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RESEARCH ARTICLE

IMPACT OF HEAT TREATMENT METHOD AND MILLET POD TYPE ON REAL DENSITY AND POZZOLANIC ACTIVITY INDEX BY ASH RESISTANCE

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Abstract

Artificial pozzolans derived from agricultural by-products are generally obtained by heat treatment. The thermal treatment method used and the type of waste influence the quality of the final product. The aim of this study was to measure the actual density and pozzolanic activity index of millet pod ash produced in three different ways. Ash A is produced by direct calcination of the husks from which the millet seeds are removed (without the stalk). Ash B is obtained by burning and then calcining the millet husks. Ash C is produced by direct calcination of the millet straw (husks + stalks). The actual density was determined in accordance with standard NF EN 1097-6. The pozzolanic activity index by resistance was measured on the basis of the recommendations of American standard ASTM-C618. For the ashes A, B and C produced, we respectively obtained true densities of **2.256 g/cm^3**; **2.150 g/cm^3** and **2.033 g/cm^3**. The pozzolanic activity indices per strength obtained were **0.42**, **0.23** and **0.70** respectively**.** These results showed that the ash produced from direct calcination of raw millet waste (straw) had the best reactivity and the lowest density. It is therefore well suited to the production of low-density cementitious matrix composites.

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Introduction:-

Pozzolans have been identified by researchers as good substitutes for Portland cement in mortars and concretes used in civil engineering (Nguyen et al 2011; Zerbino et al 2011; Zain et al 2011; Ferraro et al 2010; Cordeiro et al 2009; Nair et al 2006). They can be both natural and artificial. Artificial pozzolans are generally obtained by thermal treatment of agricultural waste or other by-products to be valorized. (Stroeven et al 1999) have shown that agricultural waste ash can be used to produce low-cost hydraulic binders. There are two waste combustion processes for obtaining ash. A controlled combustion process with advanced technologies and an uncontrolled process with rather simple technologies. Several studies have shown that the quality of the pozzolan obtained depends on the heat treatment method used. In 2008, Bere and colleagues (Bere et al 2008) worked on the design of an artisanal furnace for the production of rice husk ash. They obtained good quality ash due to the lower temperature and relatively short production time. In a paper published in 2006, Nair and colleagues compared various simple incineration techniques. They concluded that an annular incinerator was best for ash production. Various boiler and power plant technologies are available for controlled combustion processes. Researcher Pitt proposed a technique known as the fluidizedbed reactor, for which he obtained a patent in 1976 (Pitt 1976). (Nehdi et al 2003) studied another controlled combustion technology. They used a TORBED reactor consisting of a toroidal fluidized bed. These techniques produced ash with very interesting characteristics. However, the properties required of ash vary from one technique to another.

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Different production methods produce different ash qualities, depending on calcination temperatures, particle diameters, calcination times, etc.

Controlled combustion processes are costly and not widely used in Africa. It is therefore necessary to find simple but effective techniques for producing ash. In the above-mentioned studies, the waste materials used vary according to the researcher and the availability of waste materials in his or her region. Since millet pods are widely available in West Africa, in our study we used an uncontrolled combustion technique to produce millet waste ash. Various types of millet waste were used. The density of these ashes and their pozzolanic activity index by resistance were measured. The results showed that millet waste could be calcined without sorting and still produce good quality ash.

Materials And Methods:-

Millet waste: millet pods

The millet harvest waste (millet pods) used in our work comes from the north of the Republic of Benin. For the studies, we first used them in their raw state (photo 1) and then sorted them.

Sorting consisted in separating pods and stems (photo 2).


Photo 1:- Unsorted millet waste**Photo 2:-** Sorted millet waste.

Calcination method

The choice of calcination method is based on the means available on site, opting of course for the most efficient method according to the literature. Calcination is carried out in a ceramic enclosure. Millet pods are calcined in ceramic canaries over a charcoal ember fire at a temperature of around 500°C to 700°C, as recommended in the literature.

Waste preparation and specimen formulation

After harvesting the millet and collecting the millet kernels, we obtained the raw millet pod waste, consisting of the stems and husks from which the millet seeds are removed (the pods themselves). After a few calcination tests, we selected three calcination techniques for our trials. Each technique produces a different type of ash. Ash A is produced by direct calcination of the husks from which the millet seeds are removed (without the stalk). Ash B is obtained by burning and then calcining the millet husks. Ash C is produced by direct calcination of the millet straw (husks + stalks).

Two types of mortar were produced for the pozzolanic activity index test. The mass composition of each mortar is shown in the following table:

Table 1:- Proportion by mass of mortar components.

Mortar type	Cement (g)	Sand (g)	Ash (g)	Water (g)
Control mortar (cement only)	450	1350	0	225
Mortar with substitution (cement + ash)	337,5	1350	112,5	225

It should be noted that mortar specimens with substitution are made with each ash.

Analysis methods

The characteristics we have determined are the actual density and the pozzolanic activity index per strength of the ash produced.

Density was measured in accordance with NF EN 1097-6. The pozzolanic activity index is measured according to ASTM-C618 recommendations. For the pozzolanic activity index tests, we prepared test specimens measuring 4x4x16 cm^3. Control mortars with 100% cement and others with substitutions at 25% of cement mass were produced. Indices are obtained by dividing the 28-day compressive strength of mortars with millet bean ash substitution by that of control mortars. When the ratio is greater than or equal to 67%, the ash is pozzolanic.

Results And Discussion:-

In this section, we present the results of the various tests carried out. These results are then interpreted and discussed.

Real density

The results obtained for the density of each ash are presented in the following tables.

Table 2:- Real ash density A.

Ash A	**Real density**	**Average**
Test 1	2,295	**2,256**
Test 2	2,217	

Table 3:- Real ash density B.

Ash B	**Real density**	**Average**
Test 1	2,138	**2,150**
Test 2	2,162	

Table 4:- Real ash density C.

Ash C	**Real density**	**Average**
Test 1	2,034	**2,033**
Test 2	2,032	

Of the three ashes produced, "ash A", produced by direct calcination of the husks from which the millet seeds are removed (without the stalk), has the best density. It represents the value closest to the density of cement. Ash A" would be the best in terms of density. To obtain millet pod ash of good density, it is necessary to separate the stems from the husks before calcination. However, this value remains lower than the absolute density values of natural pozzolans studied by other authors. Ash C produced by direct calcination of millet straw (husks + stalks) has the highest density value, but remains acceptable in view of literature values. Prior grinding of the ash may improve its absolute density.

Activity index by resistance

The results of the compressive strength test are given in Table 5.

Table 5:- Compressive strength test results.

Test tubes	Half-cube 1 (dc1 in MPa)	Half-cube 2 (dc2 in MPa)	Average Mi= (dc1+dc2)/2	Compressive strength at 28 d in MPa R= (M1+M2+M3)/3
ET1	16,29	21,05	18,67	**21,40**
ET2	25,77	20,36	23,065	
ET3	22,9	22,06	22,48	
Ash A-1	11,13	10,47	10,8	**8,97**
Ash A-2	8,34	8,61	8,47	
Ash A-3	7,00	8,29	7,64	
Ash B-1	5,65	4,99	5,32	**4,99**

Ash B-2	4,84	4,64	4,74	
Ash B-3	4,72	5,14	4,93	
Ash C-1	15,19	14,67	14,93	**15,13**
Ash-2	15,49	15,13	15,31	
Ash-3	15,09	15,24	15,16	

From this table, we can see that the average compressive strength at 28 days of age of our control mortar is 21.40MPa. This value will serve as a reference for the other mortars with the substitution of 25% by weight of cement by each of the three types of millet pod ash. These results were used to calculate the pozzolanic activity index for each ash.

Table 6:- Pozzolanic activity index value for ash.

	Ash A	Ash B	Ash C
Reference value VR in MPa	21,40	21,40	21,40
Compressive strength R in MPa	8,97	4,99	15,13
Activity index (R/VR) in % of sales	**41,92**	**23,34**	**70,70**

From the results of this table, we can easily see that only ash C is pozzolanic in the sense of the ASTM standard, with a reactivity of 70.70%. As the activity index of ash B is so low, we conclude that the production of millet pod ash by burning and then calcining millet husks should be avoided. We note that to obtain an ash with good reactivity, it is not necessary to separate the stems from the millet husks. However, it is better to separate them to obtain a better density.

Conclusion:-

This study demonstrated the suitability of millet pod ash for use as pozzolan in concrete production. However, the production technique is a determining factor, as it can lead to the ash obtained not being sufficiently reactive. By testing several millet pod ash production techniques, we found that only one resulted in an ash of acceptable quality and with an interesting absolute density. We therefore recommend the use of this technique for future millet pod ash production under conditions similar to our own.

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