders were cast for each percentage replacement of cement with sugarcane straw waste ash and 5 cubes from each mix (i.e. 30 cubes) and 18 cylinders from each mix (i.e. 18 cylinders) were tested at 7, 14, 21 and 28 days of curing and at least three cubes test result out of five (5) of each percentage mix of SSWA was taken and recorded. The cubes and cylinder were cast using 0, 5, 10, 15, 20 and 25% of sugarcane straw waste ash as partial replacement of cement and slump test was carried out during casting to check the workability of each concrete mix. Casting of the cubes and cylinders were carried out immediately after the workability test, to determine the compressive strength; the cubes were left for 24 h before de-moulding. At the end of each curing period (7, 14, 21 and 28 days), five cubes and three cylindrical specimens from each mix were tested for compressive strength and flexural strength at room temperature, but only three out of five cubes were considered and the average value was recorded.

Results and Discussion

The summary of chemical composition of cement and sugarcane straw waste ash is shown in Table 1. The Chemical analysis indicates that the SSWA has cementitious compounds like calcium oxide, alumina and iron oxide. Calcium Oxide (CaO) content in SSWA is about 65.05%, which indicate hydrated lime when slaked with water, with a value of loss on ignition (LOI) of about 27.92%.

Table 1: Chemical Composition of Cement and Sugarcane Straw Waste Ash

Chemical compound	Type I cement Reddy *et al.* (2013)	Sugarcane straw waste ash
SiO_2	22.00	68.42
Al_2O_3	5.00	5.812
Fe_2O_3	3.50	2.56
CaO	65.00	4.58
SO_3	1.00	4.33
MgO	0.2	0.57
K_2O	1.00	1.28
Na_2O	0.77	0.92
LOI	0.20	5.60
Blaine fineness m^2/kg	350.00	410.00
Relative density	3.15	2.12

Setting time test result

The water requirement of SSWA blended cement paste at various percentages of mix increased. It was noted that the setting time increases with an increase of partial replacement of SSWA with cement. As the SSWA content is increased from 0 to 25%, the initial setting time was found to increase from 105 to 142 min and the final setting time increased from 195 to 351 min. This is logical as the increase of SSWA content reduces the cement content in the mix and also decreases the surface area of the cement. As a result hydration process slows down, causing setting time to increase. The delay in hydration means a low rate of heat development. The final setting time of all additional level was within the specification of the code (BS 812 part 3, 1975), which stipulate a final setting time of not more than 600 min.

Table 2: Physical characteristics of OPC and SSWA-Cements

Additional level (%)	0	5	10	15	20	25
Initial setting time (min)	105	112	115	123	129	142
Final setting time (min)	195	235	248	277	303	351
Specific gravity	3.16	3.09	3.02	2.97	2.86	2.80
Fineness (m^2/kg)	310	309	306	313	317	221
Soundness, expansion (mm)	0.73	0.98	1.30	1.10	1.36	1.35

Table 3: Slump test

Water cement ratio	0.60					
Additional level (%)	0	5	10	15	20	25
Slump (mm)	77	85	97	122	148	173
Description of workability	High	High	High	High	High	High

Workability of fresh concrete

Workability of the fresh concrete mix is shown in Table 3. A high quality concrete is one which has acceptable workability in the fresh condition and develops sufficient strength. Essentially, the higher the height of the slump, the better the workability, which shows that the concrete flows freely and free from segregation; A slump value of 77 mm was determined for control specimen. The workability of fresh SSWA concrete increased with increase in the percentage of SSWA by weight and acceptable workability, this is due to the increasing in the surface area of sugarcane ash.

Compressive strength and flexural strength of concrete

a. Compressive Strength of concrete

The compressive strength of hardened concrete specimens was done on compression testing machine in accordance with BS1881-119 (1983) using (150 x 150 mm) cubes loaded uniaxial in the universal compressive machine. Compressive strength of sugarcane ash contain concrete cubes was determined after 7, 14, 21 and 28 days moist curing. The average compressive strength values of the concrete specimens at each percentage of addition and age are presented in Fig. 1 (Table 4). The compressive strength of SSWA concrete increased with age, the compressive strength at 28 days ranged from 29.50 to 25.20 N/mm^2, which depends on the percentage addition of SSWA. This result indicated that the SSWA mixture could be used as a cementitious material in concrete.

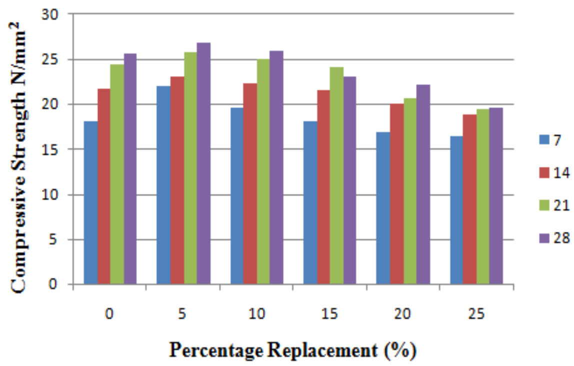

Fig. 1: Comparison of compressive strength result at 7th, 14th, 21th and 28th days

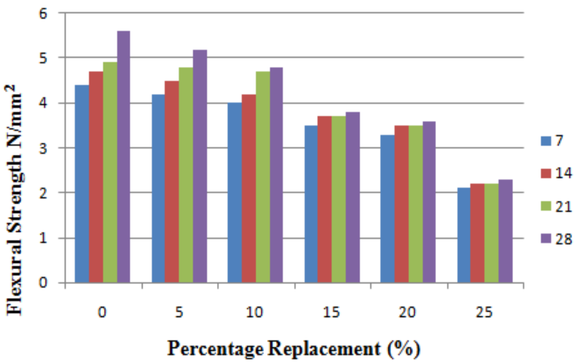

Fig. 2: Comparison of flexural strength result at 7th, 14th, 21th and 28th day

b. Flexural strength of Concrete

Flexural strength test was carried out in accordance with BS: 516 (1959). Beams were tested for flexure in Universal testing machine. The axes of the specimen are aligned with the axis of the loading device. The beam was loaded till it fails and the maximum load applied to the beam during test is noted. The flexural strength increase with curing age, but decreased with increase in SSWA content (Fig. 2). Though, the flexural strength of SSWA content at 5% is comparable to that of control sample. The decrease in the flexural strength with increase in SSWA content is attributed to dilution effect of Portland cement and weaker formation of C-S-H gel as a pozzolanic reaction of SSWA.

Conclusion

This investigation of the potential of sugarcane straw waste ash on the properties of concrete has demonstrated how the use of suitable technology can transform abundantly available, cost-effective, non-conventional and locally available materials which could be potential environmental hazards into a natural resource and hence, it can be suitable for construction, especially those that can partially replace cement, which may also help to prevent environmental pollution. The results obtained from the experimental works showed that sugarcane straw waste ash can replace cement in concrete production. Pulverized SSWA is a suitable pozzolanic material for use in concrete. From the experimental results and it can be concluded that replacement of sugarcane straw waste ash with cement can be up to 10% by weight of cement without significant loss in strength of concrete.

The following conclusions are drawn:

- ✓ Compressive strengths increases with age, but reduces with increase in SSWA content in the mix, especially when more than 10% SSWA is used.
- ✓ Concrete with SSWA constitute about 5, 10, 15, 20 and 25% is still stable and could be acceptable in most concrete work.
- ✓ SSWA replacement of 5, 10, 15, 20 and 25% in concrete with OPC showed no significant loss in strength compared to the control sample.

Conflict of Interest

The authors declare that there is no conflict of interest related to this study.

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