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Comparative Analysis of the Properties of Concrete Composed of Granite Stone and some selected local gravels in Anambra State

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Abstract: *This study was to find alternatives to reduce the cost of construction by finding cheaper aggregate to be used in construction by replacing well-known granite chipping with locally sourced materials which are not that expensive by carrying out some concrete tests on granite stone with the locally sourced stones to know their properties and made some adjustment as the case may be. The test carried out on the materials depends on the state of the material, for example, the tests done on aggregates were abrasion test, impact value, crushing test, and water absorption, while for wet concrete slump test was observed and on hardened concrete, compressive, flexural, tensile, permeability test was carried out. Some statistical and mathematical equations were used to Analyze the Obtained data.*

Keywords: *British standard (BN), Euro code (EN), India Standard (IS), BS 8110 standard*, Anambra state.

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I. INTRODUCTION

Concrete is a manmade building material that looks like stone. It is used in building construction, consisting of a hard, chemically inert particulate substance, known as an aggregate (usually made from different sand and gravel), bonded together by cement and water (Chijioke 2021). It also has the potential for immense compressive strength and the ability to adapt to virtually any form when poured. Urbanization causes growth in construction and infrastructure sectors resulting in rapid production of concrete and related waste (Madumita, 2021) Concrete is fire-resistant and has become one of the most common building materials in the world. Concrete is characterized by its mix ratio which can be determined during the concrete design. Concrete can be named in different ways depending on what kind of binder is used. For instance, if the concrete is made with non-hydraulic cement, it is called non-hydraulic cement concrete, if the concrete is made of hydraulic cement, it is called hydraulic cement concrete, if the concrete is made of asphalt, it is called asphalt concrete, if the concrete is made of polymer, it is called polymer concrete. Both non-hydraulic and hydraulic cement need water to mix in and react. They differ here in the ability to gain strength in water. Non-hydraulic cement cannot gain strength in water, while hydraulic cement does. When water is added to a concrete mix, a cement paste will be formed. Cement paste has three functions in concrete: binding, coating, and lubricating (Zongji Li, 2011). The correct choice of stone aggregate for railway ballast is directly related to the stability, safety, efficiency, and maintenance costs of the track (Daniela et al, 2025). The aggregate must meet several criteria to ensure it is the most appropriate material hydration of cement is greatly affected by both the time and the temperature of the hydration. Therefore, strength

gain is controlled by these two factors (Powers et al, 1946). A good fact in the cement industry speaks that an
excessive water content leads to a reduction in the strength of cement mortar, but insufficient water content incurs poor workability (S.B. Singh n et al, 2015)

The cost of purchasing and transporting conventional aggregate (crushed granite or river gravel) is high compared to locally sourced stone. The locally sourced stone is cheaper and readily available for use as coarse aggregate for concrete production. These stones are classified generally by people of Anambra state as iron-stone and also identified in three forms which are "Ekeleke" which was identified as sample "B" in this experiment, "Adora" which was identified as sample "A", and "Wuli-wuli" which was also recognized as sample "C". Sample "B" (Ekeleke) is dark red which almost takes the color of charcoal, while sample "A" (Adora) is pure red and has a more shining surface while sample "C" (Wuli-Wuli) is reddish and has a little plasticity sand that joins them in lumps. In recent times, increasing demand for raw aggregate has emphasized the need for the construction industry to adopt sustainable practices by exploring alternative materials, such as agro-waste, to address resource depletion and reduce environmental pollution (Oluwarotimi et al, 2025). The creep failure of rocks is related to their microstructure, external loading, and time (Chunzhe et al, 2025). The Concrete is a commonly used engineering material because of its exquisite mechanical interpretation, but the addition of constituent amounts has significant effects on the concrete's fresh properties. The workability of the concrete mixture is a short-term property, but it is anticipated to affect the concrete's long-term property (Naga et al, 2022).

Granite chipping is rock aggregates derived from rock blasting, which derives different sizes of boulders, and then reduces the boulders to the desired sizes in primary and secondary crushers.

II. MATERIAL PREPARATION

a) River sand (fine aggregate): This is one of the main materials used, it was extracted from river Niger in Onitsha Anambra state.
b) Water: Clean and potable water free from chemical substances which is suitable for construction used in this experiment is readily available in the faculty of engineering workshop at Nnamdi Azikiwe University (NAU) Awka, Anambra state.
c) Granite chipping: the granite chipping used was sourced from Ebonyi state "Afikpo Amasiri". This stone served as a control during the experiment.
d) Sample B (ekeleke): The sample "B" used was sourced from "Umunya" Anambra State
e) Sample A (adora): The sample "A" used was sourced from "Ogbunike" in Anambra state
f) Sample C (wuli-wuli): The sample "C" used was sourced from "Nkwere" in Anambra. Samples A, B, and C were used to compare with granite chipping.

These four stones served as coarse aggregate in the experiment.

III. RESULTS AND DISCUSSION

During the research, certain results were obtained that were used for classifying the properties of the aggregates (Fine, Granite, Sample A, Sample B, and Sample C).

a. Particle Size Distribution of sand (sieve analysis)

The result shown in Fig. 1 below aims to achieve sand particles that can pass through a sieve hole as low as 0.15 mm in size. According to the percentage passing, the sand passes through each sieve size without residual, a sand sample of 100% which was filtered on a 5 mm sieve hole and almost all escaped to the next sieve shows a good sample for our experimental purpose.

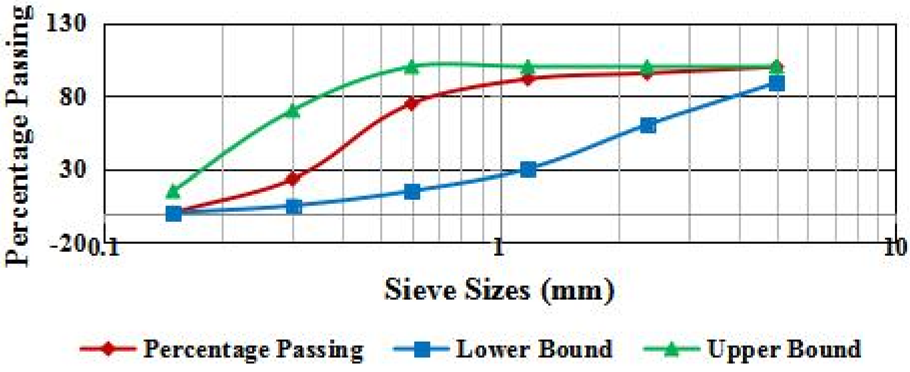

Fig. 1: Particle Size Distribution of Sand

b.Particle Size Distribution of Granite

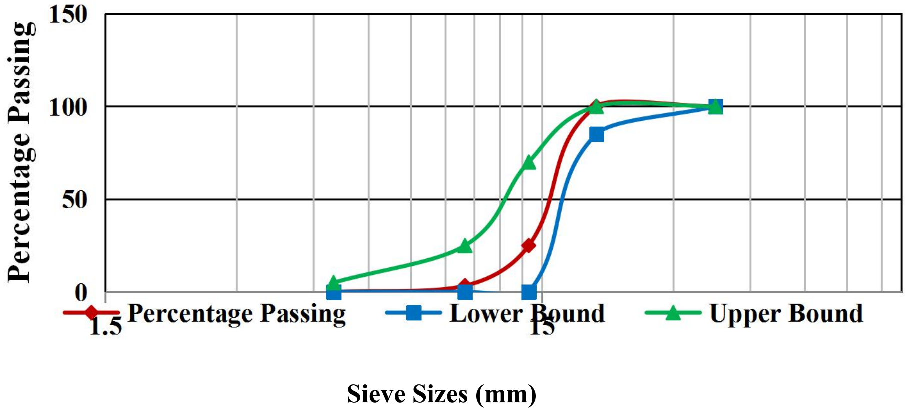

Fig. 2: Particle Size Distribution of Granite

Fig. 2 shows that the stones passed through the 37.5 mm hole but just a few passed through a 10 mm sieve size which satisfies the size required for this experiment as a control. The particle size distribution indicates that the granite used falls within the limit for 20mm single-sized aggregate (BS 882, 2002) making it suitable for concrete production.

c. Particle Size Distribution of Sample A (Adora)

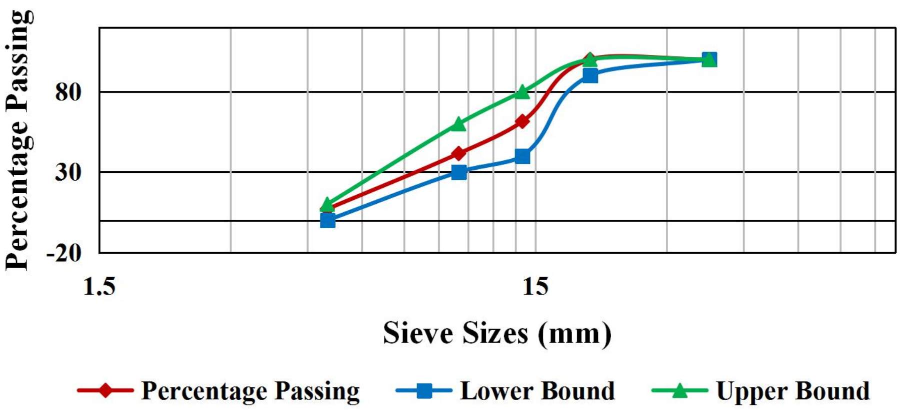

Fig. 3: Particle Size Distribution of Sample A (Adora)

b. Particle Size Distribution of Sample B (Ekeleke)

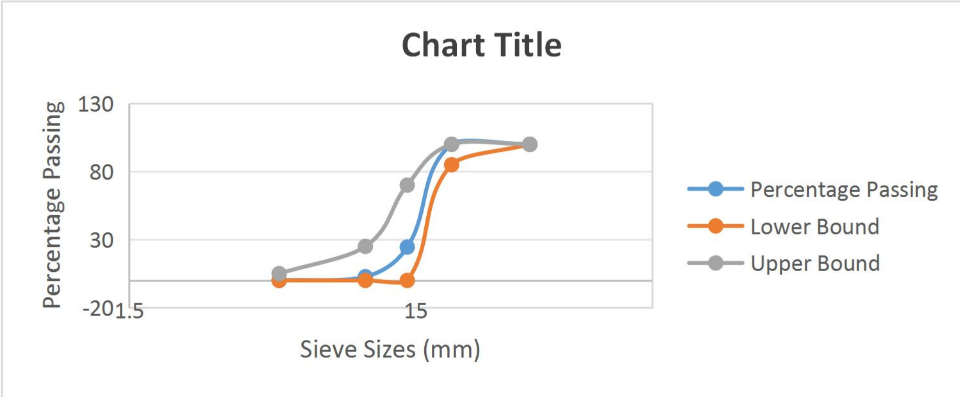

Fig. 4: Particle Size Distribution of Sample B (Ekeleke)

Fig. 3 and Fig. 4 above show that even in further crushing the percentage retained in a 10 mm sieve is more than the percentage of granite retained in the same sieve size. The particle size distribution falls within the lower and upper bound limit for 20mm single-sized aggregate (BS 882, 2002), which makes it suitable for concrete production.

c. Particle Size Distribution of Sample C

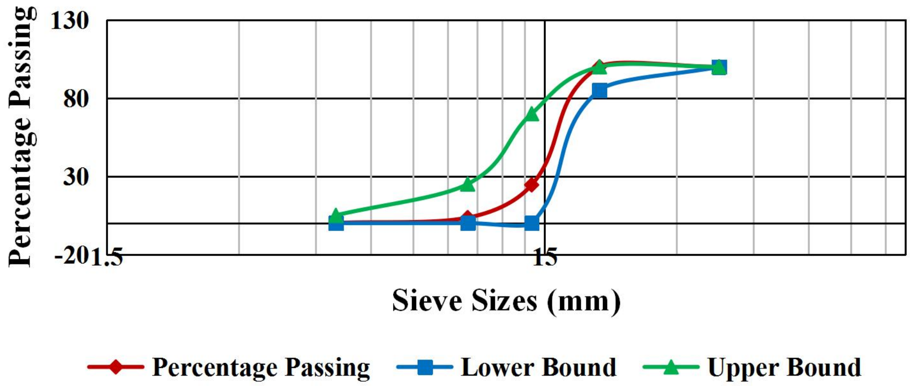

Fig. 5: Particle Size Distribution of Sample C

The percentage passing through a sieve size of 10 mm is higher than that of granite. The size of this stone is less than the size of the granite used for this experiment. The particle size distribution falls within the lower and upper bound limit for 20mm single-sized aggregate (BS 882, 2002), therefore making it suitable for concrete production.

d. Specific Gravity Test

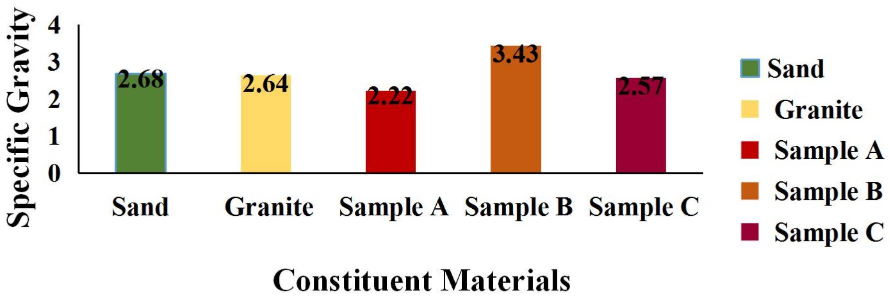

Fig. 6: Specific Gravity Test

The specific gravities of all aggregate materials obtained are shown in Fig. 6. The results show that fine aggregate falls within the standard range of 2.6 - 2.7 as stated in BS 812:107 (1995). Granite and Sample C are the only coarse aggregates that fall within the standard range of 2.5 - 3.0 as per BS 812:107 (1995). Sample A falls below the standard range and Sample B rises above the standard range.

e. Permeability (Durability Test)

Table 1: Permeability test for concrete cubes

Aggregate type	Permeability(m/s)				
	1:1:2	**1:1.5:3**	**1:2:4**	**1:3:6**	**1:4:8**
Granite	10^{-10}	10^{-10}	10^{-9}	10^{-9}	10^{-8}
Sample A	10^{-8}	10^{-8}	10^{-7}	10^{-7}	10^{-6}
Sample B	10^{-9}	10^{-9}	10^{-8}	10^{-8}	10^{-7}
Sample C	10^{-10}	10^{-10}	10^{-9}	10^{-9}	10^{-8}

This permeability is to understand how much water can pass through the aggregate, the porosity of aggregates determines how water flows through, on table one (1) the amount of water that passed through each sample varies and reduces with the increase in the mixes, this because the more the binder strength the lower space provided for water inflow.

f. Density of Aggregate Test

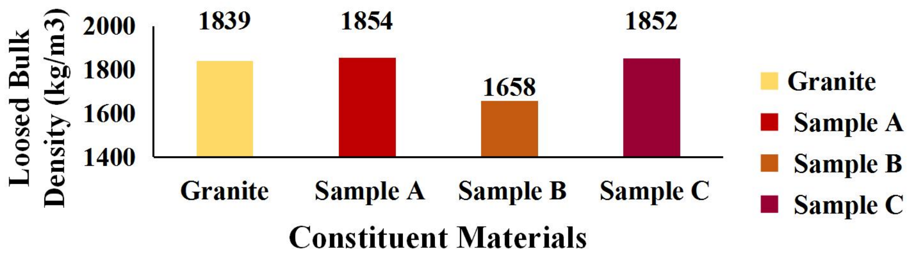

Fig. 7: Loosed Bulk Density for coarse aggregates

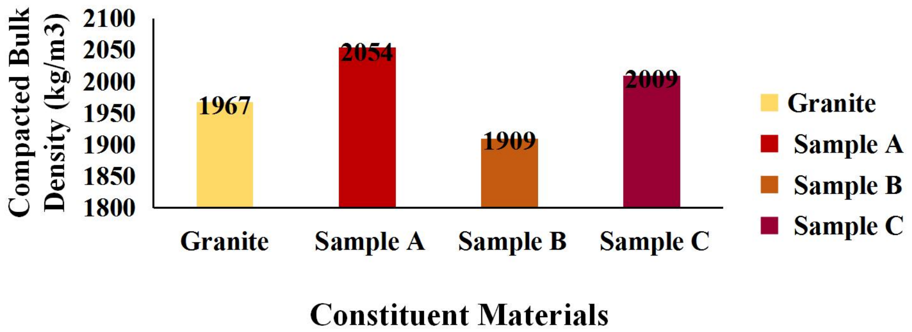

Fig. 8: Compacted Bulk Density for Coarse Aggregates

As shown in Fig.7 and Fig.8 above, it can be seen that all the aggregates fall above the specified range of values as stated in BS EN 1097-3:1998, which specified that natural coarse aggregates typically have a loosed bulk density of 1,300kg/m³ - 1,600kg/m³ and a compacted bulk density of 1,500kg/m³ - 1,800kg/m³.

g. Water Absorption Test

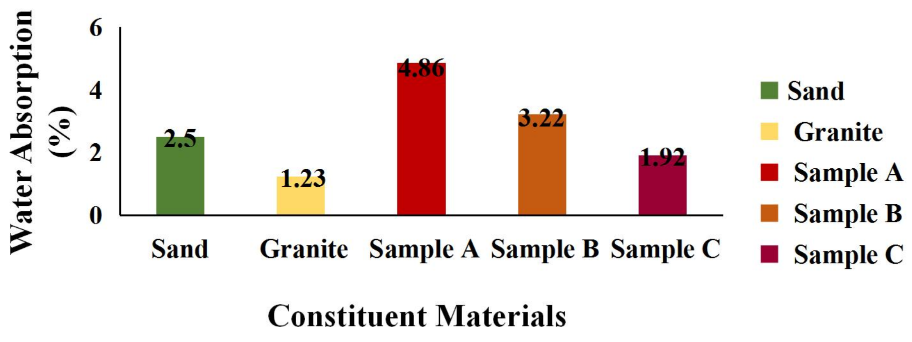

Fig. 9: Water Absorption for Aggregates

From the results obtained, sand falls within the range specified in BS EN 12620:2002, which states that water absorption of sand should not exceed 3%. All the coarse aggregates fall within the range specified in BS EN 12620:2002, which states that water absorption for Coarse aggregate should not exceed 5%. These results obtained are all within the desired specification and therefore justify the use of all the aggregate materials for this research.

h. Aggregate Impact Value (AIV)

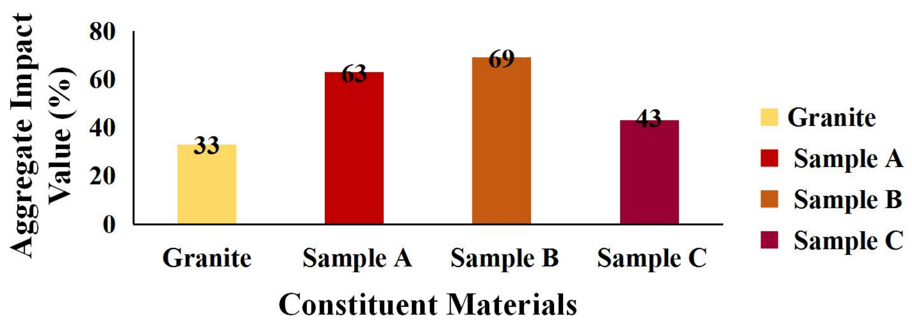

Fig. 10: Aggregate Impact Value for Coarse Aggregates

Fig. 10 shows the aggregate impact Value for Granite, Samples A, B, and C aggregates. The results obtained for all the local aggregates rise rapidly above the acceptable range for Concrete production following BS 812-112:1990, for granite it rises slightly above the acceptable range. The standard specifies that aggregates used in concrete for structure purposes should have an aggregate impact value of less than 30%.

i. **Aggregate Crushing Value (ACV)**

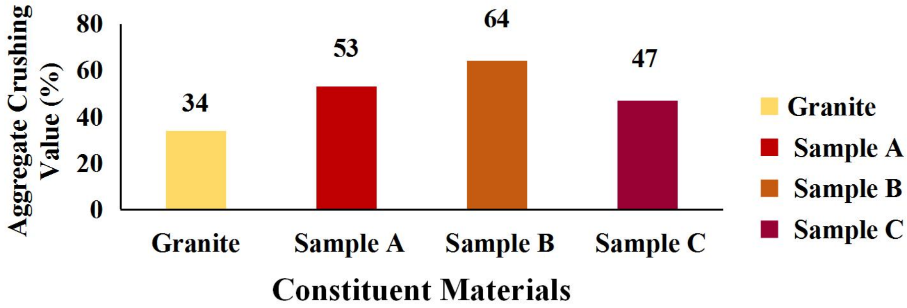

Fig. 11: Aggregate Crushing Value for Coarse Aggregates

Fig. 11 shows the aggregate crushing value of coarse aggregates used in the research. The results obtained show that the entire local aggregates rise rapidly above the specified range of value stated in BS 812 - 110:1990, for granite it rises slightly above the specific range. The standard specifies that aggregates should have a crushed Value of not more than 30% for use in heavy-duty concrete and up to 40% is acceptable for lower load-bearing structures.

j. **Slump (Workability Test)**

Table 2: Slump Test Value for Granite, Samples A B, and C aggregates

Aggregate type	Slump Value(mm)	W/C Ratio	Slump Type	Mix Ratio
Granite	150	0.55	True	1:1:2
Sample A	100		True	
Sample B	120		True	
Sample C	130		True	
Granite	90	0.60	True	1:1.5:3
Sample A	40		True	
Sample B	65		True	
Sample C	80		True	
Granite	20	0.65	True	1:2:4
Sample A	0		Zero	
Sample B	5		True	
Sample C	15		True	

Granite	5	0.75	True	1:3:6
Sample A	0		Zero	
Sample B	0		Zero	
Sample C	0		Zero	
Granite	0	0.85	Zero	1:4:8
Sample A	0		Zero	
Sample B	0		Zero	
Sample C	0		Zero	

Table 2 shows the results of the slump test carried out on fresh concrete containing all the aggregates used in the research. A true slump was observed on all concrete with 1:1:2, 1:1.5:3, and 1:2:4 at 0.55, 0.60, and 0.65 w/c ratios respectively, except Sample A which had a zero slump on 1:2:4 at 0.55 w/c ratio. This could be attributed to the high rate of water absorption of Sample "A" compared to other aggregates. However, zero slumps were observed in most cases with a 1:3:6 mix ratio at 0.75 w/c ratio and total zero slumps in all the cases with a 1:4:8 mix ratio at 0.85 w/c ratio.

k. Compressive Strength for Concrete Cubes

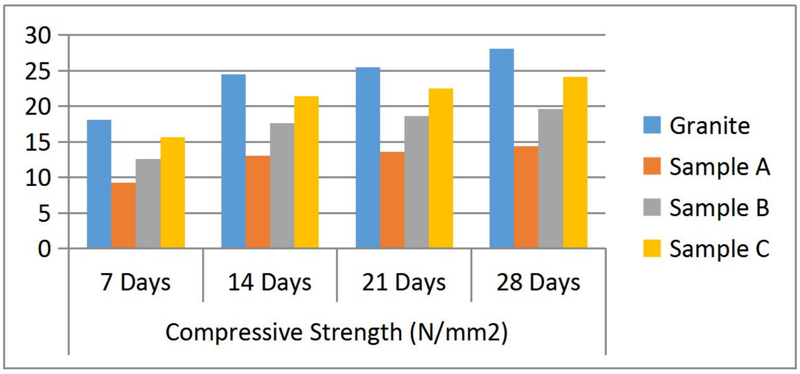

Fig. 12: Compressive Strength against Curing days for 1:1:2 at 0.55w/c ratio

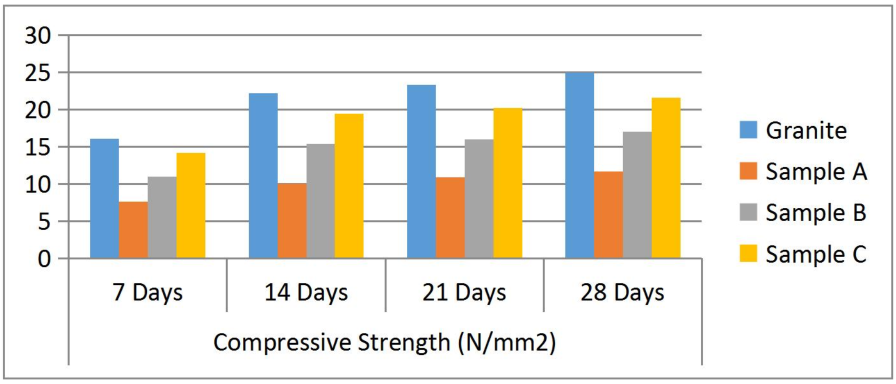

Fig. 13: Compressive Strength against Curing days for 1:1.5:3 at 0.60w/c ratio

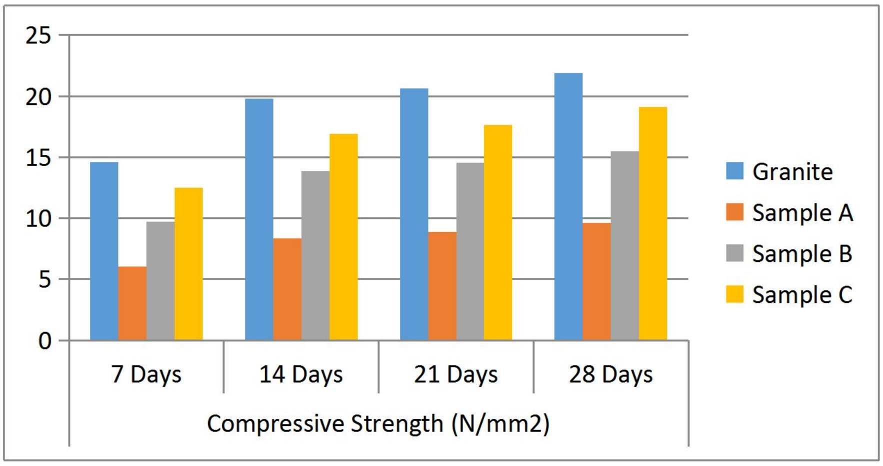

Fig. 14: Compressive Strength against Curing days for 1:1:2 at 0.65w/c ratio

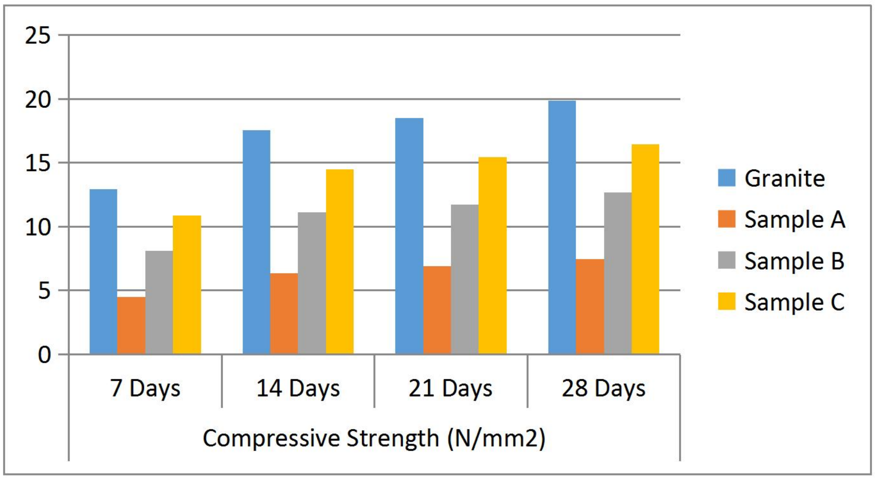

Fig. 15: Compressive Strength against Curing days for 1:3:6 at 0.75w/c ratio

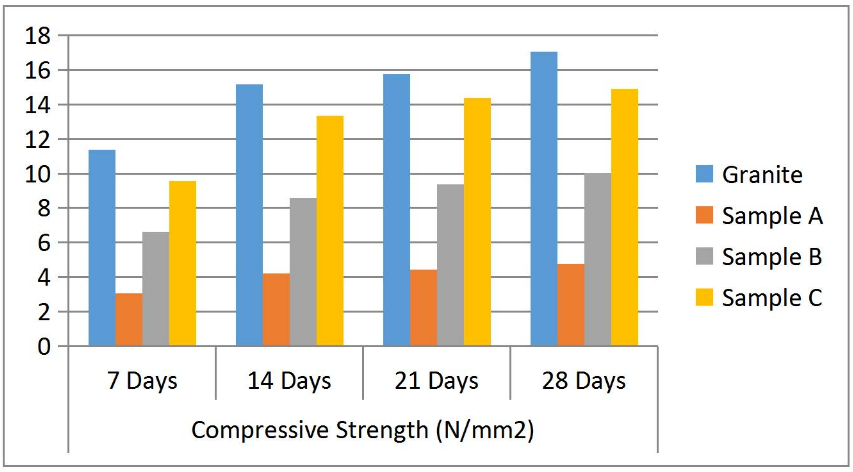

Fig. 16: Compressive Strength against Curing days for 1:4:8 at 0.85w/c ratio

The results in Fig. 12 to Fig. 16 show that the compressive strength of concrete with all aggregates increases with an increase in curing days, likewise, the strength of concrete with granite exhibits better strength than those with Samples A, B, and C aggregates. The low strength exhibited from samples A and B is because free water that could have been used for concrete mix is absorbed by the aggregates, thereby reducing the amount of water needed for complete hydration of the cement.

I. Flexural Strength for Concrete Beams

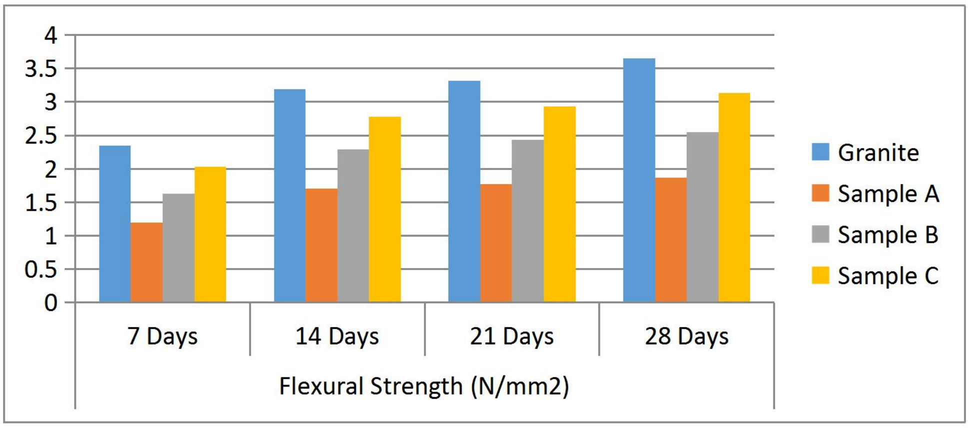

Fig. 17: Flexural Strength against Curing days for 1:1:2 at 0.55w/c ratio

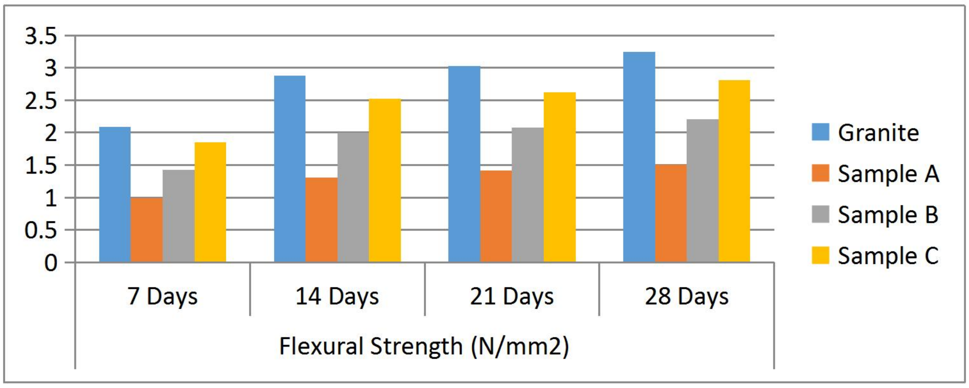

Fig. 18: Flexural Strength against Curing days for 1:1.5:3 at 0.60w/c ratio

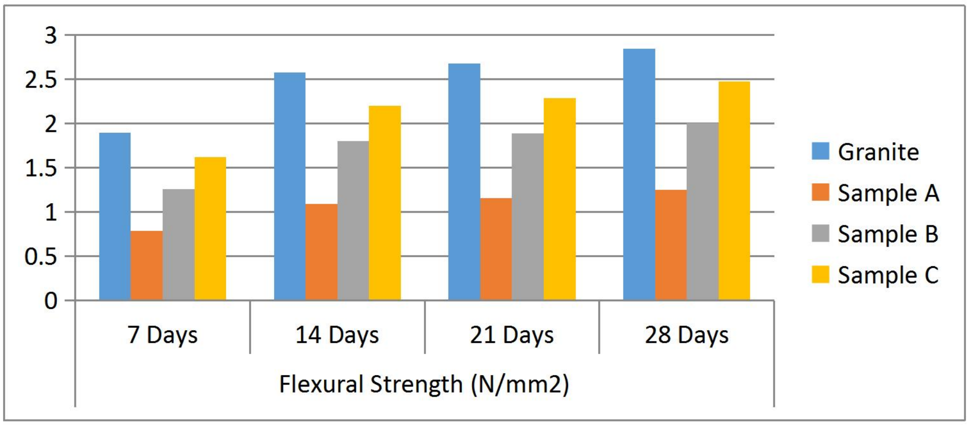

Fig. 19: Flexural Strength against Curing days for 1:2:4 at 0.65w/c ratio

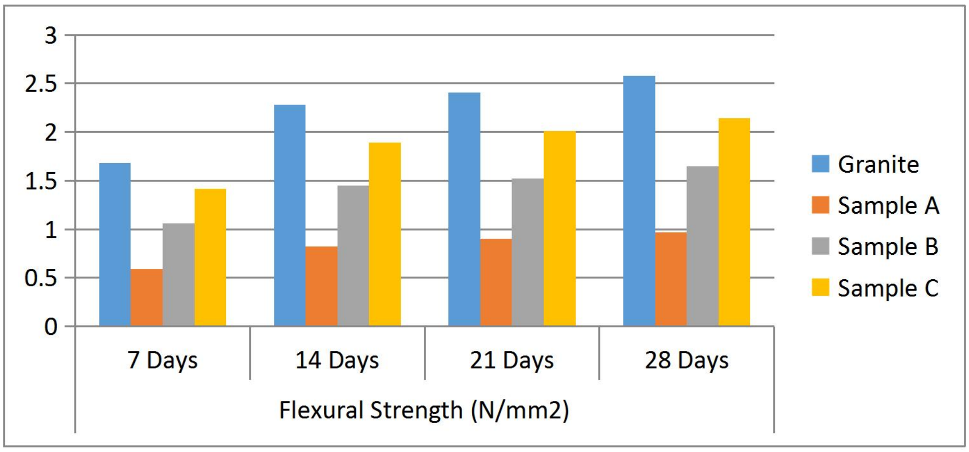

Fig. 20: Flexural Strength against Curing days for 1:3:6 at 0.75w/c ratio

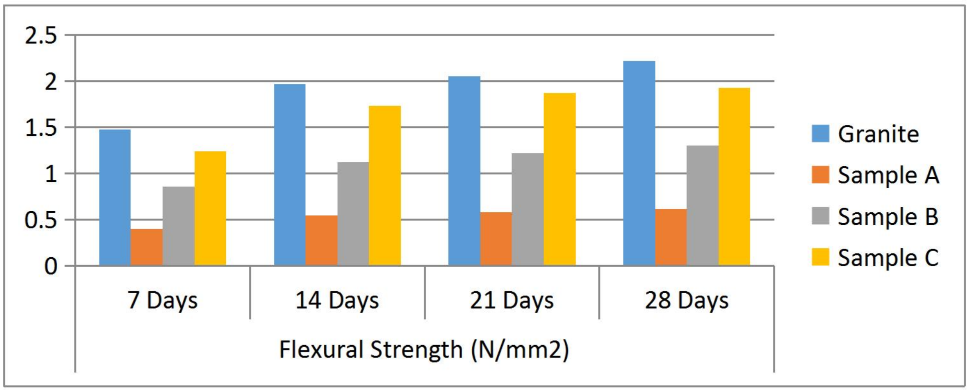

Fig. 21: Flexural Strength against Curing days for 1:4:8 at 0.85w/c ratio

From the results shown in Fig. 17 to Fig. 21 above, it was observed that the flexural strength of granite is higher than that of Samples A, B, and C materials. The flexural strength increases with an increase in curing age for all aggregate types, with Sample C exhibiting better strength than Samples A and B.

m. **Tensile Strength of Concrete Cylinde**

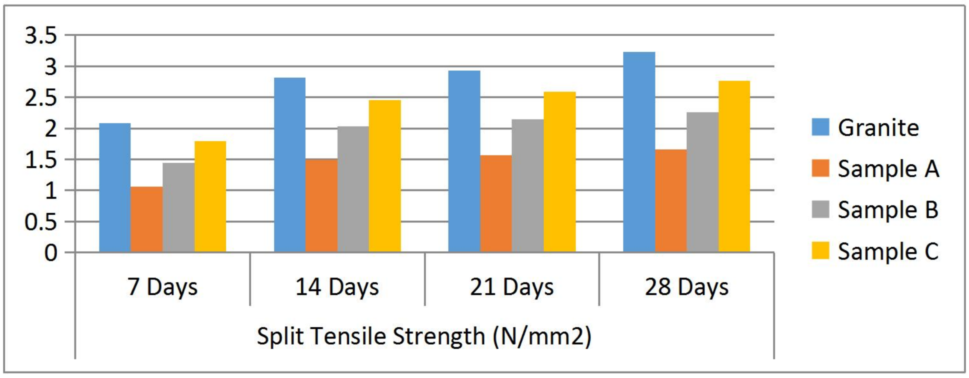

Fig. 22: Tensile Strength against Curing days for 1:1:2 at 0.55w/c ratio

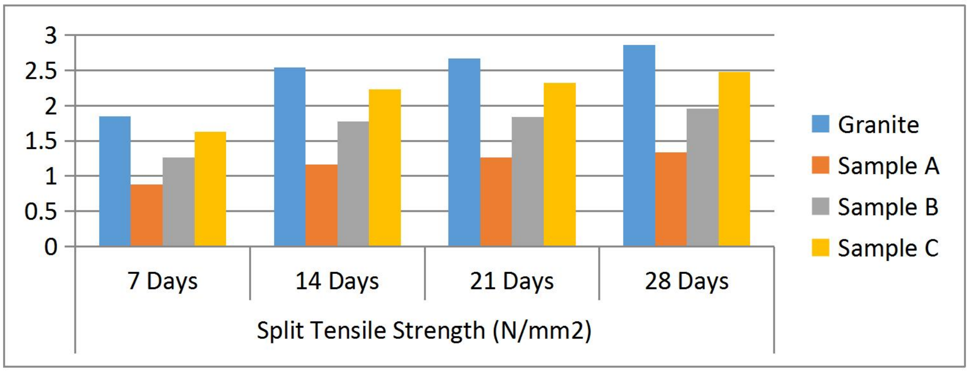

Fig. 23: Tensile Strength against Curing days for 1:1.5:3 at 0.60w/c ratio

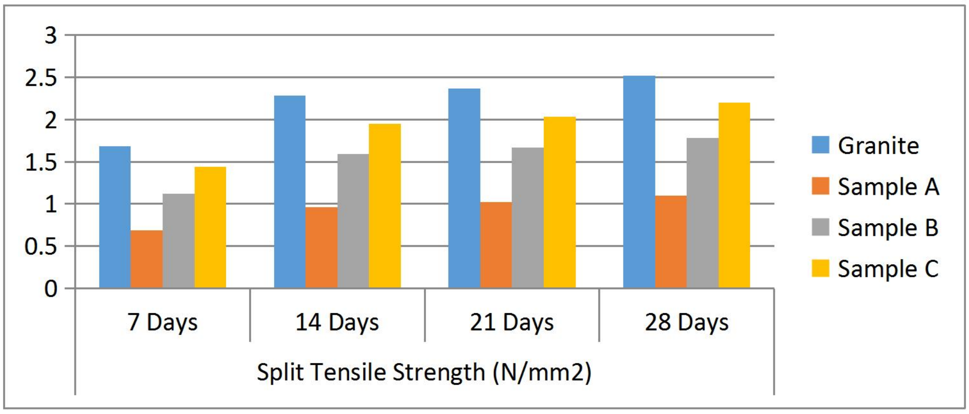

Fig. 24 :Tensile Strength against Curing days for 1:2:4 at 0.65w/c ratio

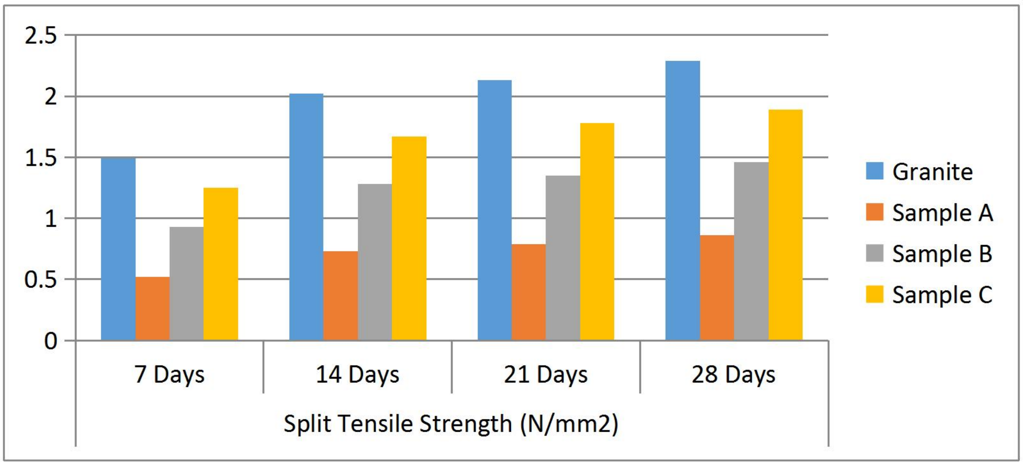

Fig. 25; Tensile Strength against Curing days for 1:3:6 at 0.75w/c ratio

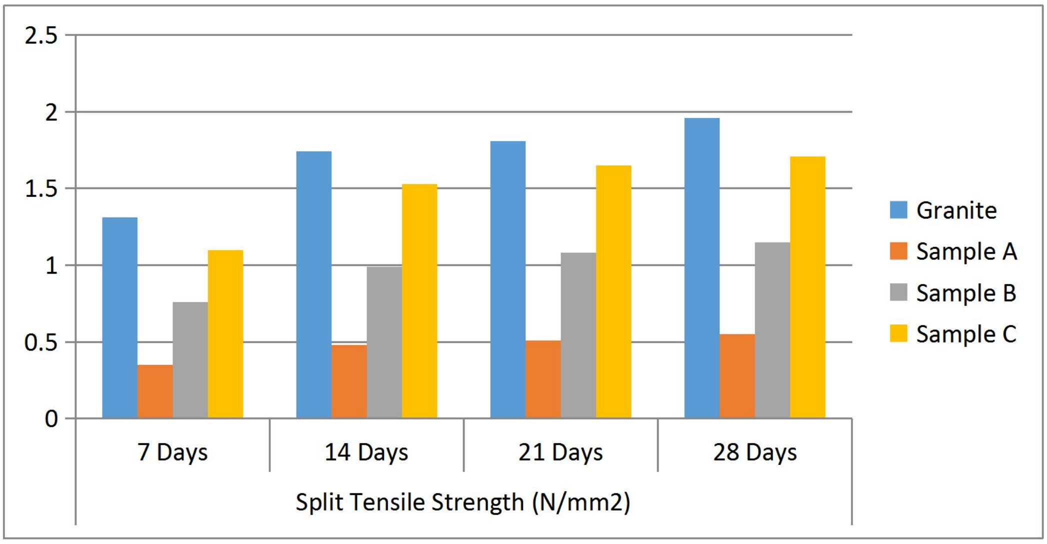

Fig. 26:Tensile Strength against Curing days for 1:4:8 at 0.85w/c ratio

The achieved result followed the same trend as flexural strength but the tensile strength also depends on how each aggregate behaves when crushed. The aggregates show how tensile they are, when highly tensile materials are subjected to loadings they stretch and crack during failure but when low tensile material is subjected to loading it will destroy into pieces instead of showing cracks as the initial failure sign.

IV. CONCLUSION

The following conclusions were drawn from this research

i. The results obtained on the concrete made with locally sourced gravel as aggregate show a compressive strength of 24.09 N/m and a mix ratio of 1:1:2 at a water-cement ratio of 0.55. This result is excellent and can be used to construct so many structures.

ii. The optimum compressive strength of concrete made with granite and locally sourced gravels was 28.08 N/m and 24.09 N/m at a mix ratio of 1:1:2 and a water-cement ratio of 0.55, respectively.

V. RECOMMENDATIONS

Since sample C shows a good comparison with the generally used granite then it should be used to replace the granite in the engineering works, especially in areas where granite is costly maybe due to the cost of transportation at a very long distance like Awka town which is located in an area not just close to any granite query site or deposit.

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