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Comparative Study on the Compressive Strength of Concrete Produced Using Local Gravel from Umunya and Nkpor Gravel Deposits in Anambra State with Granite Aggregate Concrete

Onwasigwe, G. S and Onodagu, P. D
Department of Civil Engineering, Nnamdi Azikiwe University Awka, Anambra Nigeria.
*Corresponding Author's E-mail: onwasigwesopulu@gmail.com

Abstract
The primary aim of this research is to determine the suitability of the local gravel found in Umunya and Nkpor, Anambra state for concrete production. Properties of concrete material such as aggregate impact value (AIV) and crushing value test (ACV), sieve analysis test, specific gravity test were investigated. Slump and compressive strength test were also conducted on the concrete samples. Sieve analysis test revealed that the local gravel sourced from Nkpor and Umunya had coefficient of uniformity of 2.23 and 1.86 respectively. With AIVs of 41.05% and 43.92% the local gravels sourced from Umunya, and Nkpor showed unsatisfactory result. Similarly, the gravels sourced from Umunya and Nkpor revealed unsatisfactory result with ACVs of 32.46% and 37.96% respectively. In contrast, granite had satisfactory AIV and ACV of 33.15% and 27.52% respectively. The specific gravity test indicated satisfactory density levels for all materials used in this research. The workability test revealed a moderate slump of 46mm for the concrete made with granite aggregate. The concrete made with gravel from Umunya had a slump of 42mm while that from Nkpor had a slump of 51mm. With a compressive strength of 15.73N/mm^2, 24.39N/mm^2, 27.90N/mm^2 and 31.01 N/mm^2 at 7, 14, 21 and 28 days respectively, the gravel sourced from Umunya performed better of the two gravels gotten from Anambra state. The gravel sourced from Nkpor had a compressive strength of 14.41N/mm^2, 21.76N/mm^2, 23.56N/mm^2 and 27.93N/mm^2 at 7, 14, 21 and 28 days respectively. Granite had a compressive strength of 18.24N/mm^2, 26.51N/mm^2, 32.55N/mm^2 and 35.02N/mm^2 at 7, 14, 21 and 28 days respectively. Due to their poor performance in the ACV and AIV tests, the gravels sourced from Umunya and Nkpor are unsuitable for concrete production intended for applications subjected to wear and impact when no modification is done. However, it is suitable for conventional construction.

Keywords: Coarse aggregate, gravel, Aggregate impact value, Aggregate crushing value, compressive strength

1. Introduction

Comprising more than one-third of the total volume of concrete (depending on the concrete mix ratio) (Mamaru, 2021), coarse aggregate serves a vital function in concrete mechanical properties. All over the world, various types of coarse aggregates such as granite, limestone, gravel, sand stone, basalt, dolomite, etc. are utilized in concrete production, depending on the local geology and availability of materials. The selection of coarse aggregates is typically based on factors such as cost, local availability, project requirement and engineering properties.

Several studies, including those by Mansur and Tahar, (2017) and Awoyera et al (2021), identified the use of inferior construction materials as a major cause of building failures in Nigeria. Even with appropriate design and mix ratios, concrete failures persist, suggesting a gap in meeting quality production requirements (Ajagbe, Tijani and Agbede, 2018.) Subpar concrete aggregates have been identified as contributing factors to structural failures, with issues such as unsuitability, unsoundness, reactivity, and contamination (Gollu, Allam. and Erla, 2016). Ensuring the proper sourcing of concrete constituents is crucial for enhancing the quality of construction materials, as the quality of aggregates can significantly vary based on geographical locations and environmental conditions. In Nigeria, granite is widely used as coarse aggregate due to its strength and durability, compatibility with cement, versatility, and local preference and tradition. In Anambra state, Nigeria, there is an increasingly growing demand for locally sourced stones to be used as coarse aggregate due to it being available in the state and relative cheaper cost when compared to granite.

2.0 literature review

In their study, Salvador and Amusu (2021) in their study, aimed to compare the mechanical characteristics of concrete made with both washed and unwashed gravel as coarse aggregate in Nigeria's construction industry. They conducted analysis of particle size distribution and slump tests, using concrete mix ratios of 1:2:4 and 1:1.5:3 with sharp sand as the fine aggregate. The study involved testing 25 cubes at 7, 14, and 21 days. Their findings indicated that concrete made with unwashed gravel exhibited improved workability, while concrete from washed gravel showed noticeable increase in compressive strength, with strength patterns varying based on curing age.

Umasabor and Okolie (2019), conducted a study focusing on the impact of Anambra State sandstone as a coarse aggregate on concrete compressive strength, utilizing response surface methodology. Regression equations were developed, linking compressive strength with fine aggregate, curing duration, cement, and water/cement ratios. The results showed that granite concrete achieved a slightly higher compressive strength of 36.25 N/mm² compared to sandstone concrete at 35.0 N/mm² after 28 days of curing with a 0.48 w/c ratio, representing a 1.04% increase. The analysis of variance (ANOVA) supported the suitability of quadratic and linear models for predicting compressive strength in granite and sandstone concrete, respectively. This suggests that Anambra State sandstone is suitable for heavy structural applications.

Ezeokoli, Bert-Okonkwov and Onyia (2019), in their study investigated the qualities of coarse aggregate within Anambra State. They found that the crushing strength of the samples at 7 days ranged from 20N/mm^2 to 29N/mm², with samples from Ogbunike exhibiting maximum compressive strength at 29.33N/mm². Workability tests revealed varying slump values, with samples from Nsugbe having the best at 21.5%. Sieve analysis indicated fairly graded samples, with grain passage through 19.05 diameters ranging from 64.3% to 84.0%. The study recommended machine grading of stones, thorough washing to remove impurities, and further research on unwashed samples from other quarry sites not covered in the study.

The literature review revealed that concrete strength increases with curing age. Although coarse aggregate sourced from some locations in Anambra State had been studied, gravels from Umunya and Nkpor were not included in the study. The aim of this research is to determine and compare the compressive strength of concrete samples produce from locally sourced gravels from Umunya and Nkpor with granite aggregates. To get a wholistic view of the performances of these gravels, the particle distribution, aggregate impact and crushing values, and workability of these aggregates were analysed.

3.0 Material and methods

3.1 Cement

For this study, Dangote 3X Portland Limestone Cement was used as the binding material. This particular cement product is known for its high-quality standards and suitability for various construction applications. It was procured from the building material market located in Awka, a prominent marketplace for construction materials in the state.

3.2 Fine aggregate.

In this research work, River Niger sand served as the fine aggregate. It was sourced from a reputable local supplier in Awka. Fine aggregate passing the 4.75mm sieve was used. The sand was transported to the laboratory, where it was sun dried to reduce its moisture content.

3.3 Coarse aggregate

Coarse aggregates were sourced directly from quarry sites at Umunya and Nkpor. Additionally, granite aggregate was procured from a local supplier in Awka. Coarse aggregate that passed through a 25mm sieve size was utilized for this study. The test samples were unwashed so as to reflect site conditions. The local gravels had irregular shapes, while that of granite was angular.

3.4 Water.

The research utilized water sourced from the Civil Engineering Laboratory at Nnamdi Azikiwe University. This water source is characterized by its cleanliness and suitability for construction-related work.

3.5 Sieve Analysis

Sieve analysis was carried out on the aggregates to assess the distribution of particle sizes. This test helped in understanding the distribution of different particle sizes within the aggregate. The sample to be analysed were collected and weighed. With sieve stacked in order of size, the sample was placed on the top sieve and with the aid of mechanical shaker, the sieve was shaked for 5 minutes. The sample collected on each sieve were weighed and recorded. The percentage retained and passing were calculated and then plotted. The gradation test was conducted in line with BS 812-103 and BS 410-1(2000).

3.6 Slump Test

Slump test was conducted as part of this research work in accordance with BS EN 12350-2 2009. This test, also known as the slump cone test, was used determine the workability of freshly mixed concrete in the laboratory. Concrete was placed in a slump cone in layers, with the top levelled, the cone was raised up steadily. With the aid of a measuring tape, the decrease in height from the top of the cone was measured.

3.7 Specific Gravity

Specific gravity test of the aggregates was performed in the laboratory to determine the specific gravity (relative density) of the aggregate used for this research in line with BS 812 Part 2 (1995).

3.8 Aggregate Impact Value.

Aggregate Impact Value (AIV) test was conducted in accordance with BS 812-112:1990. This test, also known as the AIV test, served as a vital method in assessing the resistance of the aggregate to sudden impact or shock loads. A test sample of 320g was placed in the AIV mould in three layers. The mould was then placed in the AIV machine which was then subjected to 15 blows. The impacted sample was sieved through a 2.36mm sieve. The material passing through the 2.36mm sieve was weighed. The AIV was calculated as a percentage of the weight of the sample passing to the total sample weight. This procedure was done three times with the average taken.

3.9 Aggregate crushing value (ACV)

The Aggregate Crushing Value (ACV) test was performed in the laboratory to evaluate the resistance to crushing of the coarse aggregate samples. A representative sample from the coarse aggregate of 2.5kg was placed in the ACV cylinder in three layers. The cylinder was then placed in a compression machine in which a load of 400N was exerted. The crushed aggregate was removed and placed in a 2.36mm sieve. The sample passing through the sieve was weighed. The ACV was calculated as a percentage of the weight of the sample passing to the total sample weight. This process was done thrice with the average taken. This test was performed in accordance with BS 812-110:1990

3.10 Concrete Mix Design

Concrete mix design was a systematic process of determining the proportions of various constituents of concrete that was used in this research work. The process involved the careful selection and combination of appropriate materials, including cement, aggregates, and water, to achieve the desired strength, workability, durability, and other essential properties of the concrete. The Department of Environment (DOE) method of concrete mix design was utilized for this research. Average values of aggregates properties were used in preparing a single concrete mix. A concrete mix ratio of 1:2.2:3.7:0.6 was used, which represents the ratio of Cement: Fine aggregate: Coarse aggregate: Water.

3.11 Compressive Test of Concrete

The compressive test of concrete, commonly referred to as a concrete cube test, is a standard method test that was utilized to ascertain the compressive strength of concrete produced. This test aided in assessing the ability of concrete to withstand axial loads and was crucial for evaluating its structural performance and quality. The procedure involved subjecting the concrete cubes with a compression machine to a gradually increasing compressive load until they failed. The compressive test of concrete was carried out in this research in conformity with BS EN 12390-3 (2002).

4.0 Results and Discussions

Sieve analysis: The fine aggregate, with a coefficient of uniformity (Cu) of 2.13 and a coefficient of gradation (Cc) of 0.86, indicated a poorly graded aggregate with similar particle sizes. Figure 1 presents the cumulative percent finer against sieve size for the fine aggregate. Granite showed a coefficient of uniformity of 2.07 and the coefficient of curvature 1.13. This suggests that granite is poorly graded with a limited range of sizes. It has grain to grain contact, significant void content, considerable permeability, low stability and poses challenges for compact.
The gravel from Umunya has a uniformity coefficient of 1.86, and a coefficient of gradation of 1.11. The gravel from Nkpor with a coefficient of uniformity of 2.23 and a coefficient of gradation of 1.10 indicated a poorly graded sample. Figure 2 to figure 4 shows the cumulative percent finer against sieve sizes for the coarse aggregate.

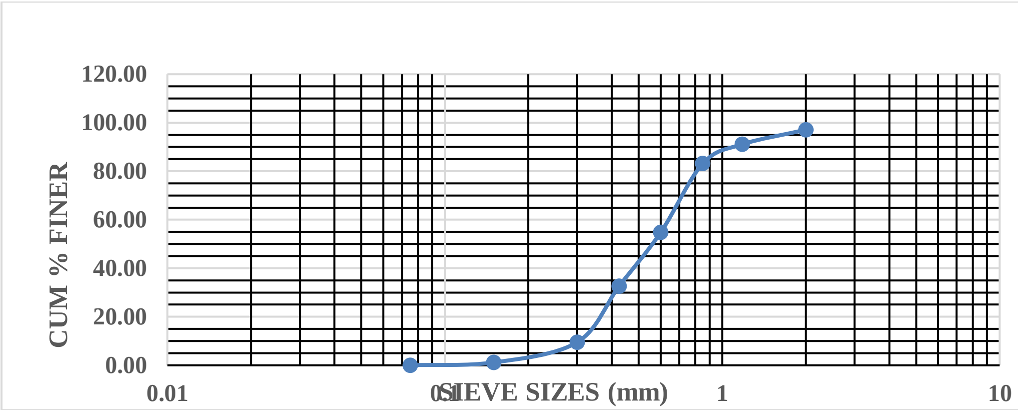

Figure 1 Cumulative Percentage Finer Against Sieve Sizes for Fine Aggregate

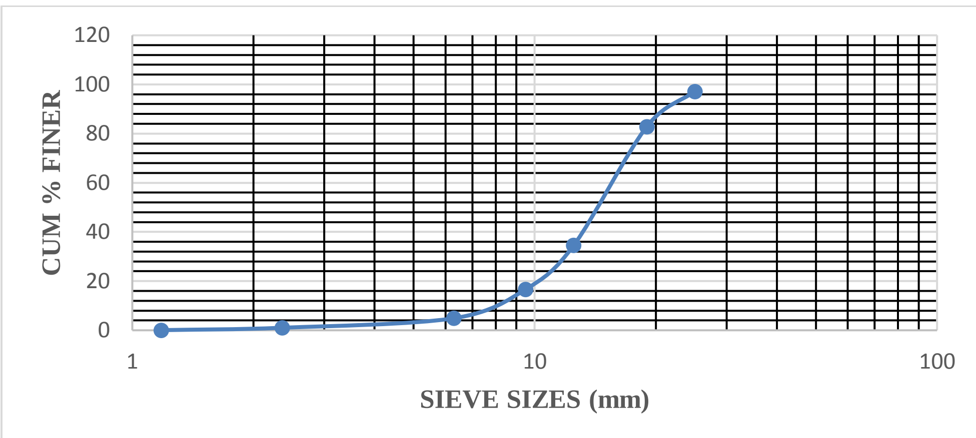

Figure 2 Cumulative Percentage Finer Against Sieve Sizes for granite

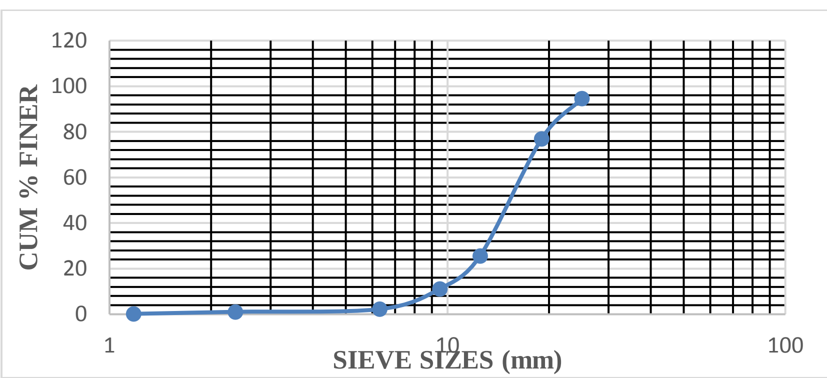

Figure 3 Cumulative Percentage Finer Against Sieve Sizes for Coarse Aggregate from Umunya

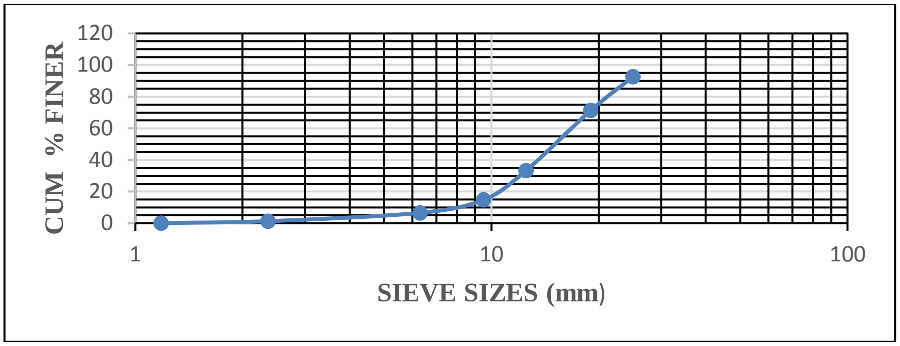

Figure 4 Cumulative Percentage Finer Against Sieve Sizes for Coarse Aggregate from Nkpor

Aggregate Impact Value: The average Aggregate impact value of granite was 33.15%. It falls comfortably within the acceptable range for aggregates used in general purpose concrete, as it is below the 45% threshold. This suggests that granite could be a suitable choice for general concrete applications.

Similarly, the stones sourced from Umunya and Nkpor exhibited AIVs of 41.05% and 43.92% respectively. These values are slightly within the recommended limit of 45% for general-purpose concrete (Shetty, 2006). While the local stone from Umunya performed slightly better and the local stones from Nkpor performed the least. Figure 5 presents the aggregate impact value of the coarse aggregates tested.

For concrete to be used as wearing surfaces and heavy-duty floors, the AIV should ideally not exceed 30%. None of the tested stones met this criterial, but comparing the AIVs, granite demonstrated the lowest value at 33.15%, a value not so far from the ideal value suggesting it is relatively resistant to fragmentation under impact compared to the other tested stones, and it can be used for wearing surfaces and high impact floors. The other tested stones may require careful consideration and potential modifications to meet the desired performance standards.

Table 1. Average Aggregate impact Value of Selected Coarse Aggregate

Test	Granite	Umunya	Nkpor
Aggregate Impact value	33.15%	41.05%	43.92%

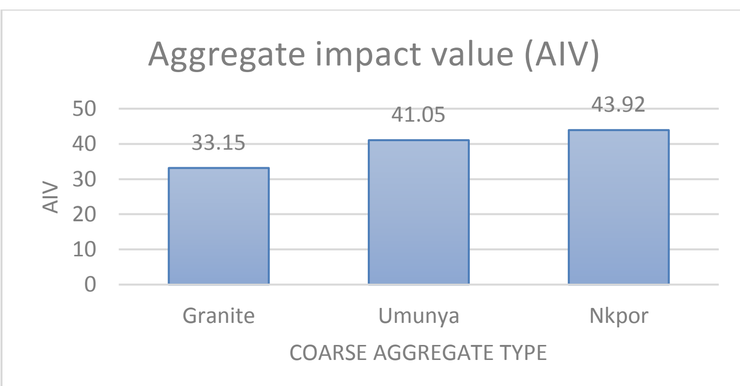

Figure 5 Aggregate impact Value against Selected Coarse Aggregate sources

Aggregate Crushing Value: The ACV test conducted in accordance with BS 812-110 is a crucial procedure used to assess the strength and durability of aggregates, particularly in determining their resistance to crushing under compressive loads.
Among the stones tested, granite exhibited the most favorable ACV result, recording a value of 27.85%. This indicates that granite possesses strong resistance to crushing and is well-suited for use in concrete applications, particularly in road and pavement construction.
However, the other stones tested, sourced from Umunya, and Nkpor, recorded ACV value of 32.46% and 37.96% respectively. Figure 6 presents the aggregate crushing value of the coarse aggregates tested. These results indicate that these stones did not meet the specified requirements for concrete used in roads and pavements without additional

measures or modifications to the concrete mix. Stones with ACV values exceeding the restricted limit of 30% may pose durability concerns and could lead to inferior performance in concrete structures subjected to heavy loads and traffic.

Table 2. Average Aggregate Crushing Value of Selected Coarse Aggregate

Test	Granite	Umunya	Nkpor
Aggregate Crushing Value	27.52%	32.46%	37.96%

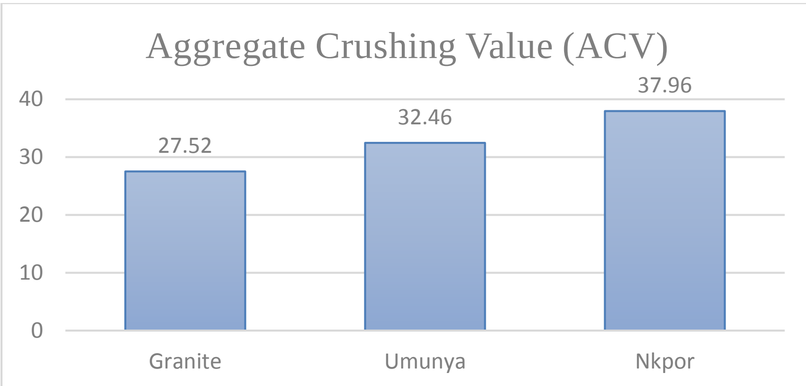

Figure 6 Average Aggregate Crushing Value against Selected Coarse Aggregate sources.

Specific Gravity result: The specific gravity test results for the aggregates, were conducted in line with BS 1377 Part 2. The specific gravity test is a method used to determine the substance density relative to that of water.
The fine aggregate from River Niger exhibited a specific gravity of 2.61, indicating a dense composition that can contribute to the strength and durability of concrete mixes. Similarly, granite, a commonly used coarse aggregate, demonstrated a high specific gravity of 2.70, suggesting excellent density and stability in construction projects.
Local stones from Umunya and Nkpor showed specific gravity values of 2.65 and 2.62 respectively indicating satisfactory density levels for coarse aggregate use. Figure 7 presents the specific gravity of the concrete materials used in this research.

Table 3. Average specific gravity of various materials

S/N	MATERIALS	SPECIFIC GRAVITY
1.	Fine Aggregate (Onitsha River Sand)	2.61
2.	Granite	2.70
3.	Local stone from Umunya	2.65
4.	Local stone from Nkpor	2.62

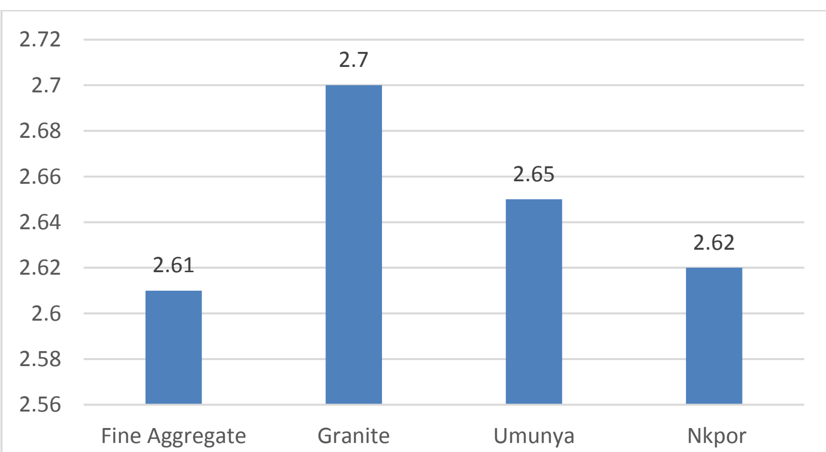

Figure 7 Average specific gravity against concrete materials sources

Slump Test Results: The slump tests, were conducted according to BS 1881 Part 102. Slump test serves as a pivotal measure to assess the workability and consistency of fresh concrete.

For this research, concrete was made using granite and aggregates sourced from Umunya and Nkpor. Each mix underwent the slump test, yielding varying slump values.

The concrete mix made with granite aggregate exhibited a moderate slump value of 46mm. This indicates a good level of workability and ease of placement, making it suitable for various construction applications. The concrete mix made with aggregate from Umunya exhibited a slump value of 42mm. This lower slump value suggests a stiffer, less workable concrete. The concrete made with aggregate from Nkpor exhibited a relatively high slump value of 51mm, indicating good workability and flowability. Figure 8 shows the slump values of the concretes studied.

Table 4 Slump Test Values for Selected Coarse Aggregate Types.

S/N	Coarse aggregate type	Slump (mm)
1	Granite	46
2	Umunya	42
3	Nkpor	51

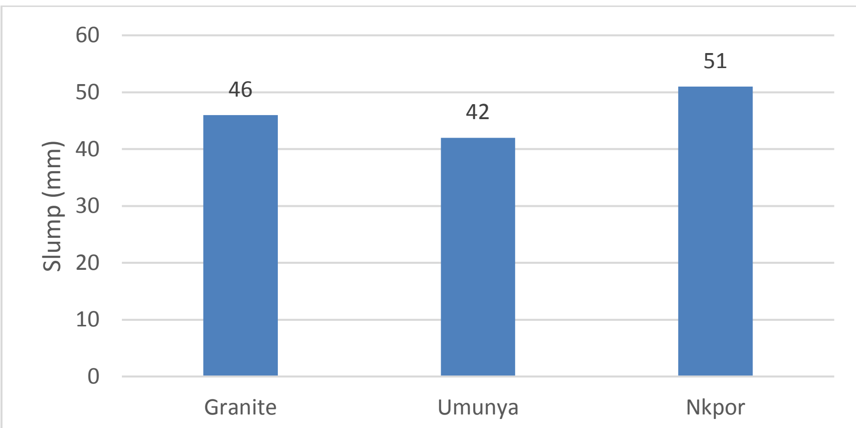

Figure 8 Slump Test Value Against Coarse Aggregate Sources

Compressive Strength Test: For concrete made with granite. The compressive strength values consistently increased from 18.24 N/mm² at 7 days to 35.02 N/mm² at 28 days. This indicates that concrete made with granite demonstrated substantial strength development over time.

The compressive strength of the stones sourced from Umunya and Nkpor at 28 days, were 31.01N/mm^2 and 27.93N/mm^2 respectively. A consistence increase was also noticed from the 7 days test to the 28days test. Figure 9 shows the compressive strength of the concrete against days.

Several factors such as the mechanical and physical characteristics of the aggregate can influence the strength of concrete being produced. For the test conducted, the aggregates were unwashed. This was done in order to reflect site conditions. The presence of impurities or weaker particles in the local aggregates may have led to lower overall strength compared to granite.

Table 5. Compressive Strength at 7, 14, 21 and 28days Curing Age

Location	7 days(N/mm^2)	14 days (N/mm^2)	21 days (N/mm^2)	28 days (N/mm^2)
Ebonyi (granite)	18.24	26.51	32.55	35.02
Umunya	15.73	24.39	27.90	31.01
Nkpor	14.41	21.76	23.56	27.93

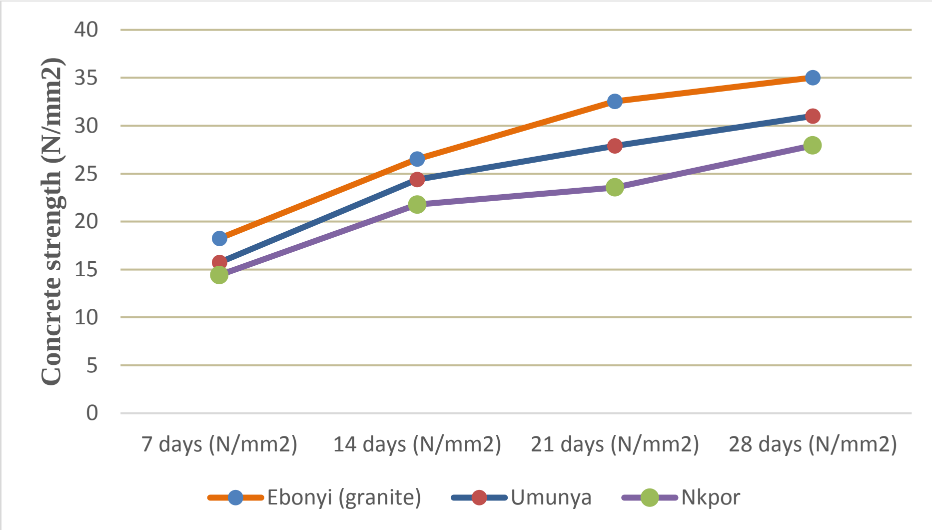

Figure 9 Compressive Strength At 7, 14, 21 And 28days Curing Age Against Coarse Aggregate Sources

5.0. Conclusion

From this study, useful and valuable insight has been gotten as regarding the stones used as coarse aggregate in Anambra State. Below are key conclusions made.

1. The gravel found at Umunya and Nkpor should not be utilized for construction of structures subjected to high impact and wearing surface due to poor AIV and ACV.
2. Concrete strength increases with curing age.
3. The gravel found at Umunya have better AIV and ACV results than that of Nkpor.
4. The concrete produced using gravel from Umunya have better compressive strength than that of Nkpor.
5. The gravel found at both Umunya and Nkpor can be used for conventional construction such as building construction.

6.0 Recommendation

Based on the discoveries and objectives of this research, the following recommendations are made to enhance standard and practices:

1. Gravels from Umunya and Nkpor should not be used for concrete production subjected to high impact and crushing loads except when appropriately enhanced.
2. Standard curing period of 28 day should be adhere to for optimal strength development of concrete.
3. Given the superior performance of Umunya gravel compared to that of Nkpor, it is advisable to prioritize Umunya gravel for concrete production when both options are available.
4. Appropriate quality control measures should be carried out on aggregates before concrete production to ensure they meet the required standards.
5. Further studies should be conducted on improving the gravels from Umunya and Nkpor through blending with stronger aggregates, addition of admixtures, etc.

References

Ajagbe, W. O., Tijani, M. A. and Agbede O. A. 2018. Compressive Strength of Concrete Made from Aggregates of Different Sources. *Journal of Research Information in Civil Engineering,* Vol.15, No.1.

Awoyera, P.O., Alfa, J., Odetoyan, A. and Akinwumi I.I. 2021. Building Collapse in Nigeria during recent years – Causes, Effect and Way Forward. *Material Science and Engineering*. 1036 012021

BS 410: Part 1:2000. Test Sieves. Technical Requirements and Testing. Test Sieves of Metal Wire Cloth.

BS 812 Part 2. 1995. Testing aggregates. Methods for determination of density (AMD 9195) (AMD 10379).

BS 812-103 1985.Testing aggregate method for determination of particle size distribution, Sieve test.

BS 812-110:1990 Testing aggregates. Methods for determination of aggregate crushing value (ACV).

BS 812-112.1990. Testing aggregates Method for determination of aggregate impact value (AIV).

BS EN 12350: Part 2. 2009. Testing Fresh Concrete.

BS EN 12390: Part 3 (2002). Testing hardened concrete. Compressive strength of test specimens.

Ezeokoli, F.O. Bert-Okonkwov, C.B. and Onyia, C.I. 2019. A Study into the Qualities of Concrete made with Coarse Aggregate obtained from Selected Quarry Sites in Anambra State. *PM World Journal.* Vol. VIII, Issue VI, July.

Gollu, V. K.. Allam. D. and Erla S. 2016. Causes of concrete failure. *International Journal of Advanced Technology in Engineering and Science*. 4(4), pp198-206

Mamaru, D.B. 2021. Evaluating the Effects of Coarse Aggregate Size on Concrete Properties. *Journal of Construction Research*. Volume 03, Issue 02. December 2021.

Mansur, H and Tahar, K. 2017. Causes of Building Failure and Collapse in Nigeria: Professionals View. *American Journal of Engineering Research*. 2017. Volume 6, issue 12, pp289-300.

Salvador, K.A. and Amusu, O.R (2021). Proportional Examination of Pf Mechanical Composition of Concrete Produced with Washed and Unwashed Gravel. Current Trends in Civil & Structural Engineering. 7(1): 2021. CTCSE.MS.ID.000652. DOI: 10.33552/CTCSE.2021.07.000652

Shetty, M.S. 2006. Concrete technology theory and practice. Indian S. Chand & company ltd., New Delhi

Umasabor, R.I and Okolie, J.N. 2019. Locally Sourced Coarse Aggregate Effect on the Compressive Strength of Concrete: Case Study of Anambra State Sandstone. *Journal of Science and Technology Research*. 1(1) 2019 pp. 63-71