

# The Use of Yam Peel Ash as Partial Replacement of Cement Towards Achieving Low Cost Housing

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**Abstract:** Yam Peels are the wastes produced when yam are processed for human consumption. This research investigated the structural strength characteristics of concrete with Yam peel ash (YPA) used as partial substitute for cement. The YPA was subjected to pozzolanicity and setting time tests to ascertain its potential as a pozzolan. Water/cement ratio of 0.6 was used to produce the blended concrete of mix 1:2:4, 1:3:6, 1:4:8 by which cement was replaced partially by YPA at 5%, 10%, 15% and 20% replacement by weight of cement. A total of 64 concrete cubes of size 50×50×50mm were molded and cured for 7, 14, 21 and 28 days. While 36 concrete beams of size 50×50×150mm were molded and cured for 7 and 28 days. The workability, compressive strength and flexural test were conducted. The result revealed that the water/cement ratio is adequate to make the blended concrete workable. The best 28<sup>th</sup> day compressive strength of the blended concrete was observed for mix ratio of 1:3:6 at 5% YPA replacement of cement with a value of 9.857N/mm<sup>2</sup>, an approximate 64% of the strength of the concrete without replacement of cement. The best flexural strength of the concrete was observed at mix ratio of 1:2:4 at 5% YPA replacement with a value of 5.112N/mm<sup>2</sup>, an approximate 97% of the strength of the concrete without replacement of cement. The result further revealed that the increase in %YPA replacement of cement does not have any significant effect on the density of the test specimens of the blended concrete.

**Keywords:** Yam Peels Ash, Cement, Compressive Strength, Flexural Strength, Concrete

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## 1. Introduction

Availability of affordable housing is very essential to the human race because it helps to fulfill human basic need for shelter and improve the vitality of the economics of communities and/or world as a whole [1]. Due to the tremendous increase in the world population, there is high demand for affordable housing, but there is limited supply due to high cost of building/construction materials, high cost of labor and land, government regulations, slow pace of construction due to use of old conventional construction methods etc. [1, 2].

According to Ofuyatan, et al. [3], almost 60% of total cost of constructing an affordable house is ascribed to building/construction materials such as concrete, sandcrete blocks and steel. During this Covid-19 era, there has been remarkable increase in the price of these building materials

due to drastic reduction in their production which arise as a result of depletion in resources used and labor required.

Sandcrete blocks and concrete are the most commonly used construction material because of its economical values, resilience, and flexibility [4, 5]. Reference [6] indicated that sandcrete blocks and concrete are important construction because more than 90% of physical infrastructures in Nigeria are being constructed using them.

Cement is a key ingredient in concrete and sandcrete production. Despite its advantageous use, the production process of cement generates a lot of CO<sub>2</sub>, reduction of lime stones reserves and high energy demand [7, 8]. These disadvantages have led several researchers to seek out other alternatives to replace cement. Through research, some agricultural byproducts such as rice husk ash [9, 10], banana peel ash [11], cassava peel ash [12-14], corn cob ash [15], sugar cane bagasse ash etc. Have been observed to

have good cementitious properties and have been effectively used in partial replacement of cement. This has helped in drastic reduction of construction cost of houses and effective in reduction of disposal of agricultural wastes to the environment at very low cost. Despite these advantages, the availability of some of these agro wastes in large quantity is still a challenge.

Yams (*Dioscorea* spp.) are staple foods in humid and sub-humid tropical countries of the world such as Nigeria. Food and Agriculture Organization (FAO) statistics indicate that Nigeria produced 31 million metric tons of yam tubers in 2007. It is also reported that Nigeria is the single largest producer of yam accounting for about 71% of total world production [16].

Yam is among the oldest recorded food crop and ranks second after cassava in supply of starch in West Africa [17]. Naturally, yam is rich in starch and produces energy. Yam tubers are peeled and prepared for consumption by boiling, roasting, grilling, frying or pounding boiled tubers. Although several studies show that the waste peels from yam can be used as ingredient for animal feeding, the peels are still largely discarded [18].

Thus, a good way of utilizing Yam Peels is to burn it into ashes and use it for making "high performance concrete" which means high workability and very high early strengths, and long term durable concrete and sandcrete [19].

Thus, this research work shall be focused on the structural behavior of blended cement-yam peel ash concrete.

## 2. Materials

### 2.1. Yam Peel Ash (YPA)

Yam peels were collected from different cafeterias within Offa metropolis, sun dried and were later burnt in an electric furnace (Thermo cline Brand) at 950°C for 2½ hours at the Forgery and Moulding Workshop, Mechanical Engineering Department of the Federal Polytechnic Offa, Kwara State.

### 2.2. Aggregates

Clean river sand, free from waste stone and impurities were used in the production of the blended cement- yam peel ash concrete, while crushed granite of maximum nominal particle size of 19 mm was used as coarse aggregate.

### 2.3. Cement

The cement used was Dangote Ordinary Portland Cement which conforms to NIS 444 – 1: 2003 as evidenced by the certification mark NIS 444 -1:2003 on the product bags.

### 2.4. Water

Water collected from a borehole within the Federal Polytechnic Offa was used in the mixing of concrete for effective workability. The water was ensured to be free from suspended particles, salts and oil contamination.

## 3. Methodology

### 3.1. Chemical Composition Test on YPA

The chemical composition of YPA was determined by subjecting the sample to analysis using the combination of Atomic Absorption Spectrophotometer and Gravimetric methods at the SMO Laboratory Services, Ibadan, Nigeria.

### 3.2. Setting Time Test

The effect of Yam Peel Ash (YPA) on the setting times (Initial and Final) of cement paste was determined at water content of 21% using a Vicat plunger.

### 3.3. Sample Preparation

The concrete investigated was of mix ratio of 1:2:4, 1:3:6 and 1:4:8 (cement and yam peel ash: sand: granite) with a constant water/cement ratio of 0.60. The cement was replaced with yam peel ash at 0%, 5%, 10%, 15% and 20% by weight of cement and mixed with sand and granite as fine and coarse aggregates respectively. Batching of the concrete mix was by weight. The concrete cube moulds of 50mm x 50mm x 50mm and concrete moulds of 150mm x 150mm x 150mm were used. They were first polished with black oil to reduce friction and aid the removal of the concrete cubes before pouring concrete mix. After mixing, each of the moulds was filled with concrete in three layers, and each of these layers was tempered with tamping rod for 25 times. The hand trowel was used to smooth the top of concrete in the moulds after which they were marked for identification. The concrete cubes were allowed to set for 24 hours before removing the mould and then the cubes were taken to curing tanks for curing, and they were carefully placed in the curing tank filled with water. Three (3) sets of cubes for each concrete mix were cast and cured for 7, 14, 21 and 28 days. Concrete beams of sizes 150x150x150 mm were cast and cured for 7 and 28 days.

### 3.4. Slump and Density Test

Slump test was done in accordance with BS 1881 (102) [20] to ensure the workability of the blended concrete, while the density was determined by following the procedures specified in BS1881 (107) [21].

### 3.5. Compressive Strength

After the required age of curing, the concrete cubes were removed from the curing tank and allowed to surface dry after which they were weighed on a balance to obtain the weight of each cube. The weighed cubes were carefully placed in a Universal Testing Machine (UTM) with a capacity of 100kN at the National Centre for Agricultural Mechanization (NCAM), Idofin, Kwara State. The concrete cubes were crushed at age, 7 days, 14 days, 21 days and 28 days. The compressive test results were downloaded from the UTM.

### 3.6. Flexural Test

The weighed beams were carefully placed in the Universal Testing Machine (UTM) for maximum, 36 cubes were crushed at age 7 days, and 28 days. The result of the Bending Strength was obtained from Universal Testing Machine (UTM).

## 4. Results and Discussions

### 4.1. Chemical Properties of YPA

The result of the chemical analysis conducted on the Yam Peel Ash (YPA) compared with Ordinary Portland Cement (OPC) chemical properties are presented in Table 1.

**Table 1.** Chemical composition (%) of ordinary portland cement (OPC) and yam peel ash (YPA).

S/No	Parameters	OPC	YPA		
			1	2	Average
1	SiO <sub>2</sub>	6.39	35.74	35.89	35.82
2	Al <sub>2</sub> O <sub>3</sub>	0.88	3.27	3.34	3.31
3	Fe <sub>2</sub> O <sub>3</sub>	0.05	0.74	0.78	0.76
4	CaO	72.26	2.04	2.11	2.08
5	MgO	2.60	1.76	1.74	1.75
6	K <sub>2</sub> O	0.39	22.51	22.46	22.5
7	Na <sub>2</sub> O	1.58	1.83	1.80	1.82
8	SO <sub>2</sub>	0.73	0.48	0.51	0.49
9	CO <sub>2</sub>	0.00	-	-	-
10	H <sub>2</sub> O	0.62	-	-	-
11	Loss of Ignition	0.98	1.72	1.74	1.73

From Table 1, the chemical composition of the YPA was observed to be different from that of the ordinary Portland cement. The SiO<sub>2</sub> + Al<sub>2</sub>O<sub>3</sub> + Fe<sub>2</sub>O<sub>3</sub> was less than 50% or 70%, thus the YPA cannot be classified as Class C or Class F pozzolan. The YPA was observed to have high K<sub>2</sub>O and Na<sub>2</sub>O content which could likely lead to alkali-silica reaction.

### 4.2. Physical Properties of Blended Cement-YPA Paste

The results of physical properties of the blended cement-Yam Peel Ash such as specific gravity, initial and final setting time are presented in Table 2.

**Table 2.** Physical properties of blended cement-yam peel ash.

% of YPA	Specific Gravity	Initial setting time (min)	Final setting time (min)
0	2.92	120	165
10	2.89	125	360
20	2.85	185	375

From Table 2, it was observed that the specific gravity of the paste decreases from 2.92 of the control sample (0% yam peel ash content) to 2.85 at 20% Yam Peel Ash (YPA) replacement of cement. The specific gravity of the Yam Peel Ash paste only (i.e. 100% YPA) is 2.60. It is thus concluded that the specific gravity of the paste reduces with increase in the YPA content.

### 4.3. Slump Test

The results of slump test for different mix ratios and different percentage of (yam peel ash) in concrete are as shown in Table 3.

**Table 3.** Table showing the results of slump test of different mix ratios and different percentage of YPA in concrete cubes.

S/N	MIX RATIO	SLUMP HEIGHT (mm) WITH PERCENTAGE OF YPA					REMARK
		0%	5%	10%	15%	20%	
1.	1:2:4	70	55	45	37	15	True
2.	1:3:6	27	25	35	37	38	True
4.	1:4:8	35	36	37	38	39	True

True slump was exhibited for all the mix ratios and for each increment in the partial replacement of cement. It was observed from Table 3, that the slump value increases with increase in YPA for all mix ratios except for mix ratio of 1:2:4. Thus it can be concluded that workability of the concrete improves with increase in the YPA content.

### 4.4. Density Test

The mean densities of concrete cubes and flexural beams

of different mix ratios; 1:2:4, 1:3:6, and 1:4:8 of different percent of pozzolanic (YPA); 0%, 5%, 10%, 15%, 20% for curing age between 7- 28 days were given in tables 4 to 9. The result reveals that density of all concrete cubes produced fall within the range of 2000Kg/m<sup>3</sup> – 2240 Kg/m<sup>3</sup>, while density of flexural beams produced fall within the range of 2466 Kg/m<sup>3</sup> – 2644 Kg/m<sup>3</sup>. The result revealed that the increase in %YPA replacement of cement does not have any significant effect on the density of the test specimens of the blended concrete.

**Table 4.** Table showing density of concrete cubes of mix ratio 1:2:4 ( $\text{kg/m}^3$ ).

%YPAREPLACEMENT	DENSITY VALUES ( $\text{kg/m}^3$ ) AT DIFFERENT CURING DAYS			
	7DAYS	14 DAYS	21DAYS	28DAYS
0	2000	2080	2160	2240
5	2000	2080	2160	2240
10	2000	2080	2160	2240
15	2000	2080	2160	2240
20	2000	2080	2160	2240

**Table 5.** Table showing density of concrete cubes of mix ratio 1:3:6 ( $\text{kg/m}^3$ ).

%YPAREPLACEMENT	DENSITY VALUES ( $\text{kg/m}^3$ ) AT DIFFERENT CURING DAYS			
	7DAYS	14 DAYS	21DAYS	28DAYS
0	2000	2080	2160	2240
5	2000	2080	2160	2240
10	2000	2080	2160	2240
15	2000	2080	2160	2240
20	2000	2080	2160	2240

**Table 6.** Table showing density of concrete cubes of mix ratio 1:4:8 ( $\text{kg/m}^3$ ).

%YPAREPLACEMENT	DENSITY VALUES ( $\text{kg/m}^3$ ) AT DIFFERENT CURING DAYS			
	7DAYS	14 DAYS	21DAYS	28DAYS
0	2000	2080	2160	2240
5	2000	2080	2160	2240
10	2000	2080	2160	2240
15	2000	2080	2160	2240
20	2000	2080	2160	2240

**Table 7.** Table showing density of flexural beams of mix ratio 1:2:4 ( $\text{kg/m}^3$ ).

%YPAREPLACEMENT	DENSITYTOF CONCRETE BEAM ( $\text{kg/m}^3$ )	
	7DAYS	28DAYS
0	2000	2240
5	2000	2240
10	2000	2240
15	2000	2240
20	2000	2240

**Table 8.** Table showing density of flexural beams of mix ratio 1:3:6 ( $\text{kg/m}^3$ ).

%YPAREPLACEMENT	DENSITYTOF CONCRETE BEAM ( $\text{kg/m}^3$ )	
	7DAYS	28DAYS
0	2000	2240
5	2000	2240
10	2000	2240
15	2000	2240
20	2000	2240

**Table 9.** Table showing density of flexural beams of mix ratio 1:4:8 ( $\text{kg/m}^3$ ).

%YPAREPLACEMENT	DENSITYTOF CONCRETE BEAM ( $\text{kg/m}^3$ )	
	7DAYS	28DAYS
0	2000	2240
5	2000	2240
10	2000	2240
15	2000	2240
20	2000	2240

#### 4.5. Compressive and Flexural Strength

Figures 1 to 6 shows the average compressive strength of concrete cubes after being cured 7, 14, 21 and 28days and flexural strength of concrete beams after being cured for 7 and 28days of different mix ratio and varying replacement of cement by YPA. The compressive strength of Cement-YPA

blended concrete decreases as the YPA content increases. The best 28<sup>th</sup> day average compressive strength of the blended concrete was observed for mix ratio of 1:3:6 at 5% YPA replacement of cement with a value of 9.857N/mm<sup>2</sup>, an approximate 64% of the strength of the concrete without YPA replacement. Similar trend was observed for flexural strength as for the compressive strength. The flexural strength of

Cement-YPA blended concrete decreases as the YPA content increases for all mix ratios. The best flexural strength of the concrete was observed at mix ratio of 1:2:4 at 5% YPA replacement with a value of 5.112N/mm<sup>2</sup>, an approximate 97% of the strength of the concrete without YPA replacement.

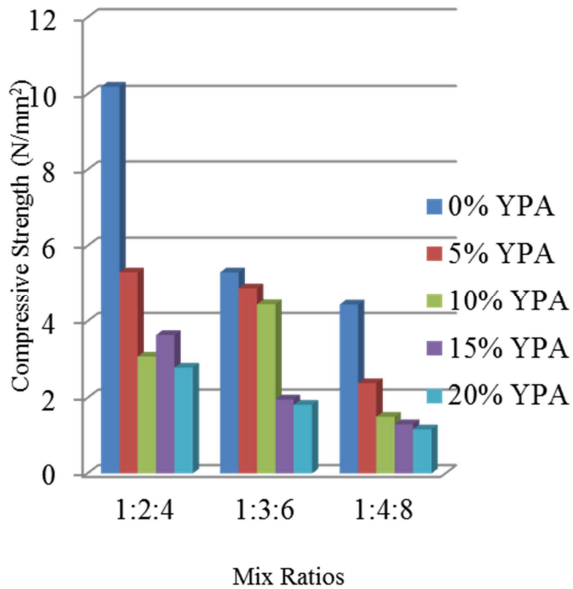


Figure 1. Compressive strength of concrete cubes for 7 days.

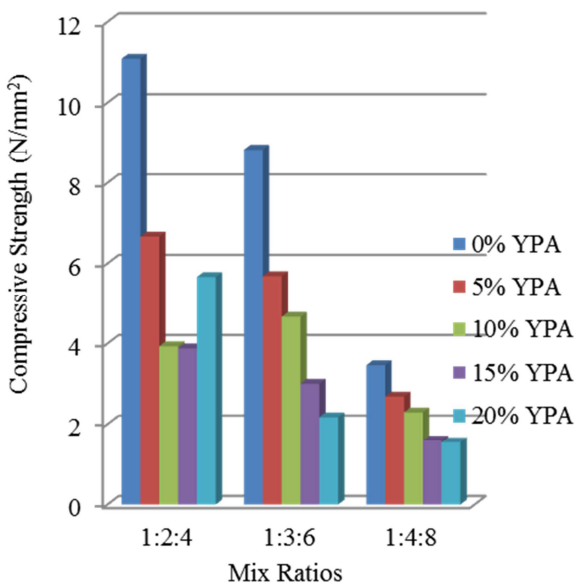


Figure 2. Compressive strength of concrete cubes for 14 days.

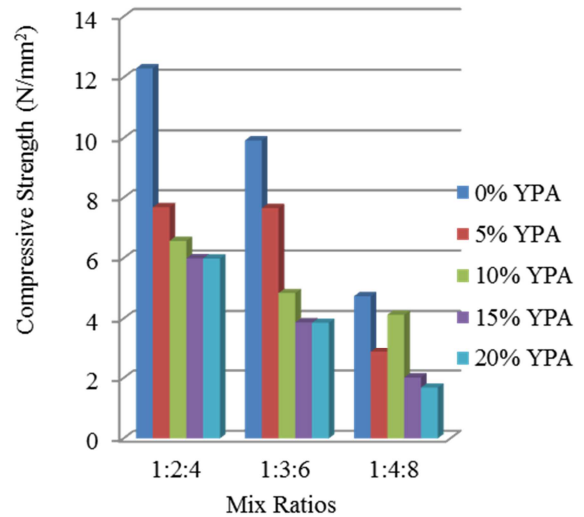


Figure 3. Compressive strength of concrete cubes for 21 days.

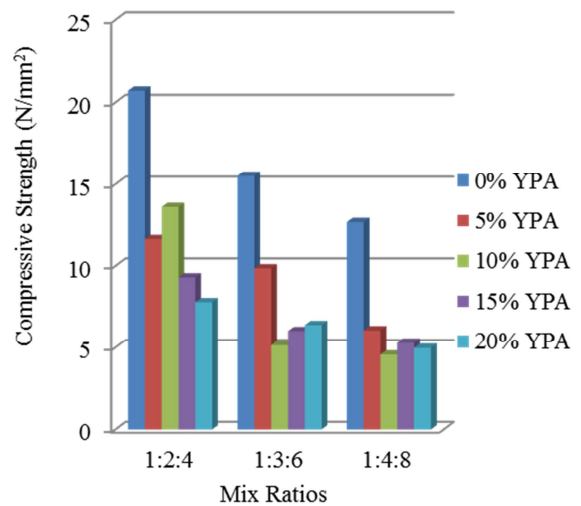


Figure 4. Compressive Strength of concrete cubes for 28 days.

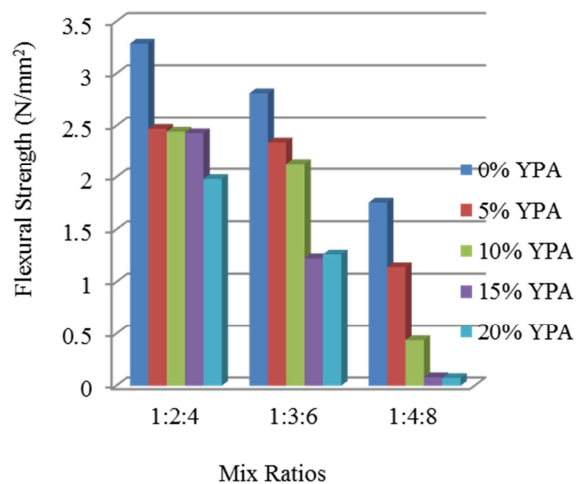


Figure 5. Flexural strength of concrete beams for 7 days.

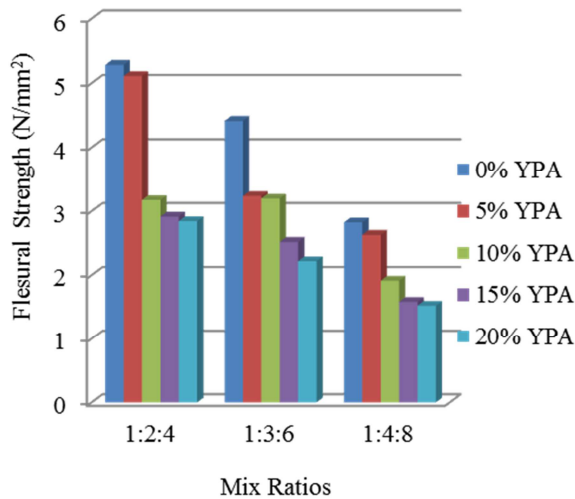


Figure 6. Flexural Strength of concrete beams for 28days.

## 5. Conclusion

The following conclusions were made from this research work:

The result revealed that the YPA has a slow reaction rate compared to cement.

Increment in YPA replacement of cement does not have any significant effect on the density of the test specimens of the blended concrete.

True slump was exhibited for concrete containing 5% - 20% YPA for the three mixes of concrete.

Compressive and flexural strengths increase with age but reduce with increase in CPA content in the mix.

The Yam peel ash is suitable for replacement of cement in concrete when a mix ratio of 1:2:4 at 5%YPA replacement is used for concrete beams.

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