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An Assessment of Pozzolanic Properties of Wheat Husk Ash (WHA)

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Abstract— *This paper title an assessment of pozzolanic properties of wheat husk ash. It entails collecting the husk from kusa, jibia local government area of katsina State burning it in electric kiln at 680^{0}C until it turns to ashes. The physical as well as chemical test was conducted on the ash to determine it is pozzolanic properties The paper concludes that the physical tests as: sieves analysis with 79% passing through 212mm, bulk density of 0.216g, specific gravity of 2.17, initial and final setting time of 10 minutes and 4hours50 minutes, and also water absorption of percentages of cement replacement at 0%, 10% and 30% of 10.23, 15.51, 17.34 respectively which are all acceptable in determining pozzolana as recommended by British standard and American standard. The Chemical properties indicated that Silica (SiO2) has the highest percentage meaning the soil has contained high clay, the Magnesium, Sodium and Potassium Oxide were all within the recommendation of pozzolana with only Calcium Oxide that was below. Therefore, wheat husk ash can be use as pozzolana The paper recommends determination of soundness of wheat husk ash, production of sandcrete blocks with wheat husk ash replacement up to 60%, potentiality of using wheat husk ash in reduction of the cost of cement, and determination of aluminium Oxide present in the wheat husk ash*.

Keywords— *Pozzolana, Wheat husk ash, Chemical properties*.

I. Introduction

Wheat husk ash is obtained from wheat husk that is the outer covering material obtained in the processing of kernels for consumption. Wheat appears like much field grass when young, individual wheat stalks can grow up to one and half peds tall and may have almost one fore in length. Packed tightly kernels wheat forms the head on the top of the stem, the head kernels usually hold between 50-60 small kernels. (Nagdeve, 2021)

Wheat can be used to make various types of noodles and also can be used to make flour which is used to make bread, cheese balls and cakes. (Arnarson, 2019) In Nigeria, it is typically grown in kano state and it account for most of its production it also grown in some part of kaduna, katsina, plateau and Bauchi state. The covering materials of this plant known as wheat husk which is used for feeding livestock and poultry occupants on a millers farm. However, wheat husk ash (WHA) is a material that may be use as pozzolana. American society for material testing ASTM 612 defined pozzolana as siliceous and aluminous materials that in themselves possess little or not binding but in the presence of water chemically react with calcium hydroxide at certain temperature to form compound possessing cemeteries properties.

according to the testing methods of pozzolanas technical brief, pozzolana are materials which contain relative silica and alumina and on their own has not binding property but when mixed with lime in the presence of water will set and harden like cement. Pozzolana are an important ingredient in the production of alternative cementery materials to ordinary Portland cement. Pozzolana have been used for many years ago as the building materials, the Greek and Roman were the first civilization that started using pozzolana in their building as binding agent, it has some advantages in the sense of eliminating less gases during production as of cement (Abdlu, 2008).

II. Literature Review

Malguori (1960) suggested that materials which have pozzolanic activity should be defined in respect of their use, as cementious materials quite apart from the interpretation of the chemical and physical co-chemical phenomena which are responsible for the hardening of hydraulic binder. Roman used crushed pottery, bricks and tiles which formed the first artificial pozzolanas. But still found that some were very excellent for producing a hydraulic mortar nowadays, therefore, wide variety of siliceous or aluminous materials are used for producing pozzolanas the common materials being calcite clay, pulverized fly ash, volcanic ash and ash from agricultural residue such as rice husk, acha husk, acha straw etc. (Abdul, 2008)

2.1 Classification of Pozzolana

Neville (1996) grouped pozzolana into two main namely;

a. Natural pozzolana
b. Artificial pozzolana

2.1.1 Natural pozzolana

Natural pozzolana are usually materials for volcanic origin and also certain diatomaceous earth which may further be divided into two groups as reported by malgouri (1960)

i- These are those derived from volcanic rocks which are the amorphous constituent is glass by fusion these are example volcanic ashes and tuffs, pumice, scoria and obsidian
ii- Others derives from rocks or earth for which the silica constituent contains opaling either from precipitation of silica solution or from the remaining of organismis, examples of these are diatomaceous earth, charts, opaling, silica, lava containing substantial amount of glassy component. In Africa some of the known sources of pozzolana of volcanic origin may be found in cameroun, Burudi, Ethiopia, Tanzania, Kenya, Rwanda and Algeria

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2.1.2 Artificial pozzolana

Artificial pozzolana are mostly the one mainly obtained by the heat treatment of natural materials such as clay, shales and coal. The artificial pozzolanas may also be divided into two main groups as reported by malgouri (1960), those of in-organic and organic origin. The most obtained from calcium clay and shales, bauxite, calcined, bauxite-waste and sarki (brick powder)

These sources of artificial pozzolanas of organic includes most agricultural waste such as rice husk, coffee herb, coconut shell, sugarcane baggase, palm nut shell, fibre and acha husk. There was also investigation into the use of cocoa pods, makuba and juth fibre for pozzolana product, of all these rice husk (RHA) has been well investigated and documented as reported in low cement services entitled pozzolana.

2.2 Chemical Composition of Pozzolana

Pozzolanas, by their diverse and different nature end to have widely varying characteristics. The chemical makeup of pozzolanas varies a lot depending on where it comes from and how it's made. Pozzolanas often contain different amounts of silica, alumina, iron oxide, and a range of oxides and alkalis. This is a problem for small-scale manufacturers who want to use pozzolana in lime or a regular Portland cement-pozzolana mix because there aren't enough laboratory facilities to test the raw materials. It's difficult to maintain standards and produce constituent product when there aren't enough lab facilities. It is also widely accepted that the chemical composition of raw materials determines whether they are pozzolanic and will react when mixed with lime or conventional Portland cement. The type of reaction and subsequent strength of the hydrated mixture cannot be accurately deduced from just a chemical composition (except for a small number of known pozzolanas). In most cost no direct correlation can be found between chemical content and reactivity. Other characteristics of the pozzolana also affects its reactivity such as fine and crystalline structure, as reported by the testing methods or pozzolanas technical report.

TABLE 2.1 Physical and chemical requirement for pozzolanas property by ASTM

Property	ASTM Requirements
Water-soluble (max. percent)	10.0
Fine amount refined when wet sieved No.30 sieved (max. percent) No. 200 sieved (max. percent)	2.0
No. 200 sieved (max. percent) increase in dry shrinkage of Portland pozzolana cement mortar bars atv 28 days (max. percent)	30.0
Pozzolana activity index with cement at 28 days (min. percent of control) silicon dioxides (SiO_2 + Aluminium oxide)	2.5
(AL2O3) + Iron Oxide (FE2O3) (Min percent)	70
Magnessium oxide (MgO) (Max. percent)	5.0
Loss of ignition (LOI) (max. percent)	12.0

Source ASTMC 618-78

2.3 Mechanism of lime-pozzolana reaction

Nevilee (1978) explained that the reaction between silica and lime [$Ca(Oha)_2$] at ordinary temperature result in stable calcium-silicate which have cementious properties. The essential property pf pozzolana as reported by Ikpong (1989) is their affinity to lime in the presence of water this affinity is brought about by the presence of silicate in finely divided pozzolana.

However, Orchard (1979) confines that aluminium and iron oxide where present, also take part in the chemically as well as which was reported by Barret, *et al (*1976).

Two theories proposed by lea (1988) explain the reactions of these exchange and direct composition.

a- Natural pozzolana are zeolitic compounds that own their properties to the base exchange. Zeolites are group of insoluble hydrate alumina-silicate of the alkalis and the alkaline earth, which have the property of exchanging some of their base constituent for others when immersed in salt solution. In base exchange of the zeolitic compound remain unchanged and one base iron is exchanged for other fitting into similar position to form crystal lattice given the cementious substance

b- the course of the combination of lime with pozzolana can be followed by the flouretum method, which is based on the solubility in the same reagent of the lime pozzolana reagent product. The amount of $SiO_{2,}$ AL_2O_3. Dissolved is determined as a percentage of ignited weight of the pozzolana and high calcium lime is then made and the procedure repeated, calculating back to the original ignited pozzolana weight there is a progressive increase with age in the amount of soluble silica and alumina in the lime, but with little increase in soluble Fe_2O_3

Pozzolana reported by Lea (1988) is mix with lime, generally form a hydrated calcium-silicate similar to calcium-hydro silicate [$(C_2SH)0,8$ - CaO_3,$SO_{2\ aq}$] and tetracalcium – aluminate hydrate. When calcium sulphate is also present astringe appears initially and later transforms slowly into the mono sulphate, 3CaO, AL_2O_3, $CaSO_4$ aq as gypsum is removed from the solution.

In the mixture of pozzolana with Portland cement, the reaction products obtained from the pozzolana are similar to those in mixes with lime and gypsum. The presence of hydrogenates has also occasionally been reported and said to be favoured by a high alumina content in the pozzolana

2.4 Uses of Pozzolana

The modern pozzolana as a cement or enhancing admixture in concrete began many decades ago, although it is not new or alternative to the construction industry, but a trend in the past decades towards greater achievement is redefining acceptable practices. Often restricted by building codes to small fraction of the cementious materials in a concrete mix. Pozzolana have considered to held a relatively minor role in the concrete industry, but three trends are now active that can change that minor role to a much bigger one and they include;

a- Economy
b- Durability
c- Environment

Pozzolana belongs to the class of admixtures that is materials added to concrete or mortar of normal constituents to produce certain properties or to derive non-technical believes. Pozzolana in concrete either replaced cement that pozzolana have been used to replaced fine aggregate in light weight concrete to improve workability and other properties including weight of the final product.

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In china pozzolana cement is a chief constituent for stream cure, large well panels, said Bihao (1984) large numbers of which are used in the construction of residential buildings. Pozzolana are also used in conjunction with water reducing agents and are said to be more effective in combination than plan mixes. Pozzolanic materials are also used in aerated concrete to improve thermal properties and fire proofing as it offers better fire resistance than ordinary concrete.

For building items, bricks and tiles Mehta, (1981) reports that since 1963 block incorporating pozzolana have been put into commercial use of residential building. Mix of 1:6 (cement/sand) with 45 percent pozzolana replacement is reported by Nnana (1988) as being suitable for the production of load bearing sandcrete blocks.

2.4.1 Advantages of pozzolana

Major advantages of alternatives to Portland cement are

a. They are usually cheaper to produce.
b. Need much lower or negligible capital input to get started
c. Require for less imported technology and equipment
d. Can be produce on a small scale to supply a local market greater degree and reduced transportation cost a much greater degree of local accountability in the supply of building materials
e. Lower heat of hydration
f. Improved workability
g. Improved water retention/reduce bleeding
h. Improved resistance to alkali-aggregate reaction
i. Lower production cost, means lower price for the consumer enabling those who could not afford to purchase cement and use a quality binding materials

2.5 Method for testing of pozzolana

Pozzolanas are argued to be used for a variety of different application, such as in concrete, mortars, blocks manufacture etc. and mixed with a variety of other materials such as lime, ordinary Portland cement (which can also radically affect the pozzolana). The properties of the mixture in the context for which it intented. This provides valuable information for specific application of the pozzolana which is not specific. This approach, along with that of fine testing forms the basis for most field test as reported by the (testing method for pozzolana technical briefs)

2.6 Reasons for testing of pozzolana

Tests are required for certain reasons, some of which include

a- To assess the viability for a new potential pozzolanic deposit
b- To provide quality control on a day-to-day basis as part of production process
c- To provide long term quality control of pozzolanic resource Abdul (2006)

2.7 Chemical composition of some pozzolana

Compact material (tuffs); the deposits of volcanic pozzolana could contain compact layers as a result of weathering, which can cause Zeolitisation or agrillation. Zeolitisation increase in it.

TABLE 2.2 Results of chemical composition of some pozzolanas.

Pozzolana	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**SO_3**	**LOI**
Bacoli	52.12	18.29	5.81	4.94	1.2	1.48	5.06	-	11.1
Barlie	62.45	16.47	4.41	3.39	0.94	1.71	2.06	-	7.41
Salone	55.69	15.18	6.43	2.83	1.01	-	-	0.26	7.41
Vizzini	73.01	12.28	2.71	2.76	0.41	-	-	0.10	6.34
Volvic	54.68	17.7	3.82	3.66	0.95	3.43	6.38	-	9.11
Santorin earth	67.7	11.32	2.66	3.73	1.64	-	-	0.18	7.27
Rhine tuffash	40.9	12.0	14.0	14.6	1.45	-	-	-	12.06
Rhyohr pumicite	71.63	10.03	4.01	1.93	1.22	2.35	2.35	3.05	-
Furue shirasu	71.65	11.77	0.81	0.88	0.52	1.8	3.44	0.34	9.04
Higashi	71.11	11.79	2.57	2.07	0.15	1.66	1.66	0.27	9.5

III. METHODOLOGY

The wheat husk was collected in sacks from Kusa jibia local government, the husk was put inside electric kiln Dry AD lacseister and was subjected to high temperature of about 680^0C until it turns to ashes at ceramic workshop of the department of Industrial design of ATBU Bauchi. The wheat husk ash (WHA) was also subjected to the physical tests as according to BS 812 of 1973, 1975 and ASTMC 618- 68 standard, the physical tests were specific gravity, fineness, sieve analysis, bulk density, specific gravity, water absorption, initial and final setting time at 10% and 30% Concrete cubes of 50x50mm cement replacement. The wheat husk ash was digested of in order to prepare it for chemical test that is Atomic absorption spectrometer test (AAS) by weighing of 1g and put into conical flask a 20 ml of 2% nitric acid was added, the mixture was the shake well to final dissolution and filtered, the filtrate was taken for Atomic absorption spectrometer Analysis in the chemistry department laboratory of ATBU Bauchi. Using AAS machine model DW-AA 320NR.

IV. RESULT AND DISCUSSION

TABLE 4.1 Result of sieve analysis/fineness test of wheat husk ash

Sieve Size (mm)	**weight retained**	**Percentage Retained (%)**	percentage passing (%)
212	21.00	21.00	79.00
100	51.00	51.00	49.00
63	13.00	13.00	87.00
Reciever	15.00	15.00	0
Total	100	100	0

From the result the 212mm sieve with 79% passing fall within the recommended pozzolana ranges of 75-100% as according to ASTMC 618-78 (1978).

TABLE 4.2 Result of some physical test

TEST	Result
Bulk density	0.216g
Specific gravity	2.17
Initial setting time at 30% replacement	10minute
Final setting time at 30% replacement	4hours 50minues

The bulk density shown in table 4.2 is lower as it compares to that of cement but also have advantages of improve workability, long term strength, increase cohesiveness and decrease permeability as opined by Abdul, O (2008). The specific gravity obtained was 2.17 is also within the ASTMC recommended of pozzolana range of 1.9-2.4. The initial setting time revealed 10minutes which is also within the BS 12 (1978) recommended for cement that is not less than 45 minutes and also final not more than 10 hours. Which both satisfied since pozzolanas are cement alternatives.

TABLE 4.3 Water absorption test of WHA

CUBE SIZE (mm)	(WHA)Percentage Replacement (%)	Weight of Cube 1 Immersed in Water At 24 Hours	Weight of Cube 2 Immersed in Water At 24 Hours	Average Weight of Water Absorb by the Cubes (g)	Average Age Moisture Content (%)
50x50	0	287	284	26.5	10.23
50x50	10	283	283	38.0	15.51
50x50	30	277	271	40.5	17.34

The water absorption/moisture content of the cubes indicate that water absorbed was very small but is increasing with the increase in wheat husk ash implying that wheat absorbing more water than the cement as control.

TABLE 4.4 Result of Chemical Analysis of Wheat Husk Ash

Constituent Oxide Elements Composition	Percentage Present (%)
SiO_2	92.86
CaO	0.19
MgO	0.0081
NaO	0.18
K_2O	0.14
Ld	0.0013 mg/l
Cd	0.0060 mg/l
Zn	0.022 mg/l
Cr	0.0045 mg/l

From the table above the silicon has the highest percentage of 92,86 which is greater than that of even Cement and recommended for pozzolana indicating that the soil grown has high amount of Clay and is right to be Used as pozzoalana, the Magnessium Oxide (MgO), Sodium Oxide NaO, Potassium Oxide (K_2O) are all within the recommendation of pozzolana but Calcium Oxide is below the recommended the remaining element were not calculated in percentages but in milligram per litre such as lead Ld, Cadmium Cd, Zinc Zn, and Chromium Cr but the aluminium was not determined due to the faulty of its lamp in the machine

V. Conclusion

The paper concludes that the physical tests as: sieves analysis with 79% passing through 212mm, bulk density of 0.216g, specific gravity of 2.17, initial and final setting time of 10 minutes and 4 hours 50 minutes, and also water absorption of percentages of cement replacement at 0%, 10% and 30% of 10.23, 15.51, 17.34 respectively which are all acceptable in determining pozzolana as recommended by British standard and American standard.

The Chemical properties indicated that Silica (SiO_2) has the highest percentage meaning the soil has contained high clay, the Magnessium, Sodium and Potassium Oxide were all within the recommendation of pozzolana with only Calcium Oxide that was below.

Therefore, wheat husk ash can be use as pozzolana

Recommendations

The paper recommends determination of soundness of wheat husk ash, production of sandcrete blocks with wheat husk ash replacement up to 60%, potentiality using wheat husk ash in reduction of the cost of cement and determination of aluminium Oxide present in the wheat husk ash.

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