INVESTIGATING THE INFLUENCE OF CASSAVA STARCH AS A PARTIAL SUBSTITUTE FOR CEMENT IN LATERIZED CONCRETE

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ABSTRACT
The astronomical increase in prices of materials for building construction in Nigeria is causing a lot of concern, creating need for research into indigenous materials as alternatives in building and rural infrastructures. Research efforts are directed towards enhancing the use of locally and readily available material such as lateritic soils for the construction of low-cost but effective dwellings, farm structures and other rural infrastructures. This research work presents the properties of lateritic concrete using cassava starch as a partial replacement for cement. It was aimed to find the optimum replacement level. The aggregate type in this experiment was laterite obtained from Shika Zaria. The laterite was reddish brown. The coarse aggregate sample was sieved through the 20mm sieve and particles retained were pulverized and sieved again whereas the fine is sieve through the 5mm sieve. The starch was obtained from Zaria in Kaduna State, Nigeria. It was manually Processed by rural dwellers within Zaria environs and sold at the Tudun wada market. Slump test and cube test were carried out in the concrete laboratory. The slump test results show that the workability of the concrete decreased as the cassava starch content increased. Water binder ratios of 0.6 was used for the concrete mix 1:2:4 with varying percentage of cassava starch as replacement for cement. Concrete cubes were cast, cured and tested at curing ages of 7, 14, and 28 days using 0, 5, 10 and 15 percentage replacement levels. The optimum compressive strength of 18.72N/mm2 was obtained at 10% replacement at 28 days of age compared to the control of 15.45 N/mm2. Cassava starch can be used optimally in concrete work as it appears that it a suitable material. Therefore, the use of agricultural product as pozzolan cementitious materials in concrete production should be encouraged.

Keywords: concrete, cement, laterite, cassava starch, supplementary cementitious material (SCM)

INTRODUCTION
Concrete is a widely used composite material composed of aggregate bonded together with fluid cement, which hardens over time. When mixed with water, the cement chemically reacts to form a hard matrix that binds all the materials together into a durable, stone-like substance (Savilla, 2019). Historically, the term "concrete" originates from the Latin word "concretus," meaning compact or condensed. Roman concrete, known as opus caementicium, was a revolutionary building material made from quicklime, pozzolana, and pumice aggregate. Its use during the Roman Empire marked a key development in architectural history, allowing for innovative structural designs free from the limitations of stone and brick (Naushad, 2018).

Modern structural concrete differs from Roman concrete in several ways. Notably, modern concrete is fluid and homogeneous, allowing it to be poured into forms rather than requiring hand layering, as was often the case in Roman construction. Aggregate in modern concrete typically includes coarse materials like granite or limestone and fine materials like sand. Portland cement, the most common type of cement today, is made by heating limestone with clay and grinding the resulting clinker with gypsum (Oluwakeyisi, 2021).

Recent research has explored alternative materials for concrete production due to the

high cost and scarcity of traditional materials. One such alternative is lateritic soil, a product of tropical weathering, which can be used to replace conventional aggregates. Lateritic soil, characterized by its reddish-brown color, is prevalent in regions with poor natural drainage and has been considered for use in construction due to its abundance and potential cost-effectiveness (Oluwakeyisi, 2021).

Since its development, concrete has remained the strongest and most versatile building material, with extensive applications in dams, highways, and various structures. The Romans advanced concrete technology by incorporating lightweight aggregates and embedded reinforcement, innovations that are still relevant today (Lasii & Ogunumi, 2019). However, despite these advancements, housing delivery in Nigeria continues to face significant challenges. The national housing shortfall is estimated to be between 16 and 18 million units, and the rapid increase in building material costs has exacerbated the affordability crisis (Ajanlekoko, 2019; Oresegun, 2017). Cement availability in Nigeria is marked by high costs, fluctuating prices, and scarcity. These challenges have driven research into alternative materials that are both cheaper and more readily available.

This study aimed to investigate the properties of concrete produced using lateritic soil as fine aggregate and cassava starch as a partial replacement of cement, with the goal of identifying viable substitutes for scarce materials such as river sand. This exploratory study was conducted under normal laboratory conditions, focusing on physical and mechanical tests on the materials. The curing period for all specimens was limited to 28 days. The findings aim to contribute to the ongoing search for sustainable building materials, particularly in addressing Nigeria's housing challenges.

LITERATURE REVIEW

The use of alternative materials in concrete production has been increasingly explored as a response to the high cost and scarcity of traditional construction materials, particularly in developing countries like Nigeria. Concrete, as a fundamental building material, has evolved significantly since its early use by the Romans, who utilized a mix of quicklime, pozzolana, and pumice aggregate to create durable structures that have stood the test of time (Naushad, 2018). Modern concrete, which typically consists of Portland cement, sand, and gravel, offers enhanced workability and strength, but its production is resource-intensive and environmentally impactful (Abedide,2020).

Alternative Aggregates and Binders

Recent studies have focused on incorporating locally available materials into concrete to reduce reliance on traditional resources (cement, river sand and coarse aggregate) and lower production costs. One such material is lateritic soil, a product of tropical weathering processes, widely available in Nigeria and other tropical regions. Lateritic soil has been studied as a potential replacement for fine aggregate in concrete, with promising results regarding its suitability and performance (Oluwakeyisi, 2021). Laterite’s use in concrete not only provides a cost-effective alternative but also contributes to sustainable construction practices by utilizing locally sourced materials.

Similarly, cassava starch has been proposed as a binder in concrete as an alternative to conventional cement. Cassava, a staple crop in many tropical countries, produces starch that, when processed, can exhibit binding properties. Research into the use of cassava starch in concrete has shown potential for producing eco-friendly and affordable building materials, particularly in areas where cement is costly or scarce (Oyelakin, 2020). However, the long-term durability and structural performance of cassava starch

as a binder in concrete remain areas requiring further investigation.

Challenges in Housing Delivery

The high cost of building materials and the scarcity of cement have significantly impacted housing delivery in Nigeria. The national housing deficit is estimated to be between 16 and 18 million units, and this shortfall is exacerbated by the rapid increase in the prices of construction materials (Ajanlekoko, 2019). The Nigerian government's efforts to address this issue have been hampered by these economic challenges, prompting a need for alternative building materials that are both affordable and sustainable (Oresegun, 2017).

The use of lateritic soil and cassava starch in concrete production presents a viable solution to these challenges. Studies have demonstrated that lateritic soil can effectively replace sand in concrete, while cassava starch has shown potential as a binder, offering a more sustainable and cost-effective alternative to Portland cement (Basmus, 2021). These materials are readily available in Nigeria and other tropical regions, making them attractive options for addressing the housing deficit and promoting sustainable construction practices.

Durability and Environmental Impact

Durability is a critical factor in the acceptance of alternative materials in concrete. Research has shown that concrete made with lateritic soil can achieve satisfactory strength and durability when appropriately mixed and cured (Olutoge et al., 2020). Additionally, the use of cassava starch as a binder has been explored for its potential to reduce the environmental impact of cement production, which is a significant contributor to global carbon emissions (Oyelakin, 2020).

However, while the initial findings are promising, further research is needed to fully understand the long-term performance and environmental benefits of using lateritic soil and cassava starch in concrete. This includes studying the material properties under various environmental conditions and assessing their impact on the overall sustainability of construction projects.

MATERIALS AND METHODS

MATERIALS

The research focused on evaluating the strength of laterized concrete by partially replacing cement with cassava starch.

Laterite (reddish-brown) was used as the aggregate, sourced from Shika Zaria, Nigeria. The coarse aggregate was sieved through a 20mm sieve, and fine aggregate through a 5mm sieve BS EN 933-1:2012.

Cassava starch, processed manually and air-dried into powder form, was obtained from Zaria, Kaduna State.

Potable drinking water from the Building Department taps at Ahmadu Bello University, Zaria, was used.

All experiments were conducted in the university's departmental laboratories, following relevant British standards.

- Sieve Analysis: BS EN 933-1:2012 - Tests for geometrical properties of aggregates. Determination of particle size distribution. Sieving method
- Specific Gravity: BS EN 1097-6:2013 - Tests for mechanical and physical properties of aggregates. Determination of particle density and water absorption
- Moisture Content: BS EN 1097-5:2008 - Tests for mechanical and physical properties of aggregates. Determination of the water content by drying in a ventilated oven
- Workability: BS EN 12350-2:2019 - Testing fresh concrete. Slump test
- Compressive Strength: BS EN 12390-3:2019 - Testing hardened concrete. Compressive strength of test specimens
- Water Absorption: BS 1881-122:2011 - Testing concrete. Method for determination of water absorption.

- Abrasion Resistance: BS EN 1338:2003+A1:2006 - Concrete paving blocks. Requirements and test methods.

DATA PRESENTATION, ANALYSIS AND DISCUSSION

The results presented here are based on the tests carried out on the types of aggregate, starch and concrete used for the study.

Particle Size Distribution

Table 1 Particle size distribution of the Coarse aggregates

Aparture Size	Weight Retained	Weight Passed	Percentage Passing
38.1mm	0g	5400g	100
20mm	1184g	4215g	78
15mm	984g	3230g	60
10mm	1698g	1531g	27.5
5mm	636g	897g	16
<5mm	897g	0g	0

Source: laboratory test 2023

The sieve analysis results provide valuable insight into the particle size distribution of the coarse aggregate sample, based on BS 882:1992. An initial 5.4 kg of aggregate was used, with 100% passing through the 38.1 mm sieve, indicating that all particles are smaller than this size. As the sieve size decreases, the percentage of material passing also reduces, with 78% passing through the 20 mm sieve, 60% through the 15 mm sieve, and 27.5% through the 10 mm sieve. Notably, 16% of the aggregate passed through the 5 mm sieve, while no particles smaller than 5 mm were retained. This gradation suggests that the aggregate is well-graded, with a majority of particles between 5 mm and 20 mm. Such a distribution can enhance packing density, reduce voids, and improve the strength of concrete. The absence of particles smaller than 5 mm suggests that the aggregate is primarily coarse and may require additional fine aggregate for optimal concrete mix design. Overall, this aggregate appears suitable for use in medium to large structural applications where strength and durability are required.

Table 2 Particle size distribution of the fine aggregates

Aperture Size	Weight Retained	Weight Passed	Percentage Passing
5mm	10g	990g	99
2.36mm	350g	640g	64
1.18mm	324g	316g	32
600um	170g	146g	15
300um	88g	28g	6
150um	14g	10g	5

Source: laboratory test 2023

The sieve analysis of the fine aggregate sample, based on an initial 1 kg sample, reveals the particle size distribution across various sieve sizes. The analysis shows that

99% of the fine aggregate passed through the 5 mm sieve, indicating that almost all particles are smaller than this size. As the sieve size decreases, the percentage of material passing also reduces significantly, with 64% passing through the 2.36 mm sieve, 32% through the 1.18 mm sieve, and only 15% through the 600 µm sieve. By the time the material reaches the 300 µm sieve, only 6% of the particles pass through, and just 5% pass the finest 150 µm sieve. This distribution indicates a fine aggregate sample with a broad range of particle sizes but with a concentration of particles in the coarser range (above 600 µm). Overall, the aggregate appears suitable for use in concrete where moderately fine particles are required, though its lower fine content might affect the mix's workability and may require a complementary fine material to optimize performance.

Table 3: Physical Properties of Aggregates and Starch

S/No	Properties	Coarse	Fine	Starch
1	Specific gravity (SSD)	2.51	2.62	1.43
2	Absorption capacity (%)	7.23	11.58	
3	Moisture content (%)	10.62	16.73	15.4
4	Low bulk density (kg/m^3)	1.28	1.48	
5	Compacted bulk density (kg/m^3)	1.54	1.62	

Source: laboratory test 2023

The field observation reveals the colour of the laterite to be reddish-brown, which means that the sample contain certain percentage of iron and aluminium during localization (Osinubi and Katte, 1997). The physical properties of the aggregates and starch indicate significant differences in their suitability for construction. The specific gravity of the coarse and fine aggregates (2.51 and 2.62, respectively) falls within normal ranges, while starch, with a lower specific gravity of 1.43, is much lighter and unsuitable for structural use. Both coarse and fine aggregates exhibit high absorption capacities (7.23% and 11.58%), signalling weakness due to their porosity, which exceeds the 1% threshold typical for strong aggregates. This high absorption, coupled with moisture content values of 10.62% for coarse and 16.73% for fine aggregates, suggests that these lateritic aggregates retain significant water, potentially compromising the strength and durability of concrete. The relatively low bulk density values (1.28–1.54 kg/m³ for coarse and 1.48–1.62 kg/m³ for fine aggregates) further emphasize their lightweight nature, which may not provide the robustness required for load-bearing applications. Overall, while these materials can be used in construction, their high porosity and moisture content necessitate careful consideration to avoid compromising the strength and performance of the final concrete product. Properties of Concrete.

Chemical properties of starch.

Property	Value	Chemical Implication
Amylose Content	20–30%	Contributes to gel formation and moisture retention.
Amylopectin Content	70–80%	Enhances viscosity and potential binding with cement.

Moisture Absorption	High	Facilitates hydration by retaining water in the mix.
pH Level	6.0–7.0	Neutral; compatible with cement hydration processes.
Calcium Hydroxide Interaction	Possible	May form C-S-H in presence of water and during hydration.
Water Absorption Capacity	High (e.g., >10%)	Increases workability and can support hydration reactions.

While cassava starch does not meet the traditional criteria for pozzolanic materials due to its low reactive silica and alumina content, its ability to form gels, retain moisture, and potentially interact with calcium hydroxide suggests that it may exhibit some pozzolanic-like properties under certain conditions. Therefore, with further research and experimentation, cassava starch could be considered for its beneficial effects in concrete, particularly in enhancing workability and contributing to strength in non-structural applications.

Slump results

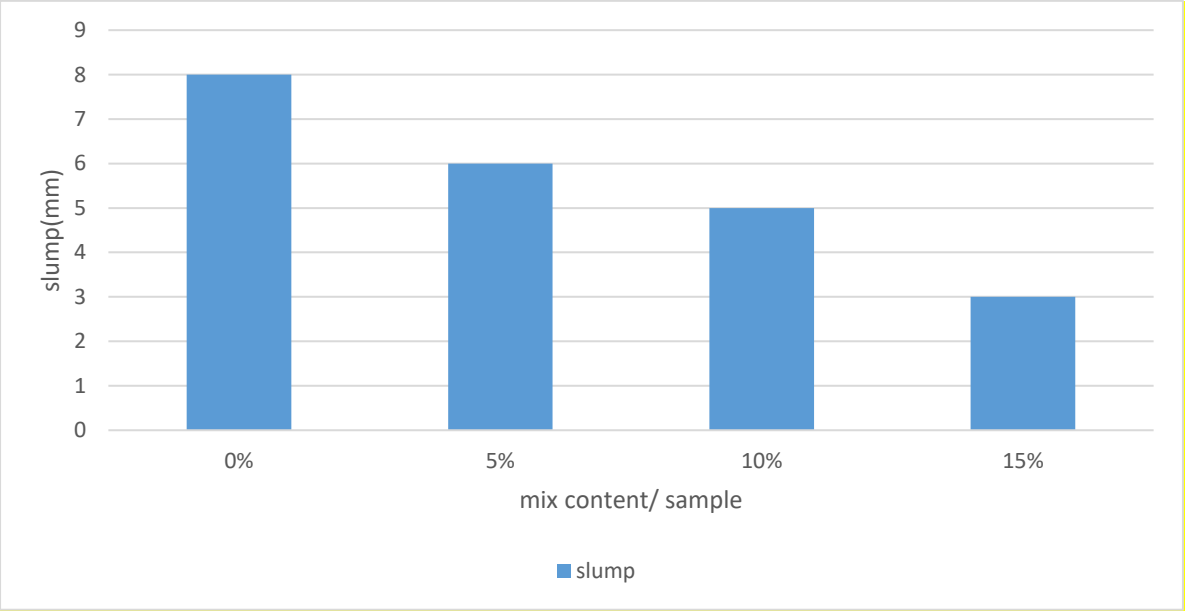

Figure 1 Slump test chart

The slump test results reveal a decrease in concrete workability as the percentage of cassava starch in the mix increases. Concrete's workability, indicated by the slump value, is crucial for ensuring proper handling, placement, and compaction. In this experiment, the starch appears to absorb a significant amount of water, reducing the moisture available in the mix, which in turn lowers the slump and makes the concrete less workable. This suggests that as starch content increases, the concrete becomes stiffer and harder to manage. The cement component typically helps stabilize the concrete when wet, but the presence of starch seems to interfere with the balance of water and cement, diminishing the overall workability and potentially affecting the final structural strength. Therefore, adding cassava starch may negatively impact concrete's fresh-state properties, particularly its workability.

Compressive strength

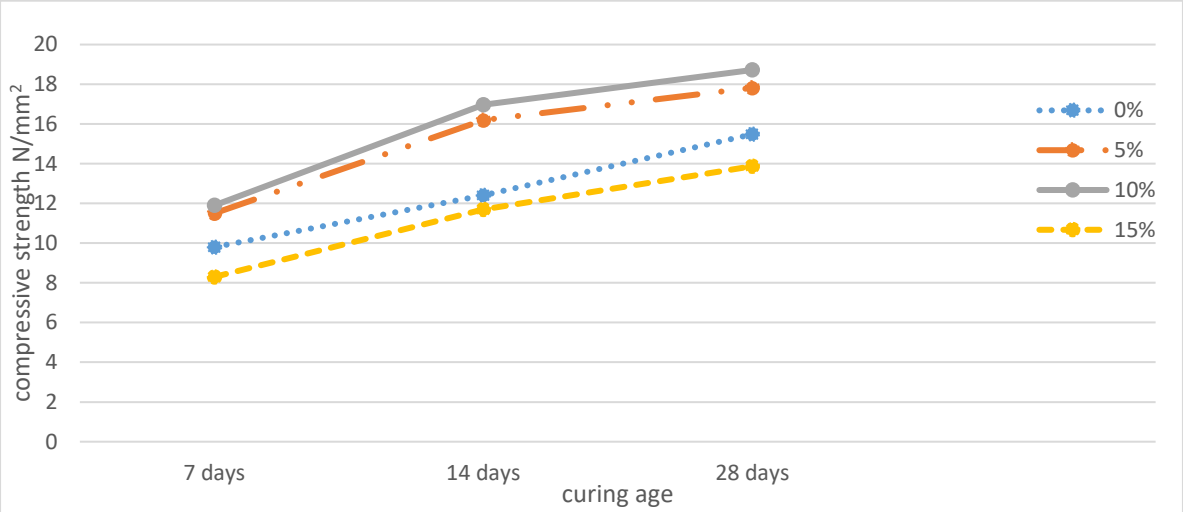

Figure 2 Comparism of compressive strength

The compressive strength of concrete is a critical factor in determining its ability to bear loads, which is heavily influenced by the cement, aggregate, and sand quality. In this experiment, the addition of cassava starch to the concrete mix shows an interesting trend. The compressive strength increases as the starch percentage rises, peaking at 10% starch replacement, where the concrete achieves a strength of 18.72 N/mm². This suggests that at 10% starch, the concrete mix achieves optimal stability and strength, likely due to a favorable interaction between the starch and cementitious materials. However, beyond this point, the compressive strength drops sharply to 13.87 N/mm², indicating that higher starch content negatively impacts the structural integrity. This reduction in strength could be due to excessive starch interfering with the hydration process or reducing the bond between cement and aggregate. Therefore, a 10% starch replacement appears to be the optimal level, beyond which the strength and load-bearing capacity of the concrete diminish.

Water absorption

$$Absorption(\%) = \frac{(wt\ after\ immersion - wt\ before\ immersion)}{wt\ before\ immersion} \times 100\%$$

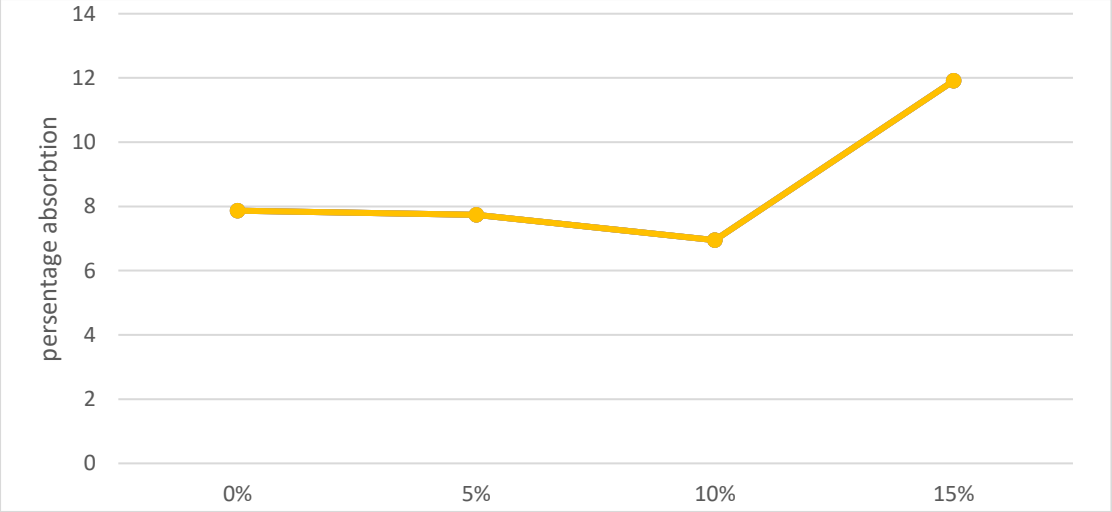

Figure 3: Water Absorption

The absorption test results highlight the concrete's response to water immersion and its capacity to absorb moisture, which is critical for predicting how it will perform under wet conditions, such as in flood-prone areas or regions with high groundwater tables. From the results, the water absorption of the concrete remains relatively stable at around 6.95% up to a 10% replacement of cassava starch, indicating that the concrete has a moderate ability to resist water penetration. However, beyond this point, at 15% starch replacement, the absorption rate increases sharply to 11.91%. This suggests that higher starch content significantly compromises the concrete's resistance to water absorption, potentially making it more vulnerable to moisture-related damage, such as cracking or degradation. In flood-prone or high-moisture environments, this increased absorption could weaken the structural integrity of buildings. The rapid rise in absorption at higher starch levels indicates that 10% replacement is likely the optimal limit for maintaining water resistance in the concrete mix. Beyond this threshold, the concrete's ability to withstand prolonged moisture exposure deteriorates, making it less suitable for wet conditions.

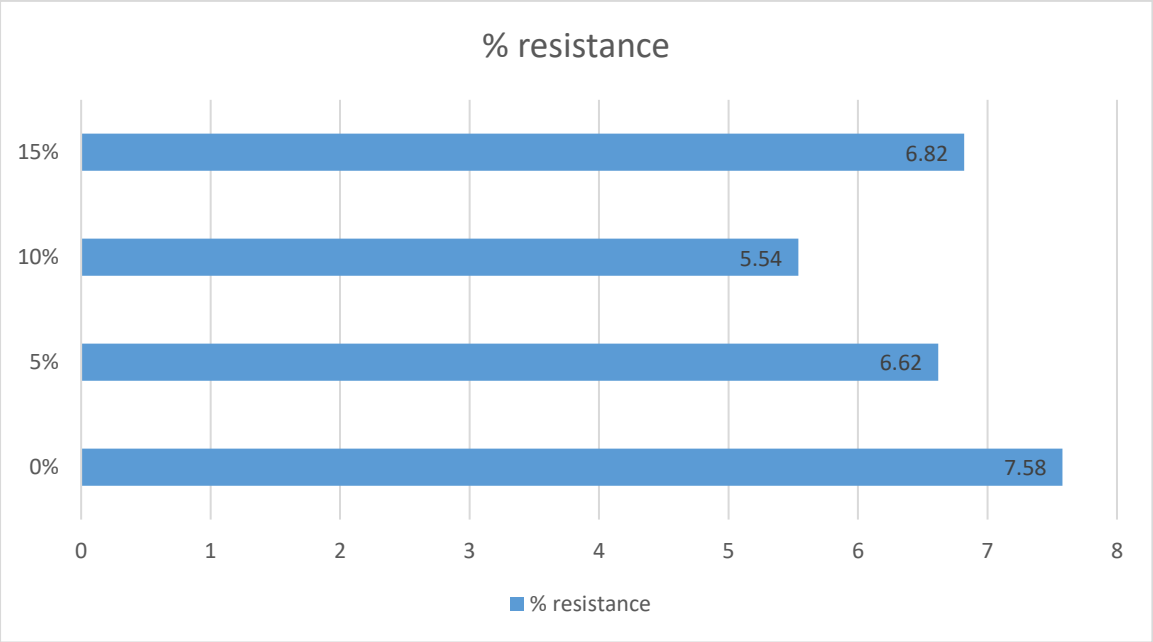

Figure 4: abrasion resistance

The abrasion resistance of the concrete, as shown in Figure 4, improves as the percentage of cassava starch replacement increases from 0% to 10%. This suggests that up to 10% starch replacement, the concrete becomes more resistant to surface wear and friction, possibly due to better particle bonding and improved surface hardness. However, at 15% starch replacement, the abrasion resistance begins to decline. This drop indicates that the higher starch content may negatively affect the integrity of the surface layer, leading to reduced resistance to abrasion. The optimal level for maintaining or enhancing abrasion resistance is thus around 10% starch replacement, beyond which the concrete's durability under abrasive forces decreases. This trend is important for applications where the concrete will be subjected to significant wear, such as in pavements or industrial floors.

CONCLUSION

The study explored the potential of using lateritic soil and cassava starch as alternative materials in concrete production, addressing the challenges of traditional construction material scarcity and high costs in Nigeria. The resulting concrete exhibited satisfactory durability and strength characteristics, with abrasion resistance and water absorption rates comparable to conventional concrete. Compressive strength increased with up to 10% replacement of cement with cassava starch, after which it decreased. The findings suggest that lateritic soil can effectively replace sand, and cassava starch can be used as a partial substitute for cement, offering a more sustainable and cost-effective alternative for concrete production.

RECOMMENDATIONS

The research findings suggest that cassava starch can be effectively used as a partial replacement for cement in concrete, offering a sustainable and cost-effective alternative for construction in Nigeria. To optimize the benefits of this indigenous material, further studies should focus on refining the mix proportions and curing conditions to enhance the strength and durability of laterized concrete. Additionally, standardization and guidelines for using cassava starch in concrete production should be established to ensure consistent quality and performance. It is recommended that the construction industry embrace the use of agricultural products as pozzolan cementitious materials, promoting sustainable practices and supporting the development of affordable and resilient infrastructure in rural areas.

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