Effect of Fermented Cassava Waste Water as Admixture on Some Physic-Mechanical Properties of Solid Sandcrete Blocks

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Abstract

This study investigated the effect of cassava waste water on sandcrete blocks. For the purpose of this study, two groups of sandcrete blocks were produced with fine aggregates to cement ratio of 6:1. A water/cassava waste water to cement ratio (w/c) of 0.5 was adopted. The blocks were cured by sprinkling method using fresh tap water.Preliminary investigation of some of the physical characteristics (Sieve analysis, porosity, moisture content and specific gravity) of the fineaggregates was carried out. The tests results revealed that the fine aggregates met the Nigerian Industrial Standard (NIS); the silt content was 3%, porosity 41.5%, and specific gravity 2.62. In addition the compressive strength, thewater absorption rate and thedrying rate of the sandcrete blocks produced with fresh water and withfermented cassava waste water were determined at 7, 14, 21 and 28 days after moulding. Results obtained showed that cassava waste water significantly ($p \leq 0.05$) affects the compressive strength, water absorption rate and drying rate of the blocks. Sandcrete blocks produced from cassava waste water had compressive strength of 3.38 N.mm^{2}at 28 curing days; while the fresh water sandcrete blocks recorded compressive strength of 2.04 N/mm^{2}at 28 curing days. The results further revealed that sandcrete blocks produced with cassava waste water had a lowerwater absorption rate (4.73%), when compared with result ofthe sandcrete blocks produced with fresh water (8.10%). These results showed that thesandcrete blocks produced with cassava waste water satisfied both NIS and BS requirement. In addition, the results obtainedsuggest that sandcrete block produced using cassava waste water is a durable building material, mostly in areas exposed to high moisture levels and temperature.

Keyword: *Cassava waste water, sandcrete blocks,physical characteristics, compressive strength, water absorption, drying rate*

I. Introduction

Cassava (*Manihotesculenta*Crantz) is one of the most popular crops found in Africa and Latin America. It is extensively cultivated for its edible starchy root, which is a major source of carbohydrates [1]. Cassava root is rich in carbohydrate, but poor in protein and vitamins. According to statistic from the Food and Agriculture Organization- FAOSTAT, (2019), some of the world leading cassava producers are Nigeria (59.49 million tonnes), Democratic Republic of the Congo (31.59 million tonnes), Thailand (30.97 million tonnes), Brazil (18.87 million tonnes) and Cambodia (10.57million tonnes) [2].The fresh cassava root contains toxic substances like hydrocyanic acid, which can be rendered harmless through adequate processing like boiling, roasting, soaking or fermentation. Concentration of hydrocyanic acid in a cassava root depends on its maturity age, harvesting period, farming method, cassava cultivar, etc.[3]. The hydrocyanic acid content of cassava roots ranges from 1-1550 parts per million (ppm) [30]. Apart from the harmful impart of cassava cyanide on human lives, there are several documented reports of negative impact of cassava waste water on the environment. From documented reports[4];[5];[6];[7], the physical and biochemical properties of soilswere adversely affected after contamination by cassava waste water.

Sandcrete block is a composite materialconsisting of cement (binding medium), fine aggregates (usually sand), water, and if possible additive, moulded into different shapes and sizes. Sandcrete blocks are small precast masonry units that are assembled together and bound by means of a cementitious material [8]. Sandcreteblocks are important building and construction materials that arewidely employed in the construction of load and non-loading bearing walls in several countries of the World. The use of sandcrete blocks in building construction has gainedpopularity over the past decades due to their cheapness and durability whencompared with other conventional materials. About 70% of physical infrastructures in Nigeria are constructed using sandcrete blocks, making them avital component of building and construction industries[9].The qualities of sandcreteblocks are highly dependent on the mixing ratio, production method, mixing methods, curing method and the properties of the constituent materials. Water is one of the vital constituent of a sandcrete block. Since water is needed for the hydration process, sufficient amount of water should be used during sandcrete block production so that the hydration reaction can take its full course. Excess water has the capability of lowering the strength of the block. Water-cement ratio is an important concept because other than the recipe for the concrete mix, the amount of water used strongly influences its final strength [10];[11].

The Committee on Review of Decision in Nigeria [12] specifies 2.1N/mm^2 as the minimum 28 day average compressive strength, for load bearing walls of 2 to 3 story height; and minimum compressive strength of 1.75N/mm^2. Admixtures are organic or inorganic compounds often used to modify some engineering properties of concrete and sandcrete blocks in order to meet their intended design target. Hewaydee*et al*. [13] reported that admixtures contributed to increased compressive strength and low porosity. Silica fume, also particularly contributed to the resistance of concrete to H_2SO_4. Mahmoud *et al*. [14] observed adecrease in compressive strength of blocks, with increase in groundnut shell ash fillers. From their results, the blocks made with 20%, 10%, and 0% groundnut shell ash replacementsafter 28 days of curing had compressive strength of 3.58N/mm^2, 4.03N/mm^2, and 4.50N/mm^2 respectively.Duna and Wamyil[15] reported that Tetraoxosulphate VI acid when used as admixture slightly increased the compressive strength of hollow sandcrete blocks. According to [15] the water absorption rate of sandcrete blocks immersed in H_2SO_4 (pH 1.3) was significantly higher when compared tosandcrete blocks immersed with fresh water (pH 7)for 28 days.Exposure of concrete structures to attacks from cassava waste water or effluent-contaminated soil significantly reorganized the internal microstructure of concrete elements [16].Furthermore, [17] observed a general decrease in the compressive strength of concrete produced with salt water, which they attributed to the presence of chlorides and sulphates in the salt water.

Presently, there is not much information on the effect of fermented cassava waste water onengineering properties of solid sandcrete blocks. Therefore the objective of this study is to evaluate the effect of fermented cassava waste water on some physic-mechanical properties (compressive strength, water absorption rate and drying rate) of solid sandcrete blocks. The data obtained will be compared with set standards, to determine if the sandcrete blocks meet international (NIS and BS) standards.

II MATERIALS AND METHODS

A. Materials used

The sandcrete blocks used for this study were produced with the following materials:

Cement: Ordinary Portland cement (produced by Dangote) was used as binder for this study. The cement was factory tested and documented as grade 42.5; which was in compliance with Nigeria Industrial Standard [18].

Fine aggregates: The fine aggregates used for this study were obtained from a local sand dredger in Delta State, Nigeria. The fine aggregateswere free from deleterious materialsand were air dried at the Civil Engineering Technology soil laboratory of the Delta State Polytechnic, Ozoro, Nigeria for a period ofone week.

Water: Fresh tap water obtained from a motorized borehole within the premisesof theSchool of Engineering, Delta State Polytechnic, Ozoro, Nigeria, was used for the study. The water (pH 7.5 andelectrical conductivity 45 µS/cm) was free from aquatic plants, foreign materials, oil contamination, etc.

Cassava waste water: Cassava (cv. TME 419) roots were harvested from the Department of Agricultural and Bio-Environmental research farm. The cassava roots were peeled manually and washed to remove all debris, before they were cut into smaller sizes. They were soaked in water under ambient environmental conditions for five days. Soaking of the cassava roots allows forgreater extraction of soluble cyanide from the cassava roots into the water. At the fifth day, the cassava roots were removed from the water,and the waste water was sieved using a75 µmm stainlesssteelsieve to remove all solid particulate materials from it.

B. Methods

Mixing: Mechanically mixing method was employedfor themixing of the sandcrete block constituents; cement, fine aggregates and water/waste water. This was done to obtain a homogenousmixture of the constituents.

Sandcrete block production: For the purpose of this study, two groups of sandcrete blocks were produced with fine aggregates to cement ratio of 6:1. A water/cassava waste water to cement ratio (w/c) of 0.5 was adopted.The first group was produced with cement, fine aggregates and 100% fresh tap water (pH 7.2); while the second group was produced with cement, fine aggregates, and 100% fermented cassava waste water (pH 2.7). The same mixing method (mechanical) was adopted for the two groups. During the moulding, the thoroughly mixed constituents were filled into standard moulds, rammed 36 times and leveled with a flat stainless steel trowel. The blocks were demoulded after 24 hours.

Curing: The blocks were cured twice daily (morning and evening), by sprinkling. Fresh tap water was used for the curing of the blocks for both groups. Curing is important to the sandcrete blocks because it facilitates proper hydration and hardening of the blocks. All the sandcrete blocks were cured under ambient laboratory conditions (temperature 25±5^{0}C).

C. Laboratory Tests

The study involved two major laboratory tests. Firstly, preliminary investigation of some of the physical characteristics of the constituents of the sandcrete blocks was carried out. Secondly, Determination of the compressive strength and water absorption rate of thesandcrete blocks produced usingfresh water and cassava waste water. All tests were cured under ambient laboratory conditions.

All the laboratory tests were carried out at the department of Civil Engineering Technology's concrete laboratory,atDelta State Polytechnic, Ozoro, Nigeria, in accordance with BS and NIS standardrequirements.

Sieve analysis: Sieve analysis was also carried out on the fine aggregates to ascertain their suitability for block making in accordance with BS standard [31]. The fine aggregates were air-dried in the laboratory at ambient temperature (25±5^{0}C) for two weeks. During the analysis, the sieves set was arranged in descending order; the largest aperture sieve was placed at the top, followed by the immediatesmaller one, until the smallest aperture sieve was placed at the bottom. One kilogram of the fine aggregates was weighed with electronic weighing balance, and poured into the uppermost sieve of the arranged sieve set. The set was carefully inserted into a mechanical sieve shaker, and ran for twenty minutes. After that, each sieve was carefully removed from the set, and the fine aggregates retained in each sieve was weighed and recorded. Cumulative weight of fine aggregates passing through each sieve was calculated as a percentage of the total sample weight [27].

Moisture content determination: The moisture content of the fine aggregates was determined gravimetrically, in accordance with the standard procedures described by [6];[19] and calculated using equation 1.

$$Moisture\ content = \frac{weight\ of\ wet\ sample\ - weight\ of\ dry\ sample}{weight\ of\ wet\ sample} \times 100 \quad (1)$$

Porosity and Specific gravity determination: The porosity and specificgravityof the fine aggregates were determined usingstandard methodsstated by AOAC [20].

Porosity (υ) of the fine aggregates was calculated using equation 2.

$$\upsilon = \frac{V_v}{V} \times 100 \quad (2)$$

Vv = Void volume,
V = Total volume

Specific gravity of the fine aggregates was calculated using equation 3.

$$S_g = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (3)$$

W_1 = Weight of the empty bottle
W_2 = Weight of the bottle filled fine aggregates.
W_3 = Weight of the bottle and its content filled with distilled water up to the meniscus.
W_4 = Weight of the bottle filled with distilled water to the meniscus.

Physicochemical analysis of the cassava waste water: The Calcium (Ca), Magnesium (Mg), Iron (Fe), Copper(Cu), and Zinc (Zn) concentrations of the cassava waste water were analyzed using Atomic Absorption Spectroscopy (AAS) at specific wavelengths as recommended by [21]. While the electrical conductivity and pH of the cassava waste water were determined with a digital electrical conductivity meter (EMCEE Model 1152, India).In addition, APHA approved methodwas employedfor the determination of the cyanide in the cassava waste water[7];[22].

Compressive strength determination: The compressive strength of the sandcrete block was done in accordance with NIS-87, 2004 [23], using an electronicConcrete Compression Testing Machine (STYE 2000), manufactured in China. Crushing test was conducted on the blocks at 7, 14, 21 and 28 days after moulding. Duringcrushing, each block was clamped between two flat plates (placed above and below the bed surfaces of the block) in the loading chamber of the compression machine, loadedaxially at constant speeduntil failure occurred.Thecompressive force was read from the machine at the failure point. The compressive strength was calculated by dividing the crushing load by the effective surface area of the sandcreteblock (equation 4). On each testing day, four sandcrete blocks from each group were tested, and the average value was recorded.

$$Compressive\ strength = \frac{Crushing\ load}{Effective\ surface\ area\ of\ block} \quad (4)$$

Water absorption rate: The water absorption rate was carried out in accordance with standard recommended by BS EN 771. Four dried sandcrete blocks were selected atrandomand weighed using electronic weighing balance, and their individual weight recorded. The blocks were completely immersed in cool water atambient water temperature

(23 ± 4^0C) for 24 hours. Then they were brought out of the water, wrapped dry with trowel,weighed again, and their water absorption rate was calculated usingequation 5.

$$Water\ absorption\ = \frac{M_a - M_b}{M_b} \quad (5)$$

M_a = weight of block after soaking in water
M_b = weight of block before soaking in water

Block drying rate: Four dried sandcrete blocks were selected at random and were completely immersed in cool water at ambient water temperature (23 ± 4^0C) for 48 hours. After that they were brought out of the water, wrapped dry with trowel, weighed using electronic weighing balance, and then put inside anelectric laboratory oven, preset at a temperature of 40±5°C. This temperature was considered as the average highest temperature attained in tropical regions of the world. At an interval of every six hours, the blocks were taken from the oven and their weight immediately taken. The drying rate of the blocks was calculated using equation 6.

$$Dry\ rate\ = \frac{W_a - W_b}{W_b} \quad (6)$$

W_a = Final weight of block
W_b = Initial weight of block

D. Statistical Analysis

The data obtained from this research were statistically analyzed using the Statistical Package for Social Statistics (SPSS version 20.0), and the means were separated using The Duncan's New Multiple Range (DNMR) Test (P ≤0.05).

III. RESULTS AND DISCUSSION

A. Physical characteristics

The results of the physical characteristics of the fine aggregates used for this study are presented in Table 1. Generally, the results showed that fine aggregates met the NIS standards.

Table 1: Physical characteristics of the fine aggregates

Parameter	Value
Moisture content (%wb)	14± 0.81
Porosity	41.50±0.92
Specific gravity	2.62±0.017

Values are means ± standard deviation

Moisture content: The results (Table 1) showed that the mean moisture content of the fine aggregates was 14 %. This value was slightly higher than NIS maximum requirement of 12%.

Specific gravity: As seen in Table 1, the mean specific gravity of the fine aggregates used for the block production was 2.62. This falls within the standard limits recommended by NIS. The higher the specific gravity of the aggregates, the denser and stronger the sandcrete blocks produced.

Porosity: The results shown in Table 1, the mean porosity of the fine aggregates was 41.5 %. When exposed to high moisture levels for long periods of time, a highly porous block will absorb excess water, become weakened and eventually failure. The amount of moisture absorbed by sandcrete block is directly proportional to its porosity. The presence of admixture can increase, decrease or maintain the porosity of sandcrete blocks depending on the aggregates size.

Sieve analysis: The result of the sieve analysis is presented in Table 2 and Figure 1. As seen in Table 2, only 3% of the fine aggregates passed the 75 µmm sieve size and by Unified Soil Classification System (USCS) the sample is classified as Sand Well-Graded denoted by SW [15]; [24]. Fine aggregates with silt content of ranges 3% to 8% is permissible for sandcrete blocks production.

Table 2: Result of sieve analysis of fine aggregate: Total weight of sample = 1000 g

Sieve Diameter	Weight Retained	Cumulative Weight Retained	% Retained	% Passing
3.35mm	0	0	0	0
2.36mm	10	10	1	99
1.18mm	25	35	2.5	96.5
850µm	40	75	4	92.5
600µm	150	225	15	77.5
425µm	340	565	34	43.5
212µm	365	930	36.5	9.5
75µm	65	995	6.5	3
Pan	5	1000	0.5	0

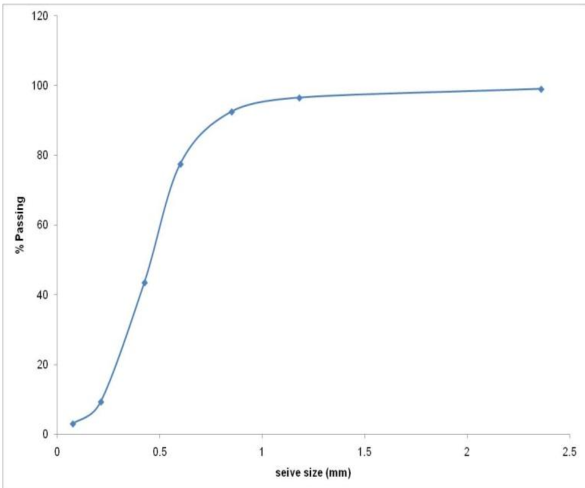


Figure 1: Sieve analysis of fine aggregates

B. Physicochemicalproperties and cyanide content of the cassava waste water

The results of the physicochemical and cyanide content of the cassava waste water are shown in Table 3. The results showed that the fermented cassava waste water was acidic, with high cyanide content.

Table 3: Chemical analysis of cassava waste water

Parameter	Value
Ph	3.13±0.15
Electrical conductivity (μS/cm)	2312±51.09
Cyanide (mg/L)	13.78±0.02
Chromium (mg/L)	2.33±0.54
Lead (mg/L)	3.66±0.43
Nickel (mg/L)	2.29±0.14
Zinc (mg/L)	3.95±0.57
P (mg/L)	35.39±0.45
K (mg/L)	48.2±2.11

Values are means ± standard deviation

C. Analysis of Variance

The results of the analysis of variance (ANOVA) of the effect of cassava waste water on some physic-mechanical properties of sandcrete blocks are presented in Table 4. As shown in the ANOVA table, cassava waste water had significant ($p \leq 0.5$) effect on all the parameters evaluated in this study. Likewise, curing period significantly ($p \leq 0.5$) influenced the three parameters evaluated in this study. Lastly, the interaction of curing period by treatment had significant ($p \leq 0.5$) effect on all the three parameters studied, as shown in Table 4.

Table 4: The ANOVA of effect of treatment and curing period on the physic-mechanical properties of sandcrete blocks

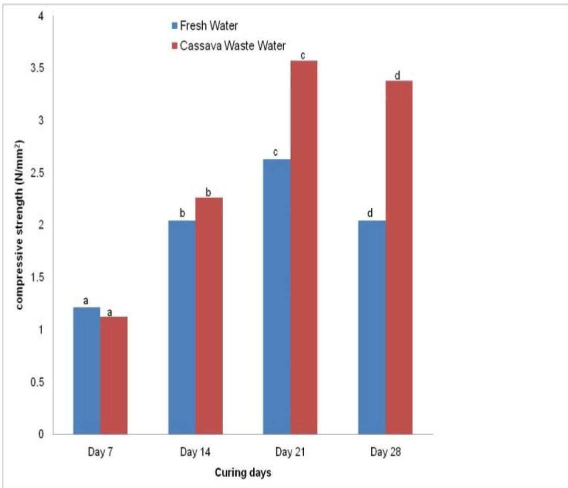
Source of variation	df	Compressive strength	Water absorption rate	Drying rate
Treatment	1	2.39E-08*	9.81E-05*	1.42E-16*
Curing	3	2.34E-13*	7.13E-09*	3.94E-14*
Treatment x Curing	3	3.76E-08*	3.12E-06*	7.48E-07*

* Significant at $p \leq 0.05$

D. Compressive strength of the sandcrete blocks

The results of the compressive strength of the sandcreteblocks are presented in Figure 2. As shown in the chart (Figure 1), the compressive strength of the sandcrete blocks increased steadily during the first 21 curing days. Within the first 21 curing days, the compressive strength of the sandcrete blocks produced with fresh water increased from 1.214 to 2.63 N/mm^2; while that of cassava waste increased from 1.12 to 3.57 N/mm^2. The results showed a reduction in the compressive strength of the blocks, from 2.63 to 2.04 N/mm^2 for the fresh water blocks and from 3.57 to 3.38 N/mm^2 for the cassava waste water blocks, at the 28th curing day when compared with the expected result given by [25].

With reference to the results obtained, it can be seen that the compressive strength of the cassava waste water produced concrete blocks were significantly ($p \leq 0.05$) higher than the fresh water produced sandcrete blocks, apart from the curing day 7 blocks. The lower compressive strength (1.12 N/mm^2) observed for the sandcrete blocks produced with the cassava waste water at day 7, when compared with sandcrete blocks produced with fresh water (1.214 N/mm^2) could be attributed to delay in the setting of the blocks. Similar results were obtained by previous researchers. Aiyewalehinmi and Akande [26]recorded compressive strength of 4.06 MPa for sandcrete blocks treated with cassava waste water, when compared with 1.03 MPa recorded for untreated sandcrete blocks at 28 curing days.Duna and Wamyil [15] reported higher compressive strength of hollow sandcrete blocks (5.59 N/mm^2) immersed in acidified water (pH 1.4) for 24 hours, when compared to the sandcrete blocks (5.50 N/mm^2) immersed in fresh water (pH 7). On the contrary, [28] observed a continuous declined in the compressive strength of concrete cubes casted with cassava waste water instead of fresh water.



Columns with the same colour and common letter are not significantly different ($p \leq 0.05$) according to Duncan's Multiple Range Test

Figure 2: Compressive strength of sandcrete blocks

E. Water Absorption Rate

Water absorption is the ability of a sandcrete block to absorb moisture for the environment. The effect ofcassava effluent on the water absorption of sandcrete blocks is presented in the chart shown in Figure 3. As shown in (Figure 3), the average water absorption rate of the blocks produced with fresh water was comparatively higher (8.1%) than that ofblocks produced with cassava waste water (4.73%)after 28 days of curing. These results fall below the NIS and BS recommendation maximum standard limit of 12%.The higher water absorption rate of the sandcrete blocks produced with fresh water could be attributed to the higher void ratio withinthe block, leading to higher water permeability and water holding capacity. Cassava waste water had the ability of decreasing soil porosity, due to the starch content of the cassava effluent [6]. Water absorption is appreciable to an extent in sandcrete blocks, but excessive water absorption causes various defects suchas, shrinkage of block after drying, cracking of blocks,opening of the joints, etc. [29].Sandcrete blocks used for the construction of external walls in tropical humid climates, or areas exposed to high moisture content should have low water absorption value, to minimize penetration of moisture into the interior of the building [26].

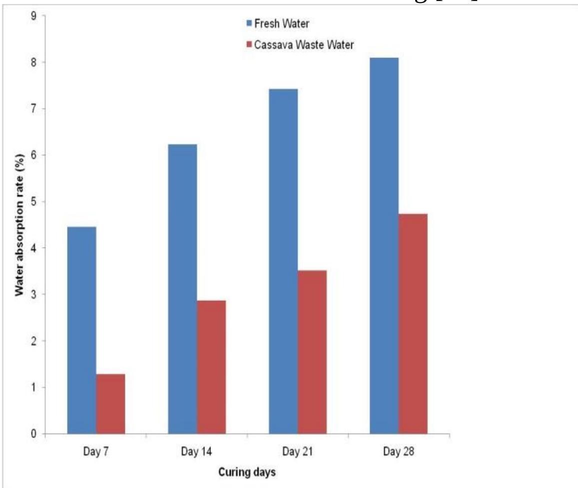


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Figure 3: Water absorption rate of sandcrete blocks

F. Drying rate

The results of the drying rate of the sandcrete blocks are presented in Figure 4. As shown in Figure 4, there was no significant moisture loss between drying period at18 h and 24 h in the sandcrete blocks produced with fresh water. The results showed that sandcrete blocks produced with cassava waste water retain more water than fresh water produced sandcrete blocks. Therefore, cracking of the walls resulting from rapid expansion and contraction of the blocks may not occur easily with sandcrete blocks produced with fermented cassava waste water, due to lower water absorption rate of the blocks.

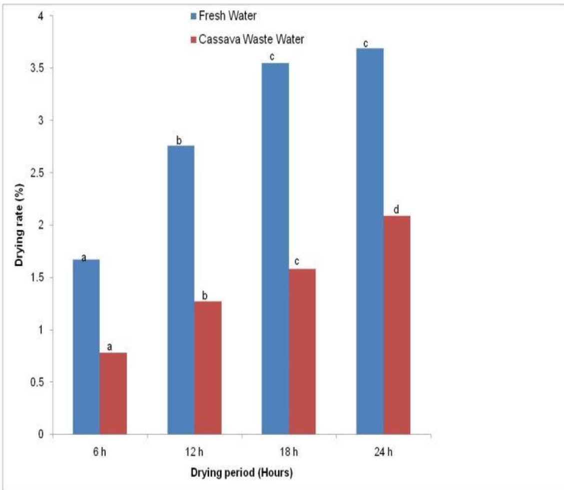

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Figure 4: Drying rate of sandcrete blocks

IV. CONCLUSION

This study was carried out to evaluate the effect of fermented cassava waste water (as admixture) on some physic-mechanical (compressive strength, water absorption rate, and drying rate) properties of sandcrete blocks. The sandcrete blocks were produced with fine aggregates to cement ratio of 6:1. A water/cassava waste water to cement ratio (w/c) of 0.5. Results obtained from the compression tests showed that cassava waste water had significant effect on the compressive strength of the sandcrete blocks. Within the 28 curing period, the compressive strength of the sandcrete blocks produced with fresh water increased from 1.214 to 2.63 N/mm^2; while that produced with fermented cassava waste water, increased from 1.12 to 3.57 N/mm^2. Water absorption rate of 4.73% was recorded for the cassava water blocks, which was lower than 8.10% recorded for the sandcrete blocks produced with fresh water. These results showed that the sandcrete blocks produced with cassava waste water satisfied the NIS 87: 2000 and BS 3921 requirement. These results suggest that fermented cassava waste water sandcrete block is a durable building and construction material for areas exposed to high moisture levels and temperature.

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