Partial Replacement of Ordinary Portland Cement (OPC) with Bambara Groundnut Shell Ash (BGSA) in Concrete

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Abstract

This paper examines Ordinary Portland Cement (OPC) and Bambara Groundnut Shell Ash (BGSA) concrete. The ash contained 10.91% CaO, 2.16% Fe_2O_3, 4.72% MgO, 33.36% SiO_2, 1.75% Al_2O_3, 16.18% K_2O, 9.30% Na_2O, 6.40% SO_3, 6.02% CO_3 and 9.20% HCO_3. 10%, 20%, 30%, 40% 50% and 0% ash was used in the mix to replace cement. The strength of cement/ash concrete increased with curing period but decreased with increasing ash percentage. The highest strength was 31.24N/mm^2 and 20.68N/mm^2 at 28 days for 0% and 10% ash respectively. Substitution of cement with ash in concrete formation was relatively possible not exceeding 10%.

Keywords

Bambara Groundnut, Ash, Cement, Concrete

Introduction

The construction industry relies heavily on cement for its operations in the development of shelter and other infrastructural facilities. It then becomes extremely difficult for majority of the people to own their own houses or many collapse structures in attempt to reduce cost. A way out is either by reducing the energy costs in the burning of clinker or by increasing the production of the composite cement. The later involves replacing a proportion of the clinker-high calorie consuming portion by other products that are suitable and do not require further heat treatment.

Various research workers in the recent past had look into the utilization of agricultural wastes that are known to be pozollanas to partially substitute cement that is the major component of concrete. The use of Ordinary Portland Cement (OPC) and Rice Husk Ash (RHA) concrete in minimizing thermally induced expansion cracks has been identified [5]. This is because the OPC/RHA paste hydrates slowly and therefore evolved low heat making their suitable for use in concrete in the tropics.

Okpala recommended the use of 40% partial replacement of the OPC with RHA[4]. Mbachu and Kolawole examined the influence of coarse aggregate on the drying shrinkage and elastic moduli of concrete with OPC partially replaced with RHA [6]. Results showed that OPC/RHA concrete cast with quarry granite as coarse aggregate exhibited the least drying shrinkage over time and also gave the highest values of elastic moduli when compared with river gravel. In a related work on Groundnut Shell Ash, Yusuf reported that 30% partial replacement of cement with Groundnut ash gave better results in the strength of the composite concrete when compared with the control [7].

The partial replacement of OPC with BGSA in concrete production is a welcome development especially is Nigeria. The cost of BGSA when compared with OPC is very low due to the availability of Bambara Groundnut shell in large quantities as agricultural farm wastes in Northern parts of Nigeria such as Sokoto, Kebbi, Zaria, Borno and Yobe States.

The utilization of Bambara Groundnut shell will promote waste management at little cost, reduce pollution by these waste and increase the economic base of the farmer when such waste are sold thereby encourages more production. Also, BGSA production required less energy demand compared with cement production and safe the needed foreign exchange spent on importation of cement or its constituents.

The main objective of this study is to investigate the suitability of BGSA as partial replacement for cement in concrete.

Materials and Methods

The Bambara Groundnut shell was obtained from farmers within Birnin-Kebbi, Kebbi State, Nigeria free of charge after threshing/separating the shell from the nut using the threshing machine.

10kg of the shells was obtained and burnt to ash completely at temperature 500°C in a furnace at Nigerian Mining Corporation, Jos. The burnt ash was sieved through British Standard sieve of 75 microns after grinding. The portion passing the sieve was reported to the required degree of fineness that is 63 microns and below while the ash retained on the sieve was reground and sieve again [4, 6].

Chemical analysis of BGSA was carried out at Chemical Laboratory of Nigerian Mining Corporation, Jos. The X-ray Analyzer together with Atomic Absorption Spectrophotometer (AAS) were employed for the analysis except for Sulphur Oxide, Sodium and Potassium Oxide where the Flame Analyzer was used, gravimetric method was employed in the determination of the Carbonate and Hydrogen Carbonate.

Medium concrete workability and mix ratio of 1:2:4 (cement : sand : coarse aggregate) by mass was adopted [5]. In this investigation, OPC/ BGSA ratio of 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 percentages by mass were used. 72 concrete cubes of 150mm×150mm ×150mm were cast. The specimens were cured in curing tank containing clean water at a temperature of 18°C to 22°C and not less than 90% relative humidity as temperature effect the development of strength of concrete. The compressive strengths of the cubes were obtained from the crushing test at ages 7, 14, 21 and 28 days of curing.

Results and Discussions

Ash Analysis

The analysis of BGSA showed that it contained 10.91% Calcium Oxide (CaO), 2.16% Iron Oxide (Fe_2O_3), 4.72% Magnesium Oxide (MgO), 33.36% Silicon Oxide (SiO_2), 1.75%

Aluminum Oxide (Al_2O_3), 16.18% Potassium Oxide (K_2O), 9.30% Sodium Oxide (Na_2O), 6.40% Sulphur Oxide (SO_3), 6.02% Carbonate (CO_3) and 9.20% Hydrogen Carbonate (HCO_3). These compounds are known to have cement properties that would be beneficiary to the concrete. However, the total percentage of Iron Oxide, Silicon Oxide and Aluminum Oxide is less that the minimum of 70% specified by ASTM 618 for pozzolanas [1].

Compressive Strength

Fig. 1 below shows the result of the compressive strength test. This figure depicts the behaviour different proportions of OPC/BGSA concrete with age. Generally, the strength increases with age.

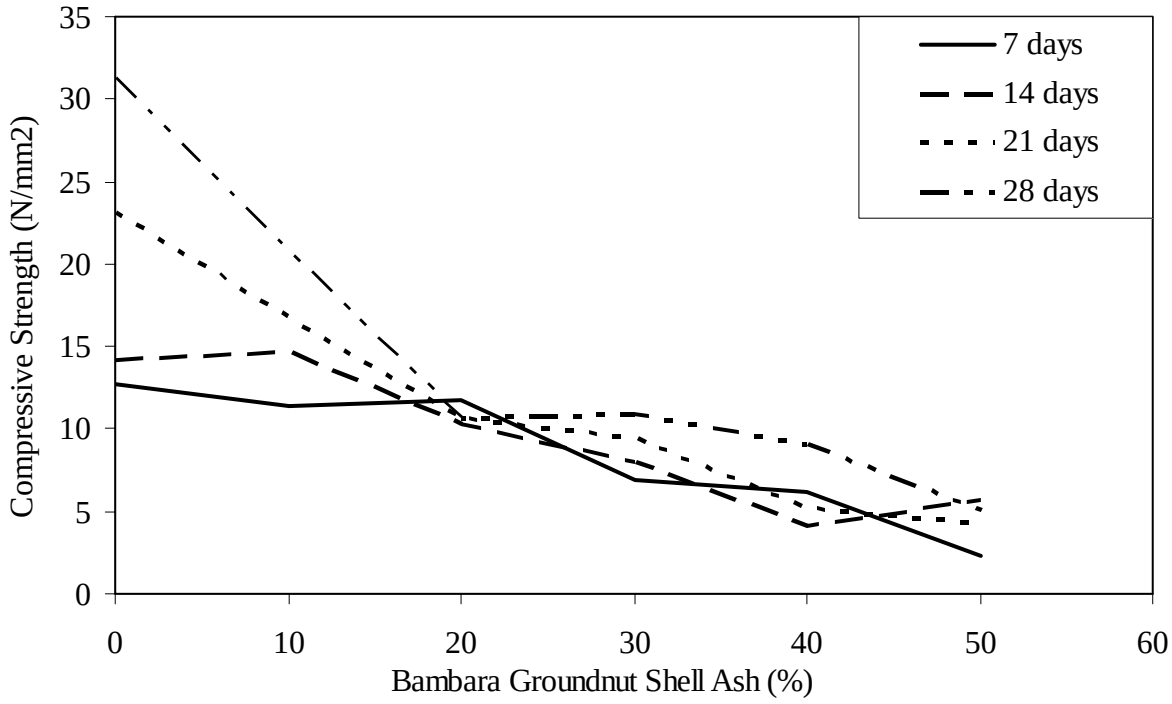

Fig. 1. Compressive Strength of Concrete with Various Percentage of Bambara Groundnut Shell Ash

As the percentage ash in the ash-cement composition increases, the compressive strength decreases. At 0% ash and 100% cement that serve as the control, strength increased from 12.71 N/mm^2 at 7 days to 31.24 N/mm^2 at 28 days that is about 150% increment. Strength of 90:10 cement/ash increased from 11.34 N/mm^2 at 7days by about 81.81%. At 20% ash, strength decreased by 10% while increases of about 36.79%, 32.01% and 55.66% were recorded with 30%, 40% and 50% ash respectively from 7days to 28days curing period.

According to BS 8110, a grade 20 concrete of 1:2:4 mix design without any blending of the cement should have acquired a strength of 13.5 N/mm^2 within the first seven days of wet curing and 20 N/mm^2 within 28 days [2]. Based on the above and the result obtained from this work, OPC/BGSA ratio of 90/10 would be suitable for concrete. OPC/BGSA ratio of 80/20 presents a challenging result where the strength remained virtually the same from 7 to 28 days. It may be a good combination but a lot of investigation is required to ascertain this unique behaviour.

FAO reported that cement blended with pozzolanas would produce 65 to 95 % strength of OPC concrete in 28 days. Further, they reported that their strength normally improves with age since pozzolanas react more slowly than cement due to different composition and at one year about the same strength is obtained. Though, this experiment was extended beyond 28 days, the above may account for the low strength values recorded with the addition of ash in the mixture [3].

Though, Okpala recommended 40% partial replacement of cement with RHA, there is significant difference between the 0% and 40% BGSA replacement in this study which may suggest that RHA could be a better pozzolana that BGSA [4].

Conclusions

From the results of the tests and analysis carried out in this study, the following conclusion can be drawn.

1. There exists a high possibility for partial replacement of cement with Bambara Groundnut shell ash in concrete.
2. Partial replacement of Ordinary Portland Cement with about 10% Bambara Groundnut Shell ash in concrete is acceptable.
3. Though the strength of OPC/BGSA concrete was lower than that of 100% cement, it can be used for light load bearing elements.

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