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COMPARATIVE ANALYSIS OF THE STRENGTH OF CONCRETES MADE FROM DIFFERENT AGGREGATES

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ABSTRACT: *The paper aimed to explore the replacement of river sand in concrete with iron fillings and sawdust at various percentages (10%, 20%, and 30%). The study used a 1:2:4 mix design and a water-cement ratio of 0.5. Wooden square cubes of dimensions 100 x 100 x 100 mm were employed, resulting in 42 concrete cubes. Tests were conducted to assess particle size distribution, specific gravity, bulk density, aggregate impact value, aggregate abrasion value, and compressive strength at 7th and 28th days of curing. Notably, after 7 days, compressive strength results showed that concrete with a 10% iron fillings replacement (18.5 N/mm²) had a higher average strength than concrete with 100% river sand (17.6 N/mm²). However, as the percentage of iron fillings increased to 20% (9.8 N/mm²) and 30% (7.1N/mm²), the compressive strength decreased. On the other hand, concrete with sawdust replacements at 10% (3.7 N/mm²), 20% (1.4 N/mm²), and 30% (0.5 N/mm²) exhibited significantly lower load-bearing capacity. These trends persisted at the 28th day, with the compressive strength decreasing with increasing percentages of iron fillings (10%: 20.3 N/mm², 20%: 11.2 N/mm², 30%: 11.6 N/mm²) and sawdust (10%: 3.4 N/mm², 20%: 2.3 N/mm², 30%: 1.4 N/mm²). The findings suggest that a low percentage of iron fillings can be used in combination with river sand to maintain load-bearing capacity, but sawdust or wood particles should be avoided as they adversely affect compressive strength. This research contributes valuable insights into the use of these materials in concrete mixtures.*

KEYWORDS: Concrete, Compressive strength, Aggregate, Specific gravity, Bulk density, Impact value

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INTRODUCTION

Concrete is currently the material used most frequently in the building sector. A specific proportion of water and an admixture are used to hold together a mixture of fine aggregate, coarse aggregate, and cement to form concrete. Buildings, bridges, weirs, and other structures all employ concrete [1]. Portland cement (10–15%) and water (15–20%) are blended to produce a paste, which is then used to make concrete. A 65–75 percent mixture of aggregates, such as sand, gravel, or crushed stone, is then added to the paste. The aggregates are combined into an impenetrable rock-like mass as the cement and water harden and solidify during mixing [2]. The qualities of the aggregates, which make up 75% of concrete by volume, have a big impact on the material's resilience and structural performance. Depending on the design mix needed for building, there are different ratios for fine and coarse aggregate. [2]. Its aggregates are made of geological materials such as gravel, sand and crushed rock. The size of the particles determines whether it is a coarse aggregate (e.g. gravel) or a fine aggregate (e.g. sand). Particles that pass through a 4.75 mm sieve but remain on a 0.075 mm sieve are considered fine aggregates. Common fine aggregates such as sand, surki, stone screens, burnt clays, cinders, fly ash, etc. are frequently used in concrete.

It has various properties; its tensile strength, compressive strength, flexural strength, permeability. For the purpose of this study, we would be working on its compressive strength which is a very important feature of concrete. Compressive strength of concrete can be defined as the capacity of concrete to withstand loads before failure. Of the many tests applied to the concrete, the compressive strength test is the most important, as it gives an idea about the characteristics of the concrete [3]. The compressive strength of concrete depends on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, and grading, shape, strength and size of the aggregate. [4]. Fine aggregate has been extensively used in the construction industry as a key component of concrete production. Although river sand is one of the major sources of fine aggregate, different sources exhibit different properties by virtue of the geological formation of the drainage basin. Further, the use of river sand as the source of fine aggregate has resulted in over-exploitation leading to depletion and environmental degradation. This has led to exploration of alternative sources to safeguard depletion and reduce the negative impacts on the environment. [2]. Most concrete works are done using river sand, clay grinded metals etc. as fine aggregate. River sand which is the most used of them all is diminishing and there is a need to replace it in our society. There are other materials which can replace the river sand in concrete. For the purpose of this study, we would be examining Iron filings and sawdust. These materials however need to be put to test to determine if they will give us a concrete of high compressive strength as concrete made from river sand.

MATERIALS AND METHODS

Materials Used

The Dangote Portland cement was used for this project. Its properties conform to the requirements of ASTM Type 1 and British Standard Code (BS EN 197-1:2000) in their compositions and properties are in compliance with the Standard Organization of Nigeria. It is a general purpose cement suitable for all uses. Its uses in concrete include pavements,

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floors, and reinforced concrete buildings, among others. It was sourced from a cement dealer in Tanke MFM, Ilorin, Kwara State. The fine aggregates used for this work are river sand, iron fillings, and saw dust. The river sand used was obtained from a nearby river in the University of Ilorin, Ilorin, Kwara State, Nigeria. The sand is brownish, odourless and free from impurities. It was air-dried to remove moisture and keep it dry. The iron fillings used for this research was obtained from the Electrical and Electronics workshop and the sawdust used for this study was obtained from the nearby sawmill on the campus.

Specific Gravity and Bulk Density

The specific gravity test was carried out on various types of aggregates to determine their specific gravity, which is the ratio of the aggregate's weight to the weight of water it displaces. The procedure involved using a measuring cylinder and a digital weighing balance. Here is how the test was conducted:

First, the weight of a dry cylinder (M1) was measured and recorded. The cylinder was then filled with river sand up to 1/3 of its capacity, and the weight was recorded as M2. Next, the cylinder was filled with water, thoroughly shaken, and the weight was recorded as M3. The cylinder was emptied and cleaned, and it was filled with water only to record the weight as M4. This procedure was repeated for another sample, and the average weight was calculated.

The specific gravity (G) was determined using the following formula:

$$Gs = \frac{M2-M1}{(M4-M1)-(M3-M2)} \qquad (1)$$

This same procedure was followed to determine the specific gravity of Iron filings, sawdust, and granite aggregates. The specific gravity test helps in evaluating the density and quality of these different types of aggregates. A bulk density test was conducted on all the fine aggregates and granite samples to evaluate their density when compacted. Bulk density, which measures the level of compaction in a material, was determined using specific equipment and the following steps: The process began by preparing air-dried samples of fine aggregates and granite. The volume of the bulk density mould (recorded as V) was ascertained, and the weight of the mould without the collar (recorded as M1) was measured on a weighing balance. The sand sample was then added to the mould in three layers, each layer compacted using 27 blows from the rammer. Subsequently, a collar was placed on the mould, and an additional layer of the sample was added and compacted with 27 blows from the rammer. After removing the collar, the sand was scraped to be level with the top of the mould. The final step involved weighing the mould along with the compacted sand on the weighing balance and recording this as M2.

$$\text{Bulk Density} = \frac{(M2 - M1)}{V} \qquad (2)$$

This procedure was repeated for various samples, including the granite. The bulk density test serves to assess the compactness of these materials.

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Batching and Mixing

The batching by weight will be used for the casting. A weighing balance, head pan and plastic containers are the tools to accomplish the batching of the material in accordance with the proportion estimated. The purpose of proper mixing is to ensure that the mass should become homogeneous, uniform in colour and uniform in consistency. There are two types of mixing that are adopted in the field i.e. Hand Mixing and Machine Mixing. This was performed using a hand mixing method.

Figure 1: Concrete Hand Mixing in the Laboratory

Slump Test

Slump flow test is to determine the workability of the fresh concrete paste prior casting. The slump flow of normal concrete is performed according to BS EN 12350 – 2:2019 testing fresh concrete slump. Slump tests can be used to measure the workability of a concrete mix. Consistency is affected by water content in the mix proportion of materials and grading of the aggregates. The experiment involved the use of several apparatuses: including a truncated cone with a height of 30mm and top and bottom diameters of 100mm and 200mm, a hand trowel, a steel rod, and a measuring tape.

The procedure began with the filling of the truncated cone in three distinct layers: the bottom layer, the middle layer, and the top layer. After each layer was added, it was firmly tapped 25 times with the steel rod to ensure proper compaction. Once both the top and bottom layers had been thoroughly tapped, the truncated cone was carefully removed. As a result of the cone's removal, the concrete within the cone settled or subsided. The difference in height between the concrete before and after this subsidence was meticulously measured and recorded as the "SLUMP." This SLUMP measurement is a crucial indicator of the workability and consistency of the concrete mixture, providing valuable information to engineers and concrete technicians for quality control and construction purposes.

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Figure 2: **The slump of concrete made by replacing river sand with sawdust at 10%**

Compressive Test

Strength of concrete is commonly considered as the most valuable property in Portland cement concrete. Although in many practical characteristics such as durability and permeability may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hydrated cement paste. Compressive strength of concrete is commonly considered to be its most valued property, although in many practical cases, other characteristics, such as durability, permeability and volume stability, may be more important. Moreover, compressive strength usually gives an overall picture of the quality of concrete. The simple compressive strength of the concrete was determined on 100 X 100 cm cubic specimens. The test is carried out according to the standard [5] compressive strength of concrete cubes. The specimens are loaded till failure in a compression testing machine conforming to the standard. The maximum load is recorded and compressive strength values were calculated as follows:

$$\partial = \frac{P}{A} \qquad (3)$$

Where, P stands for maximum load,

A stands for area of Specimen = 10000mm^2 and

∂ stands for the compressive strength in N/mm^2

This is to determine the compressive strength of concrete cubes produced at age 7 and 28 respectively (according to BS 1881: Part 116: 1983 – compressive strength of concrete cubes).

The specimen was removed from water after curing time and dried out excess water from the surface. The bearing surface of the testing machine was cleaned. Then, the specimen was

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placed in the machine in such a manner that the load would be applied to the opposite sides of the cube cast and aligned centrally on the base plate of the machine. Then, the movable handle of the machine was gently moved by hand so that it touches the top surface of the specimen. The load was applied gradually without shock and continuously till the specimen failed. This is shown in Figure 3.

Figure 3: **Compressive Machine**

RESULTS AND DISCUSSION

It was observed from Figure 4 and Figure 5 that Iron filling with specific gravity and bulk density of 2.94 and 2.86 respectively is denser than river sand of specific gravity and bulk density of 2.68 and 1.65 respectively. Saw dust of 0.735 and 0.164 specific gravity and bulk density respectively is the least dense of the fine aggregates used.

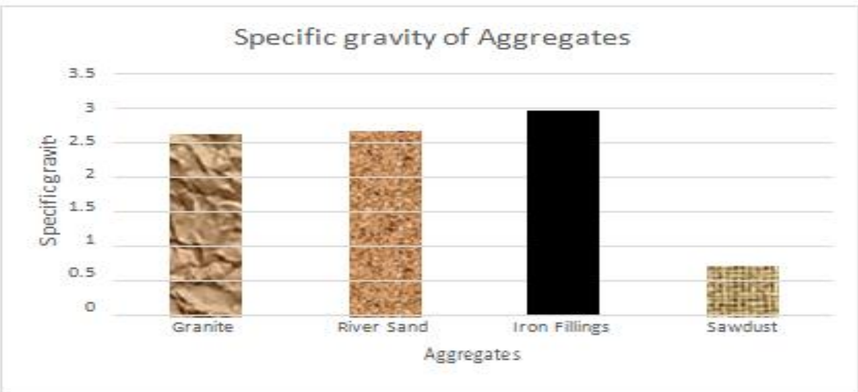

Figure 4: **Aggregates Specific Gravity**

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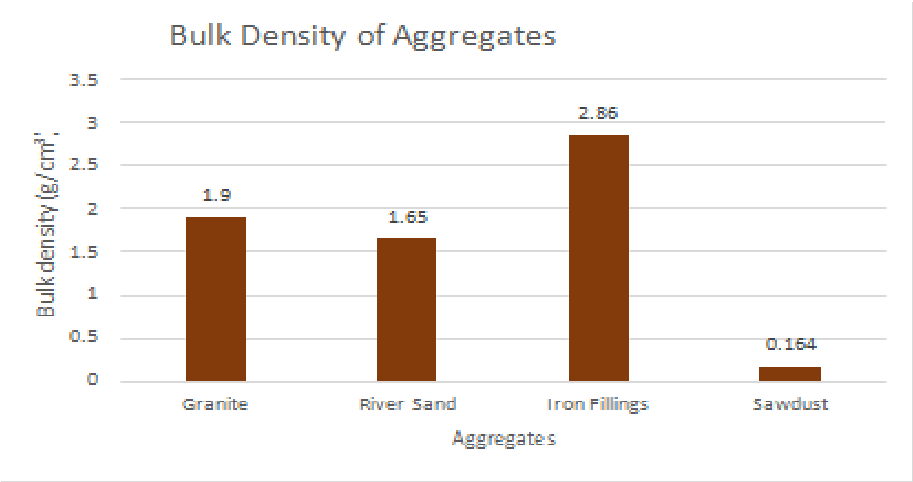

Figure 5: Bulk Density of Granite, River Sand, Iron Filings and Sawdust

Table 1 shows the slump value of the fresh concrete produced in the laboratory for all the samples at their respective percentages and Fig. 4.2 is a chart showing their variation. There is an increment in the slump of concrete mix with increment in percentage of iron filings and decrement in the slump of concrete mix with increment in the percentage of sawdust.

Table 1: Slump Test Result for Fresh Concrete made of Aggregates Proportion

Fine Aggregate	Height of Slump Cone (mm)	Height of Collapse (mm)	Slump (mm)
100% River Sand	300	215	85
10% IRON FILLINGS	300	210	90
20 % IRON FILLINGS	300	190	110
30% IRON FILLINGS	300	185	115
10% SAWDUST	300	205	95
20% SAWDUST	300	257	43
30% SAWDUST	300	290	10

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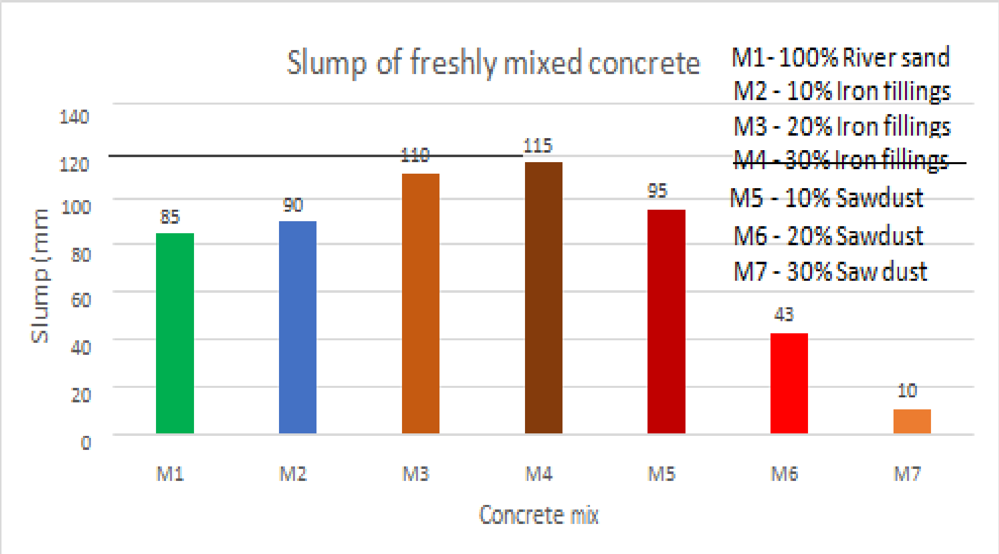

Figure 6: Slump of Concrete Made of River Sand, Iron Fillings, and Sawdust

The average value of the strength of concrete at day 7 and 28 of curing were shown Figure 7 and 8 showing the result of concrete compressive strength at different percentage replacement for day 7 and day 28 days of curing.

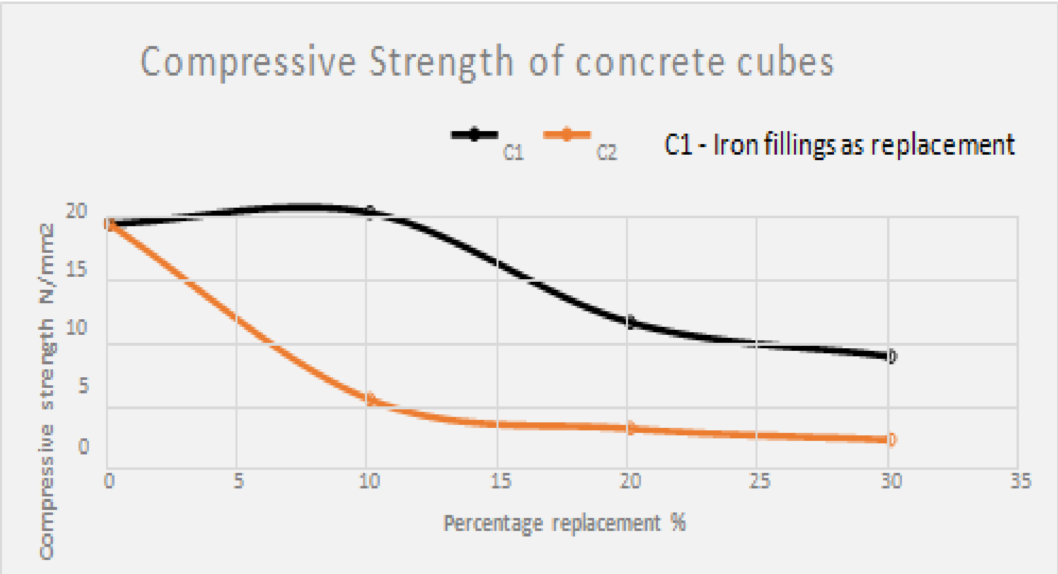

Figure 7: Compressive Strength of Concrete after Day 7 of Curing

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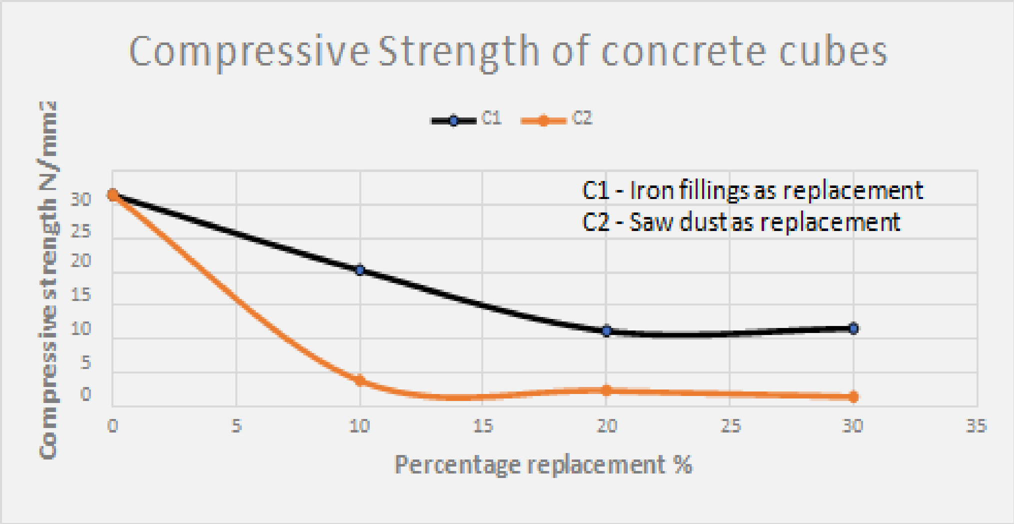

Figure 8: Compressive Strength of Concrete after Day 28 of Curing

From Figure 7, it shows that the compressive strength of concrete with any replacement is higher than when it was replaced with iron filings and sawdust. The compressive strength of the concrete was decreasing with higher replacement of both iron filings and sawdust. A similar phenomenon was observed at day 28 from Figure 8 though the compressive strength of concrete made by replacing river sand with sawdust had no significant difference in strength for both day 7 and 28.

CONCLUSIONS

After carrying out various laboratory works on the aggregates and fresh concrete using mix ratio 1:2:4, and by replacing river sand by iron filings and sawdust at 10%, 20%, and 30% replacement, the following conclusions are made with the results obtained:

i. The iron fillings showed inverse properties, that is despite the increment in the physical property of the iron fillings and the weight of concrete cube made from iron fillings, the compressive strength is still low compared to that of pure river sand concrete.

ii. Sawdust has a very low specific density and bulk density resulted in the low compressive strength of concrete made with sawdust. Also its workability of saw dust is low and decreases with increase in percentage replacement which significantly affects the compressive strength of the concrete.

iii. With increment in the percentage of iron fillings for both day 7 and day 28 the compressive strength decreases that is at 10% iron filings is a better replacement of river sand than at 30%. Concrete made by replacing river sand with saw dust is very poor in compressive strength and as the percentage increment increases the strength decreases.

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