



WHEAT STRAW ASH AS CEMENT REPLACEMENT MATERIAL IN CONCRETE

SANI ALIYU AND KASHIM IBN YAKUBU

Department of Civil Engineering

Abubakar Tafawa Balewa University, Bauchi

Department of Architecture,

Kano University of Science & Technology, Wudil

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Correspondence author:

e-mail:

esaliyu@yahoo.com

kashyakub@gmail.com

Phone:

08057278281,

07038283323

08037710166

ABSTRACT

This paper presents the effects of using Wheat Straw Ash (WSA) as a partial replacement material for cement in concrete mixes. This work is based on an experimental study of concrete made with Ordinary Portland Cement (OPC) and 10%, 20%, 30%, 40% of WSA replacing OPC. The WSA was obtained from open burning of wheat straw at a temperature of 600 - 700°C. Sieve no. 200 was used to sieve the ash. Fresh concrete properties and compressive strength were measured for concrete mixtures with WSA within the investigated replacement levels. The results indicated that the setting times of WSA concrete increased with higher ash content, while the workability and compressive strength showed a reverse trend. An optimum percentage of 10% WSA is recommended for use in concrete production.

1 Introduction

Use of Supplementary Cementitious Materials (SCMs) such as fly ash, calcined kaolin, and palm oil fuel ash as partial replacements for cement have been suggested as a response to environmental concerns about greenhouse gas production (Malhotra 1987), (Storeven et al, 1999). Moreover, disposal of agricultural waste materials such as maize cob, rice husk and wheat straw have constituted an environmental challenge, hence the need to convert them to useful materials to mitigate their adverse effect on the environment. Mehta (1994) reported that properly burnt and ground rice husk ash is also suitable for use as a supplementary cementitious material. The use of new materials as cement replacement alternatives can be an interesting area of study. In Nigeria, as in many parts of the world, a large amount of wheat straw could be obtained as an agricultural by-

product. Wheat straw ashes, and indeed other ashes, have high residual silica content. Examples of other ashes include calcined sunflower ash and calcined tobacco ash. Maize cob and rice husk ashes may be useful as pozzolans in blended cements (Bensted and Mum 2000).

Binici et al (2005) stated that wheat straw can be used in mud brick production, stressing that the use of wheat straw ash in combination with corn cob ash and plane leaf ash has been reported to increase durability of concrete structures exposed to aggressive environment. It was investigated by Wong et al (1999) that the interfacial zone of the boundary between aggregate and the matrix in concrete is improved by using fly ash. Fly ash is one of the most common pozzolanas and is being used worldwide in concrete work (Chindaprasit et al, 2007).

ASTM C 618-78 specifies that any pozzolana that will be used as a cement binder in concrete requires a minimum of 70% silica, alumina and ferric oxides. BS 3892: 1965 parts 1 and 2 have specified a maximum MgO content of 4% and maximum loss on ignition of 12% respectively. The aim of this study is to explore the feasibility of incorporating wheat straw ash as partial replacement of cement in concrete. The objectives are to ascertain the optimum replacement level of Portland cement with WSA, as well as observing how the fresh and hardened properties of the concrete are being affected.

2 MATERIALS AND METHODS

- **Cement-** Ashaka brand of ordinary Portland cement was used throughout the experimentation.
- **Fine Aggregate-** The fine aggregate used for the research was natural river sand conforming to zone 2 and with a fineness modulus of 2.99 and specific gravity of 2.63.
- **Coarse Aggregate-** Crushed gravel aggregate with specific gravity of 2.61 was used.
- **Wheat Straw-** The wheat straw used for the research was obtained from local farmers in Bauchi. After drying, it was subjected to open burning at a temperature of between 600 to 700°C and the remaining ash sieved through number 200 BS test sieve.

Water- Potable water was used for mixing of all specimens as well as for curing the cast cubes.

Concrete Mix Design- This was based on minimum design strength of 25N/mm² at 28days. The design was in accordance to BS 882, Part 2, 1973-Design of normal concrete mix. The mixing of all constituents was carried out at the Structures laboratory of the Faculty of Engineering, Abubakar Tafawa Balewa University, Bauchi. A mix ratio of 1:2:4:0.6 was adopted for all cast specimens. A total of 60 cubes were casted using 150mm x 150mm x 150mm moulds, with the control (100% OPC) and percentages of 10, 20, 30, and 40 of WSA replacing cement. After 24hours, the cubes were de-moulded and then placed in the curing tank. The specimens were allowed to cure for 3, 7, 14 and 28 days respectively. The specimens were tested using the ELE-2000 Compression machine.

3 TEST RESULTS

Table 1 shows the oxide composition of WSA, as obtained by AAS (atomic absorption spectrophotometer). Table 2 presents results of fresh concrete properties for various OPC-WSA pastes and Table 3 presents the results of the compressive strength.

Table 1: Oxide composition of Wheat Straw Ash (WSA)

Oxide	Percentage Composition (%)
SiO ₂	87
Fe ₂ O ₃	1.2
Al ₂ O ₃	1.3
CaO	1.6
MgO	1.4
LOI	4.0

Table 2: Properties of Fresh WSA concrete

% replacement	Workability		Setting time (minutes)	
	Slump (mm)	Compaction factor	Initial	Final
0	30	0.980	48	175
10	22	0.960	78	323
20	15	0.925	95	397
30	10	0.882	125	425
40	4	0.817	142	456

Table 3: Compressive Strength

% replacement	Compressive Strength (N/mm ²)			
	3days	7days	14days	28days
0	12.50	15.43	22.53	27.41
10	11.41	13.27	21.62	25.92
20	9.81	11.33	19.50	23.50
30	8.01	10.86	16.80	21.60
40	7.22	9.22	14.67	16.85

4 DISCUSSION OF RESULTS

Fresh WCA Concrete

From table 1, WSA contains 87% SiO₂, 1.2% Fe₂O₃ and 1.3%Al₂O₃, the sum of which gives a pozzolanic activity index of 89.5%. This is in accordance with the requirements of ASTM C 618-78 for pozzolanas. Thus WSA meets the requirements for a pozzolana. The MgO content of 1.4 and LOI of 4.0 both fall within the prescribed limits. Table 2 presents some of the fresh concrete properties. The workability decreased as the WSA content was increased. The control mix had a slump and compaction factor of 30mm and 0.98 respectively, whereas at 40% replacement level, the slump and compaction factor were 4mm and 0.817 respectively. The influence of WSA on the setting time of cement paste indicated that the

ash increased both the initial and final setting times. The initial setting time of the control paste was 48minutes, and that for the paste with 40% WSA was 2h, 22min. BS 12 (1978) recommends a minimum initial setting time of 45min. The final setting times at all replacement levels were within the requirements of the British standard (BS12), which prescribe a maximum of 10h.

The delay in setting times for the blended pastes is attributed to the pozzolanic activity of the ash. It takes a longer time for WSA-OPC blend to react completely with Ca(OH)₂ released during hydration. This tends to affect both fresh concrete properties and early rate of strength gain.

The variation of the setting times versus percentage replacement is indicated in Figure 1.

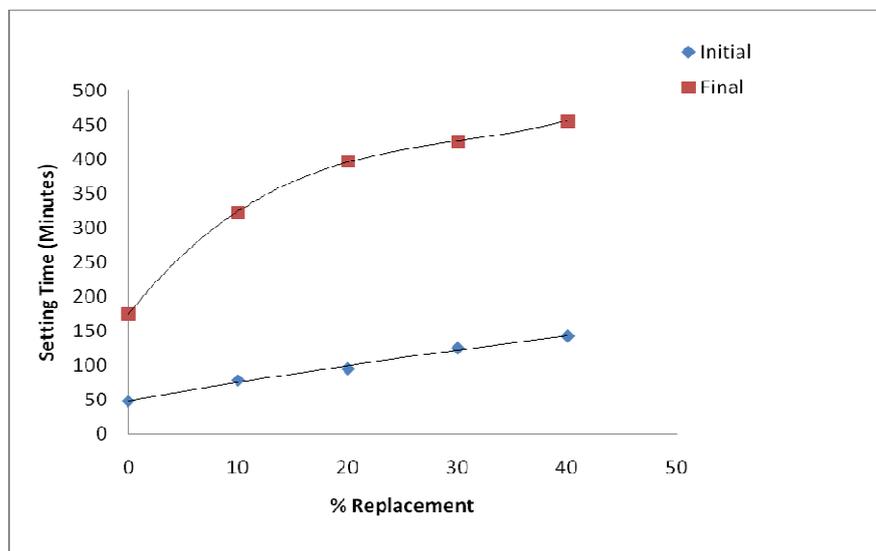


Figure 1: Setting Time against percentage replacement

Hardened WSA Concrete

The compressive strength of WSA concrete specimens at various ages is presented in Table 3. The results indicated that at all ages the strength decreased with an increase in the level

of replacement of OPC by WSA. This is due to the curing age regime of 28 days used for WSA samples. WSA exhibits a pozzolanic property as can be seen from the strength increase of the WSA concrete with age.

The 3 days strength decreases from 12.50N/mm² for OPC control concrete to 7.22N/mm² for the WSA concrete at 40% replacement level. The strength after 28days curing decreases from 27.41N/mm² at 0%WSA to 16.85N/mm² at 40%WSA. The optimal strength at 28days for OPC-WSA mix occurred at 10% replacement, which is 25.92N/mm².

The decrease in strength is attributable to slow gain of strength in the early stages of curing. As a pozzolan, it takes time for complete reaction to take place between the products of hydration of OPC and WSA. The variation of the compressive strength against percentage replacement is depicted in Figure 2.

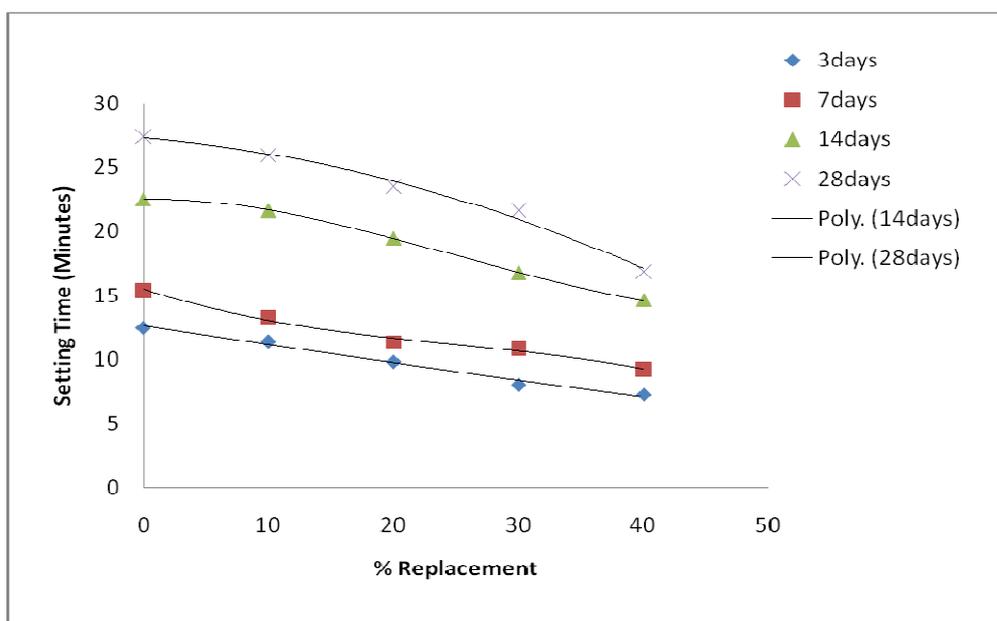


Figure 2: Compressive Strength against percentage replacement

5 CONCLUSIONS AND RECOMMENDATIONS

Based on this research, the following conclusions can be made:

- The setting time of OPC-WSA paste increased with increasing WSA content. At all percentage replacement levels, both initial and final setting times fall within the BS prescribed limits. The increased setting time of WSA concrete could be of advantage in mass concrete works, to take care of the early rate of heat evolution.
- The workability of fresh WSA concrete with a direct replacement of cement by the same mass of ash decreased with an increase in the ash content.
- The compressive strength decreased with an increase in WSA content. All the WSA concrete specimens, with the exception of samples with a 40% replacement level, have

attained at least 70% of their 28-day strength at seven-day curing.

- The results of the compressive strength test indicated that up to 10% of WSA can be used as a replacement for OPC. At this level, the reduction in strength of specimens was almost proportional to the percentage replacement, but with higher percentages of replacement, the reduction was disproportionately high. It is hereby recommended that;
 - Further work be carried on ash obtained from a controlled kiln burner at a regulated higher temperature. This may produce a highly reactive ash that will improve the pozzolanic properties.
 - Long-term properties such as durability, air and water permeability and volume changes need to be ascertained before accepting WSA as a construction material.

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