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Using Cassava Peelings to Reduce Input Cost of Concrete: A Waste-to-Wealth Initiative in Southwestern Nigeria

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Abstract:

This work reports the outcome of an experiment using cassava peelings ash (CPA) of varying quantities to supplement cement in concrete work. The design of the experiment used 0, 5, 10, 15, 20, 25 and 30 per cent cassava peeling ash. The concrete was batched with a ratio of 1:2:4. The cubes produced were allowed to cure for 28 days. Compressive strength test was conducted on the samples at interval of 7 days. The result obtained showed that compressive strength of the concrete increased with increase in length of setting, but decreased as the percentage of CPA. However, the strength still remained in the allowable range of workability for concrete in line with the British standard. With concrete mix using 15 – 20 per cent CPA was found to be the most suitable mix considering the strength and safe use of the concrete. It was concluded that this alternative use of cassava peelings will at the long run create supply paucity, attract higher economic value to cassava peelings, increase the economic return of the farmers and improve the environmental management of the study area.

Keywords: Cassava Peelings, Compressive strength, Concrete batching, Slump, Waste management

1.0 Introduction:

Cassava (Manihot spp) is one of the most popular stable crops in the Southern Nigeria. Cassava production in Africa is expected to continue to rise at an annual rate of 2.4% per year and to reach 109 million Tonnes in 2005, accounting for over half of the world's production. In order to address food security challenges confronting the developing countries in the world, rapid food production is a necessity. This can be achieved in a short term through cultivation of highly prolific crop that matures early. The crop should also be able to withstand pests and diseases, tolerant to adverse weather and tolerate poor soil conditions. Cassava does not only meet the above set conditions but also does not require high input cost. The yield per unit area of land is relatively high. This and other favourable conditions were the reasons why cassava became the prime crop of farmers in Africa. Cassava is easy to process into quite a number of derivatives such as tapioca, gari, flour, etc. Meanwhile, Nigeria supplies the bulk of African cassava production (Adegbola et al., 2013; VOA, 2009). Much of the Nigerian cassava is obtained in the southern part of the country. Cassava products consist majorly of the tuber. Other products like the leaves, and stem could also be valuable (Eco-Business, 2013; Livraria Embrapa, 2013; Nangayo et al., 2007). Cassava tuber can be processed into a variety of products such as gari, starch, chips, flour, flakes tapioca etc. Much of the processing takes place in the backyard cottage firms. The waste of this industry consists majorly of the peelings. The peelings could be fed to ruminants and pigs (Adegbola et al., 2013; VOA, 2009; Phengvichith and Ledin, 2007). Cassava waste may soon become a major waste to contend with particularly in Ekiti state because the crop is being considered for mass production for use in the biofuels industry. Ekiti State is planning to establish multi Million Dollar ethanol factory. The raw materials for this proposed factory is cassava. Several Hectares of land had been allocated for the cultivation and production of cassava. More cassava will be sourced from out growers. The implication of this development is generation of more wastes from cassava peelings. Caution is necessary in the use of cassava peelings as feed because of its high concentration of hydrogen cyanide (Waste Management and McDonough 2013; Noharm, 2013; Eubios, 2013). Otherwise it could be injurious to livestock especially if given in large quantity. The bark could serve as fuel if properly dried and may supplement fuelwood in the processing industry (Eubios, 2013; Serpagli et al., 2010; Phengvichith and Ledin, 2007). But the Southwestern Nigeria is located in the humid tropical region where drying could be a huge task. Rainfall here could be as high as 2400 mm per year and could span 8-9 months. Humidity could reach 82.0 % during the wet season and about 65.0 % in the dry season (NIMET, 2013). This condition does not favour open air drying of cassava peelings. Very few will have passion to dry cassava peelings particularly when it is only used as fuel supplement (FAO, 2013; FIDAfrique, 2013; Pattarant WUTTIWAI, 2013). There are abundant firewood supply both from the forest directly or from the sawmill industry. It became natural for the people to dump the peelings around the processing centres even in the market place since the law to enforce non-dumping of refuse is not properly administered (Waste management and McDonough, 2013; Ettu et al., 2013a). Gradually, as more of the cassava tuber is processed the heap of cassava peelings continued to grow. Previous field survey revealed that the rate of growth of peelings heap around some selected factories in Ado Ekiti Nigeria, showed that the volume of cassava peelings heap had more than doubled in the last 3 years. (UN Daily-news, 2013; Agro2, 2013; FAO, 2013). The rate of dumping of cassava peelings is 5-8 times greater than the rate of bio-degradation in the open air dumpsites (Waste Management and McDonough, 2013; Ettu et al., 2013b).

Another observation showed that open air dumping of cassava peelings does more damage than any other solid waste such as paper, metal, glass etc. because when cassava peelings degenerate, it produces the effects of other forms of waste like liquid and gaseous wastes. It brings out noxious and offensive odour, emits heat and gases, attracts flies and other vectors in this way the heap site occupy more than double their physical perimeter coverage (Noharm, 2013; IISD, 2013; Liveraria Embrapa, 2013; Eubios, 2013).

Should cassava peelings dumping continues in the business as usual scenario, Southwestern Nigeria might be in for a tough time ahead in terms of waste management challenges. The reason for this fear is justifiable from the analysis of the recent discovery of market opportunities for cassava products in China, India and Malaysia (Guardian, 2013). Composting and organic fertilizer and manure production will not be able to slow down the rate of growth of cassava peeling heap because there is a pessimistic view already in the air over the possibility of cyanide poisoning in fruits and vegetables (Ettu et al., 2013a; Ettu et al., 2013b). Investigation into the potentials of cassava effluent as an organic herbicide is being carried out. Should the report prove feasible, then direct usage of cassava peelings in organic composting will be jeopardized. The question then is the need to find alternative use for this by-product so as to keep the economic food security potential of cassava and at the same time reduce environmental pollution and soil toxic contamination. Many alternatives are showing up as experts and researchers suggest the diverse rich potentials of cassava peelings, its derivatives and constituents. Among these alternatives is the use of cassava peelings powder/ash as a filler and binding agent in concrete works (Ettu et al 2013a; Ettu et al 2013b).

2.0 Materials and methods:

2.1 Materials:

This research was carried out in the campus of Federal Polytechnic Ado Ekiti in Ekiti State Nigeria.

Fig. 1: Map of Ekiti State showing Ado Ekiti Town

The major materials for this investigation is cassava peelings, cement, sand aggregate and water, while equipment used include: 150 x 150 x 150 mm^3 concrete cube mould (Wykeham Ltd model WF 5309 and WF 53012); Concrete crushing machine (CONTROLS Industries model CR2-021), slum test machine (Wykchan Farrance model WF 52532).

2.2 Methods:

Cassava peelings was converted to ash at 500 ^{o}C in muffle furnace (Carbolite Model CWF 1400) and batched in a concrete mix of 1:2:4 Cement/Cassava peel ash/river-sand and aggregate. Cement was mixed with varying percentages of Cassava Peel Ash (CPA); 0% (pure cement); 5, 10, 15, 20 25 and 30 per cent CPA content and were used as binding agent in concrete batches of 1:2:4. (1 part binding agent, 2 parts river sand and 4 parts aggregate). The concrete mix under the CPA treatments were tested for (i) Absorption, (ii) Compressive strength using hydraulic compression machine CR 2, (ii) Grading specific gravity and (iii) abrasion slump test using Wykenham Farrance's slump machine. The results obtained were presented in a format that support its clear explanation.

3.0 Results and Discussion:

3.1 Absorption Test:

Absorption test was conducted to observe the response of the concrete samples to immersion in water and the rate at which they imbibe water. This is necessary to predict the concrete behavior under moist condition A condition that may arise in flooded area. At the peak of rainy season, surface flow may rise to inundate our structures. The capacity of such structure to withstand the flood will be determined by the absorption rate of the material with which it is constructed. Groundwater table can rise particularly in the wet season or if water from a reservoir intrudes into an area. Such area is prone to wetness. Any structure built in that vulnerable area could come under threat of instability. This is why absorption test of the concrete is necessary.

3.2 Slump Test:

This is the test used to check how stable a material is as a result of its moisture content. Concrete is batched and worked when moisture is present in it. The structural strength of concrete when wet will depend on the concrete mix. The cement component often play a major role of stability when concrete is still fresh and wet. So this test is targeted at the effect of cassava peeling ash on the stability of the samples of concrete in this experiment.

3.3 Compressive Strength Test:

Compressive strength of concrete determines to a great extent the ability of structure to withstand the load imposed on it. In order to predict the load bearing capacity of a structure therefore, the compressive strength of the concrete of the prescribed mix could be used. This characteristic is usually determined by the cement component. The aggregate and the sand quality also play major roles in determining the compressive strength of a concrete.

Table 1: Absorption Test of Concrete of Different Cassava Peel Ash Treatments

CPA Content (%)	Wt. before immersion	Wt. after immersion	Absorption (%)
0	4.52	4.75	4.09
5	4.71	4.92	7.04
10	5.12	5.01	10.2
15	5.23	5.62	10.25
20	5.24	5.62	11.0
25	5.24	5.64	11.19
30	5.26	5.69	11.20

$$Absorption(\%) = \frac{(wt\ after\ immersion - wt\ before\ immersion)}{wt\ before\ immersion} \times 100\%$$

Table 2: Slump Test of Concrete of Different Cassava Peel Ash Treatments

CPA Content (%)	Slump (mm)	Comment
0	40	decreasing stability
5	38	
10	37	
15	36	↓
20	36	
25	36	
30	35	

Table 3: Standard Values of Slump Required for Different Conditions

Workability	Slump (mm)	Condition of Working
Very Low	0 – 25	Road vibrated by mechanical power operated machine
Low	26-50	Road vibrated by hand operated machine
Medium	51-100	Manually compacted slabs
High	101 - 175	Sections with longest reinforcement. Not normally suitable for vibration

-BS 4550 method of testing cement British Standard Institute London. Adapted from Nervile and Brooks, (1987)

Table 4: Compressive Strength Test of Concrete of Different Cassava Peel Ash Treatments

% CPA v/s Age	0	5	10	15	20	25	30
7	15.1	10.7	9.0	7.2	3.6	3.0	2.1
14	21.7	11.0	11.8	7.9	4.7	3.8	2.6
21	24.1	12.4	12.0	8.7	6.7	4.5	2.9
28	26.6	14.6	13.9	10.4	9.8	5.2	3.4

The absorption values shown in table 1 above revealed that using Cassava Peeling Ash (CPA) in concrete increased its absorption from 4.1 that of pure cement to about 12 percent. This value indicated that CPA based concrete has very high absorption value. This may not be too suitable for serious concrete operations. However, it could be observed that increasing the percentage CPA constituent in concrete from 10 to 30 only changed the absorption value by just 1.20. This indicates that using larger quantity of CPA does not significantly affect the absorption of the concrete. That means concrete work can accommodate more CPA incorporation. If that be the case, more of cassava peeling may be required in the concrete industry. This will translate to a reduction in the quantity that will end up on the peeling dump site. In other words, using CPA will assist effective waste management in the study area. 4.0 kg is needed to obtain 1.0 kg of CPA. If 30 percent of CPA in concrete batching is adopted in any construction policy, it means 15.0 kg CPA will be required per bag of cement. Therefore any construction that consumes a bag of cement under this scenario will mop up 60 kg (15.0 kg x 4) cassava peelings from the environment. The back cover of cassava is just 5.0 per cent of the entire tuber. Of the 10 Tonnes per hectare average yield of cassava, only 500 kg of CPA is expected. It means that 8-9 bags of cement will eat up the CPA from 1.0 hectare. Cassava cultivation in Ekiti State of Nigeria covers less than 1000 Ha. With the projection, Any construction that will require 400-450 Tonnes of cement is enough to mop up the whole cassava peelings produced in the state in a year.

Table 2 presents the values of slump test performed on the concrete treated with varying quantity of CPA. The slum only reduced from 40 mm (pure cement) to 35 mm in the 30 percent CPA constituent. The concrete stability still remained within the range of low-medium workability that require just manually operated vibrator to carry out in accordance with the provision of the -BS 4550 method of testing cement British Standard Institute London shown in Table 3 (Nervile and Brooks, 1987). In other words, the concrete embedded with CPA up to 30 percent constituent is still stable and could be acceptable in most concrete work in building industry.

Table 4 presents the compressibility strength of the concrete treated with varying quantity of CPA. The strength increased as the age of the concrete increased while the strength decreased as the quantity of CPA used increased. The data revealed that CPA quantity of 15-20 per cent is the range where concrete work is most appropriate. Above this value the strength of the concrete will be too low as it had dropped by more than half.

4.0 Conclusion:

Finding alternative economic use for waste is quite sustainable as the incentive to pay adequate attention to the environment will be high. Cassava peeling that currently constitutes waste concern in Southwestern Nigeria can best be managed through alternative use. This research is providing information on one of the ways of using cassava peelings in the most economic manner, with high return both socially and infrastructural development. The absorption test conducted on the cassava peeling ash ranged from 4.0 to 12.0 percent. The slump test conducted reveled that concrete with cassava peeling constituent had a low workability category described as road compacted with hand operated compactor. It was concluded that concrete embedded with CPA up to 30 percent constituent is still stable and could be acceptable in most concrete work This type of duty is ideal for concrete work in building construction. This was the original target of the concrete with cassava constituent. Implementing the outcome of this research, the industrial demand for cassava peelings may in no distant time outweigh supply. This mechanism will put a higher premium on cassava peelings. The economic return of cassava production will creep from its poor status to higher level. The environment will be better maintained, the cost of construction will be reduced the farmers will reap more economic return on their investment and the entire social and economic system in the country will benefit. The multiplier effect of the implementation of this research is highly promising.

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