WOOD ASH FROM BREAD BAKERY AS PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

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Abstract

This paper reports the results of experiments evaluating the use of wood ash from bread bakery as partial replacement for ordinary Portland cement in concrete. The chemical composition of the wood ash as well as the workability and compressive strength of the concrete were determined. Wood ash was used to replace 5% - 25% by weight of the cement in concrete. Concrete with no wood ash serves as the control. The mix ratio used was 1:2:4 with water to binder ratio maintained at 0.5. The Compressive strength was determined at curing ages 3, 7, 28, 56, 90 and 120 days. The results showed that wood ash from bread bakery is a Class F fly ash since the sum of (SiO2 +Al2O3 +Fe2O3) is greater than 70%. The compressive strength of wood ash concrete increases with curing period and decreases with increasing wood ash content. There was a sharp decrease in compressive strength beyond 10% wood ash substitution. It was concluded that a maximum of 10% wood ash substitution is adequate for use in structural concrete.

Keywords: *Wood ash, Bread bakery, Pozzolan, Workability, Compressive strength*

1.0 Introduction

Concrete is a versatile construction material that is widely used in virtually all structural works. It is a composite material comprising cement, aggregates, water and admixtures. Wood ash concrete is a type of concrete with wood ash as partial replacement for cement.

Fly ash is defined as a material collected from a practical combustion device after the fuel is consumed [1]. It is an industrial by- product that possesses hydraulic and pozzolanic properties. This type of material imparts technical advantages to the resulting concrete and also enables larger quantities of cement replacement to be achieved [2]. Wood ash is similar to fly ash since it is obtained from a practical combustion device – bread bakery in this case.

2.0 Literature Review

The fly ashes that have been widely studied are those obtained from power plants where coal is used as a fuel [3-8]. This study sought an alternative source of fly ash by investigating the properties of the wood ash obtained from bread bakery. Bread is a staple food in Nigeria that is consumed regularly by a large number of people. Thus, bread bakery is located in every nooks and cranny of the country to cater for the high demand for the product. The bakeries use wood as fuel for their operation thereby resulting in high volume of ash as by-product. The ash particles solidify as microscopic, glassy spheres that are collected from the bakery's exhaust before they can "fly" away, hence the product's name - fly ash [9].

Fly ash with potential for use in concrete is classified into two categories as Class C and Class F [10]. The classification is based on sum of (SiO2 +Al2O3 +Fe2O3). Where the sum is greater than or equal to 70%, the ash is classified as Class F, while it is Class C if the sum is greater than or equal to 50% [11].

This study examines the use of wood ash from bread bakery as partial replacement for ordinary Portland cement in concrete. It involves the determination of the chemical composition of the ash and evaluation of the workability and compressive strength of the concrete.

3.0 Methodology

The methodology adopted in carrying out the study is discussed under two sub headings of Materials and Specimen Preparation for the tests carried out.

3.1 Materials

The wood ash used for this study was collected from Ladoke Akintola University of Technology Ogbomoso, Nigeria, bread bakery located behind Food Science and Engineering Laboratory (Owodunni Building). The wood ash was carefully collected at the exhaust of the bakery, after the fuel had burned out, with the aid of hand scoop. It was sieved to separate the ash from any unwanted material.

The wood ash was ground to fine powdery form and only those retained on a 0.425 μm sieve was used for the experiments. The ash was taken to Larfarge Cement, West Africa Portland Cement Company (WAPCO) Sagamu, Ogun State, Nigeria, for chemical analysis. The Ordinary Portland cement (Dangote, Brand) used was obtained from a local retailer in Ogbomoso. Sharp sand obtained from river bed was used as fine aggregates and granite as coarse aggregates. The fine and coarse aggregates used were also obtained from Ogbomoso, Nigeria.

3.2 Specimen Preparation

Wood ash was used to replace 5% - 25% by weight of the cement in concrete. Concrete with no wood ash serves as the control. The mix ratio used was 1:2:4 (binder, sand and granite) with water to binder ratio maintained at 0.5. The details of the concrete mixtures used in the tests are listed in Table 1.

Table 1: Proportioning of Concrete

Percentage of Wood Ash (%)	Cement (kg)	Wood ash (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
0	21.48	-	42.96	85.92
5	20.406	1.074	42.96	85.92
10	19.332	2.148	42.96	85.92
15	18.258	3.222	42.96	85.92
20	17.148	4.296	42.96	85.92
25	16.11	5.370	42.96	85.92

Compressive strength measurements were made on 150mm cube concrete specimens. The specimens were cast in three layers, each layer being tamped with 35 strokes of the tamping rod spread uniformly over the cross section of the mould. The top of each mould was smoothened and leveled and the outside surfaces cleaned. The moulds and their contents were kept in the curing room at temperature of 27 + 50C and relative humidity not less than 90% for 24hours. All specimens were demoulded after 24hours and cured in water at 27 + 50C. The Compressive strength was determined at curing ages 3, 7, 28, 56, 90 and 120 days; using compression machine with maximum capacity of 1500 kN (Model 50- C34AC and Serial no 02094910). The strength value was the average of three specimens.

Slump and compacting factor tests were carried out to check the effect of wood ash on the workability of fresh concrete. The tests were carried out in accordance with the requirements of BS 1881: Part 102 (1983) [12] for slump test and BS 1881: Part 103 (1983) [13] for compacting factor test.

4.0 Results and Discussion

This section discusses the results obtained from the various laboratory tests carried out.

4.1 Chemical Composition

The elemental oxides present in the wood ash sample are shown in Table 2. The results indicated that the wood ash had combined percentages of SiO2, Al2O3 and Fe2O3 of more than 70% (73%). This indicates that it is a good pozzolanic material in accordance with the requirements in ASTM C 618. As reported by [11], wood ash from bread bakery falls under the category of Class F fly ash since the sum of (SiO2 +Al2O3 +Fe2O3) is greater than 70%.

Table 2: Chemical Composition of Wood Ash

Chemical Constituents	Percentage Composition (%)			
	Sample 1	Sample 2	Sample 3	Average
SiO2	61.12	62.75	61.74	61.18
Al2O3	7.05	7.95	7.57	7.52
Fe2O3	3.22	2.91	3.44	3.19
CaO	10.56	12.94	11.80	11.77
MgO	2.34	2.00	3.11	2.48
SO3	1.84	1.80	1.82	1.82
Na2O	1.15	1.00	1.11	1.09
K2O	3.56	4.11	3.75	3.81
CaCO3	6.12	6.22	6.31	6.22
LOI	2.95	3.20	2.99	3.05
LSF	1.20	1.37	1.27	1.28
SR	4.15	4.25	4.56	4.32
AR	7.48	7.56	7.62	7.55
Total SiO2 + Al2O3 + Fe2O3	71.39	73.61	72.75	72.58

4.2 Sieve Analysis

The results of the sieve analysis for fine and coarse aggregates are presented in Figures 1 and 2 respectively. It could be observed from the Figure 1 that the coefficient of uniformity (Cu) and coefficient of curvature (Cc) for fine aggregates are 4.95 and 1.24 respectively. Thus, the sand is classified as being well graded [14]. Similarly, the Cu and Cc for coarse aggregates as obtained from Figure 2 are 0.89 and 1.75 respectively. This shows that the granite is uniformly graded [14]. Therefore, the fine and coarse aggregates are suitable for making good concrete.

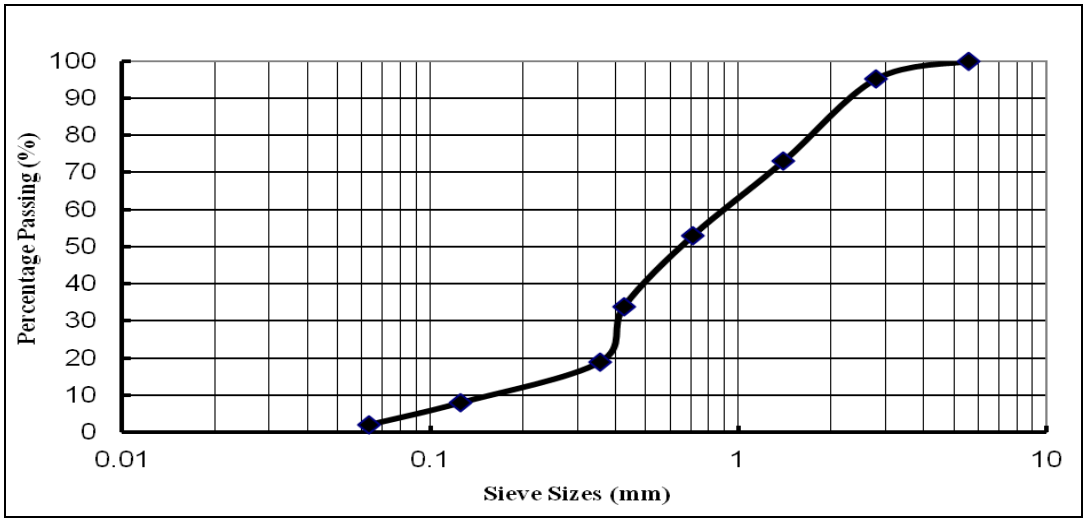

Figure 1: Particle Size Analysis Graph for Sand

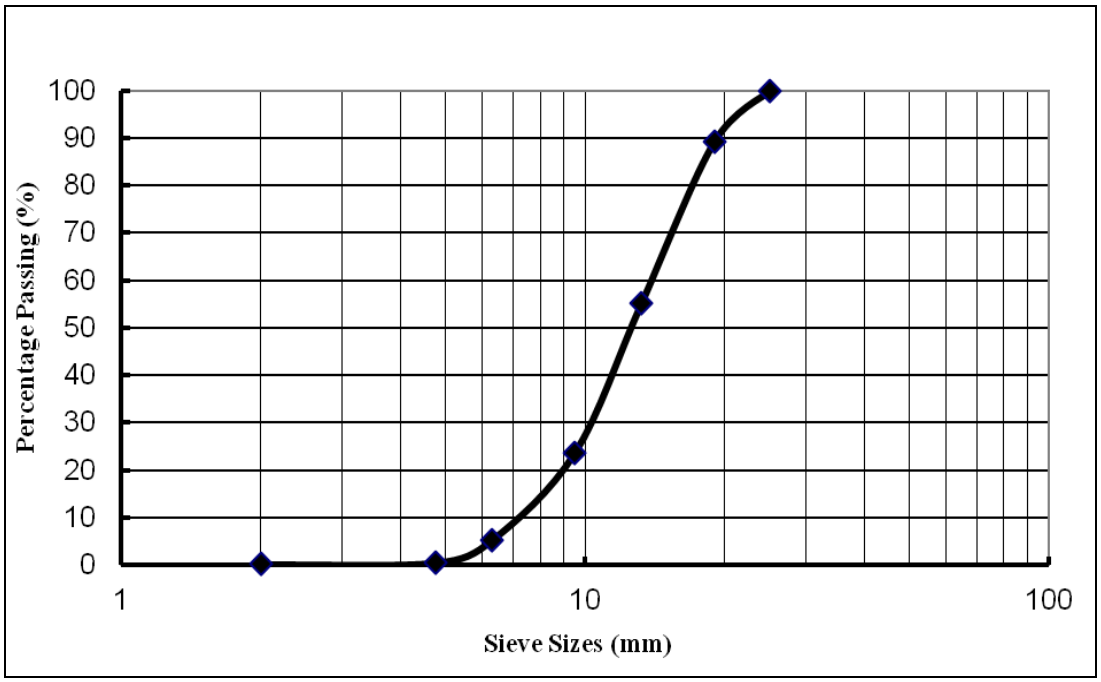

Figure 2: Particle Size Analysis Graph for Granite

4.3 Workability

The results of the slump and compacting factor indicating the workability of the wood ash concrete are shown in Table 3. The table indicates that the slump first decreases for up to 10% wood ash replacement, and then increases with increasing wood ash content. The compacting factor also follows a similar trend. These results indicate that concrete containing wood ash beyond 10% replacement level becomes more workable as the wood ash content increases meaning that less water is required to make the concrete workable. The lower water demand can be attributed to the finer ash particles with filling role in concrete mix.

Table 3: Slump and Compacting Factor of Wood ash Concrete

Percentage of Wood ash replacement (%)	Slump (mm)	Compacting Factor
0	110	0.98
5	85	0.97
10	45	0.96
15	100	0.98
20	140	0.98
25	170	0.98

4.4 Compressive Strength

The compressive strength of concrete cubes tested at 3, 7, 28, 56, 90 and 120 days are presented in Figure 3. The figure indicates that compressive strength generally increases with curing period and decreases with increasing wood ash content. The result at 3 days showed that the compressive strength of concrete with 5% wood ash content is the highest at this level. Similarly, both 5% and 10% wood ash concrete have higher strength than the control at 7 days. These results are in line with the findings of [4] that addition of fly ash increases the early compressive strength of concrete.

At 28 days, the compressive strength ranges from 18.44 Nmm-2 for the control, to 6.67 Nmm-2 for 25% wood ash replacement. The 5% and 10% wood ash replacements have values of 19.10 Nmm-2 and 21.11 Nmm-2 respectively which are greater than that of the control concrete. This shows that pozzolanic action has commenced as evident from the higher percentage of strength increase by the wood ash concrete which can be attributed to the reaction of wood ash with calcium hydroxide liberated during the hydration of cement. This is in line with previous studies on pozzolans [15 - 19].

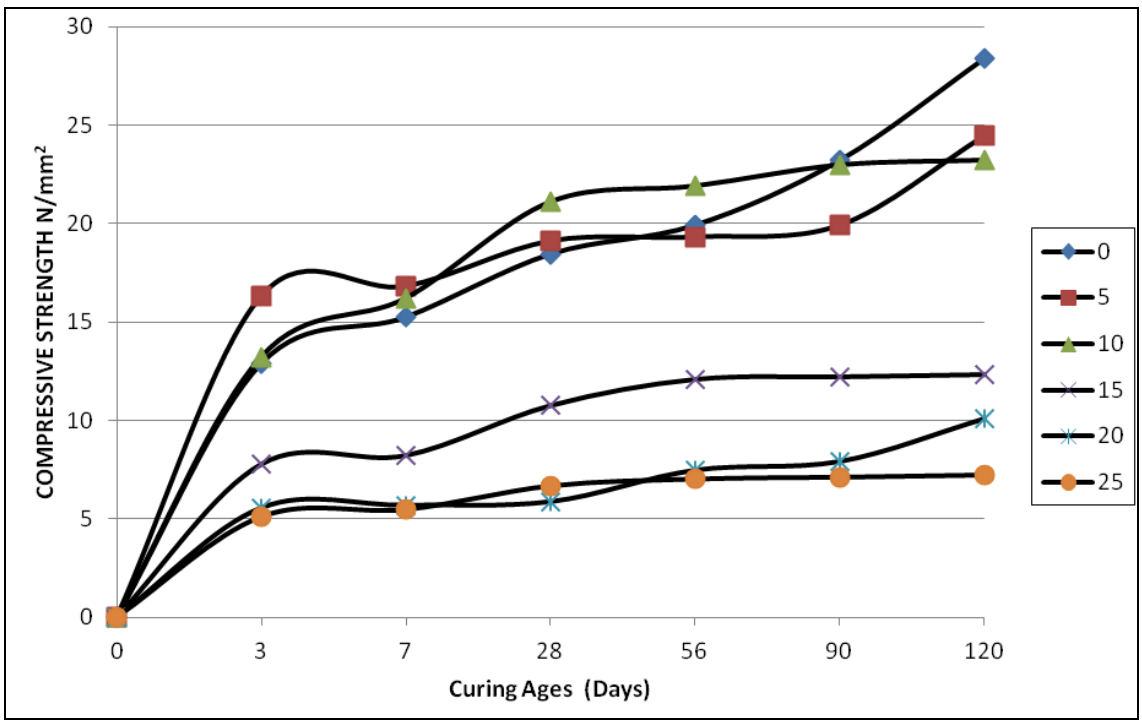

Figure 3: Effect of curing age on the compressive strength of concrete

There was continuous and significant improvement in strength development at 56 and 90 days. This confirms the continuous pozzolanic reaction in wood ash concrete. It is an indication of the role of reactive silica in strength development of pozzolan cement concrete. As the wood ash content increases, more silica is available to react with the lime produced during hydration of cement, thus producing more cementing materials, which contribute to the higher compressive strength [15]. The 10% wood ash replacement still maintains the lead in strength development.

At 120 days, there was continuous increase in compressive strength but the control has the highest value in this case. The 5% wood ash replacement also has a higher value than its 10% counterpart. It could also be observed from Figure 3 that there is a sharp decrease in compressive strength beyond 10% wood ash substitution. This is an indication that the use of wood ash beyond 10% replacement level is not advantageous for structural concrete.

Figure 4 shows the effect of wood ash percentage replacement on the compressive strength of concrete.

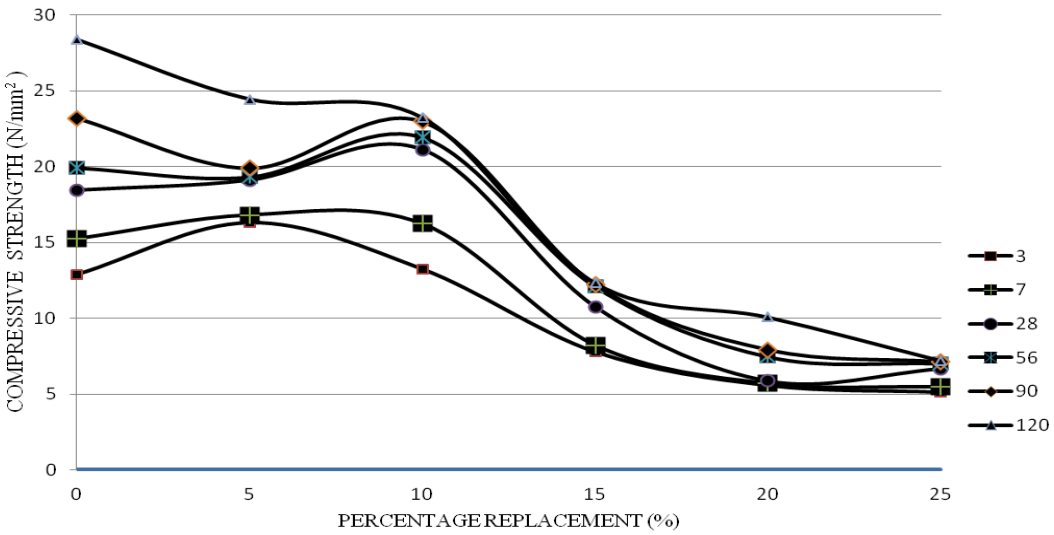

Figure 3: Effect of wood ash percentage replacement on the compressive strength of concrete

As could be observed from the figure, there is a general decrease in compressive strength as the wood ash content increases. However, a notable increase in strength can be observed between 5% and 10% replacement level. Thus, it could be concluded that only up to 10% wood ash substitution is adequate for use in structural concrete. However, since all the concrete cube specimens meet the minimum strength of 6Nmm-2 after 28 days of curing recommended by BS 5224: 1976 [20] for masonry cement, they could be used for general concrete works where strength is of less importance such as in mass concrete, floor screed and mortar.

5.0 Conclusion

From the results of the various tests performed, the following conclusions can be drawn:

1. Wood ash is a suitable material for use as a pozzolan, since it satisfied the requirement for such a material by having a combined (SiO2 +Al2O3 +Fe2O3) of more than 70%. It is classified as a Class F fly ash.

2. Concrete becomes more workable as the wood ash content increases. This means that wood ash concrete has lower water demand.

3. The compressive strength generally increases with curing period and decreases with increasing wood ash content. Wood ash concrete has higher strength than the control at early ages.

4. Only up to 10% wood ash substitution is adequate for use in structural concrete.

It is recommended for further studies that other properties of concrete such as tensile strength, flexural strength and durability characteristics be investigated in order to provide an enlarged database on the performance characteristics of wood ash blended cement concrete.

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