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Effect of Cassava Starch on the Durability Characteristics of Hollow Sandcrete Block

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ABSTRACT

This research investigates the effect of Cassava Starch (CS) floor on the durability characteristics Hollow Sandcrete Block (HSB). Specimens were prepared by adding CS to the cement by weight at percentages of 0.3, 0.7, 1.5, 2.5 and 3.0%. The sandcrete block were cured for 7, 14, 21 and 28 days and then tested for compressive strength before subjected to ponding in ironic solutions of sodium hydroxide and sulphuric acid, and sodium chloride. Five sandcrete block mixes were prepared, each with varying levels of Cassava Starch, to evaluate its effect. The results showed a reduction in slump value with increasing doses of CS, attributed to the viscous nature of the Cassava Starch paste. Generally, the addition of Cassava Starch to HSB improved resistance to sulphate and chloride attacks, as the muddy-like starch gel blocked the pore spaces in the hardened sandcrete block samples. This reduced the rate at which water and other aggressive chemicals penetrated the blocks. Therefore, the addition of CS to HSB by weight of cement significantly improved the durability characteristic. There is a general increase in the compressive strength of block at varying substitution cement by CS with the maximum increase of 57% was recorded at 2.5% of CS admixture. The study recommends that HSB made with CS be used for construction in areas prone to sulphate, chlorine, and alkaline attacks.

Keywords: *Hollow Sandcrete Block · Durability characteristics · Strength properties of HSB · Cassava Starch · Resistance to Sulphate*

1. Introduction

The use of hollow sandcrete blocks (HBS) has gained popularity in Nigeria including Kano State [1, 2]. They are widely used as walling units or partition, often as a load bearing walls [2]. Hollow sandcrete blocks, as precast masonry units, are assembled and bonded by cementitious materials to form walls which can either be, load bearing wall, enclosed wall or back up wall. On the other hand, certain environments such as marine, seawater, soils containing sulphates, water and waste treatment environments, exposes block wall to sulphates, chloride and alkaline attacks resulting to deterioration of walls, causing a diminution in the durability properties of hollow sandcrete block. In addition, it has been observed that most external walls in buildings constructed with hollow sandcrete block to a certain level of elevation appeared to be weird. Therefore, hollow sandcrete block walls required to be protected for it to serve the purpose for which they are built throughout its service life. Sulphate attack on block wall is characterized by its mass and strength loss [3]. This occurs when mono-sulphate aluminate hydrate crystals, formed during secondary cement hydration, become unstable and revert to larger-sized crystals which lead to cracking and deterioration of cementitious materials when subjected to sulphate attack [4]. The process of the first order and second order cement hydration is described in equation 1 and 2 respectively.

$C_3A + 3CSH_2 + 26H \rightarrow C_6AAS_3H_{32} + Heat$ (1)
[Tricalcium aluminate + gypsum + water = Ettringite + Heat]

$2C_3A + 3C_6AS_3H_{32} + 22H \rightarrow 3C4ASH18$ (2)
Tricalcium aluminate + Ettringite + water = Mono-sulphate aluminate hydrate

The resistances of hollow sandcrete block to sulphate attack will depend on the use of sulphate resisting cement and/or the use of retarding admixtures to inhibit the formation of the monosulphate aluminate hydrates within the sandcrete mixed [5]. Besides, hollow sandcrete block walls are also attacked by the ingress of chlorides into its pore structure, thereby leading to deterioration; the binding property of the block becomes lose. Therefore, the penetration of chlorides into block wall can be controlled either by providing a good cover rendering e.g. sand and cement or by reducing the interconnectivity of the pore spaces in hollow sandcrete block which depends on its sorptivity [6, 7]. Sorptivity is an important parameter in measuring the resistance of block wall to aggressive environments. A high sorptivity value shows that the hollow sandcrete block pore spaces are well connected and vice versa. This means that the diffusion of an aggressive chemical will be high in hollow sandcrete block having high sorptivity. It was reported that the block containing cassava starch had lower water abortion rate, compared to block produced without cassava starch [8]. Cassava Starch is a carbohydrate polymer that is composed of two molecular components: linear amylose and branched amylopectin, figure 1 shows the chemical structure the amylose and amylopectin in CS.

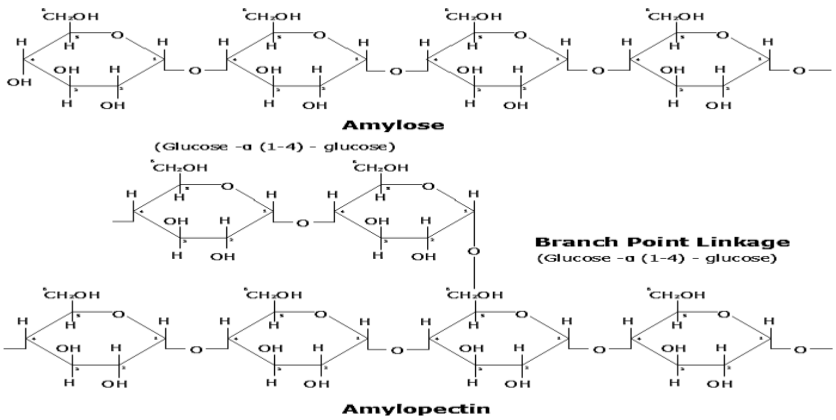

Figure 1. The chemical structure of the amylose and amylopectin in Cassava Starch [9].

The interaction between the Amylose-Amylopectin improves the viscosity and textural properties of starch, which include cohesiveness and adhesiveness. A viscous and thickening gel is formed when starch is dissolved in hot water by allowing the hydrogen bonding sites (the hydroxyl, hydrogen and oxygen) to engage more water [10].This eco-friendly and cheap material has various applications in construction as reported by various researchers. CS cassava starch could be used to increase the workability of cement and sandcrete block mix [9]. CS improved the compressive strength of hollow block [11, 12]. It was also noted that the creep behaviour and shrinkage characteristics of sandcrete block mixed with cassava starch were improved [12].

HSB wall has been extensively used in both the industrialized and unindustrialized nations to substitute the fired brick masonry playing an important role in contemporary building industry [13]. HSB is used for both load and non-load bearing walls [14] particularly owing to its capability to conserve energy, reduce the use of raw materials, reduce the impact on the environment, fire-resilient, and needs low maintenance through its lifetime [15]. HBS possesses very low compressive strength making then susceptible to any tragedy such as seismic activity. HSB are composite material made up of cement, sand and water, molded into different sizes. It is widely used in Nigeria and most part of African countries, as walling and partition unit in one story building, schools, and houses etc. The quality of blocks produced however, differs from each industry due to the different methods employed in the production and the properties of the constituent materials. Previous researchers have identified that most commercially available HBS in Nigeria fall below minimum compressive strength of 1.5-1.97 N/mm^2 which is well below 2.5 N/mm^2 and 3.45 N/mm^2 standard requirement [16]. Most HBS that are available for the construction of load bearing and non-load bearing structures, do not conform to building code and regulations [17]. The HBS commercially produced currently for building and construction material markets in Nigeria are not uniform to both quality and compressive strength. This suggests that there is a need for more improvement and control in building and construction materials in Nigeria.

Cassava is an important root crop in Africa, Asia, South Africa and India, providing energy for about 500 million people. The economic justification for incorporating cassava starch as an admixture in hollow sandcrete block production in Nigeria is robust, primarily determined by the nationally ample supply of cassava derivatives and the persistent demand for sandcrete blocks within the Nigerian construction sector. This approach offers a synergistic advantage to both the agricultural and building materials industries. Abundant Availability and Underutilized Potential of Cassava in Nigeria holds the distinction of being the world's largest producer of cassava, with an annual output estimated to be around 59.5 million metric tons as of 2020 [18] [19]. This substantial production volume underscores a readily available and consistently supplied raw material base. Cassava cultivation is widespread, spanning over 24 states across Nigeria's diverse agro-ecological zones, which inherently reduces logistical complexities and transportation costs associated with sourcing [20]. Despite its leading global position in cassava production, a significant proportion (approximately 90%) of Nigeria's annual yield is directed towards domestic food consumption (e.g., Garri, Fufu), leaving substantial untapped potential for industrial processing, particularly into starch [21]. The estimated annual demand for cassava starch in Nigeria exceeds 350,000 metric tons, while domestic production capacity remains below 20% of this figure, highlighting a critical market deficit and a lucrative opportunity for increased local starch processing [22]. Furthermore, the valorization of cassava through industrial starch production contributes to economic diversification, moving beyond petroleum dependency, and fosters job creation within the agricultural and manufacturing sectors [23]. The utilization of starch also aligns with principles of waste valorization, as it leverages a high-value derivative of a major agricultural commodity.

Hollow sandcrete blocks constitute a foundational building material in Nigeria's construction industry, accounting for an estimated **90% of all residential building constructions [24]. This indicates an enormous and sustained demand driven by rapid population growth, ongoing urbanization, and continuous infrastructural development across the nation [25].

However, a significant challenge within the Nigerian block industry is the prevalent issue of substandard quality. Numerous studies and field observations consistently report that a considerable proportion of commercially available sandcrete blocks fail to meet the minimum compressive strength and other critical quality parameters stipulated by standards such as the Nigerian Industrial Standard (NIS 87:2004) and ASTM C129/C90 [26] [27]. This quality deficit leads to compromised structural integrity, increased construction waste, and heightened maintenance costs, thereby creating a compelling economic incentive for quality improvement through innovative admixtures. The incorporation of cassava starch into sandcrete block formulations presents several compelling economic benefits by enhancing performance and potentially optimizing material usage: Stronger blocks minimize breakages during handling, transportation, and laying, leading to less material waste and reduced rework costs on construction sites. Production of blocks that consistently meet or exceed strength requirements contributes to safer and more durable building structures, potentially lowering long-term maintenance and replacement expenditures for property owners.

Cassava roots are potentially toxic due to the presence of cyanogenic glycosides especially Linamarin. Physiological deterioration occurs in cassava roots, 2-5 days after harvesting followed by microbial deterioration 3-5 days later. Cassava farming population has empirically developed several processing methods for stabilizing cassava and reducing its toxicity. In addition, the roots contain large quantities of the anti-nutrient factor cyanide and it changes in cassava into cyanogenic glycosides, linamarin and lotaustralin. During the fermentation there is disintegration of tissue structure of linamarin with linamarase, located in the cell walls and subsequent hydrolysis to glucose and cyanohydrins, which easily breakdown to hydrocyanic acid (HCN). HCN is produced on an industrial scale and is a highly valuable.

Thermal properties of most cementitious materials are found to change with the presence of admixtures [26]. Changes found depend on the admixture's grain structure or interstitial arrangement within the main material and other micro structural parameters including the volumetric fraction of each constituent, the shape of the particles, and the size distribution of the particles. In predicting the thermal performance of buildings, it is necessary to consider the dynamic effects of this variation.

CS boiled at control temperature of 75^0C to 100^0C turns to a sticky liquid, confirming that it possessed an appreciable quantity of silica and alumina for used as pozzolan in hollow concrete. Mechanical and some durability properties of concrete containing about 15% of cassava content as a replacement for cement have been studied with hopeful results [27]. The replacement levels of 0.3%, 0.7%, 1.5%, 3.0% by weight of binder was informed by a blend of experiential evidence and experimental design philosophies intended at understanding the influence of biopolymer additives on the durability characteristics of sandcrete blocks. [28] investigated cassava starch concentrations ranging from 0.4% to 2.0% in concrete and found that moderate additions improved permeability, and enhanced the formation of a denser microstructure. The observed improvements were attributed to starch' gel-forming ability, which helps to seal micro-pores and limit aggressive ion ingress. The current study contains dosage of 1.5% and 2.5%, and 3.0% in order to examine whether higher concentrations could yield further enhancements or indicate a threshold beyond which performance declines while the lower percentages of 0.3%, and 0.75 examine the marginal influence of starch.

2. MATERIALS AND METHODS

The materials and methods employed in this research were selected in accordance with the British Standard (BS) guidelines. The materials used include: Ordinary Portland Cement, sharp sand, cassava starch and distil water.

2.1 Materials

The sharp sand of smooth texture with low silt and clay content used in this study was obtained from Wudil river, Kano state. It passes through sieve 4.75mm of British standard test sieve size. The particle size distribution was check in accordance with the method prescribe by BS EN 1097-2-2010. Dangote Portland Limestone Cement Grade 42.5R that complied with NIS 444-1; 200 3 standards. It is used to bind the fine aggregates together to form a mortar. The cassava starch powder was procured from Yankaba local Food market, Kano, Nigeria. The distil Water conforming with to the requirements of ASTM C33 was used.

2.2 Methods.

2.2.1 Characterization and Activation of Cassava Starch (CS).

The cassava starch was dried in sunlight before characterization and activation as shown inn figure 2. The particle size of CS was determined with the aid of a Laser Diffraction Particle Size Analyzer (LDPSA). It measures the sizes of fine materials such as clay muds and starches using a light scattering method. The proximate analysis of CS was carried out at the Central laboratory of Aliko Dangote University of Science and Technology Wudil, Kano. The starch solution for each mixed batch was prepared by dissolving the CS powder in hot water at a temperature between 80°C and 100°C, cooled to a room temperature and added to the sandcrete mixed. The water used for the activation was 10% of the mixing water.

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Figure 2. Activated Starch

2.2.2 X-ray Diffraction (XRD) Analysis

The chemical composition of CS was analyzed with the used of XRD shown in figure 3. The XRD was done to obtain further evidence about the structure of the sample. The XRD Analysis of CS was achieved by a Shimadzu XDS 2400H Diffractometer with Cu anode, λ1cu = 1.541838 [A°], attached to digitized computer along with graphic assemble on uncompressed powder in order to collect the maximum of diffraction lines and a better identification of the phases and tungsten filament operated with a voltage of 40KV and a current of 30mA and Nal(TI) scintillator dictator. The prepared sample was placed in a Lucite holder on the goniometer of the instrument which was configured with a graphic monochromator shown in figure 4. The diffraction beam monochromator operated at 40KVA and a current of 40mA with the 20 range of 0 – 70° and deviation of ±0.05° and at a scan speed of 2O°C/minute with step size of 0.02° for 120 minutes to create x – ray patterns with enough intensity to produce lines to identify minerals at the 20 angles. The parameters selected were peak: positions (20Θ), plane and relatives intensities.

Figure 3. X-ray Diffractometer Detector

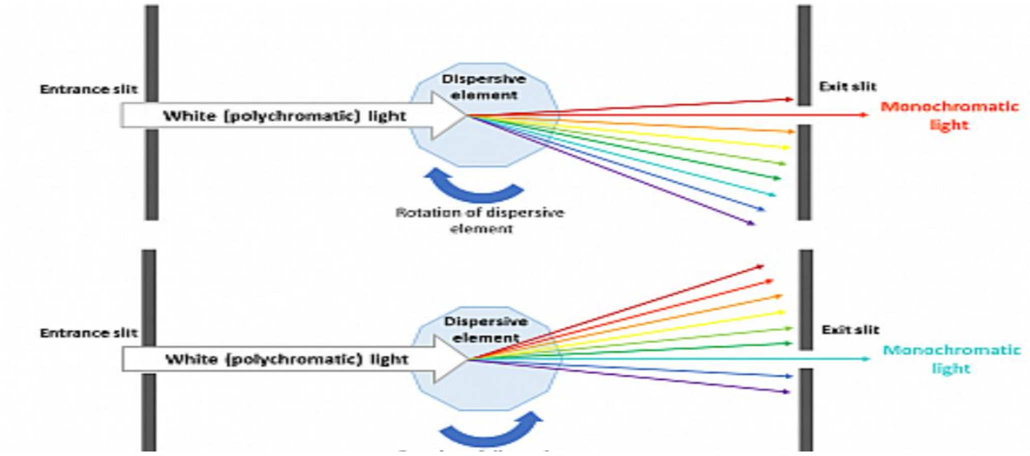


Figure 4. Monochromatic

2.3 Hollow Sandcrete Block Mix Design and Specimen Preparation

Mechanically mixing method was used for the production of the hollow sandcrete block. The cement and sand were batched in the ratio of 1:6 and mixed thoroughly until uniform colour and consistency appeared. For the purpose of this study, volumetric batching method was adopted. Also cement to fine aggregate ratio of 1:6. The sandcrete blocks cube were produced by adding cassava starch, at the rate of 0%, 0.3%, 0.7%, 1.5%, 2.5% and 3.0% as admixture. The sizes of the block produced are 150 x 150 x 450 mm (6 inches).

The highest proportion of CS addition was limited to 3.0% by weight of cement (50g per kilogram of cement) to determine its effect. The specimens were cured by complete immersion in an open-air water tank at room temperature (25C ± 1) for a period of 7, 14, 21 and 28 days before ponding in the test solutions for the evaluation of durability.

2.3.1 Curing of Block Samples

The block samples were immersed in a distil water for a period of 7,14, 21 and 28 days. The purpose of curing is to regulate and maintain the moisture required for a complete hydration process of the hollow sandcrete blocks samples.

2.3.2 Compressive Strength Test on Samples

The block samples were removed from the curing tank at different period of 7 days, 14 days, 21 days and 28 days and allow to dry. The cube samples were crushed by compressive testing machine. The crushing test was carried out for each treatment level of the block. Again, the cube samples are ponded for sorptivity test for a period of 45 day and 60 days.

2.3.3 Workability, Water Absorption and Sorptivity Tests.

The workability of the fresh hollow sandcrete block mould was determined using the slump tests. The tests were carried out in accordance with BS EN 12350-2:2019. The water absorption of hollow sandcrete block was determined using a companion cubes (for material properties-casting solid cubes using the exact same sandcrete mix that makes the hollow sandcrete) 100mm cube sizes following the procedure specified in BS 1881-122:2011+A1:2020 as shown in figure 5. The sorptivity for the specimen for each treatment level was determined using 100 ± 6 mm diameter specimens of thickness 50 ± 5 mm after curing for 28 days. The reported values of the initial and final rates of water absorption are an average of three (3) measurements.

Figure 5. Preparation of companion 100 mm cubes

2.3.4 Chloride Sorptivity Penetration Test

The chloride penetration was determined using the grey colorimetric method of detecting free and water – soluble chlorides. The specimens were ponded in a 3% Sodium Chloride (NaCl) solution for a period of 45 and 60 days after initial curing for 28 days. The cylinder specimens were longitudinally split into two using a universal testing machine before spraying the surface with a 3% Silver Nitrate (AgNO3) solution. Equation 3 shows the reaction between the Silver Nitrate and Sodium Chloride.

$$AgNO3 + NaCl \rightarrow AgCl + NaNO3 \quad (3)$$

Hence, the chloride penetrated area will show white precipitates of silver chloride as seen in equation (3). while the uncontaminated area will show a dark brown appearance. The chloride diffusion coefficient was determined using the equation x = 4y D.t proposed by Collepardi 2022, where x is the chloride penetration, D is the diffusion coefficient and t is time elapsed. This equation is based on the solution obtained from Fick's second law of diffusion under non - steady state conditions and boundaries in a semi - infinite solid.

2.3.5 Sulphate and Alkaline Attack Test

Companion cubes of 100mm were weighed after 28 days of curing and ponded in a sulpharic acid solution of pH 3.0 and for a period of 45 and 60 days to determine its resistance to ingress of sulphate ions into the hollow sandcrete block. Another set was ponded in sodium hydroxide solution of pH 12.0 for a period of 45 and 60 days to determine its resistance to hydroxyl ions. The specimens were subjected to wire brush at 7 days interval to remove the corroded products from the surface. The pH of the solution was measured periodically with the aid of a pH meter. The specimens were surface dried, weighed and tested for compressive strength to determine the weight and strength loss after 45 and 60days of ponding in agreement with the method adopted by [9], which gives the intensity of sulphate ion attack on hollow sandcrete block.

3. Results and Discussion

3.1 Sieve Analysis Results

The result of sieve analysis of the soil samples is indicated in the figure 6 below. The results show is fine grain sand with more than 90 percent passed through 6.3mm about 21.60 percent pass through 0.6mm. The soil is well graded and it is good for the production of hollow sandcrete blocks.

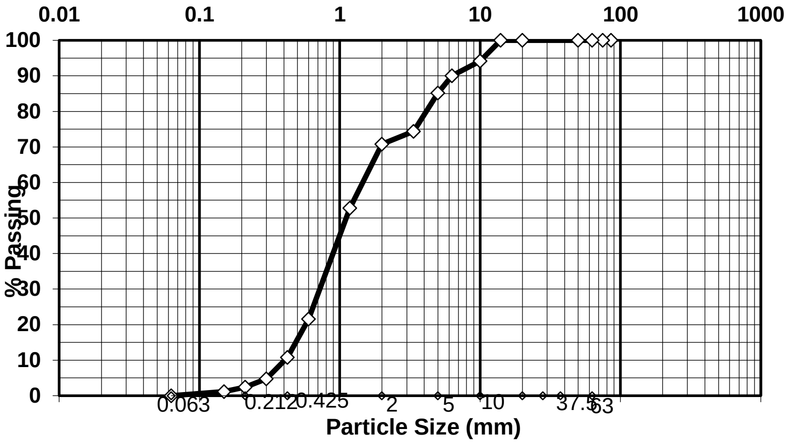


Figure 6. Particle Size Analysis Chart.

3.2 Compressive strength of sandcrete.

The compressive strength result of the hollow sandcrete block is shown in Table (1). It is observed that as the CS percentage increases there is an increase in compressive strength. There is also an increase in compressive strength with the increase in days of curing with maximum compressive strength of 4.28N/mm2 at 28 days of curing. The 3.0% CS is having an increase of 57% compressive strength.

Table 1: Compressive strength of sandcrete

% of Cassava	Age of Cubes (days)	Size of Cubes	Average Strength N/mm^2
	7		1.69
0%	14	150X150	1.80
	21		2.69
	28		3.11
	7		1.81
0.3%	14	150X150	1.92
	21		2.84
	28		3.44
	7		2.00
0.7%	14	150X150	2.04
	21		3.15
	28		4.25
	7		2.58
1.5%	14	150X150	2.77
	21		2.99
	28		3.99
	7		2.70
2.5%	14	150X150	3.73
	21		3.97
	28		4.90
	7		2.52
3.0%	14	150X150	2.52
	21		3.81
	28		4.28

3.3 Characterization of Cassava Starch (Xray diffraction of CS results)

The result of the particle size analysis of Cassava Starch is presented in Table 2.

Table 2: Particle size of Cassava Starch CS.

Constituent	**Values (%)**
Mean size	15.08609 µm
Median size	14.14354µm
Specific surface area	4422.4cm^2/g

From the result, the specific surface area and the mean size of CS grains were 4422.4cm2/g and 15.086µm respectively. The result appears to be higher than that of [29], whose previous studies shows an average mean particle size of 15µm and 14.294µm respectively. The specific surface area of cassava starch is (4422.4cm^2/g), which is higher than the cement (4145 cm^2/g) shows that the cassava starch is finer than cement. Cassava starch will affect the cement in such a way that its granules will be adsorbed into the cement, thereby, leading to retardation during the stimulation period of cement hydration. This process slows the reactivity of C3A which is majorly responsible for the set properties of cement, while reducing the formation of ettringite in hollow sandcrete block. The reduction in the rate at which ettringite is formed also reduces the formation of mono sulphate aluminates, hence makes sandcrete hollow block more resistant to sulphate attack. The close analysis for the chemical composition of cassava starch used for this study is presented in Table (3).

Table (3): Mineral Composition of Cassava Starch

Constituent	**Values (%)**
Dray Matter (DM)	87.93
Ash	0.42
Ether Extract EE (Fat)	0.54
Crude Protein (CP)	1.81
Crude Fibre (CF)	0.73
Soluble Carbohydrates (NFE)	93.64

The starch content of the material is represented by the soluble carbohydrate content of 93.64%. This contains hydroxyl groups in its amylose and amylopectin structure which are partly responsible for the retarding effect of starch granules by reducing the reactivity of C_3A when added to the block mix and there by reduces the formation of undesired hydration products such as unstable mono - sulphate aluminates. These products contribute to the vulnerability of hollow sandcrete block to sulphate attack.

3.4 Workability

The slump of the different mixes contained different percentages of CS is presented in Fig. (7). A decrease in the slump of hollow sandcrete block with CS was observed as the CS content was increased, while other mix variables were kept constant. The slump of the mix (CS 0.0, CS 0.3, CS 0.7, CS 1.5, CS 2.5 and CS 3.0) were 33mm, 25mm, 21mm, 18mm, 15mm and 13mm respectively. While at CS 3.0 has very low workability, which is also suitable for hollow sandcrete block. The reduction in the workability of mix can be linked to the reduction in the flow characteristics of the resulting mix due to the viscous and thickening nature of the activated starch. Starch thickening occurs when starch is activated through gelatinization. Another factor is the water - absorbing nature of CS which will reduce the ratio of water to cement in the mix. A decrease in the water-cement ratio is expected to reduce the porosity of Sandcrete block while increasing its strength. However, the absorption capacity of CS has to be optimized to ensure that there is enough water to aid full hydration of cement.

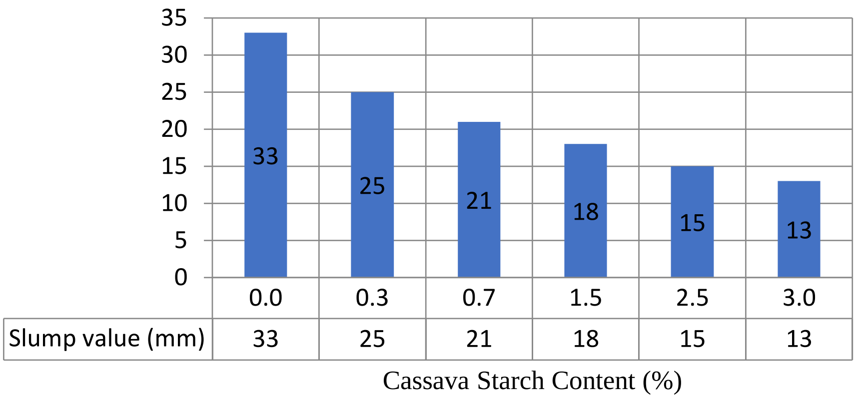


Figure 7. Workability of Hollow Sandcrete Block

3.5 Water Absorption

The test result of the water absorption of hollow sandcrete block is presented in Fig. (8). The results showed a gradual decrease in the water absorption capacity of sandcrete mix with addition of cassava starch by weight of cement respectively. The decrease in the water absorption can be linked to the reduction in micro - cracks within sandcrete due to the improved bonding between the fine aggregate and cement in sandcrete admixed with Cassava starch and the ability of the muddy-like starch paste to retard the flow of water into the pore spaces. However, the increase in water absorption at 1.5% and 3.0% addition of cassava starch can be directly linked to less dense sandcrete block achieved at those percentages. This tends to increase the pore spaces in sandcrete block which increases the access of water into the hollow sandcrete block until the spaces are saturated.

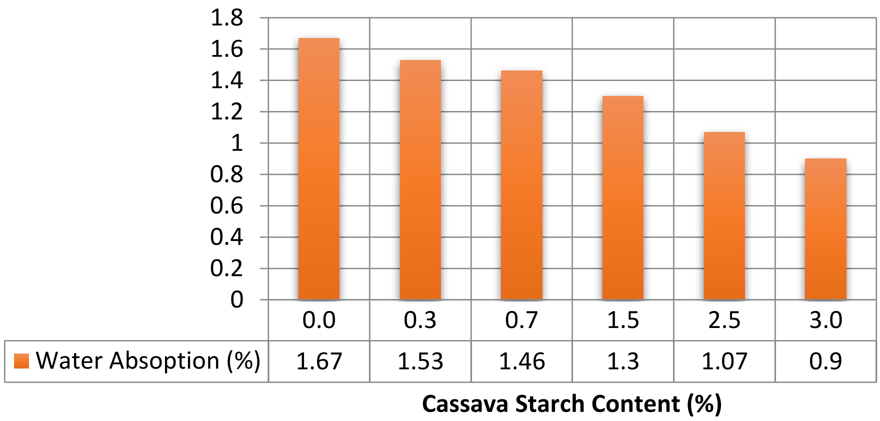


Figure 8. Water Absorption of Hollow Sandcrete Block

3.6 Sorptivity Test Result HSB.

The results of the sorptivity of hollow sandcrete block are illustrated in Fig. (9). Sorptivity of sandcrete block is a measure of the rate of absorption of water due to capillary action. This is influenced by the bendiness of the micro-pore spaces, which allows the capillary rise of water in mould sample. The initial and final rate of absorption, which was determined by the slope of the best fit line plot of the sorptivity values against the square root of time, is presented in Fig. (11). Observations showed that the initial rate of water absorption decreased from 0.0146 mm/s^2 representing the control mix to 0.0107 mm/s^2 at 1.5% addition of Cassava Starch before increasing to CS 2.5 and CS 3.0. The decline can be linked to the muddy-like nature of activated cassava starch which blocks the pore spaces, thereby reducing the rate at which water can freely move within sandcrete block. However, the increase noted at 2.5% and 3.0% addition of cassava starch can be said to be due to the less dense sandcrete block achieved for each mix. This is because the viscous nature of the cassava starch and an increase in its dosage led to a low workable sandcrete mix. Hence, causing an increase in the number of pore spaces in the sandcrete until initial saturation occurs. However, once saturation occurs within the first 6 hours, the rate at which water rise due to capillary action will reduce as results show in the final rate of water absorption. The final rate of water absorption which was measured between the interval of 6 hours and 9 days of the test, showed a decrease from 0.00066mm/s^2 for the control mix to 0.00045mm/s^2 for 3.0% addition of cassava starch. The higher sorptivity rates as observed denote the existence of highly connected pore structure within the sandcrete block and vice versa. A lower sorptivity value of sandcrete block will reduce the rate at which aggressive chemicals such as chloride and sulphate ions diffuse into the sandcrete block which will help its resistance to deterioration. It was seen that the initial rate of water absorption was lower than the final rate of water absorption for all mixes. This is can be attributed to the fact that the rate of water absorption reduced after the first six hours of the test due to sandcrete block being saturated. The reduction in sorptivity values of hollow sandcrete block due to cassava starch addition as observed reduces the rate at which water and moisture move within the hollow sandcrete block, thereby improving its durability characteristics.

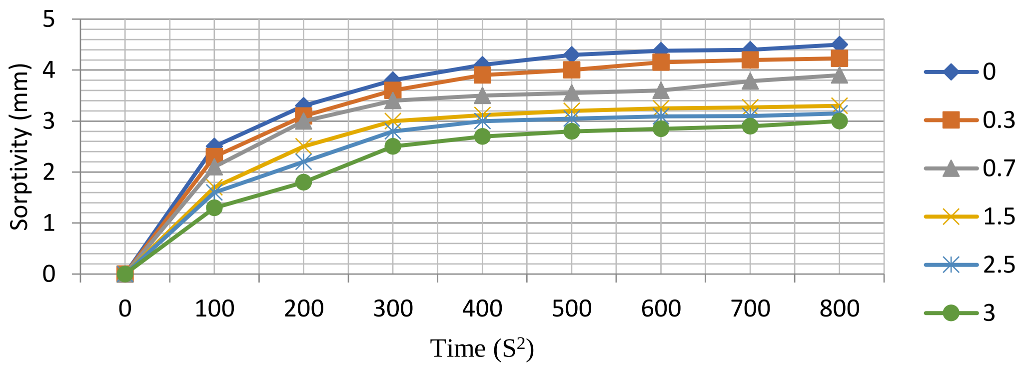


Figure 9. Sorptivity of Hollow Sandcrete Block

3.7 Chloride Penetration of Hollow Sandcrete Block.

The chloride penetration of hollow sandcrete block is shown in Fig (10). The result showed a decrease in the penetration of chloride ions in sandcrete block from 11.41mm representing the control to 9.27 mm representing cassava starch of 3.0% at 45days of ponding in sodium chloride solution, while the 60 days ponding also showed a decline from 12.10 mm for the control to 9.44 mm. The decrease in the extent of chloride penetration in sandcrete block as the percentage of cassava starch increased showed that the permeability of sandcrete block is reduced with the addition of starch. The decrease in permeability of sample can be ascribed to the jelly and muddy-like nature of activated cassava starch which fills the pore spaces in the structure of the cement paste thereby leading to a reduction in the ease at which water moves in sandcrete block. This decline in depth of penetration of chloride ions in sandcrete block reduces the risk of deterioration. The result of the chloride penetration coefficients which further supports the ability of cassava starch to reduce the diffusion of chloride ions into the hollow sandcrete block is presented in fig 4.8. The result showed that at 45 days, the chloride diffusion coefficient reduced from 0.2418cm^2/s for cassava starch content at 0.0% to 0.0911cm^2/s at 3.0%. The same trend was noticed at 60days of exposure where the value reduced from 0.2835cm^2/s to 0.1048cm^2/s. Also, the diffusion coefficient of each mix designation at 60 days was lower than the value determined at 45 days, which suggests that the penetration of chloride ions in the sandcrete block reduces with exposure days. The depth of penetration of chloride ions in Sandcrete block after 45 and 60 days of ponding was determined by measuring the depth of the formation of white precipitates of Silver Chloride on the hollow sandcrete block surface when 3.0% Silver nitrate solution was sprayed on it.

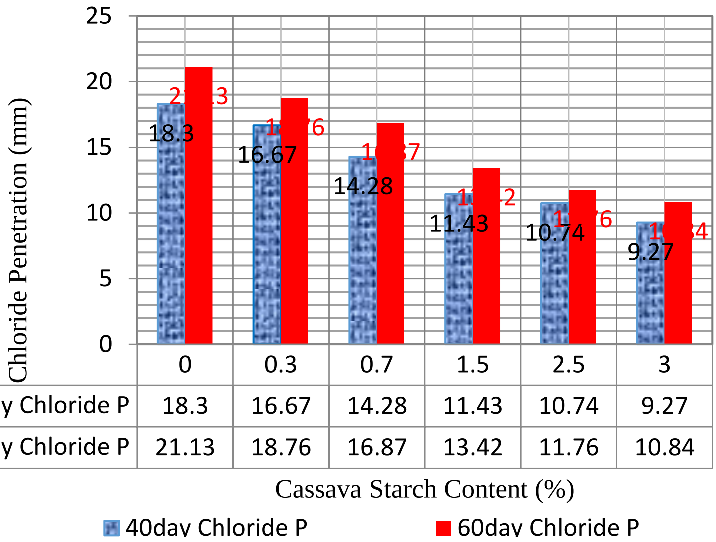


Figure 10. Chloride Penetration of Hollow Sandcrete Block

3.8 Sulphate Attack Test Results

The gradual deterioration of hollow sandcrete block after ponding in a sulphuric acid solution is shown in Figure 11; this attack is characterized by the formation of white sludge on the sandcrete block surface after exposure to sulphate ions. This causes an onward dissolution of the calcium silicate hydrates for as long as the sandcrete block remains in the sulphate environment thereby causing a mass loss. The rate of dissolution of the sandcrete block, hydrates is reduced as the CS dosage increases. This suggests that cassava starch reduces the reactivity of calcium silicate hydrates with sulphate ions due to the ability of the starch granules to be adsorbed to the surface of the cement grains. The results agree with the findings of [29]. The effect of sulphate on sandcrete block was measured by the percentage loss in weight and strength after ponding in a sulphuric acid solution of pH 3 for a period of 45 and 60 days. At 45 days of ponding in sulphuric acid solution, a 3.42% loss in weight was observed for the control sandcrete block while a 0.54% loss in weight was observed for 3.0% addition of cassava starch. At 60 days of ponding, the control lost 3.47% of its weight while CS 3.0 lost 0.68%. The loss in weight was caused by the gradual deterioration of hollow sandcrete block surfaces due to the sulphate ion attack. From the data shown above, it was observed that the sulphuric acid solution had a damaging effect on the strength properties of hollow sandcrete block. This can be linked to the loss of hydration products in block which is unstable in the presence of sulphate ions. Also, it can be seen that the rate of strength loss was reduced with an increase in cassava starch content in sandcrete block. This suggests that cassava starch can help reduce the rate at which sandcrete block is attacked in sulphate environments. A 3.42% loss in strength was observed for the control (cassava starch content 0.0%) while 0.54% loss in strength was observed for cassava starch content at 3.0%.

Similarly, 3.47% loss in strength was observed for the control at 60 days ponding and 0.68% loss was observed for cassava starch at 3.0%. The improvement in the resistance of sandcrete block admixed with cassava starch can be linked to the decrease in the formation of unstable mono-sulphate aluminate hydrate, which is a second-order hydration product in cement hydration. This is so because CS reduces the formation of the first-order hydrate, ettringite by the adherence of the starch granules to C3A and C3S, thereby, reducing the susceptibility of sandcrete block to sulphate attack. This result is in line with the findings of [29], who concluded that "hollow sandcrete block produced with CS as additive gave more resistance to the penetration of sulphate ions".

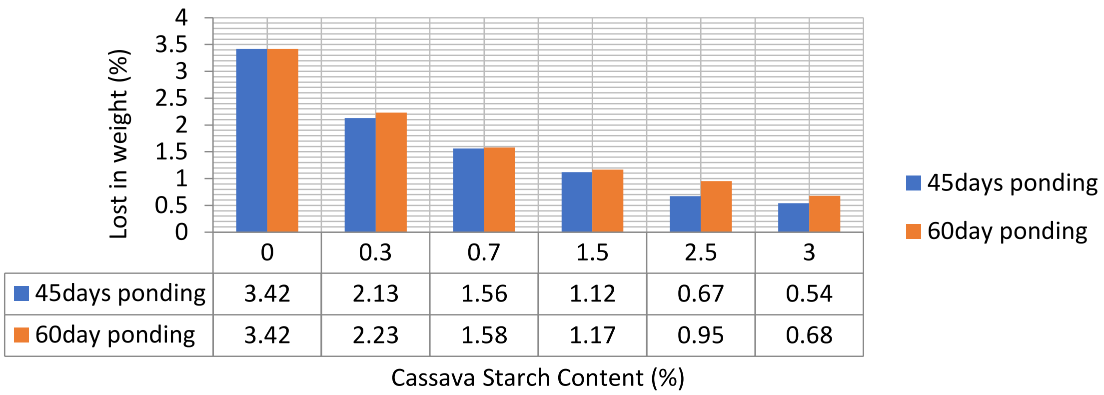
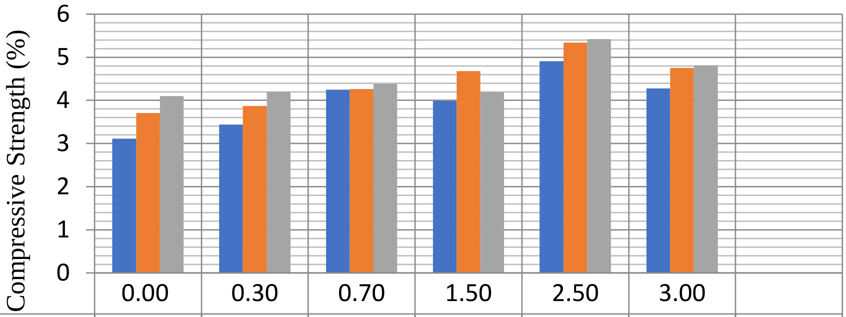


Figure 11. Lost in weight of hollow sandcrete block in sulphuric acid solution

3.9 Effect of Sodium Hydroxide on Hollow Sandcrete Block Results.

From the result of the effect of sodium hydroxide solution on hollow sandcrete block after ponding is shown in fig (12). From the results it can be seen that, there is no deterioration of the sandcrete block after ponding in sodium hydroxide solution of pH 12. This suggests that sodium hydroxide ion does not have any adverse effect on hollow sandcrete block in contrast to what was noticed when hollow sandcrete block was ponded in sulphate environment. The result of the change in strength when hollow sandcrete block was ponded in sodium hydroxide solution. However, there is an increase in the strength of hollow sandcrete block as observed in fig. (4.10) in comparison to the 28-day mean strength for all mixes. The 45-day strength for all sandcrete block mixes cassava starch (0.0%, 0.3%, 0.7%, 1.5%, 2.5% and 3.0%) are 3.71, 3.86, 4.26, 4.68, 5.34 and 4.75 MPa, while the 60day strengths are 4.10, 4.20, 4.38, 4.19, 5.47 and 4.81 MPa respectively. These results show that sodium hydroxide does not adversely affect the strength properties of sandcrete block asserting the fact that sandcrete block is an alkaline material. However, it was observed at 2.5% of cassava starch we have the highest strength. The cassava starch which increases the concentration of hydroxides within the matrix of the cement hydration products which otherwise shows a positive effect in the strength of hollow sandcrete block.



	0.00	0.30	0.70	1.50	2.50	3.00	
28days Strength	3.11	3.44	4.25	3.99	4.91	4.28	0
45days Strength	3.71	3.87	4.26	4.68	5.34	4.75	
60days Strength	4.1	4.2	4.38	4.19	5.42	4.81	

Figure 12. Strength of hollow sandcrete block in sodium hydroxide solution

5. Conclusion

Based on the sieve analysis, the soil is well graded and is good for the production of hollow sandcrete blocks. The conclusion centred on the investigation of the effect of CS on the durability characteristics of hollow sandcrete block; the addition of CS to sandcrete block by weight of cement reduces sandcrete block mix workability. CS helped reduce the rate of water movement within the pore structure of sandcrete block, hence, improves its resistance to chloride penetration. The retarding ability of CS helped reduce the formation of mono-sulphate aluminates, hence, makes sandcrete block less vulnerable to sulphate attack. It was observed that hollow sandcrete block was less vulnerable to attack from sodium hydroxide solution when compared to sulphuric acid solution. The comparative analysis of the sandcrete block mixes showed that CS at 3.0% gave a higher resistance to chloride penetration and sulphate attack. The compressive strength of the hollow sandcrete blocks increased with the addition of CS admixture at varying percentages: 0.0%, 0.3%, 0.7%, 1.5%, 2.5%, and 3.0%. The maximum increase in compressive strength, recorded at 57%, was observed at 2.5% CS content.

5.1 Recommendations

Cassava Starch is recommended as an admixture to hollow sandcrete as it is assessable, cheap and highly improve both the strength and durability of the block.

References

[1] S. O. Odeyemi, O. O. Otunola, A. O. Adeyemi, W. O. Oyeniyan and M. Y. Olawuyi, “Compressive strength of manual and machine compactedsandcrete hollow blocks produced from brands of Nigeriancement,” *American Journal of Civil Engineering,* vol. 2, no. 3, pp. 6-9, 2015.

[2] M. Mohammed and A. R. Anwar, “Assessment of Structural Strength of Commercial Sandcrete Blocks in Kano State,” *NIGERIAN JOURNAL OF TECHNOLOGICAL DEVELOPMENT,* vol. 11, no. 2, December 2014.

[3] M. I. R. Susilorini, R. D. Kristina and T. Wibowo, "THE PERFORMANCE OF EARLY-AGE CONCRETE WITH SEAWATER CURING," *Journal of Coastal Development,* vol. 8, no. 2, pp. 89-94, February 2005.

[4] S. Mindess and Y. J. Francis, Concrete, Englewood Cliffs: Prentice-Hall, Inc, 1981.

[5] U. Subhan and W. K. Sayed, "Evaluation of Sulphate Resistance of Supplementary Cementitious Material," vol. 10, no. 3, 2022.

[6] M. Raphaele, G. R. Meira, M. Lima and N. Perazzo, "Influence of mortar rendering on chloride penetration into concrete structures," vol. 33, no. 2, 2011.

[7] J. Gaurang and J. R. Pitroda, "Evaluation of Sorptivity and Water Captivation of Concrete with Partial Replacement of Cement by Hypo Sludge," in *14th International Conference on Concrete Engineering and Technology*, 2018.

[8] G. Agbi and H. Uguru, "Assessing the Impact of Cassava Starch on the Structural Properties of Sandcete Blocks Produced from Recycled Paper," *Saudi Journal of Engineering and Technology ,* vol. 6, no. 5, pp. 99-103, 2021.

[9] O. Danial, M. John and K. Charles, "The Effect of Cassava Starch on the Durability Characteristics of Concrete," *The Open Civil Engineering Journal,* vol. 14, pp. 289-301, 2020.

[10] T. Masakuni, T. Yukihiro, T. Takeshi and T. Yasuhito, "The Principles of Starch Gelatinization and Retrogradation," *Food and Nutrition Sciences,* vol. 5, pp. 280-291, 2014.

[11] A. A. Akindehinde, S. Wolfram, C. U. Herbert and E. I. Sunny, "The Influence of Starches on some Properties of Concrete," 2013.

[12] F. O. Okafor, "The performance of Cassava Flour as a water-reducing admixture for concrete.," *Nigerian Journal of Technology,* 2010.

[13] H. Muttaqin, S. Taufiq, S. David and Bunyamin, "The strength of hollow concrete block walls, reinforced hollow concrete block," *Journal of King Saud University - Engineering Sciences,* 2021.

[14] J. C. Ezeokonkwo and C. U. Nwoji, "The Load Carrying Capacity of Hollow Sandcrete Blocks," *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS),* vol. 3, no. 1, pp. 75-80, 2012.

[15] H. Muttaqin, H. Taufiq, S. David and Bunyamin, "The strength of hollow concrete block walls, reinforced hollow concrete block beams, and columns," vol. 34, no. 8, 2022.

[16] NIS, "Nigerian Industrial Standard for Sandcrete blocks," *NIS 87; 2000,* 2005.

[17] D. I. Akpokodje and H. Uguru, "Effect of Fermented Cassava Waste Water as Admixture on Some PhysicMechanical Properties of Solid Sandcrete Blocks," *International Journal of Engineering Trends and Technology (IJETT),* vol. 67, no. 10, 2019.

[18] FOASTAT, "FAOSTAT Production Data (Crops- Cassava- Nifgeria)," Food and Agriculture Organization of the United Nations, 2022.

[19] N. B. o. statistics, "Agricultural Production Survey (cite relevant NBS report for specific cassava production figures)," NBS, 2021.

[20] IITA, "Cassava in Nigeria," International Institute of tropical Agriculture, 2018.

[21] NPC, "National Development Plan," National Planning Comission, 2019.

[22] RMRDC, "Investment profiles for Industrial Raw Materials in Nigeria," Raw Materials research and Development Council, 2017.

[23] CBN, "Annual Report (cite a relevant section on economic diversification or Agricultural Development)," Cental Bank of Nigeria, 2020.

[24] O. A. Afolayan, A. O. Ogunleye and O. S. A., "Quality Assesment of Sandcrete blocks production in Ado-Ekiti state, Nigeria," *journal of Engineering Research and Reforts,* vol. 1, no. 4, pp. 1-10, 2017.

[25] U.-. Habitat, "Urbanization Review (cite a relevant UN-Habitat refort)," UN-Habitat, 2018.

[26] O. Amana, P. E. Stephen and M. Y. Sanni, "An Investigation into the Thermal Performance of Rubber-Concrete," vol. 3, no. 5, 2014.

[27] O. Olatokumbo, E. Antony and O. O. Solomon, "ASSESSMENT OF STRENGTH PROPERTIES OF CASSAVA PEEL ASH-CONCRETE," vol. 9, no. 1, 2018.

[28] A. O. Oni, L. O. Onundi and T. S. Abdulkadir, "The Effect of Cassava Starch on the durability Characteristics of Concrete," *The Open Civil Engineering Journal,* vol. Vol. 14, pp. 289-301, 2020.

[29] A. A. Akindahunsi and H. C. Uzoegbo, "Strength and Durability Properties of Concrete with Starch Admixture," *International Journal of Concrete Structures and Materials,* pp. 1-13, Jun 2015.

[30] X. Zhou, J. Du, Q. Peng and P. Chen, "Hollow sandcrete block structural configuration: Seismic behavior analysis".

[31] E. E. Ambrose, R. A. Etim, O. D. Atoyebi and K. J. Orire, "Quality assessment of sandcrete blocks produced in Adeta, Kwara State, Nigeria," *Nigerian Journal of Technology,* vol. 37, pp. 53-59, 2018.