Characteristics of Wood ASH/OPC Concrete

M. Abdullahi

Civil Engineering Department, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria, abdulapai@yahoo.com

Abstract

The study presents the behaviour of wood ash / OPC concrete. Chemical analysis of wood ash, bulk density, sieve analysis and specific gravity of wood ash and aggregates, consistency, setting time and slump test of the fresh paste were conducted to determine the suitability of the materials for concrete making. Mix ratio of 1:2:4 and percentage replacement level of 0, 10, 20, 30 and 40 percents of cement by wood ash were used. 150mm×150mm cubes were cast, cured and crushed at 28 and 60 days to determine their compressive strength. Test result indicates that the wood ash is slightly pozzolanic, water demand increases as the ash content increases and the setting time of the paste increases as the ash content increases. Compressive strength of wood ash / OPC concrete it increases with age at curing with optimum replacement of cement by wood ash of 20%.

Keywords

Wood ash, OPC concrete, Chemical analysis

Introduction

Concrete is a construction material composed of Portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite [1]. The major constituent of concrete is aggregate, which may be natural (gravel or crushed rock with sand) or artificial (blast furnace slag, broken brick and steel shot). Another constituent is the binder, which serves to hold together the particles of aggregate to form concrete. Commonly used binder is the product of hydration of cement, which is the chemical reaction between cement and water [2]. Admixtures may also be added to concrete mixes to change some of its properties.

Wood ash in this study is an admixture: a pozzolana. A pozzolana is a material rich in silica and alumina which in itself has little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties [3]. Wood ash is obtained from the combustion of wood. It can be related to fly ash since fly ash is obtained from coal, which is a fossilized wood [4]. Rice husk ash is also of plant origin. This implies that wood ash could be used as a pozzolana in concrete. Tarun, Rudolph and Rafat [5] reported the following elements in wood ash: carbon (5% to 30%), calcium (5% to 30%), carbon (7% to 33%), potassium (3% to 4%), magnesium (1% to 2%), phosphorus (0.3% to 1.4%) and sodium (0.2% to 0.5%). The following compound composition limits were also reported: SiO_2 (4% to 60%), Al_2O_3 (5% to 20%), Fe_2 O_3 (10% to 90%), CaO (2% to 37%), MgO (0.7% to 5%), TiO_2 (0% to 1.5%), K_2O (0.4% to 14%), SO_3 (0.1% to 15%), LOI (0.1% to 33%), moisture content (0.1% to 22%), and available alkalis (0.4% to 20%). The study revealed that all the major compounds present in wood ash are present in fly ash.

Materials and Methods

The wood ash used in this work was powdery, amorphous solid, sourced locally, from a bakery in Minna. The wood ash was passed through BS sieve 0.075mm size. The chemical composition of the wood ash was conducted at the Agric. Laboratory of Federal University of Technology, Minna, Nigeria. Bulk density, sieve analysis and specific gravity tests were conducted on the ash, fine and coarse aggregates in accordance to [6] and [7].

The mix used for all concrete cubes cast in this work is 1:2:4, with the cement partially replaced by wood ash in varied percentages of its volume (0%, 10%, 20%, 30% and 40%). The workability of each of the mixes was determined using slump test according to [8]. Cubes were cast using wooden moulds (150mm×150mm) and compaction was done manually. The cubes were cured and crushed to determine their compressive strength at 28 and 60 days according to [9].

Results and Discussions

Chemical Analysis of Wood Ash

The results of chemical analysis of wood ash are shown in Table 1. The total percentage composition of Iron oxide (Fe_2O_3 = 2.34%), aluminium oxide (Al_2O_3 = 28.0%) and silicon dioxide (SiO_2 = 31.80%) was found to be 62.14%. This is less than 70% minimum required for pozzolana [3] (ASTM C 618-94, 1994).

Table 1. Chemical Composition of Wood Ash

Constituent	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	NaO	L.O.I
Composition [%]	31.8	28	2.34	10.53	9.32	10.38	6.5	27

This reduces the pozzolanicity of the wood ash. The percentage composition of silicon dioxide (31.8%) is within the range specified by [5]. However, the percentage composition of Iron oxide and aluminium oxide were not in agreement with the work [5]. The loss on ignition obtained was 27%. The value is more than 12% maximum as required for pozzolana [3]. This means that the wood ash contain appreciable amount of un-burnt carbon which reduces its pozzolanic activity. The un-burnt carbon is not pozzolanic and its presence serves as filler to the mixture. The alkali content (Na_2O) was found to be 6.5%. This value is higher than the maximum alkali content of 1.5% required for pozzolana. The alkali content is important were the wood ash is to be used with reactive aggregate [10]. Wood ash will not be suitable for construction work where reactive aggregate is to be used.

Specific Gravity Test

Table 2 shows the result for the specific gravity test of aggregates and wood ash. The specific gravity of wood ash was found to be 2.13. This value is far less than 3.15 for Portland cement.

The value is close to the value reported by [11] and [12] which was 2.13 for rice husk ash and 2.12 for acha husk ash.

It is also within the range for the specific gravity of pulverized fuel ash [10]. The specific gravity of the sand and gravel were found to be 2.62 and 2.66.

The value obtained falls within the limit for natural aggregates with value of specific gravity between 2.6 and 2.7 as reported in [10].

Table 2. Specific Gravity of Materials

Data	Wood Ash		Sand		Gravel	
	Test1	Test 2	Test1	Test2	Test 1	Test2
Mass of gas jar, plate, soil (RHA) and water (m_3) [g]	1595.0	1599.0	1685	1678	1732.90	1730.9
Mass of gas jar, plate and soil (RHA) (m_2) [g]	686.6	689.4	820.0	815.5	876.5	875.5
Mass of gas jar, plate and water (m_4) [g]	1504.6	1506.4	1495.9	1493.5	1507.1	1506.9
Mass of gas jar and plate (m_1) [g]	515.6	515.6	515.6	515.6	515.6	515.6
$(m_2 – m_1)$ [g]	171.0	173.8	304.4	299.9	360.9	359.9
$(m_4 – m_1)$ [g]	989.0	990.8	980.3	977.9	991.5	991.3
$(m_3 – m_2)$ [g]	908.4	909.6	865.0	862.5	856.4	855.4
$(m_4 – m_1) - (m_3 – m_2)$ [g]	80.6	81.2	115.3	115.4	135.1	135.9
Specific gravity of the particles $G_s = (m_2 – m_1)/((m_4 – m_1) - (m_3 – m_2))$	2.12	2.14	2.64	2.60	2.67	2.65
Mean of specific gravity	2.13		2.64		2.66	

Bulk Density Test

Table 3 shows the result for the compacted bulk density of wood ash and aggregates. The bulk density of wood ash was found to be 760 kg/m^3.

Table 3. Compacted Bulk Density of Materials

Data	Wood Ash		Sand		Gravel	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
Weight of empty cylinder (w_1) [kg]	4.35	4.35	4.35	4.35	4.35	4.35
Weight of empty cylinder + weight of compacted materials (w_2) [kg]	5.10	5.12	5.96	5.98	5.85	5.85
Weight of compacted materials (w_3) [kg]	0.75	0.77	1.61	1.63	1.5	1.5
Volume of Cylinder (v) [Litre]	1	1	1	1	1	1
Compacted Bulk density (w_3/v) [Kg/m^3]	750	770	1610	1630	1500	1500
Mean Bulk density [Kg/m^3]	760		1620		1500	

The [11] report obtained the compacted bulk density for rice husk ash to be 530 kg/m^3 and [12] reported a value of 740 kg/m^3 for acha husk ash. These values are reasonably close to one another indicating that they are all lightweight materials. The silica in pozzolana can only combine with calcium hydroxide when it is in a finely divided state. Pozzolana in this state has uniform particles which are difficult to compact very closely resulting to a low compacted bulk density. The compacted bulk densities for sand and gravel were found to be 1620 kg/m^3 and 1500 kg/m^3.

Sieve Analysis

Tables 4 and 5 show the result for the sieve analysis of sand and gravel.

Table 4. Sieve Analysis of Fine Aggregate

Sieve Size [mm]	Mass of Sieve (w1) [g]	Mass of Sieve + Sample (w2) [g]	Mass of Sample Retained (w3) [g]	Percentage Retained [%]	Cumulative Percentage Retained [%]	Percentage Passing [%]
5.00	478.60	483.10	4.50	0.90	0.90	99.10
3.35	468.87	477.42	8.55	1.72	2.62	97.38
2.36	435.99	459.34	23.35	4.67	7.29	92.71
1.18	390.85	423.25	32.40	6.48	13.77	86.23
0.60	337.30	438.30	101.00	20.20	33.97	66.03
0.30	317.10	558.95	241.85	48.37	82.34	17.66
0.15	296.01	302.06	6.05	1.21	83.55	16.45
0.075	301.08	331.18	30.10	6.02	89.57	10.43
Pan	295.53	347.68	52.15	10.43	100.00	0.00

Table 5. Sieve Analysis of Coarse Aggregate

Sieve Size [mm]	Mass of Sample Retained [g]	Percentage Retained [%]	Cumulative Percentage Retained [%]	Percentage Passing [%]
28	0.00	0.00	0.00	100.00
14	323.79	16.19	16.19	83.81
10	1466.21	73.31	89.50	10.50
6.3	166.12	8.31	97.81	2.19
5.0	21.16	1.06	98.87	1.13
Pan	22.70	1.13	100.00	0.00

Test result reveal that the sand is fine grading sand and the gravel is single-sized aggregate of 14mm nominal size confirming the aggregates suitable for construction work [13].

Consistency and Setting Times Tests

Table 6 shows the result for the consistency test. Result reveals that the water demand increases with the wood ash content. The wood ash introduced into the cement increases the carbon content and this increases the water required to achieve a reasonable workability.

Table 6. Consistency Test

Replacement of Opc by Rha [%]	0	10	20	30	40
Opc [g]	400	360	320	280	240
Rha [g]	0	40	80	120	160
Water [ml]	125	132	138	146	153
Water/Binder Ratio [%]	31	33	35	37	38

The result for the setting times test is shown in Table 7.

Table 7. Setting Times Test

Replacement of Opc by Rha [%]	0	10	20	30	40
Initial Setting Time [minutes]	100	218	321	395	436
Final Setting Time [minutes]	160	334	523	698	789

The initial and final setting times increases with increase in wood ash content. The exothermic reaction between cement and water result into liberation of heat and evaporation of water and eventually hardening of the paste. The rate of reaction and quantity of heat liberated reduces with the introduction of wood ash leading to late stiffening of the paste. As the hydration process was prolonged, greater amount of water was required in the process.

Slump Test

The result for the slump test is shown in Table 8. Test result shows that mixes with greater wood ash content requires greater water content to achieve a reasonable workability.

Table 8. Slump Values

Replacement of Opc by Rha [%]	0	10	20	30	40
Water/Binder Actual Ratio	0.6	0.66	0.67	0.68	0.69
Slump [mm]	30	35	40	40	35

The increased water demand was due to the relatively high carbon content in wood ash. The slumps observed were from low (15 to 30 mm) to medium (35 to 75 mm) [8].

Compressive Strength Test

Table 9 show the result for the compressive strength of wood ash / OPC concrete at 28 and 60 days. The result shows that the cubes containing 0% wood ash had the highest compressive strength. The mix containing 20% wood ash had higher strength than that containing 10% wood ash at 28 and 60 days.

This was due to the fact that the silica provided by 10% wood ash was inadequate to react with the calcium hydroxide produced by the hydration of cement. Increase in wood ash content beyond 20% resulted in a reduction in strength at 28 and 60 days. In this case the silica present in the mix was in excess of the amount required to combine with the calcium hydroxide from the hydrating cement. The excess silica had no pozzolanic value but only served as filler.

Table 9. 28 and 60 day Compressive Strength

Cube ash [%]		Weight [Kg] 28 day	Weight [Kg] 60 day	Crushing Load [KN] 28 day	Crushing Load [KN] 60 day	Compressive Strength [N/mm²] 28 day	Compressive Strength [N/mm²] 60 day	Average [N/mm²] 28 day	Average [N/mm²] 60 day
0	A	7.84	7.86	535	498	23.78	22.13	23.96	24.15
	B	8.58	8.08	540	590	24.00	26.22		
	C	8.25	7.92	542	542	24.09	24.09		
10	A	7.95	8.08	270	312	12.00	13.87	13.09	14.06
	B	7.94	7.8	324	329	14.40	14.62		
	C	7.8	7.9	290	308	12.89	13.69		
20	A	8.07	8.1	312	428	13.87	19.02	14.13	18.60
	B	8.08	8.06	322	410	14.31	18.22		
	C	7.95	7.98	320	418	14.22	18.57		
30	A	8.19	7.92	197	198	8.75	8.80	9.02	7.91
	B	7.9	8.04	208	186	9.24	8.27		
	C	8.21	8.08	204	150	9.07	6.67		
40	A	8.3	8.3	180	197	8.00	8.76	8.59	7.82
	B	8.5	7.98	204	149	9.07	6.62		
	C	8.1	8.04	196	182	8.71	8.09		

At 60 days hydration period, the compressive strength of concrete containing 20% wood ash increased considerably indicating that greater strength can be obtained at greater days. The optimum replacement of cement by wood ash is therefore 20%.

Conclusions

From the findings of this work the following conclusions were made:

- The chemical composition of wood ash fell below the standard for pozzolana;
- The specific gravity and compacted bulk density of wood ash were found to be 2.13 and 760 kg/m^3;
- The water requirement increases as wood ash content increases;
- The setting times of wood ash / OPC paste increases as the ash content increases; the 10% and 20% wood ash paste satisfy the recommended standard for ordinary Portland cement paste. 30% and 40% wood ash paste gave higher values of setting times which do not satisfy the standard;
- The compressive strength of the concrete with 20% wood ash content increased appreciably at 60 days. The optimum replacement level was therefore 20%.

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Reinforced concrete is the most common form of concrete. The reinforcement is often steel rebar (mesh, spiral, bars and other forms). Structural fibers of various materials are available.Â A 25% strength gain between 7 and 28 days is often observed with 100% OPC (ordinary Portland cement) mixtures, and between 25% and 40% strength gain can be realized with the inclusion of pozzolans such as flyash, and supplementary cementitious materials (SCMs) such as slag cement. Strength gain depends on the type of mixture, its constituents, the use of standard curing, proper testing by certified technicians, and care of cylinders in transport.Â "Microstructural characteristics of HPC under different thermo-mechanical and thermo-hydraulic conditions". Materials and Structures. Characteristics of Wood Ash/OPC concrete, Leonardo Electronic Journal of Practices and Technologies,:8: 9-16. 5. Bjarte Oyo, 2012. Wood ash as raw material for Portland cement, Ash-2012, 6. Cheetah Chee Ban and MahudinRamli, 2011. Properties of high calcium wood ash and densified silica fume blended cement, Int. J. Phy. Sci. 6(28): 6596-6606. 7. Raft Siddique2012. Utilization of wood ash in concrete manufacturing, Resources, conservation and Recycling, 67: 27-33. 8. NynketerHeide and Erik schlangen,selfbealing of early cracksin concreteâ€™ Delft university of Technology CiTG , Micro lab, P.O Box Wood ash, OPC concrete, Chemical analysis. Introduction. Concrete is a construction material composed of Portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite [1]. The major constituent of concrete is aggregate, which may be natural (gravel or crushed rock with sand) or artificial (blast furnace slag, broken brick and steel shot). Another constituent is the binder, which serves to hold together the particles of aggregate to form concrete. Commonly used binder is the product of hydration of cement, which is the chemical Characteristics of Wood ASH/OPC Concreteâ€. Leonardo Electronic Journal of Practices and Technologies. Issue 8, January-June 2006 p. 9-16. http://lejpt.academicdirect.org.Â Some Characteristics of AHA/OPC Concretes: A Preliminary Assessment. Nigerian Journal of Construction Technology and Management, 2 (1): 22-28. Elinwa, A.U. and Mahmood, Y. A. (2002). The use of wood ash and sugarcane bagasse ash as a pozzolanic material in concrete mixtures [8 , 9] and the use of wood ash as highway pavement and subgrade reinforcement material [10 , 11] have been studied in an attempt to increase the strength and stiffness of the materials [12]. However, the study of geotechnical properties of biomass ashes lags far behind.Â Table 3. Chemical composition of wood ash, sugarcane bagasse ash, and coal fly ash Class C [25,26,27]. Constituents. Wood Ash.Â The characteristics of Ottawa 20/30 sand and biomass ashes are summarized. Hydraulic conductivity, consolidation, and shear wave velocity are following. 4.1. Basic Properties of Biomass Ashes.