Pretreatment of Recycled Aggregates in Concrete Using Cassava Effluent.

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Abstract

To minimize construction waste generated from construction activities, three main waste minimization strategies are employed, namely reuse, recycle and reduce. The performance of new concrete produced by the use of recycling of old concrete as a replacement for natural aggregates (NA) principally depends on the properties of the recycled concrete aggregates. Some substandard attributes of recycled concrete aggregates, include high water absorption, low workability, low compressive strength etc. This study is aimed at improving the properties of recycled concrete aggregates with the use of an agro waste, known as cassava effluent. This agro waste is widely available in local cassava processing mills across Nigeria. This work involved the treatment of three portions of recycled concrete aggregates. The first portion was treated in portable water, the second in the freshly obtained cassava effluent and the third in fermented cassava effluent. Presoaking was carried out for duration of 24hours, during which containing vessels were intermittently shaken to confirm a much proficient reaction of the treatment fluids in the removal of loose particles attached to the original aggregate samples. Some important properties of the treated and recycled concrete aggregates were examined and compared with those of untreated recycled concrete aggregates as well as natural aggregates. Test cubes were prepared using a standard concrete mix of 1:2:4:0.5. The concrete samples were checked for workability using the slump test. Results revealed that the treatment reduced water absorption up to 69.1% for fresh cassava effluent. A further reduced value by 70.95% was obtained when seven-day old cassava effluent was used. Investigated aggregate properties, improved in all treatment categories of recycled concrete aggregate. Workability and Compressive strengths recorded improved results, with the most significant in recycled concrete aggregate samples treated with seven-day old cassava effluent. All hardened concrete samples examined, recorded alkaline pH values within the vicinity of 12.

Keywords: Recycled Concrete Aggregate, Natural aggregate, Cassava Effluent, Compressive strength, Mortar

Introduction

Concrete is the most widely used construction material with global production reaching 21 billion tons annually (Tosic et al., 2016), and the construction sector is often considered the engine of economic as well as industrial activities, the largest consumer of global natural resources and one of the principal consumers of energy (Meddah, 2017). According to Anyaogu and Ezeh (2013), twice as much concrete is utilized in construction in Nigeria than the total of all other building materials. According to Malešev et al. (2010), the demolition of ancient and deteriorated buildings and traffic infrastructure, as well as their substitution with new ones, is a frequent phenomenon today in a large part of the world, outlining some reasons for this situation as; changes of purpose, structural deterioration, rearrangement of a city, expansion of traffic directions and increasing traffic load, natural disasters (earthquake, fire and flood), among others. To minimize construction waste generated from construction activities, three main waste minimization strategies are employed, namely reuse, recycle and reduce (Kotrayothar, 2012). In the midst of possible solutions favoring better environmental sustainability in the construction industry and material engineering, is the consideration of the

use of recycled aggregates from construction and demolition wastes in the production of new concrete (Kosior-Kazberuk and Grzywa, 2014). Various European nations have placed taxes on the use of virgin aggregates (Marinkovic et al., 2010), in an effort to encourage the reuse of concrete as aggregates in fresh construction works. Recycling aggregate has been proven to be one of the possible solutions of tackling the rising challenges to the construction industry and the environment (Orie and Mbaoma, 2015; Fanijo et al.,2023).While some researchers (Reddy et al.,2014) are of the opinion that recycling concrete aggregates by using it as replacement to new aggregate in concrete could reduce concrete waste and conserve natural source of aggregate ,others (Sharma and Singla, 2014) are of the view that concrete made with recycled aggregate is considered to be one of the most promising solutions to reduce the amount of construction and demolition waste (CDW) that may end up in landfills.

According to Bilal and Ali (2017), a 2004 record of the Federal Highway Association (FHWA) in USA revealed that 11 States incorporate recycled concrete aggregates into newly produced plain cement concrete (PCC) mixes. Furthermore, the States that utilized recycled aggregate concrete reported that concrete with recycled concrete aggregates perform comparably as the conventional natural aggregate concrete (NAC) prepared with crushed limestone aggregates. Although countless results from numerous researches reveal that the recycled aggregate concrete is inferior compared with natural aggregates, they find its usage both economically viable and technically feasible (Brett et al., 2010). RCA comprises 60-75% of natural aggregates and 25–35% of adhered cement mortar, their properties and performance measures are highly dependent on the extraction method, the extent of crushing, the amount of adhered paste and/or residual mortar with which the RCA is produced (Fanijo, et al., 2023).

Concrete recycling in particular is an approach that has a number of benefits that make it a preferred option for greater environmental awareness, more environmental laws, and the desire to keep construction cost down (Brown, et al., 2006; Wagih et al., 2012). Recycling aggregate has been proven to be one of the possible solutions of tackling the rising challenges to the construction industry and the environment (Kotrayothar, 2012). Although using recycled aggregates has great opportunity to preserve healthy environment, the properties and characteristics of recycled aggregates have not been fully investigated yet (Hyungu, 2011). Indeed, aggregates made from crushed hardened concrete can readily meet the prescriptive requirements for coarse aggregates in structural concrete (Matthews et al, 2009); however, the use of recycled concrete as aggregate has been frequently restricted to non-structural applications such as sidewalks and sub-base for roadways (FHWA, 2008).Limitations to its usage are as a result of the characteristics of the adhered mortar and the effects of concrete porosity, adhered mortar connection with aggregate, the crushing process, and the double transition zone.

In Nigeria, recycled coarse aggregate has become a major source of financial relief to some developers and a means of livelihood to concrete re-cyclists in some Nigerian cities, for example site surveys in Uyo metropolis (Akwa Ibom State, Nigeria) revealed 100% use of RCA in concrete even in structural elements (Ameh and Edike, 2014). Recycled Concrete Aggregate has the advantage of being an ecofriendly material as it protects the environment by reducing the amount of waste from construction (minimizing the problem of excess of waste material) and also preserves the natural resource (aggregate) as the consumption of natural aggregates can be reduced (Igbinigie ,2017). The cost of recycled concrete aggregate is about 20-30% less than that of natural aggregates in many regions globally (Rakshvir and Barai,2006), consequently the use of recycled concrete aggregate, has the potentials to reduce cost of concrete production and construction. The use of treated RCAs is viewed as sustainable construction material which can be used as a replacement to that of NAs, reduces the carbon dioxide emissions in atmosphere and is a cost-effective material that can be used for structural concrete (Rampit et al., 2020). Another common human activity that could result to

environmental degradation is cassava processing. Cassava processing activities are now extensively carried out in many rural and urban centers in Nigeria and elsewhere. The toxicity of cassava and its wastewater is basically associated with its pH and cyanide content. Cassava wastewater has been observed to be highly acidic, with pH as low as 2.6 (ESCAP, 1992). Also, Nok and Ikediobi (1990) reported the pH of fermenting cassava to be between 5.5 and 6.3. According to Pereira et al. (2015), this wastewater is comprised of acids, such as acetic, butyric, propionic, butyric and lactic acids, and the products of amylose and amylopectin degradation, such as dextrin, oligosaccharides and monosaccharides Since there is a high level of cassava processing activity in Nigeria and elsewhere, there is a compelling need to identify ecofriendly ways of judiciously utilizing wastes emanating from it.

Materials and Methods

Cement

The choice of cement used was Ordinary Portland cement, randomly sourced from the open market, conforming to the standards of BS12:1996.

Fine Aggregates

The Natural fine aggregates used were sourced from Imeke Industrial Quarry (Edo North). Natural fine aggregate in the form of stone dust, conforming to the standards of BS 812:1992.

Coarse Aggregates

Coarse aggregates used for this research can be categorized into two; Natural Aggregates (NA) and Recycled Concrete Aggregates (RCA). The aggregates were of minimum size 10mm and a maximum of 20mm. The Coarse recycled concrete aggregates (RCA) were obtained from waste concrete cubes and unreinforced beams from the concrete and structural workshops of the Federal Polytechnic Auchi and used to simulate crush aggregates obtained from demolished sites. The processed and crushed concrete aggregate waste passing through 20mm and retained on 10mm I.S sieve were used as coarse recycled concrete aggregates, while coarse Natural Aggregates were obtained from Imeke Industrial Quarry and used for this work. Both aggregate types were in conformity with the recommendations of BS 812:1992. Maximum size of aggregates to be used for this research was 20mm (3/4 inches). The coarse Recycled Concrete Aggregates, hereafter referred to as simply recycle concrete aggregates (RCA), were subjected to aggregate characterization to ascertain its compliance with British Standards.

Cassava Effluent

The cassava effluents used for the research were obtained from cassava processing mills situated at Paulosa Street, Waterboard area and Igbirra Camp, both in Edo North Area of Edo State, Nigeria. Two types of effluents were used for this work. The first category of cassava effluent was freshly obtained and put into use shortly after extraction from the mill. The second type of cassava effluent was left in covered containing vessels for seven (7) days after extraction, before use. Since the cassava effluent was a byproduct of the cassava mill processing, it was necessary to handle it with utmost care to avoid contamination.

Experimentation

Crushing of old concrete

A manual approach (with the aid of a sledge hammer) was used in crushing the waste unreinforced beams and cubes into smaller fractions of average diameter of 20 mm to remove much of the cement mortar from the old concrete. Resultant particles estimated to be less than 10mm were expunged.

Sieve Analysis and Flakiness Index

It was necessary to air dry the sample of crushed concrete aggregate in order to avoid lumps of fine particles being erroneously classified as large particles. The obtained concrete aggregates were subjected to sieving using the 10 mm and 20 mm sieve sizes. This involved arranging the aggregate test sieves in decreasing order from top to bottom starting with 20mm. In accordance with recommendations of BS812:1992, the 20 mm sieve was made to accommodate a minimum weight of not less than 2kg. The test sieve arrangement was mounted on a sieve shaker, equipped with a time switch so that uniformity of the sieving operation was ensured. Concrete aggregates that passed through the 20mm sieve and retained on the 10mm sieve were obtained and used for the experimental study. The value of the Flakiness Index was calculated from the expression:

$$\text{Flakiness Index} = \frac{M_3}{M_2} \text{ x } 100 \quad (1)$$

The sum of all the masses is M_1

Total combined and weighed particles passed through guage is M_3

Pre-soaking in acid

Three portions of recycled concrete aggregates were treated. The first portion was treated in portable water, the second in the freshly obtained cassava effluent and the third in fermented cassava effluent. Presoaking was carried out for a duration of 24hours (9am to 9am), during which containing vessels were intermittently shaken to confirm a much proficient reaction of the treatment fluids in the removal of loose particles attached to the original aggregate samples. Apart from the first portion of treated RCA sample, the other recycled concrete aggregate samples were taken out and washed thoroughly with portable water and dried in sunlight. Treated recycled concrete aggregates samples were then sieved using a 10mm sieve and the aggregates which were retained only, were used. Each sample was annotated as RCA_{H2O}, RCA_{CE1}, and RCA_{CE7} for samples treated with water, freshly extracted cassava effluent and seven-day old cassava effluent respectively.

Concrete Mix

Concrete test cubes measuring 150mm x 150mm x150mm were prepared using a standard concrete mix of 1:2:4:0.5 representing; cement, fine aggregate, coarse aggregate and water/cement ratio. The basis for this mix ratio was the outcome of the mix design, using the Department of Environment (DOE) approach. Concrete Samples from Five (5) coarse aggregate types were used for this investigation. They were natural aggregate (NA), untreated recycled concrete aggregate (RCA_U), recycled concrete aggregate treated with portable water (RCA_{H2O}), recycled concrete aggregate treated with freshly obtained cassava effluent (RCA_{CE1}) and recycled concrete aggregate treated with seven-day old fermented cassava effluent (RCA_{CE7}). The five (5) different concrete samples were prepared accordingly, using each aggregate type, per sample. Mixing was carried out manually. The resultant concrete mixes were annotated as NAC, RCAC, $RCAC_{H20}$, $RCAC_{CE1}$ and $RCAC_{CE7}$ for natural aggregate concrete, untreated recycled aggregate concrete, and treated recycled aggregate concrete with water, fresh cassava effluent and fermented cassava effluent respectively.

Aggregate Crushing Value test (ACV)

The test was carried out in accordance with BS812-110:1990, which describes the method for the determination of the aggregate crushing value (ACV) as a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. Aggregate crushing value (ACV) is as the percentage of crushed aggregates passing through the 2.36mm sieve. The equipment required for this test included, a steel cylinder (open ended

of 150mm diameter), test sieves, tamping rod (about 16mm diameter), compression testing machine (500kN capacity), drying oven, balance, rubber mallet, tray and a brush. Aggregate crushing value test was conducted on the five (5) coarse aggregate samples (natural aggregates, untreated aggregate samples and treated aggregate samples with the three different fluids). Coarse aggregates samples passing through the 14mm sieve and retained on 10mm sieve were used for this test. The cylinder of the test was placed on a baseplate and the test specimen will be placed in three layers of approximately equal depth; each layer being subjected to 25 strokes from the tamping rod. A crushing force was then applied on the aggregates.

The Aggregate Crushing Value (ACV) is expressed as a percentage for each test specimen from the following equation:

$$\text{ACV} = \frac{M_1}{M_2} \text{ x } 100 \quad (3)$$

Where, M_1 is the mass of the test specimen in grams (g), M_2 is the mass of the material passing 2.36mm sieve in grams (g). This test was carried out twice for each aggregate sample. The samples subjected to this test were; natural aggregates, untreated recycled aggregates and treated aggregates RCA_{H2O}, RCA_{CE1} and RCA_{CE7}).

Aggregate Impact Value test (AIV)

This technique was applied to aggregates passing at 14.0 mm test sieve and retained on a 10.0 mm test sieve. It was in compliance with the set standard, that aggregate impact value test is not appropriate for aggregate sizes larger than 14 mm. The approach involved placing the test specimen in a fixed cup and compacting it by 25 strokes of a tamping rod. A hammer was adjusted to fall freely from 380 ± 5 mm above the upper surface of the aggregate in the cup to achieve a total of fifteen (15) blows at intervals of not less than one second. Crushed aggregates were then removed and weighed. The Aggregate Impact Value (AIV) was calculated as a percentage for each test specimen from the following equation:

$$\text{AIV} = \frac{M_1}{M_2} \text{ x } 100 \quad (4)$$

Where, M_1 is the mass of the test specimen in grams (g), M_2 is the mass of the material passing 2.36mm sieve in grams (g). The Aggregate Impact Value test was carried out twice for each aggregate sample. The samples to be subjected to the test were; natural aggregate, untreated RCA and treated aggregates (RCA_{H2O}, RCA_{CE1} and RCA_{CE7}).

Los Angeles Abrasion Test (LAA)

The Los Angeles Abrasion test was carried out in accordance with ASTM C 131 – 89, which describes the test method to indicate aggregate toughness and abrasion characteristics. Apparatus required for this experiment included; a Los Angeles testing machine, test sieves, drying oven, weighing balance and a charge comprising of steel spheres. Standard Los Angeles Abrasion test, involved subjecting the five (5) coarse aggregates samples to abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres. This was carried out by placing the test sample in the Los Angeles testing machine and rotating the machine at a speed of 30 to 33 rpm for 500 revolutions. After being subjected to the rotating drum, the weight of aggregate that was retained on a No.12 (1.70 mm) sieve was subtracted from the original weight to obtain a percentage of the total aggregate weight that had broken down and passed through the No. 12 (1.70 mm) sieve. The resultant Los Angeles Abrasion values were calculated by expressing the loss (difference between the original mass (m_1) and the final mass (m_2) of the test sample as a percentage of the original mass of the test sample from the equation:

$$\text{LAA Value} = \frac{m_1 - m_2}{m_1} \text{ x } 100 \quad (4)$$

The LAA test was carried out twice for each of the five (5) aggregate samples.

Water Absorption

Test samples were placed in the wire basket and immerse in the water at a temperature of about 20 °c with a cover of at least 50 mm of water above the top of the basket. The entrapped air was then removed after immersion from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at a rate of about one per second. Basket and aggregates remained completely immersed during this operation and for a period of 24 h. The basket and sample were weighed in water at a temperature of 20 °c (mass B). The basket and aggregate were removed from the water and allowed to drain for a few minutes, after which the basket was emptied on to one of the dry cloths, and the empty basket was returned to the water, and weighed. The water absorption was calculated using the following equation:

$$\text{Water Absorbtion}(\%) = \frac{\text{A}-\text{D}}{\text{D}} \text{ x } 100 \quad (5)$$

Where; A is the mass of saturated surface dry aggregate in air (g) and D is the oven dried aggregate in air (g).

Slump Test

Workability assessment of the fresh concrete samples using the slump test was carried out. Slump tests were conducted in accordance with BS 1881: Part 102: 1983, for each of the five (5) concrete samples evaluated. The apparatus required for this test, consisted of a cone of height of 300mm, top diameter of 100mm, bottom diameter of 200mm and a tamping rod of about 60mm long.

Compressive strength test

The Compressive strength experiment is a mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The test sample, usually in the form of a cube, prism, or cylinder, is compressed between the platens of a compression-testing machine by a gradually applied load. The equipment used for the experiment includes; compression testing machine, balance moulds of cast iron with removable base plate (measuring 150x150x150mm), scoop, vibrating table or steel compacting bar, sampling tray and a shovel. Concrete cube specimens were of 150mm X 150mm X 150mm. The compressive strength, CS was determined as:

$$\text{CS} = \frac{P}{LB} \quad (6)$$

Where, P is the load at fracture (N), L is the length of cube (mm), B is the breadth of cube (mm).

Concrete PH Test

The experiment was carried out in accordance with ASTM C25 (2006). Crushed concrete samples were collected from the cast concrete elements and pulverized. Aqueous solutions of the powdered material were prepared by mixing 10 g of each sample 200 ml of deionized water. Samples were stirred for 30minutes and made to stand for 30 minutes. The pH of each sample was then measured with a pH meter and recorded. Test was repeated for each of the five samples cast.

Results.

Recycled Concrete Aggregate Characterization

Primarily, the recycled concrete aggregate was tested to verify its compliance with the requirements established in the British standards. The outcomes presented non-compliance for the recycled aggregate as regards water absorption. Water absorption value of 8.64% was recorded, exceeding the 7% limit. Conversely, the British code (BS EN 1097-6, 2013) allows its use in concrete with compressive strength inferior to 30 N/mm^2, such as the concrete tested in the current research. Table 3.1 presents the outcomes of the RCA Characterization. The

water absorption of untreated RCA was compared with those of natural aggregate concretes and treated samples of RCA (RCAH2O, RCACE1, RCACE7). The outcomes from aggregate samples are presented on table 3.2. Although untreated RCA was reflected to have exceeded the acceptable limit of 7%, treated RCA samples showed more acceptable values (but not less than those of naturally occurring aggregates). The high-water absorption values of untreated RCA obtained, can be attributed to the high presence of the cement paste and the natural aggregate.

Table 1 Characterization results of the recycled aggregate sample.

TEST	Particle Size Analysis (D/d)	Fines Content	Water Absorption	Los Angeles Coefficient	Flakiness Index
STANDARD	BS EN 933-1 (2012)	BS EN 933-2 (1996)	BS EN 1097-6 (2013)	BS EN 1097-2 (2010)	BS EN 933-3 (2012)
LIMIT VALUE	≥ 1.4	≤ 1.5 %	≤ 7%	≤ 40%	≤ 35%
RESULT OBTAINED	5.75	1.26%	8.64%	22.80%	19.65%

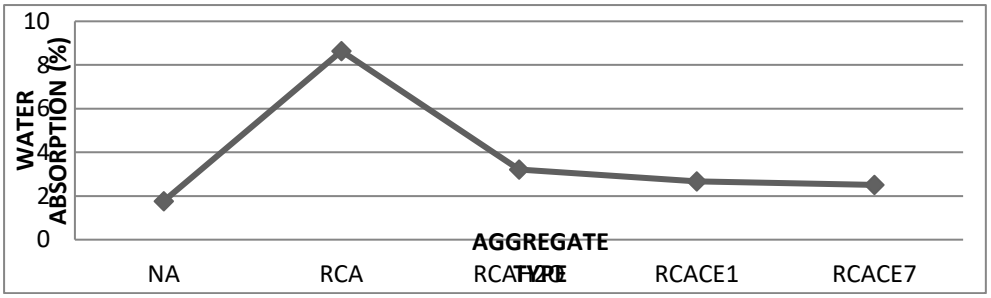


Figure 1 Water Absorption values of aggregate samples

Aggregate Abrasion, Crushing and Impact Test Results

The least abrasion value was obtained from the Natural aggregates (NA) while the highest value was obtained from the untreated RCA sample with a value of 4.97%. However, treatment with the various fluids resulted in reduction in Los Angeles Abrasion value with respect to values obtained for untreated RCA. Basically, LAA values with respect to untreated RCA reduced by 29.33%, 31.59% and 35.96% for RCA_{H2O}, RCA_{CE1} and RCA_{CE7} respectively. The least aggregate impact value recorded was for NA with a value of 4.79%. Highest AIV were obtained for untreated recycled concrete aggregate samples, with a value of 17.39%. Results showed a reduction in aggregate impact values for treated recycled aggregate samples. AIV obtained, with respect to untreated RCA reduced by 54.69%, 64.69% and 67.51% for RCA_{H2O}, RCA_{CE1} and RCA_{CE7} respectively.

The least crushing value recorded, was for NA with a value of 9.13% while the highest ACV was obtained for untreated recycled concrete aggregate samples, with a value of 28.27%. Results showed a reduction in ACV for treated recycled aggregate samples. ACV obtained, with respect to untreated RCA reduced by 17.37%, 20.48% and 27.41% for RCA_{H2O}, RCA_{CE1} and RCA_{CE7} respectively.

Table 2 Water Absorption values of aggregate samples

Replicates	NA		RCA		RCA_{H2O}		RCA_{CE1}		RCA_{CE7}	
	A	B	A	B	A	B	A	B	A	B
Mass of soaked aggregates and container (g)	40.56	41.85	52.22	48.14	46.26	47.94	43.08	42.14	45.19	46.58
Mass of dry container (g)	14.98	15.02	15.08	14.88	15.03	15.10	15.05	15.25	14.86	14.96
Mass of soaked aggregates(g)	25.58	26.83	37.14	33.26	31.23	32.84	28.03	26.89	30.33	31.62
Mass of dry aggregates(g)	25.15	26.35	34.57	30.28	30.20	31.88	27.18	26.17	29.54	30.71
Mass of absorbed water(g)	0.43	0.48	2.57	2.98	1.03	0.96	0.85	0.72	0.79	0.91
Percentage Absorption(%)	1.71	1.82	7.43	9.84	3.41	3.01	3.13	2.75	2.67	2.96
Average Percentage Absorption(%)	1.77		8.64		3.21		2.94		2.82	

Table 3 Aggregate Impact, Aggregate Crushing and Los Angeles Abrasion values

		AIV TEST			ACV TEST			LAA TEST	
Aggregate Sample	Replicate	Impact Value(%)	Average Impact Value(%)	Replicate	Crushing Value(%)	Average Crushing Value(%)	Replicate	Los Angeles Abrasion Value(%)	Average LAA Value(%)
NA	A	3.28	4.79	A	9.12	9.13	A	4.98	4.97
	B	3.12		B	9.18		B	5.04	
	C	3.17		C	9.08		C	4.90	
RCA	A	17.89	17.39	A	28.65	28.27	A	23.24	23.11
	B	17.12		B	28.18		B	22.98	
	C	17.15		C	27.98		C	23.10	
RCA_{H2O}	A	7.95	7.88	A	23.14	23.36	A	16.70	16.63
	B	7.89		B	23.72		B	16.15	
	C	7.81		C	23.22		C	17.05	
RCA_{CE1}	A	6.15	6.14	A	22.45	22.48	A	15.28	15.81
	B	6.20		B	22.10		B	16.02	
	C	6.06		C	22.88		C	16.12	
RCA_{CE7}	A	5.15	5.65	A	20.84	20.52	A	14.58	14.80
	B	5.86		B	20.55		B	14.86	
	C	5.95		C	20.16		C	14.95	

Values obtained for AIV, ACV and LAA tests are shown on Table 3 and Figure 2 Results showed improved resistances of aggregates for treated concrete aggregate samples. Also observed, was an improvement in aggregate resistance performance for RCA treated with older cassava effluent, than those treated with freshly obtained cassava effluent.

Figure 2

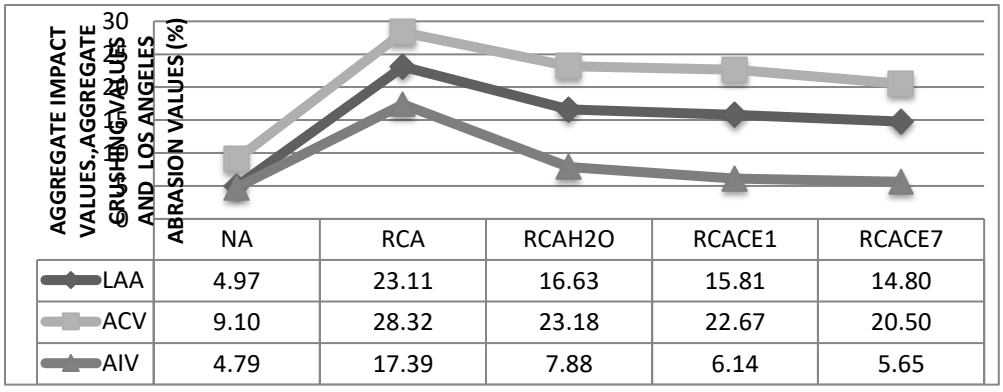


Figure 2 Aggregate Impact, Aggregate Crushing and Los Angeles Abrasion

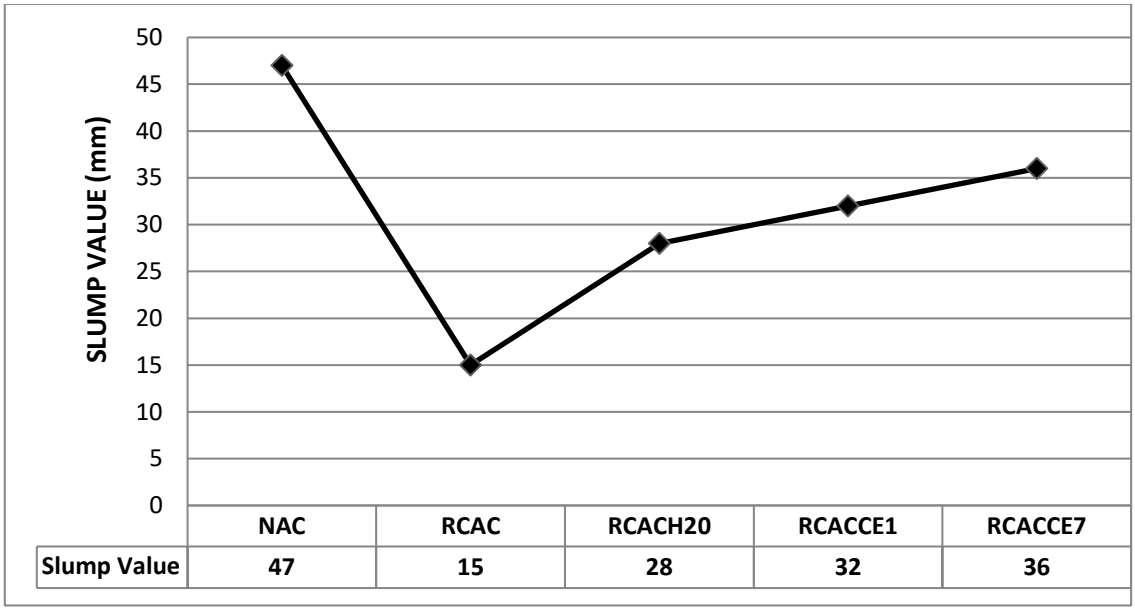


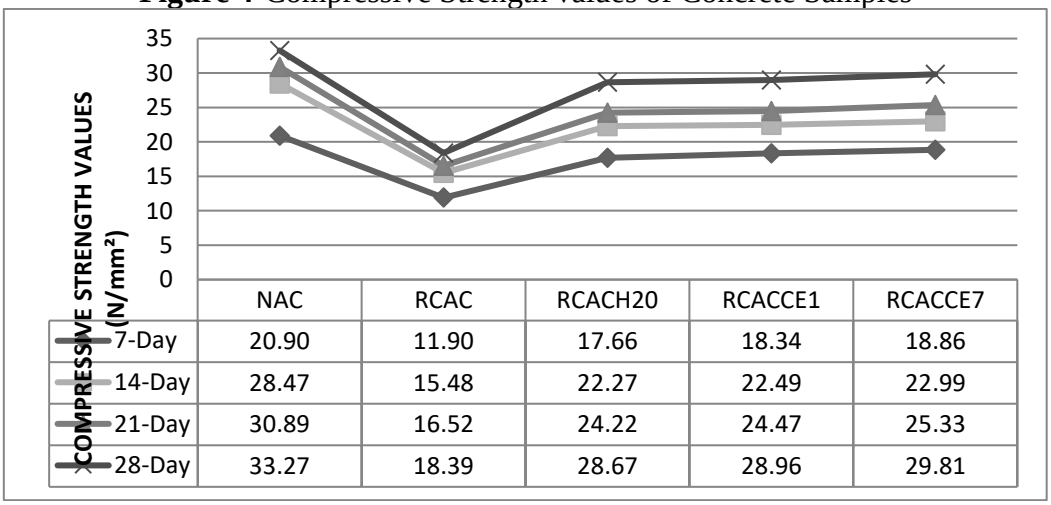
Figure 3 Slump test values of the various concrete samples

Compressive Strength Results

Compressive strength development in all concrete samples (NAC, RCAC, $RCAC_{H2O}$, $RCAC_{CE1}$ and $RCAC_{CE7}$) examined, exhibited similar strength development paths over a 28-day study period. Samples showed strength increase with age over the study period. Figure 4 illustrates this phenomenon.

The least compressive strength values were obtained on the 7th day, with concrete sample prepared from natural aggregates recording the highest values with 20.90 N/mm^2 and the lowest value for the 7th day was recorded for concrete produced from untreated recycled concrete aggregate (RCAC) with a value of 11.90N/mm^2.However, treated samples recorded better-quality results compared to untreated RCAC samples. The highest compressive strength value for treated recycled aggregate concrete was recorded by $RCAC_{CE7}$ with a value of 18.86N/mm^2.The treatment of recycled concrete aggregates with water, showed considerable progress in concrete compressive strengths compared to untreated recycled aggregate concrete (RCAC) with a value of 17.66N/m

Figure 4 Compressive Strength values of Concrete Samples



	NAC	RCAC	RCACH20	RCACCE1	RCACCE7
7-Day	20.90	11.90	17.66	18.34	18.86
14-Day	28.47	15.48	22.27	22.49	22.99
21-Day	30.89	16.52	24.22	24.47	25.33
28-Day	33.27	18.39	28.67	28.96	29.81

The highest compressive strength values were obtained on the 28th day, with concrete sample prepared from natural aggregates recording the highest values with 33.27 N/mm^2 and

the lowest value for the 28th day was recorded for concrete produced from untreated recycled concrete aggregate (RCAC) with a value of 18.39N/mm^2.Treated samples recorded improved results compared to untreated RCAC samples. The highest compressive strength value for treated recycled aggregate concrete was recorded by $RCAC_{CE7}$ with a value of 29.81N/mm^2.Treatment of RCA with water, showed an improvement in concrete compressive strengths compared to untreated recycled aggregate concrete (RCAC) with a value of 28.67N/mm^2.Details of all compressive strength values obtained for 7, 14, 21 and 28-day for all samples examine are illustrated on Figure 4.

Concrete PH Test Results

The results for the pH values of the natural aggregate concrete (NAC), untreated recycled aggregate concrete (RCAC) and the treated recycled aggregate concrete ($RCAC_{H2O}$, $RCAC_{CE1}$, and $RCAC_{CE7}$) samples are shown on Table 4. Not much difference was recorded between values obtained for samples examined. Values obtained for all samples were of alkaline nature.

Table 4 PH Values of samples

Concrete Sample	NAC	RCAC	RCACH20	RCACCE1	RCACCE7
pH Values obtained	12.59	12.50	12.62	12.48	12.52

Conclusion

Based on the observation from cassava effluent treatment on recycled concrete aggregates, following conclusions were drawn:

i. Aggregate properties such as aggregate impact value, aggregate crushing value and Los Angeles abrasion improved with the age of fermented cassava effluent;
ii. Excessive water absorption of recycled concrete aggregates can be addressed by treatment with water as well as with cassava effluent treatment;
iii. Compressive strength development pattern for treated and untreated recycled aggregates are similar to natural aggregate concrete. Although untreated recycled aggregate concrete can give compressive strength as low as 55.28% of natural aggregates, acid treatment of recycled aggregates can improve compressive strength up to 89.60% of natural aggregate concrete;
iv. The usage of agro-wastes such as cassava effluent may be a cheap option of treating recycled concrete aggregates to be used in concrete production as results shown above record acceptable results for design concrete.

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