

Use of orange peel ash in concrete to reduce waste generation

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Abstract:

Orange fruits have been part of human diet for ages due to its nutritional and medicinal values. But consumption of orange fruits generates orange peel wastes that could bring about environmental pollution and hazardous to human health if not properly handled. The study aimed towards recycling of wastes and avoiding littering and waste-related environmental degradation thereby producing sustainable engineering material additives in concrete. This research was carried to explore the potential of using orange peel ash (OPA) as partial replacement of cement on the properties of fresh concrete. Orange peel was air-dried and burnt to Ash at a temperature of 400°C in an Incinerator. It was applied in different percentages (5%, 10%, 15% and 20%) to modify the properties of fresh concrete. Experiments were conducted on consistency, fineness of cement, soundness of cement, setting times and workability to determine the effect of varying percentage addition of OPA on the properties of fresh concrete. Setting time was found to decrease with increase in OPA addition but generally lower than that of cement paste (Control). Workability also decreases with increase in addition of OPA. Consistency increases with increase addition of OPC/OPA admixture and 20% was found to be the optimum. Consistency of OPA indicated that water requirement increases with increase in OPA addition. Orange peel ash is recommended for rendering and plastering as there is color changes and as a retarder suitable for the hot weather construction, while orange peel ash content of 20% and above is recommended for concrete work in very hot and dry weather condition that are prone to rapid dehydration condition. The research has shown that OPA can be used to modify the properties of fresh concrete. Administering OPA reduced waste disposal, environmental problems, produce new engineering material and reduced cost of cement production.

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1. Introduction

Cement is used in the production of the many structures that make up the modern world including buildings, bridges, harbors, runways and roads. It is also used for facades and other decorative features on buildings. The global cement production in 2021 was recorded at 4.37 billion ton whereas the consumption was 4.27 billion ton. The constant demand for all of these structures, increasingly from the developing world, means that cement is the second most consumed commodity in the world after water. The global cement market is determined to grow at a CAGR of 5.10% over the forecasted period of 2022-2027 [1]

Nigeria generates more than 32 million tons of solid waste annually, out of which only 20-30% is collected. Reckless disposal of MSW has led to blockage of sewers and drainage networks, and choking of water bodies. Most of the wastes is generated by households and in some cases, by local industries, artisans and traders which litters the immediate surroundings [2]

These industrial by-products comprise peels, seeds, and pulp membrane residues [3]. The orange peels

importance ranging from perfume, cosmetics, antiviral, antifungal and antibacterial properties due to the presence of limuloids [4], others include biogas and ethanol production [5]. The increase in world population has driven and propelled the need for increased agricultural production globally, thus, generating enormous industrial and agro-wastes can result in environmental disposal issues [6].

Large amounts of orange peels are disposed of in large quantities as waste product annually in many countries [7] including Nigeria. Contamination of water bodies through improper disposal of agro-waste and the huge cost implication in the cement industry have become a growing concern. Owing to the huge demand for cement and high energy/production cost has resulted in the use of orange peel as an alternative fuel for linearization which did not adversely affect the quality of cement according to works by disposal of agricultural waste materials such as rice husk, groundnut husk, corn cob, coconut shell, and orange peel can constitute environmental issues, hence the need to convert these wastes to useful materials to minimize their negative effect on the environment [8]

2. Materials and Methods

2.1 Materials

The cement used was Ashaka brand of ordinary Portland cement produced at Ashaka Cement Company located at Ashaka village in Funakaye LGA Gombe State Nigeria. This cement was used throughout the course of this project, and the experiment conform to BS 1881. The orange peel was obtained from a local seller in Yola North local Government Area, Adamawa State of Nigeria. The orange peels were exposed to air under sun and dried properly before grinding. The dried orange peel was incinerated to ash at a temperature of 400°C as can be seen in Fig.1 and 2. The OPA was grinded to fine particles and sieved through a 75µm B.S Standard test sieve to obtain the OPA and for the research. Tap water that is reasonably free from contamination in the laboratory was used to hydrate the cement in the mixtures.



Figure 1; Sun dried orange peel



Figure 1: Sun-dried orange-peel ash

2.2 Methods

2.2.1 Sieve analysis

The grading was carried out in accordance with BS 812, Part 1-75 [9]. The sand was air dried for 24 hours and 1000g of the sand were weighed and passed through the following set of sieves 10mm, 5.0mm, 2.36mm, 1.18mm, 600µmm, 300µmm, 150µmm, 75µmm, and pan. The setup was shaken manually; the particles retained on each sieve were weighed and recorded. The results were expressed as a percentage by weight of materials passing each sieve.

2.2.2 Soundness Test

The cement paste was prepared by gauging cement with 0.78 times water required to give a paste of standard consistency. The gauging time was 4 minutes. The inner surface of the mould was oiled. The mould was then placed on a glass plate and filled with cement paste, taking care to keep the edges of the mould gently together. The mould was covered with another piece of glass plate and a small weight was placed on this covering glass plate and immediately submerged the whole assembly in water at a temperature of 27°C and keep it for 24 hours. The assembly was then removed from water after 24 hrs. The distance between the indicator points was measured and recorded as (D1). The mould was submerged again in water to boiling in 25 to 30 minutes and was kept boiling for three hours. The mould was removed from the water, allowed to cool and the distance between the indicator points was measured and recorded as (D2). Two samples were tested and average of the results was reported [10].

2.2.3 Consistency Test

The test was conducted in accordance with BS 196, part 3[11] which is similar to IS: 4031, Part 4 [12] 300g of cement was weighed and mixed with a weighed quantity of water. The time of gauging was about 5 minutes. The Vicat mould was filled with the cement paste and was leveled with a trowel. The plunger was lowered gently till it touched the cement surface and was released, allowing it to sink into the paste. The reading on the gauge was noted. The above procedure was repeated taking fresh samples of cement and different quantities of water until the reading on the gauge is 5 to 7mm.

2.2.4 Initial Setting Time

The test was conducted according to IS 4031 Part 5 [13] Cement paste of 300g was prepared by gauging the cement with 0.85 times the water required to give a paste of standard consistency. Stop-watch was started the moment water was added to the cement. Vicat mould was filled completely with the cement paste gauged as above; the mould resting on a non-porous plate and the surface was smooth off, making it level with the top of the mould. The cement block thus prepared in the mould is the test block. The test block was then placed under the rod bearing the needle. The needle was lowered gently in order to make contact with the surface of the cement paste and was then release quickly, allowing it to penetrate the test block. This procedure was repeated until the needle fails to pierce the test block to a point $5.0 \pm 0.5\text{mm}$ measured from the bottom of the mould. The time period elapsing between the time, water was added to the cement and the time, the needle fails to pierced the test block by $5.0 \pm 0.5\text{mm}$ measured from the bottom of the mould, was recorded as the initial setting time.

Final Setting Time

The initial setting time needle was replaced by the one with an annular attachment. The cement was considered as finally set when, the needle was released gently to the surface of the test block, and the needle

makes an impression therein, while the attachment fails to do so. The period elapsing between the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, was recorded as the final setting time.

2.2.5 Final Setting Time

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2.2.6 Workability (slump test)

The slump test was conducted in accordance with BS 1881, Part 102 [14], a truncated cone of 300mm height with 200mm and 100mm bottom and top diameter

respectively was used for this test. The cone was cleaned with damp cloth, left to dry and lightly lubricated. It was then placed on a metal plate and held in place. It was filled in three layers each being compacted by at least 15 short strokes of a tamper to ensure uniform filling of the mould. The outer surface was wiped and cleaned. After 15 seconds, the cone was raised vertically at a constant rate; the reduction in height of the specimen was measured and recorded as the slump.

3.0 Results

2.1 Fineness Test

Table 1 and Fig. 3 presents the fineness test result of OPA and that of Ordinary Portland Cement (OPC).

Table 1: Fineness test result for OPA and OPC

Cement	Total of weight cement (g)	Average Fineness (%)
OPC	300	6.6
OPA	300	5.6

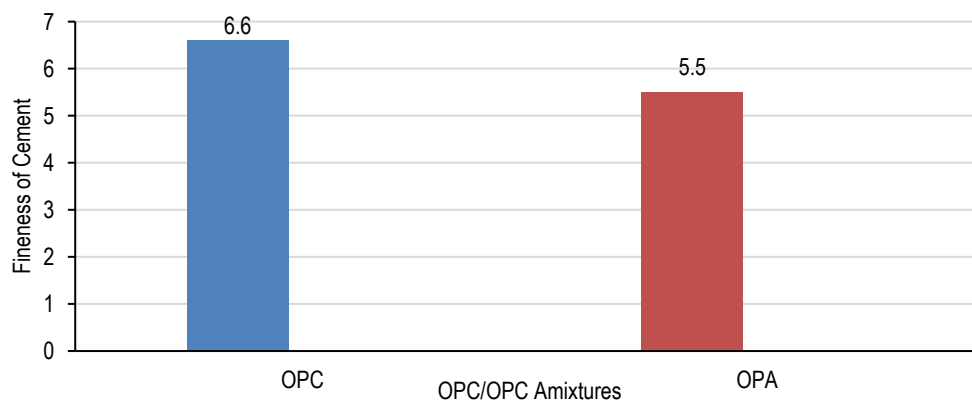


Figure 3: Fineness of Cement against OPC/OPA Admixtures

It can be seen From Table 1 and Fig.3 above that OPC is finer than the OPA that passed through sieve 75 μ m. This conforms to the finding of [15].

20% OPA addition as the optimum replacement with a 182% water was greater than that of control paste (0% OPA). This conforms to the finding of [15].

2.2 Consistency

Table 2 and Fig. 4 shows consistency result of OPA/OPC at varying percentage of orange peel ash. It can be seen from Table 2 that the consistency of OPA-Cement paste increases as the addition of OPA increases. With

2.3 Setting Time Test Results

Table 3 and Fig. 5 shows the result of initial and final setting times of OPC/OPA admixture on the properties of fresh concrete.

Table 2: Consistency OPA at Different Replacement Levels (%)

NO.	Cement Weight (g)	OPA (%)	Water Content (ml)	Percentage Water (%)	Penetration (mm)	Remark
1	300	0	100	34	5.7	Consistent
	300	5	132	44	6.3	Consistent
3	300	10	156	52	5.8	Consistent
4	300	15	174	58	5.3	Consistent
5	300	20	182	62	6.5	Consistent

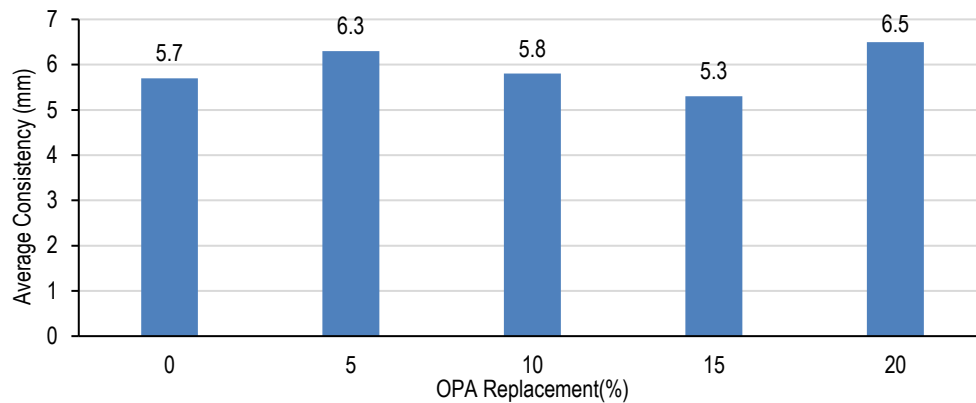


Figure 4: Average consistency at varying percentage addition of OPA

Table 3: Initial and final setting time of cement and OPA

Cement Brands	Weight of Cement(g)	Weight of Orange peel ash(g)	Volume of Water (ml)	Depth of Penetration (mm)	Consistency (%)	Initial Setting Time (min.)	Final Setting Time (min.)
Ashaka	300	0	100	13	33.33	66	201
	285	15	112	11	35.08	33	130
	270	30	133	9	37.03	18	53
	255	45	147	6	39.21	11	37
	240	60	155	5	41.66	8	18

From Table 3, it can be observed that the initial setting time for the OPA-cement paste decreases with increase in the OPA. Between 5% and 20% OPA addition, the decrease in the initial setting time was gradual within this range, the initial setting time of the OPA-cement for 5%, 10%, 15% and 20% are 33 minute, 18 minutes 11 minute and 8 minutes respectively. These values are not closer to the initial setting time of cement paste (Control) which was found to be 110 minutes. But from 5% to 10 % of OPA content, the decrease in the initial setting time becomes very high because the initial setting times

obtained for 5% and 10% cement was 33 minutes and 18 minutes respectively. These values showed a very big difference between the initial setting times of the OPA-cement and that of the cement alone.

The final setting time of the OPA-cement was also observed to decrease with percentage increase in OPA. Between OPA content of 5% and 10%, there is a rapid decrease in that of the cement paste. This has been observed in the final setting time which showed higher deviation of the final setting times for the OPA cement compared to that of the OPC.

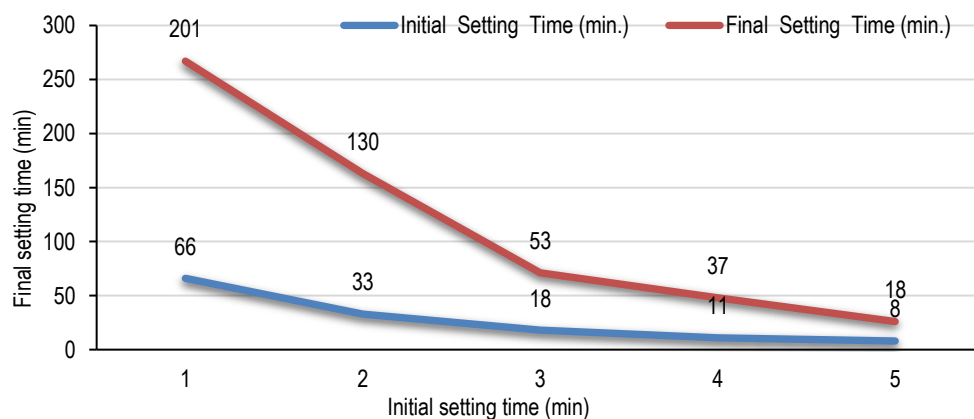


Figure 5: Effect of OPA on Setting Time of Cement

2.4 Workability (Slump Test)

Table 4 presents the results of workability Test on OPA/OPC admixture on the properties of fresh concrete.

From Table 4, it can be inferred that as the percentage replacement of OPA increases the shape and mixed of the concrete tend to show reduction in water. At a replacement of 15% and 20% the slump result was found to be a true slump.

Table 4: Workability of concrete and OPA Replacement.

NO.	Mix No.	Percentage of OPA (%)	Slump (mm)
1	M-1	0	26
2	M-2	5	19
3	M-3	10	17
4	M-4	15	14
5	M-5	20	13

3. Conclusions

The following conclusions can be drawn from this study:

- Ordinary Portland Cement (OPC) is finer than the Orange Peel Ash (OPA).
- An optimum of 20% Replacement of OPC/OPA was obtained.
- Properties of fresh concrete such as Consistency, setting time and workability decreases with increase in OPC/OPA admixture replacement.
- Orange Peel Ash can be used to modify the properties of fresh Concrete as an admixture thus reducing waste disposal on the environment.

Recommendations

- The use of OPA for concrete work in marine structure or other structures that are exposed to harsh acidic environment should be tried and investigated further.
- Orange Peel Ash is recommended for used in cement mortar due to the decreased in the final setting time.
- OPA can also be used in rendering or plastering.

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