Investigating the Influence of Cassava Starch as Admixture in Concrete Using Two Brand of Cement Subjected to Aggressive Environment

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ABSTRACT

This study investigated the influence of cassava starch as an admixture in concrete produced using two brands of cement and subjected to aggressive environmental conditions. Concrete specimens were produced using a standard mix ratio of:1:2:4 with a water-cement ratio of: w/c=0.50, Cassava starch was introduced into the concrete mixes at varying percentages of: 0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5%.Two different cement brands were used to determine the compatibility and performance of cassava starch with varying cement compositions. The concrete specimens were subjected to aggressive environmental conditions including sulphate, chloride, and acidic exposure in order to assess durability performance. The findings of the study indicated that cassava starch significantly influenced the properties of concrete. The workability of fresh concrete improved as the percentage of cassava starch increased due to the water-retention and thickening characteristics of starch. The compressive strength of concrete also improved with increasing starch content up to an optimum level of approximately 2% by weight of cement. At this percentage, the concrete achieved the highest strength values due to improved bonding and reduced permeability. However, excessive starch addition beyond the optimum level resulted in a slight reduction in compressive strength because excess organic material interfered with cement hydration. The durability assessment revealed that concrete containing cassava starch exhibited better resistance to sulphate, chloride, and acidic attacks compared to conventional concrete.. However, both cement brands responded positively to the addition of cassava starch at optimum dosage. The study therefore confirmed that cassava starch can serve as a useful natural admixture for improving concrete performance and durability under aggressive environmental conditions.

KEYWORD: ***Concrete; Cassava starch; Compressive Strength; Setting Time; Workability. Durability.***

1.0 INTRODUCTION

Concrete is one of the most widely used construction material in the world. It is a fundamental construction materials used to fulfill the housing and infrastructural need of the society having the basic constituents of conventional fine and coarse aggregate, cement and water. It has proven to be leading construction materials for more than a century and it is estimated that global production rate annually is at 1 m^3approximatelly 2,5 ton per capita (Smil, 2013). The preparation of concrete include batching, mixing, placing and compacting. It is essential to condense the concrete so that it should completely cover the reinforcement and fill all the space in the formwork to meet the strength and durability requirement (Abbas, Hassan, & Gorgis, 2023).

Concrete is a composite material that consist essentially a binding medium, such as a mixture of Portland cement and water. Within which are embedded particles or fragments of aggregates usually a combination of fine and coarse aggregates (ACI.B, 1996). Concrete is by far the most versatile and most widely used construction materials worldwide (Li et al,.2022). It can be engineered to satisfy a wide range of performance specification, unlike other building materials such as natural stone or steel which generally have to be use as they are, because of the tensile strength of concrete which is lower than its compressive strength. It is typically reinforced with steel bar in which it is known as reinforced concrete (Gonçalves, & Margarido, 2015).

The present day construction industry is under tremendous pressure of researching and producing strong but also durable building materials to accommodate the increasing need for shelter, overwhelming forces of construction and fast polluting environment (. The problem affecting construction industry observed are numerous: such as security and cost of construction materials, high demand for housing, lack of promotion of the use of locally available materials(Ahmadizadeh et al., 2024). Concrete with good qualities and properties will have more advantage over the other. The quality of the concrete depend largely on the materials used, type of concrete mix, application requirement and prevailing whether condition. Concrete is used for a variety of applications within the construction industry and has therefore proved to be useful for civil engineering (Guo, 2021). The best type of concrete and its use depends on the application and the various design specifications.

Buba, Bello & Mohammed, (2023) state that extreme North East and North Western parts of Nigeria such as Maiduguri, Yola, Sokoto, Birnin kebbi etc. are categorized as hot dry regions with temperature which ranges between 35^{0}C to 43 ^{0}C with the low relative humidity of 40%. According to Ibrahim et al., (2013) in hot dry zones, the climatic conditions are often harsh, characterized by high ambient temperature and low relative humidity. Thus, it is more difficult to control the water content of concrete mixes which is the most important factor in concrete making. It follows that hot weather generally introduces undesirable properties on concrete, such as loss of slump, accelerated set, increased water demand, and strength reduction. These undesirable properties cause concreting problems and may lead to low durability (Assal, 2017). But, EKUBAY (2019) opines that to offset the negative effects of hot weather on the cement paste of concrete certain admixtures that delay the setting of cement paste and modify concrete workability are helpful in hot weather concreting. Hence, retarder admixtures are used to slow down the reaction between cement and water by affecting the growth of the hydration products and reducing the rate of water penetration to the cement particles (Huang *et.al,* 2020).

The idea of improving concrete properties by using various admixtures is not new but known already by the first civilization (Silva *et.al.* 2021). Concrete used in ancient times were sometimes of poor quality therefore masons made use of various additives to achieve desired properties (Allen, 2015). The production and placement of concrete with an adequate strength and durability can be influenced by a number of factors, such as the prevailing weather condition, the distance between the production and the placement area, as well as the characteristics of the concrete materials; for instance, very high or low weather temperature affects the strength performance of placed concrete/mortar, and this can result in concrete that are weak in strength, and also porous (Alvarez *et.al,* 2021). One way of minimizing hot - weather problems with fresh concrete is to control the temperature of the fresh concrete and use chemical admixtures. The aim of this research is to evaluate the influence of cassava starch in concrete with a view to minimize the adverse effect of hot weather in the North eastern part of Nigeria. Therefore, the study seeks to examine the influence of cassava starch on the properties of concrete with a view to highlighting its suitability in construction.

2.0 Material and Procedure

2.1 Materials

The materials used for this research include the following: cassava starch, cement, fine aggregate (sand) and water.

2.1.1 Cement

Limestone blended cement produced by Dangote & Ashaka Company which conform to the specification BS EN 196 were used for this research work.

2.1.2 Fine Aggregate (Sand)

The river sand used for this research work were obtained within Bali, Bali Local Govt in Taraba State and kept in saturated surface dry (SSD) condition which conform with the specification of ASTM C1260

2.1.3 Water

Clean potable water, free from impurities and other organic materials were used for this research and conforming with the specification of ASTM C1602/C1602M-22.

2.1.4 Cassava

Cassava Starch were source from Bali local government area of Taraba State. The sourced Cassava Starch were sieved with BS sieve No. 85 to remove any chaff present and were conform to the standard specification.

Chemicals

The Chemical that were used in this research to check their effect on the modified concrete produced are:

- Sulphuric corrosive (H_2SO_4): Hydrogen sulphide was obtained from vendors within Jalingo metropolis. The acid were prepared at a concentration of 1.2%, adjusting to ASTM C 267 benchmarks. This concentration was chosen based on its significance to mimicking acidic environment such as those uncovered to industrial effluent or acidic soil.
- Magnesium sulphate ($MgSO_4$): magnesium sulphate was also sourced from chemical vendors within Jalingo metropolis and were prepared at a concentration of 1.2% concurring to ASTM C267 benchmars. Magnesium sulphate is used to mimic sulphate assault, which is common issues in concrete structure uncovered to soil or groundwater containing high levels of sulphates

2.2 Procedure

2.2.1 Preparation of Specimens

The mix proportion adopted was 1:2:4 by weight of cement, fine and coarse aggregate and free water/cement ratio of 0.5. Concrete mixes were prepared with cassava starch paste admixture dosage of 0%, 0.5%, 1%, 1.5%, 2% and 2.5% by weight of cement. For comparisons of properties of the various concretes with the control concrete without admixture. Mixing and compaction was by hand. The required weight of cassava starch paste was first mixed with mixing water before addition into the mixed aggregate of sand, gravel and cement. Workability measurements were carried out on the various concretes by two of three BS1881 as reported by (Thombre, More & Bhagat, 2016). All test specimens were kept under cover with wet jute bags in the laboratory until demoulding at 24 hours after which they were transferred to curing water at room temperature. The property of the hardened concrete tested was compressive strength on 100 mm cubes, three samples being tested at each age of 3 days, 7 days, 14 days, 28 days and 56 days. The setting time of cement for the various dosage level of cassava starch was determined in accordance with BS 4550 as reported by (Oluwabusayo , Mwero, & Kabubo, 2019).

3.0 RESULTS AND DISCUSSION

PRELIMINARY TEST

3.1 Chemical analysis results

Table 3.1 shows the comparative chemical composition test results of the research materials with the specified code standard to check for adequacy of the sample in accordance to BS EN 197-1: 2000 and BS 12-78 For Portland limestone cement. The chemical composition of the research materials was determined using X-Ray florescence

Table 3.1: Chemical Composition of Experimental Materials

compound	Element	(%) Content in each Material			Limit(BS EN 197-1)
		CS	DC	AC	
Silicon oxide	SiO_2	20.03	9.532	12.621	>25
Copper oxide	CuO	0.693	0.028	0.021	
Magnesium oxide	MgO	17.970	5.934	4.164	0.61-3.30%
Aluminum oxide	Al_2O_3	8.070	3.229	2.839	3 -8
Phosphorous pentoxide	P_2O_5	0.513	-	-	-
Sulfuric oxide	SO_3	1.319	2.272	1.700	< or = 3.5
chloride	Cl	9.685	0.679	0.745	< or = 0.1
Potassium oxide	K_2O	24.646	0.226	0.150	0.2 – 1.3
Calcium oxide	CaO	14.270	76.289	75.484	>50
Titanium oxide	TiO_2	0.129	0.182	0.294	-
Iron oxide	Fe_2O_3	0.767	1.162	1.581	0.5 - 6
Zinc oxide	ZnO	0.115	0.007	0.009	-

Note: CS = Cassava Starch; AC = Ashaka cement and DC = *Dangote cement*

The results for the chemical analysis of cement and cassava starch are given in Table 4.1. It is observed that cassava starch contains appreciable amounts of major compound such as SiO_2, Al_2O_3, CaO, which are the most important chemicals in cement because of their responsibility in the strength gain in concrete while aluminum and iron oxide are responsible for set properties of mortar. The minor oxide such as SO_3 found as gypsum aids in formation of ettringite, which is not desirable product during cement hydration. Aluminum oxide which can react in the presence of water to produce cementitious hydrated calcium silicates and aluminates, thereby increasing the strength of concrete

. **Fineness of cement sample x & y discussion**

3.2. **Determination of fineness of cement**

S/N	Samples	Weight of sample	Weight of residue	Fineness (%)
1	Sample X (Dangote cement)	100g	4g	4
2	Sample Y (Ashaaka cement)	100g	2g	2
3	Cassava starch powder	100g	12g	12

Source: Laboratory research work, (2026)

Table 3.2 shows the results of the fineness of cement. Conventionally, the maximum percentage of residue is 10% as prescribed by British Standard (BS812:1972 part3), for Portland limestone cement. However, the fineness of cement sample X & Y result (4 & 2%) obtained from Table 3.2 conforms to the international standard. The finer the cement, the greater the rate of hydration. Conversely, the coarser the cement, the greater the period of hydration

3.3 Specific gravity

Tale 3.3 Specific Gravity of materials

Materials/ test	**CS**	**DC**	**AC**	**S**
Specific Gravity Limits BS EN (196-2)	1.06	2.86	3.0	2.57

Note: CS: Cassava Starch, DC: Dangote Cement, AC: Ashaka Cement, S: Sand

The specific gravity of the coarse and fine aggregate as well as cassava starch were determined.

As shown in table 4.4 the value of specific gravity of the research materials which indicate the density of the research materials; sample Y (Ashaka cement) which have the highest specific gravity, follow by sample X (Dangote cement) and sand. Cassava Starch was found to be the lowest with 1.06 respectively. The specific gravity of cement sample X, Y and sand are 2.86 and 3.0 and 2.57 respectively. The value are conformed to the standard specification of British standard (BS), American Standard Testing Method (ASTM) and Nigerian standard NIN-444-1.(2002).

3.4 Sieve analysis

Sieve analysis was performed to determine the particle size distribution of the coarse and fine aggregates utilized in the mixes

Table 3.4 sieve analysis for coarse aggregates

BS Sieve sizes	**Weight retai**	**Weight passi**	**% retained**	**% passing**	**% cumulative**

(mm)	ned (g)	ng (g)			retained
19.0	0	100	0	100	0
12.5	50	95	5	95	5
9.5	100	85	10	85	15
4.75	350	50	35	50	50
pan	500	0	50	0	100

3.5 Fine aggregates

The fine aggregate's particle distribution is essentials for achieving the desired workability and strength in concrete for instance 30% retention on the 0.6 sieve ensure a balance between fine and coarse particles which enhance the concrete mix cohesiveness . the fine aggregates has a well- balanced gradation with 25% passing through the 0.30mm sieve indicating a good mix of fine particle to aid in concrete workability and strength.

Table 3.5 displays the results for sieve analysis of fine aggregate where the percentage of the fine passing through sieve 600 micron sieve sizes is 58.33% which is within the range of 35- 59 indicating the fine aggregates fall within zone II as provided by British standard EN 12620 (2002). This indicated that the sand is an ideal sand for the preparation of concrete. The particle size distribution of fine aggregates was examined to determine whether they were suitable for use in concrete. In other hand, the sand is the best sand to be use for the production of concrete as specified by BS 882: (1973).

Table 3.5 sieve analysis of fine aggregates (sand)

BS Sieve sizes (mm)	Weight retained (g)	Weight passing (g)	% retained	% passing	% cumulative retained	BS EN 12620 (ZONE)
4.75	5	2995	0.167	99.83	5	90 - 100
3.35	110	2890	3.67	96.33	115	60 - 95
1.18	1065	1935	35.5	64.5	1180	30 – 70
0.6	1250	1750	41.67	58.33	2430	15 - 34
0.3	410	2590	13.67	86.33	2840	5 - 20
0.15	120	2880	4	96	2960	0 - 10
Pan	40	2960	1.33	98.67	3000	0

Table 3.5 present the results of sieve analysis of fine aggregate which were used to determine the finesse modulus of sand sample. According to ASTM C33 finesse modulus of fine aggregates range within 2.3 to 3.0 (+0.2) and the sample of sand has fallen beyond the range stated. The percentage of fine aggregate passing sieve 600mm were found to be 58.33 from the result it was observed that the percentage of sand passing through the 4.75um sieve was 99.83. However,

most of the sand was retained on 600mm sieve with the actual figure of 1250g follow by 1.18mm sieve with figure of 1065g and only 40g were retained on pan. Generally, the lesser the content of sand silt in the pan the more suitable the sand for making concrete. Standard recommended that percentage passing within the range of 35 -59 falls within (Zone II) as medium sand. Hence the aggregate are suitable for general construction work.

3.6 Workability

The influence of cassava starch on the workability of fresh concrete is presented in Figure 1 at various admixture dosage levels. The findings show that incorporating cassava starch into concrete enhances the workability of the mix. This improvement becomes more noticeable as the percentage of cassava starch increases. The increased workability can be attributed to the presence of surface-active compounds in cassava starch, which adsorb onto cement particles and impart a negative charge. This causes repulsion among the particles, resulting in better dispersion and increased mobility within the concrete mix, as reported by Arimanwa et al. (2021).

The enhancement in workability is significant, with the slump value increasing from 10 mm in the control mix to 40 mm at a 1.5% starch dosage, while the compacting factor rises from 0.79 to 0.89. In addition, the incorporation of cassava starch improves the cohesion and plasticity of fresh concrete, producing a smoother and more uniform surface finish. During the compacting factor test, it was observed that concrete mixes containing 1.5% cassava starch or more tended to adhere to the hopper surfaces and required gentle prodding with a steel rod to facilitate flow. This behavior indicates increased cohesiveness of the mix. Nevertheless, the water-absorbing nature of cassava starch must be carefully controlled to ensure that sufficient water remains available for proper cement hydration.

At lower dosage levels of 0.5% and 1.0%, the concrete mixes exhibited relatively low workability. Furthermore, concrete containing 1.5% cassava starch may require additional mixing water to achieve adequate compaction compared with the control mix; otherwise, there is a risk of producing porous concrete. However, the tendency of cassava starch to form a gel-like or mud-like paste, particularly at 1.0% and 1.5% dosage levels, may help reduce the connectivity of pore spaces within the concrete matrix, thereby decreasing its permeability. These findings are consistent with the results reported by Akindahunsi and Uzoegbo (2010).

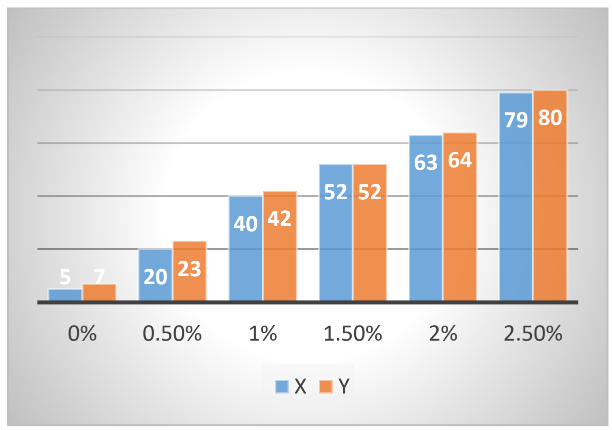


Figure 1. Effect of cassava starch on slump

Setting Times Test Results for the cement paste

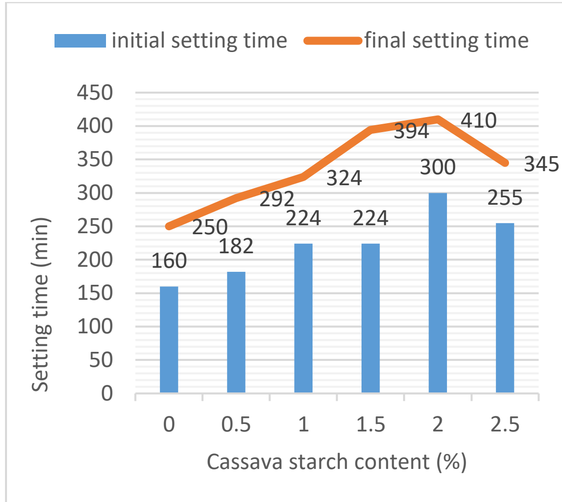
3.7 Setting Time

The results of the setting time tests are illustrated in Figure 3.1. The findings reveal that the incorporation of cassava starch significantly delays both the initial and final setting times of cement when added at dosage levels up to 2% by weight of cement. Additionally, the retardation effect becomes more pronounced as the percentage of cassava starch increases. At the optimum dosage level of 2%, the initial and final setting times were extended by approximately 5 hours and 6 hours, respectively.

However, when the cassava starch content exceeded 2%, a reduction in the initial setting time was observed. The rate of this reduction increased with higher starch dosages, while the final setting time remained relatively unchanged. This acceleration of the initial setting process may be associated with the increased cyanide content introduced by larger quantities of cassava starch. The cyanide may have altered the alkalinity of the cementitious environment, thereby promoting a faster onset of setting. As the cyanide content became depleted, the retarding effect of the carbohydrate constituents of cassava starch appeared to dominate once again, resulting in little or no change to the final setting time.

The results suggest the existence of an optimum dosage level for cassava starch when used as a set-retarding admixture. The delay in setting time observed at dosage levels up to 2% complies with the requirements of the relevant British Standards, namely **BS EN 197-1:2011** and **BS EN 196-3:2016**. Beyond this dosage level, the initial setting time begins to decrease, indicating that 2% cassava starch by weight of cement is the most effective proportion for achieving the desired retarding effect.

In all cases, the cement paste satisfied the requirements of **BS EN 196-3:2016**, which specifies that the initial setting time should not be less than 45 minutes and the final setting time should not exceed 10 hours. Therefore, despite the variations in setting characteristics caused by the addition of cassava starch, all tested mixtures remained within the acceptable limits prescribed by the standard.



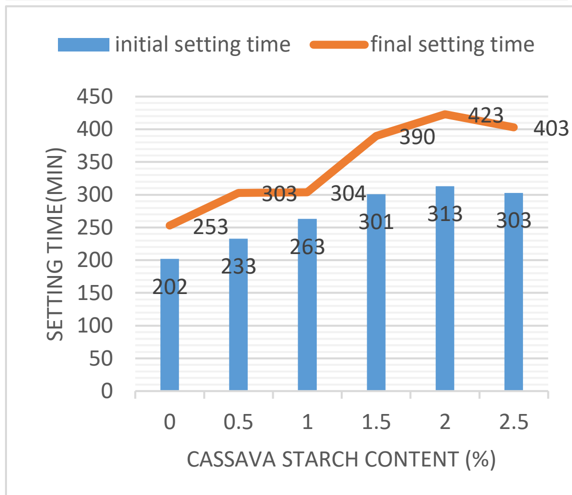


Figure 3.1 effect of cassava starch on the setting time

3.8 Compressive strength

The compressive strength of the concrete mixes was evaluated at curing ages of 28 and 56 days under different environmental exposure conditions. The results showed varying degrees of strength performance and durability among the concrete mixtures containing different percentages of cassava starch paste, ranging from

0% to 2.5%. These variations were observed when the specimens were exposed to aggressive environments containing magnesium sulfate ($MgSO_4$) and sulfuric acid (H_2SO_4), indicating that the level of cassava starch incorporation influenced the resistance of the concrete to chemical attack.

3.8.1 Effect of Cassava Starch Paste on Concrete in Magnesium Sulphate ($MgSO_4$) Solution

The results as indicated in the figure 3.8.2, the incorporation of cassava starch paste improved the sulphate resistance of concrete exposed to magnesium sulphate solution. At 28 days, the control sample (0%) achieved a compressive strength of 25.63 N/mm², while the concrete containing 0.5% cassava starch attained the highest strength of 32.09 N/mm², representing an increase of approximately 25.2%.

The improvement may be attributed to the pore-filling effect of cassava starch, which reduced permeability and limited the penetration of sulphate ions into the concrete matrix. The reduced permeability likely enhanced the durability of the concrete against sulphate attack.

At 56 days, all specimens experienced a reduction in compressive strength compared to their 28-day values, indicating progressive deterioration caused by magnesium sulphate attack. However, the cassava starch-modified concrete retained higher strength values than the control sample. The 1.5% cassava starch mix recorded the highest strength retention of 24.48 N/mm² compared with 18.95 N/mm² for the control concrete.

This suggests that moderate additions of cassava starch (between 0.5% and 1.5%) improve resistance to magnesium sulphate attack by enhancing the compactness of the concrete microstructure.

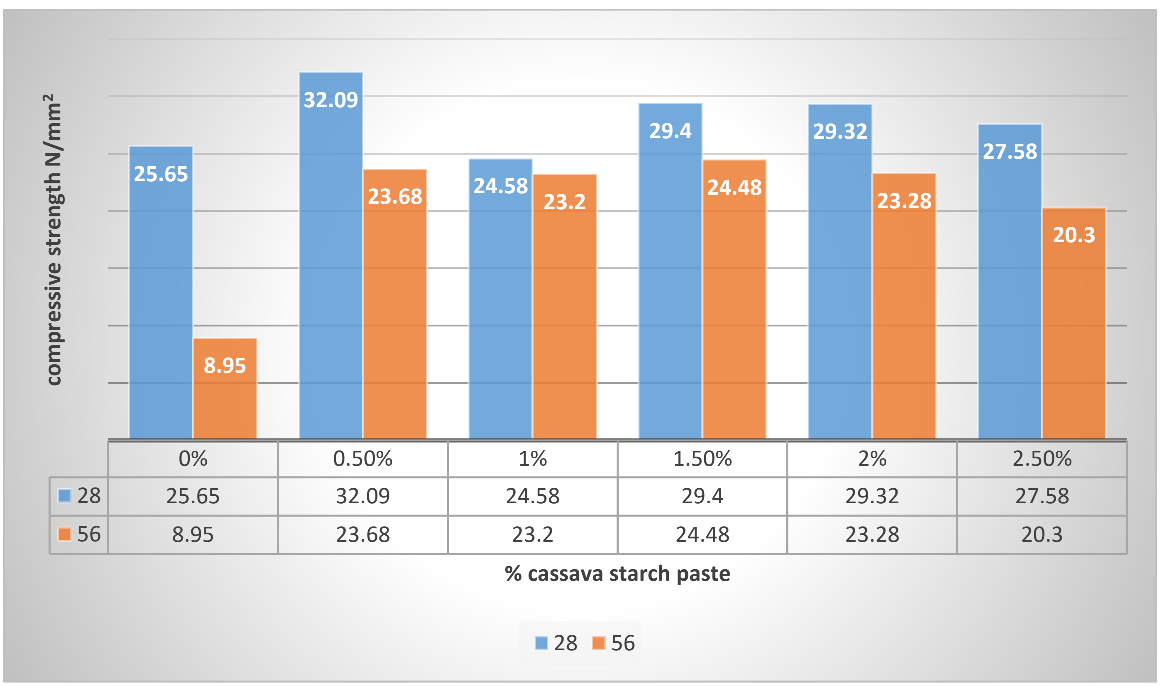


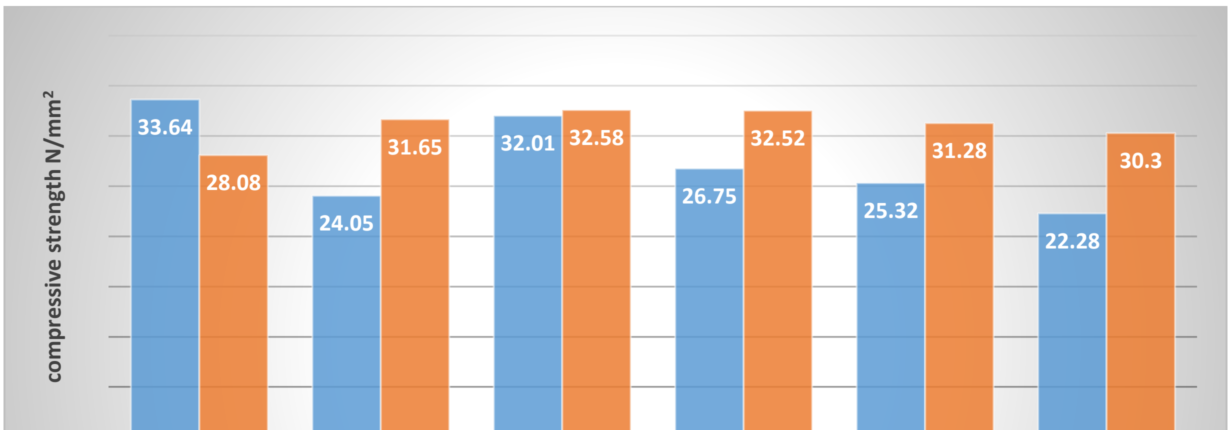
Figure 3.8.2 Effect of Cassava Starch Paste on Concrete in Magnesium Sulphate ($MgSO_4$) Solution

Compressive Strength of Concrete Samples in H_2SO_4 (N/mm²)

3.8.3 Effect of Cassava Starch Paste on Concrete in Sulphuric Acid (H_2SO_4) Solution

From the figure 2.8.3 it was observed that the behaviour of the concrete exposed to sulphuric acid differs significantly from that observed in magnesium sulphate solution. At 28 days, the control specimen exhibited the highest compressive strength of 33.64 N/mm², while the cassava starch-modified mixes generally recorded lower strengths. This initial reduction in strength may be due to delayed hydration reactions or the interaction of starch molecules with cement hydration products, which can slightly retard early strength development.

However, at 56 days, all starch-modified concrete specimens showed substantial strength improvement and outperformed the control concrete. The 1% cassava starch mix achieved the highest compressive strength of 32.58 N/mm², followed closely by the 1.5% mix with 32.52 N/mm².The improved performance at later ages indicates that cassava starch contributed to the formation of a denser cement matrix, reducing acid penetration and limiting the dissolution of calcium hydroxide and other hydration products. The results suggest that cassava starch enhances the long-term acid resistance of concrete when used at optimum dosages between 1% and 1.5%.



	0%	0.50%	1%	1.50%	2%	2.50%
28	33.64	24.05	32.01	26.75	25.32	22.28
56	28.08	31.65	32.58	32.52	31.28	30.3

Figure 3.8.3 Effect of Cassava Starch Paste on Concrete in Sulphuric Acid (H_2SO_4) Solution

3.8.3 Effect of Cassava Starch Paste on Concrete Cured in Water

From the figure 3.8.4 below it was observed that the specimens cured in water, the control sample recorded the highest compressive strength at 28 days (29.83 N/mm²), closely followed by the 2.5% and 2% cassava starch mixes. The lower strengths observed in the 0.5% and 1% mixes at 28 days may indicate that small quantities of cassava starch interfered with early cement hydration, leading to slower strength development.

At 56 days, the differences between the control and modified concretes became less pronounced. The control sample retained the highest strength of 28.01 N/mm², while the 0.5% cassava starch mix achieved 27.07 N/mm². Although the starch-modified concretes generally exhibited slightly lower strengths than the control, the reductions were relatively small. The results suggest that cassava starch does not significantly enhance compressive strength under normal water curing conditions. Instead, its primary benefit appears to be improved durability and resistance to aggressive chemical environments rather than strength enhancement under standard curing.

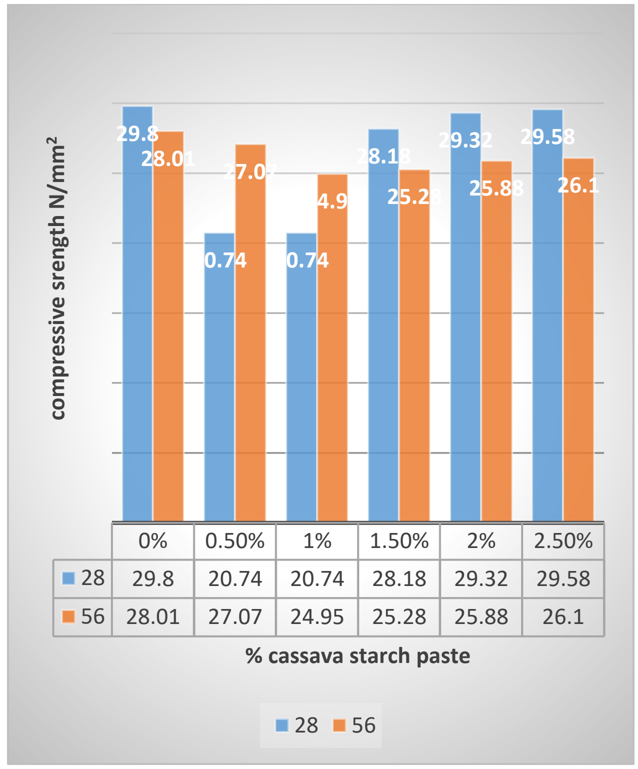


Figure 3.8.4 Effect of Cassava Starch Paste on Concrete Cured in Water

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Based on the findings obtained from the investigation, the following conclusions were drawn:

1. Cassava starch has significant influence on the fresh and hardened properties of concrete.
2. The addition of cassava starch improved the workability of concrete due to its water-retention and viscosity-enhancing properties.
3. Concrete compressive strength increased progressively with cassava starch addition up to an optimum content of approximately 1.5% after which strength reduction occurred at higher percentages.

4. Cassava starch reduced water absorption and permeability of concrete, thereby improving resistance to moisture penetration and chemical attack.
5. Concrete modified with cassava starch exhibited better durability performance under aggressive environmental conditions such as sulphate, chloride, and acidic exposure.
6. The study established that properly controlled cassava starch addition can improve concrete quality and extend the service life of concrete structures exposed to harsh environmental conditions.

4.2 Recommendations

Based on the results and conclusions of the study, the following recommendations are made:

1. Cassava starch should be considered as a natural admixture for concrete production, especially in areas where it is readily available and affordable.
2. The optimum cassava starch content of: 1.5% by weight of cement is recommended for achieving improved concrete strength and durability.
3. Excessive addition of cassava starch above the optimum percentage should be avoided because it may negatively affect concrete strength and setting characteristics.
4. Cement manufacturers and construction professionals should further investigate the compatibility of natural starch admixtures with different cement brands.

4.3 Recommendation for Further Studies

Further studies should be carried out on:

- Long-term durability performance of cassava starch concrete
- Microstructural analysis of starch-modified concrete
- Effects of cassava starch on reinforced concrete
- Performance under elevated temperatures and fire exposure
- Use of cassava starch with high-strength concrete mixes

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