IJESDS Vol: 1(1): 259-269, 2026
https://doi.org/10.68086/EMCZ9501

https://ijesds.org

International Journal of Environmental Sciences, Development & Sustainability
An official publication of the
Faculty of Environmental Sciences
Open Access | Peer-reviewed | International
ISSN (Online): 3156-4461

RESEARCH ARTICLE

Assessment of the Compressive Strength Properties of Concrete Made with Various Aggregate Sizes in Imo State

***Ugochi A. Asikogu, & Patrick I. Ashibuka**

Department of Building, Imo State University, P.M.B. 2000, Owerri, Nigeria
*Corresponding Author's Email: asklin2007@gmail.com; ugochiaskogu@imsuonline.edu.ng

ABSTRACT

The selection of coarse aggregate size is a critical factor influencing the fresh and hardened properties of concrete. This study investigated the effect of coarse aggregate size on the workability and compressive strength of concrete produced using granite aggregates obtained from Ishiagu, Ebonyi State, Nigeria, examined the compressive strength development of the concrete, and evaluated the influence of aggregate size on compressive strength using a constant mix ratio of 1:2:4. Experimental procedures involved slump tests and compressive strength tests conducted at 7, 14, and 28 days. Conversely, compressive strength decreased with increasing aggregate size. The 12.5 mm aggregate produced the highest compressive strengths of 18.3 MPa, 22.6 MPa, and 26.4 MPa at 7, 14, and 28 days, respectively, while the 20 mm aggregate produced the lowest strengths. The study concluded that 12.5 mm granite aggregate provides optimum performance for structural concrete produced with Ishiagu aggregates. The findings contribute to improved aggregate selection and concrete quality in building construction projects.

Keywords: *Aggregate size; Compressive strength; Concrete; Granite aggregate*

1. INTRODUCTION

Concrete remains the most widely used construction material globally because of its adaptability, durability, and cost-effectiveness. The quality of concrete depends on the properties of its constituent materials, particularly coarse aggregates, which occupy approximately 60–75% of the concrete volume and significantly influence workability, strength, and durability (Tam et al., 2023).

Aggregate size affects particle packing, internal friction, void content, and the aggregate-cement paste bond, thereby influencing both fresh and hardened concrete properties (Li et al., 2024). In Nigeria, granite obtained from Ishiagu, Ebonyi

State, is extensively used for structural concrete production. However, despite its widespread utilization, limited studies have investigated the effect of different aggregate sizes sourced from Ishiagu on concrete performance.

Coarse aggregates are granular materials retained on a 4.75 mm sieve and are usually obtained from crushed stones, gravel, or granite. Common aggregate sizes used in concrete production include 9.5 mm, 12.5 mm, 19 mm, 20 mm, and 25 mm. The maximum aggregate size influences workability, water demand, cement consumption, and strength characteristics of concrete. Smaller aggregates provide a larger surface area for bonding with cement paste, whereas larger aggregates reduce the total surface area requiring coating. According to Mohammed and Al-Mashhadi (2020), aggregate size directly affects the mechanical performance of both normal-strength and high-strength concrete because the aggregate-cement interface largely determines crack initiation and propagation under compressive loading.

This study therefore evaluates the influence of coarse aggregate size on workability and compressive strength of concrete produced with Ishiagu granite aggregates using a constant mix ratio of 1:2:4. On that note, this study aims to assess the effects of different sizes of coarse aggregate on the compressive strength of concrete with a view to improving the quality of concrete products and helping overcome the problem of building failure in Imo State.

The study specifically sought to: examine the compressive strength of concrete produced from various aggregate sizes sourced from Ishiagu, and determine the effect of aggregate size on compressive strength using the same mix ratio of 1:2:4.

2. LITERATURE REVIEW

The relationship between coarse aggregate size and compressive strength of concrete is complex and can vary. While some studies show that increasing aggregate size can lead to higher compressive strength, others suggest an optimal size beyond which strength may decrease. Factors like aggregate shape, water-cement ratio, and the type of cement also play a significant role.

Increased strength (with limitations): Many studies indicate that within a certain range, larger coarse aggregate size can lead to increased compressive strength. This is often attributed to a reduction in the interfacial transition zone (ITZ) volume and improved packing density.

Optimal Size: There's often an optimal aggregate size beyond which strength may decrease. This is because excessively large aggregates can create more voids and weaknesses within the concrete matrix.

Shape Matters: The shape of the aggregate also plays a role. Angular aggregate generally provides better interlocking and higher strength compared to rounded aggregates.

Water-Cement Ratio: For high-strength concrete, smaller coarse aggregates might be preferred, especially when the water-cement ratio is kept low.

Moses, Olufunke, and Segun (2018) found that compressive strength increased with aggregate size up to 12.5mm, and concrete with 20mm aggregate had higher strength than concrete with 25mm aggregates.

Ndon & Ikpe (2020) demonstrated that compressive strength increases with an increase in coarse aggregate size.

Ajamu and Ige (2015) found that coarse aggregate size is directly proportional to the slump of fresh concrete with a constant water ratio, and that compressive strength increases.

Traditionally, the strength of concrete is characterized by the 28-day value. Strength is the design property of concrete. Durability, permeability, and volume stability are also important Characteristics in some cases of designing concrete structures, but strength is the most paramount. It is expected that the Strength of concrete increases with time at a continuously diminishing rate. The process of the growth in strength is known as 'hardening'.

The concrete compressive strength to be used is required in designing a concrete structure. The design strength of the concrete normally represents the strength in 28thday.28 days is a considerable time to wait for the results of the test conducted on concrete strength in construction work. It also represents the quality control process of concrete, batching, mixing, transporting, placing, compaction, proper curing, etc. This is because concrete mix design is a process based on code recommendations and requires some previous experience (Kheder et al, 2003).

The present study is very keen to explore the concrete behavior, and for this reason, the prediction of the concrete strength is being marked as an active area of research. Therefore, many studies are being carried out in this area. Concrete fails, however, when it can no longer provide adequate strength to support the load it is designed for (Ezeokonkwo, 2014). But due to the increasing cost of producing concrete using conventional materials such as cement, river sand as fine aggregate, and granite as coarse aggregate in Nigeria, researchers have been working on alternative, economical, and readily available materials that would serve as perfect substitutes for such materials while still meeting the required standard for concrete in the industry (Udoeyo et al 2006).

It is generally recognized that aggregate particles come in various sizes that are described for engineering identification purposes by separation on square-opening sieves (Yzenas 2006). Aggregates in concrete fall into two categories based on their sizes: coarse aggregates and fine aggregates. Fine aggregates are particles that are less than 5mm, while coarse aggregates are greater than 5mm.

The influence of fine aggregate on concrete strength is almost exclusively through its shape, texture, and grading effects on mixing water demand needed for workability (Meininger, 2006). Coarse aggregates refer to aggregates of particles of size greater than 5mm. Aggregates should consist of particles with adequate strength and resistance to exposure and should not contain more than a total of 5% by weight of shale, silt and structurally weak particles.

The particle shape affects the behaviour of the water-cement ratio; harsh angular aggregates in concrete may result in high void content, giving rise to reduced strength or weak concrete. The most suitable aggregate is well-graded and angular particles with a surface texture that is not too smooth. Freshwater river aggregates are found to be well graded and more suitable; however, marine or estuarine aggregates are not suitable because of their salt content (magnesium and sodium chloride), which, when not removed, attracts moisture because of their deliquescent nature.

Umasabor and Osayogie (2020) investigated the influence of 9.5 mm, 12.5 mm, and 19 mm aggregates on compressive strength. The study found that concrete produced with 9.5 mm aggregate attained approximately 35 MPa at 28 days, while concrete containing 12.5 mm and 19 mm aggregates attained about 24 MPa and 23 MPa, respectively. The results demonstrated that smaller aggregate sizes could significantly improve compressive strength development.

Coarse aggregate is recognized as the strength determinant of concrete, as it occupies between 50 and 60% of the concrete volume depending on the mix ratio (Waziri et al., 2011). Research indicates that changes in size, content, and type of coarse aggregate can change the strength and fracture properties of concrete. Ezeldin and Aitcin (1991) studied the effect of different types of coarse aggregate on the compressive strength of concrete and observed that higher strength coarse aggregates yield higher compressive strength while in normal Journal of Research Information in Civil Engineering, Vol.14, No.2, 2017 et al. 144–strength concretes, coarse aggregate strength has little effect on compressive strength.

Studies on the effect of size of coarse aggregates on some properties of concrete like fracture energy and compressive strength have been controversial among researchers. Several studies have been carried out on the influence of various sizes of aggregates on the strength of structural concrete. Radovani (1990) studied the effect of aggregate size on the softening branch of concrete by conducting uniaxial, biaxial, and triaxial compression tests and found that the concrete made with large-sized aggregates showed more ductile behaviour. Ogundipe et al. (year?) investigated the effects of coarse aggregate sizes of 6 mm, 10 mm, 12.5 mm, 20 mm, and 25 mm on concrete compressive strength. The study found that concrete produced with 12.5 mm aggregate achieved the highest compressive strength. Strength increased as aggregate size increased from 6 mm to 12.5 mm but decreased when aggregate size exceeded 12.5 mm. The researchers attributed this behavior to improved particle packing and reduced void content at the optimum aggregate size.

Ajamu and Ige (2015) concluded in their study that coarse aggregate size is directly proportional to the slump of a fresh concrete with a constant water ratio and that the compressive strength of a concrete increases with an increase in coarse aggregate size. There has not been a unanimous agreement on how the size of coarse aggregate affects the strength development and attainable compressive strength of concrete.

3. MATERIALS AND METHODS

The research area is Imo State (provide more details/specifics on the study area). The primary data were collected through the use of specimens from the study area. The study used a total 'population' or 'census' of 27 concrete cube specimens of 150mmx 150mm x 150mm sizes made from different coarse aggregate sizes of 12.5mm, 16mm and 20mm.

The resulting data were analyzed using descriptive statistical techniques and comparative evaluation. The independent variables were the coarse aggregate sizes; the dependent variable was the compressive strength of the concrete, while the other factors that were kept constant included the cement type and constant water-cement ratio, as well as mixing and curing procedures. Each specimen was tested for compressive strength and workability at 7 days, 14 days, and 28 days, respectively.

Sampling procedure for the compressive strength test:

1. The various sample sizes of aggregates were brought to the laboratory in an air-dry condition from the study area.
2. The mix design of three different aggregate sizes was 1:2:4 of cement, sand, and coarse aggregate with water that is free from impurity, respectively, and it was mixed thoroughly to give a uniform colour as shown in the cube plate, before the desired quantity for each batch of the concrete was taken.
3. The mix ratio for each of the aggregate (coarse aggregates) sizes was constant.
4. The concrete was mixed by hand in a laboratory in such a manner as to avoid loss of water or other materials that will reduce the strength and stability of the concrete.
5. The concrete specimen was poured in the cube as fast as is practicably possible to avoid loss of water or any of the materials. To ensure homogeneous distribution of the composite, the concrete was well vibrated using hand as shown in the concrete cube plate.
6. The concrete specimen was cured in a concrete curing water pool tank that is free from impurities, with a total number of 27 concrete cubes (9 cubes for each of the 3 different sizes of aggregates). At 7 days, 3 cubes of each of the three different coarse aggregate sizes were taken to the compressive machine for crushing, making a total number of 9 concrete cubes for the age.
7. At 14 days of curing process, 3 cubes of each of the three different coarse aggregate sizes were taken again to the compressive machine for crushing, making another total number of 9 concrete cubes for the age.
8. At 28 days of curing process, 3 cubes of each of three different coarse aggregate sizes were taken to the compressive machine for crushing, making a total number of 9 concrete cubes at the 28-day age. Adding a total number of concrete cubes that were cured and crushed at 7 days, 14 days, and 28 days sum up to a total of 27 cubes of different sizes of coarse aggregate.

9. The bearing surfaces of the testing machine were wiped clean and other materials removed from the surface of the specimen which were in contact with the compression platens.
10. The specimen was placed in the machine in such a manner that the load was applied to opposite sides of the cubes.
11. The maximum load applied to the specimen was then recorded, and the appearance of the concrete and any unusual features in the type of failure were noted to determine the effects of coarse aggregate size on compressive strength.
12. The specimens were tested for compressive strength using a compression testing/crushing machine.

For Batching

The batching of aggregate was by volume.

0.15x0.15x0.15 = 0.003375x3 = 0.010125

Mix Design = 1:2:4 = 1/7 = 1/7 x 0.010125 x 2400 = 3.471kg cement

Sand = 2/7 x 0.010125 x 2400 = 6.942kg

Aggregate = 4/7 x 0.010125x2400 = 13.886kg

The soil was obtained from the Obinze River when it was fully saturated and allowed to dry for one week to get rid of the moisture content.

4. RESULTS AND DISCUSSION

Table 1. Compressive Strength of Concrete

Max. Aggregate Size (MM)	7-day Strength (MPa)	14 da Strength (MPa)	28-day Strength (MPa)
12.5	**18.3**	**22.6**	**26.4**
16	**17.1**	**20.4**	**24.2**
20	**16.2**	**19.7**	**22.8**

Table 2. Number of Specimens by Size at Curing Days

S/N	Number of Specimens	Size of Specimens (mm)	Age of Concrete at Testing	Compressive Strength (MPa)
i.	**3**	**12.5**	**7**	**18.3**
ii.	**3**	**16**	**7**	**17.1**
iii.	**3**	**20**	**7**	**16.2**
iv.	**3**	**12.5**	**14**	**22.6**
v.	**3**	**16**	**14**	**20.4**
vi.	**3**	**20**	**14**	**19.7**
vii.	**3**	**12.5**	**28**	**26.4**
viii.	**3**	**16**	**28**	**24.2**
ix.	**3**	**20**	**28**	**22.8**

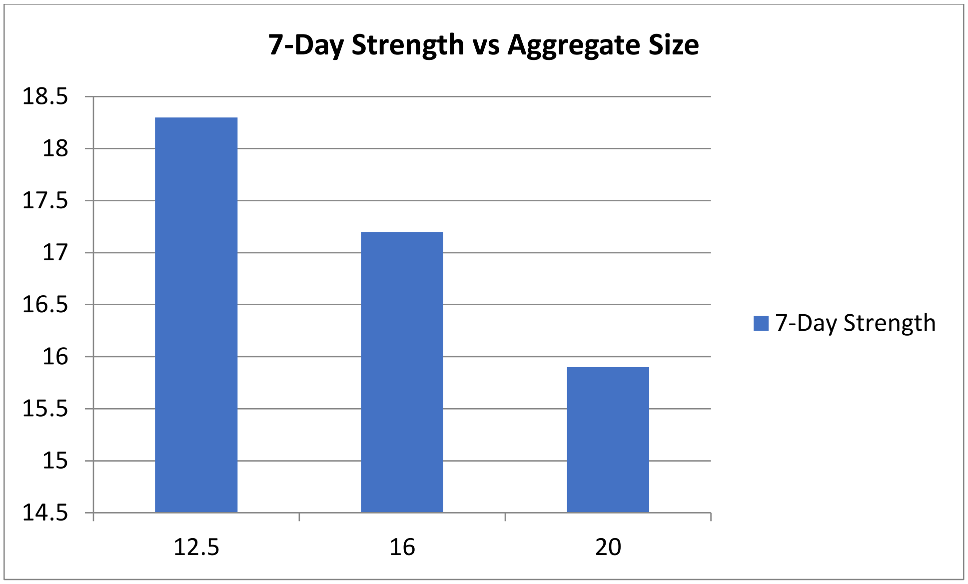

Figure 1. 7-Day Compressive Strength vs Aggregate Size

At 7 days, the compressive strength for 12.5 mm aggregate was 18.3 MPa, higher than both 16 mm (17.1 MPa) and 20 mm (16.2 MPa) (See Figure 1). This indicates that 12.5 mm aggregates support better early strength development, suggesting optimal bonding and compaction in the mix. The strength diminishes as size increases beyond this point.

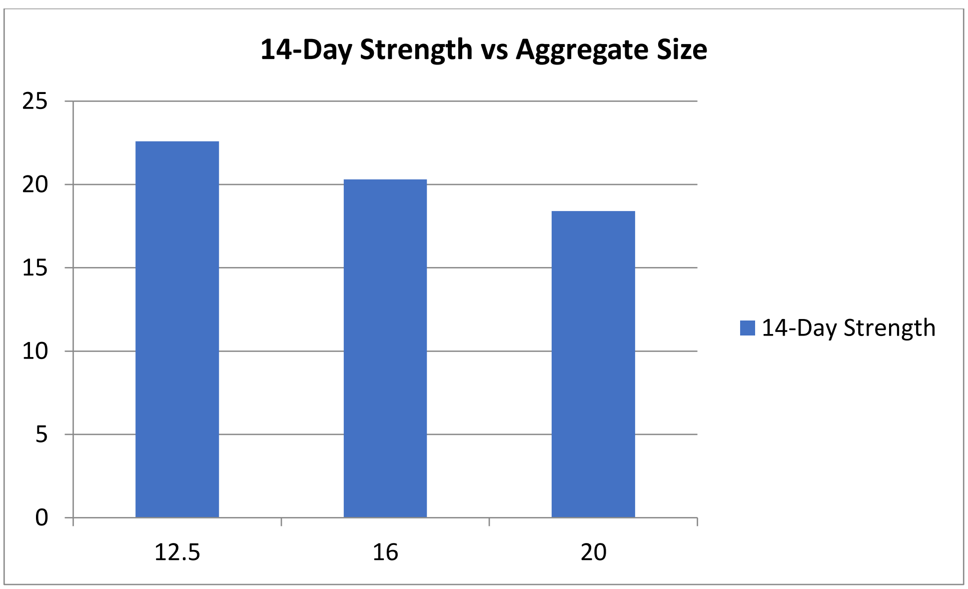

Figure 2. 14-Day Compressive Strength vs Aggregate Size

The 14-day strengths were 22.6 MPa for 12.5 mm, 20.4 MPa for 16 mm, and 19.7 MPa for 20 mm (see Figure 2). These results affirm the inverse relationship between aggregate size and compressive strength beyond a certain point. Concrete with 12.5 mm aggregate consistently outperforms larger sizes, reinforcing its role as the optimal size for mid-age strength.

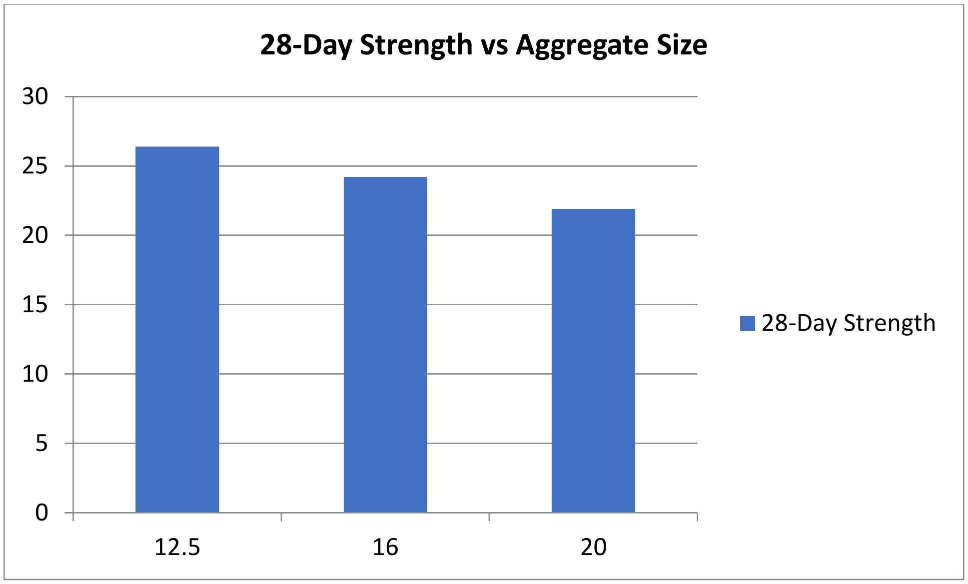

Figure 3. 28-Day Compressive Strength vs Aggregate Size

After 28 days, compressive strengths were 26.4 MPa (12.5 mm), 24.2 MPa (16 mm), and 22.8 MPa (20 mm) (See Figure 3). The same strength pattern confirms the non-linear relationship between aggregate size and compressive strength, with performance peaking at 12.5 mm. Larger aggregates reduce cement paste contact and increase internal voids, weakening the hardened matrix.

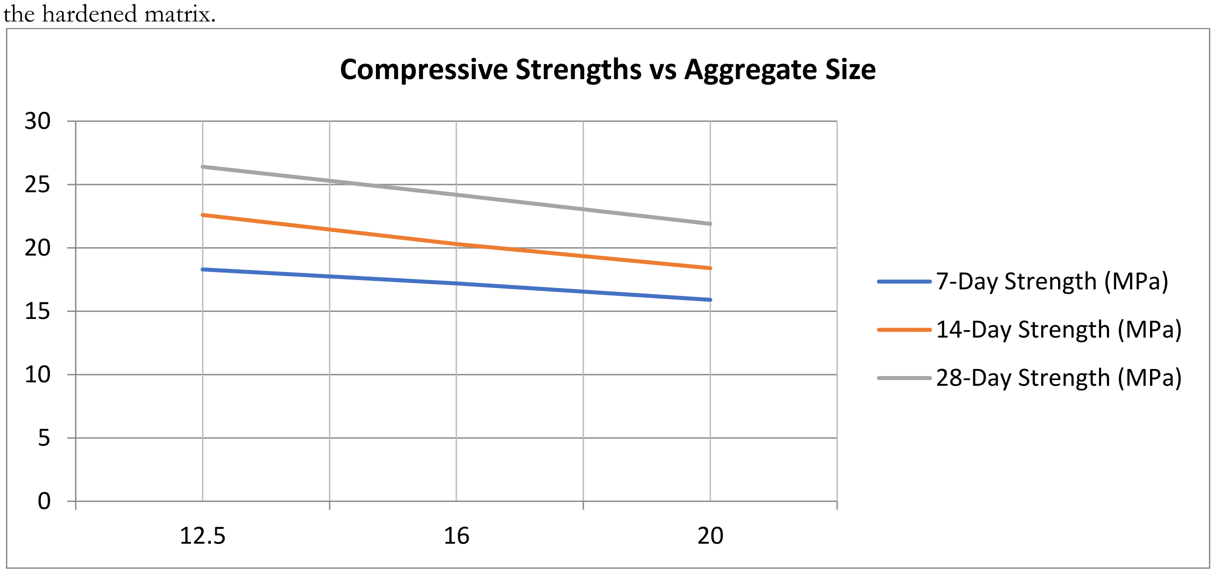

Figure 4. Combined Strengths at Different Ages

When comparing 12.5 mm, 16 mm, and 20 mm across curing periods, 12.5 mm shows superior strength at all ages, confirming it as the optimal aggregate size. The relative decline in strength with increasing size is most evident at 28 days, emphasizing the importance of moderate aggregate sizing (See Figures 4 and 5).

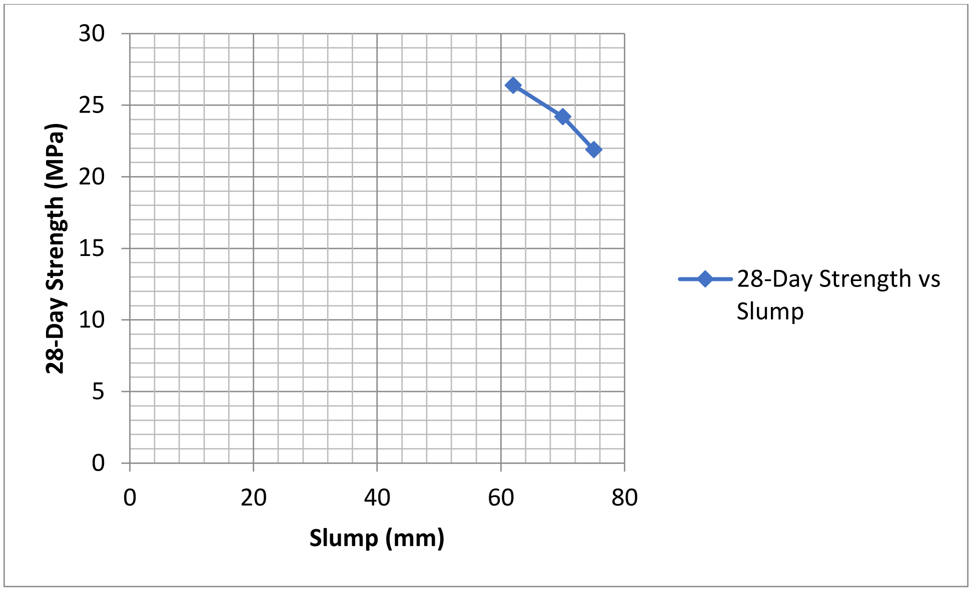

Figure 5. Relationship Between Slump and 28-Day Compressive Strength of Concrete

Table 3. Compressive Strength at 14 Days

S/No	Specimens Sizes (mm)	7-Day Strength (MPa)	Percentage %
1.	12.5	22.6	36.045
2.	16	20.4	32.536
3.	20	19.7	31.419
	Total	62.7	100

From Table 3 and Table 4, the 12.5 mm specimen at 14-day which formed a percentage of 36.045% in compressive strength after curing age at 14 days, while the 20 mm specimen has the lowest percentage of 31.419%. This implies the specimen size of 12.5mm with 36.045% has a great compressive strength in aggregate sizes for the production of concrete.

Table 4. Compressive Strength at 28 Days

S/No	Specimens Sizes (mm)	7-Day Strength (MPa)	Percentage %
1.	12.5	26.4	35.97
2.	16	24.2	32.97
3.	20	22.8	31.06
	Total	73.4	100

From Table 3 and Table 4, Also 12.5mm specimen at 28-day which formed a percentage of 35.97% in compressive strength after curing age at 28 days, while the 20mm specimen has the lowest percentage of 31.06%. This implies the specimen size of 12.5mm with 26.4% has a greater compressive strength for concrete production.

Comparison of unit pressure (MPa) for different sizes of specimens at 7, 14, and 28 days

From Table 4, compressive strength of concrete at 28 days records a total of 73.4 KN/M^2. This implies that concrete at 28 days of curing age records a maximum strength, while at 7 days of curing age records a lowest strength of 51.6KN/M^2.

Data Analysis

H01: There is no significant difference in compressive strength between concrete specimens produced with different coarse aggregate sizes

To determine whether there were statistically significant differences in compressive strength among concrete specimens made with different coarse aggregate sizes (12.5 mm, 16 mm, and 20 mm), one-way Analysis of Variance (ANOVA) was conducted.

Table 5. Descriptives Table

Specimen Sizes (mm)	Total	N	Mean	Std. Deviation
12.5	67.3	3	22.433	4.0526
16.0	61.7	3	20.567	3.5529
20.0	58.7	3	19.567	3.3020
Total	187.7	9	20.856	3.4022

Table 6: ANOVA Table

	Sum of Squares	Df	Mean Square	F	p-value
Between Groups	12.702	2	6.351	0.477	0.642
Within Groups	79.900	6	13.317		
Total	92.602	8			

Since $p=0.642 > 0.05$, we fail to reject the null hypothesis and conclude that there is no significant difference in compressive strength between concrete specimens produced with different coarse aggregate sizes. The analysis showed no significant difference, F value= 0.477, $p = 0.642$. Therefore, the null hypothesis was not rejected. This indicates that aggregate size did not significantly affect compressive strength at a 5% significance level.

Discussion of findings

All specimens were cast using a constant 1:2:4 mix. Despite the fixed ratio, aggregate size significantly influenced strength. The 12.5 mm aggregate consistently produced the highest strength. Thus, even within a standard mix, selecting the right aggregate size—such as 12.5 mm—can significantly enhance performance outcomes.

All data were generated using a constant 1:2:4 mix. This shows that even with a basic mix design, performance can be optimized by selecting the right aggregate size. The results show that strength decreased as aggregate size increased. There is a progressive increase in compressive strength. At 28 days, the concrete achieved a compressive strength of 26.4 MPa compared with 24.2 MPa and 22.8 MPa for 16 mm and 20 mm aggregates, respectively. The superior performance of the 12.5 mm aggregate can be attributed to improved particle packing and stronger aggregate-paste bonding. Similar observations were reported by Zhang et al. (2023) and Li et al. (2024). Analysis of Variance produced an F-value of 0.477 and a p-value of 0.642, indicating that the differences in strength among the aggregate sizes were not statistically significant at the 5% significance level.

Nevertheless, practical differences were evident. The 12.5 mm aggregate produced approximately 15.8% higher 28-day strength than the 20 mm aggregate. The result supports previous findings that highly workable concrete mixtures may experience reduced density and weaker aggregate-paste interactions if aggregate size becomes excessively large (Tam et al., 2023).

5. CONCLUSION

The study investigated the effect of coarse aggregate size on the compressive strength of concrete produced using Ishiagu granite aggregates. The findings showed that smaller aggregates like 12.5 mm enhance strength due to better compaction and bonding characteristics. Hence, it produced the highest compressive strengths at 7, 14, and 28 days. Also, aggregate size exhibited a strong influence on concrete performance. Furthermore, the 12.5 mm aggregate was the optimum size for producing structural concrete using Ishiagu granite aggregates.

The study concludes that aggregate size selection significantly affects concrete quality and should be carefully considered during mix design and construction operations. Granite aggregates of approximately 12.5 mm should be adopted for structural concrete applications requiring higher compressive strength due to their superior performance across all curing ages. Aggregate grading should be incorporated into quality-control procedures for concrete production. Use of 12.5 mm. In addition, further studies should investigate the combined effects of aggregate size, shape, and water-cement ratio on concrete durability and long-term performance.

6. COMPETING INTEREST

None to declare

REFERENCES

Ahmed, M., & Hassan, R. (2022). Aggregate Characteristics and Concrete Performance: A Review. *Journal of Building Materials and Structures*, 9(2), 55–68.

Ajamu, S.O., & Ige, A.J. (2015). The Effects of Coarse Aggregate Size on the Compressive Strength of Concrete. *Journal of Engineering Research and Applications*, 5 (1), 67-75.

Ezeldin and Aitcin (1991), Effect of Different Types of Coarse Aggregate.

Ezeokonkwo, J.U. (2015). The Characteristics of Aggregate indeed play a significant role in determining the Performance of Concrete.

Kumar, V., & Singh, P. (2024). Effect of Aggregate Size on Fresh and Hardened Concrete Properties. *Journal of Building Engineering*, 89, 109221.

Li, J., Zhao, X., & Chen, Y. (2024). Influence of Aggregate Size Distribution on Concrete Compressive Strength and Durability. *Construction and Building Materials*, 418, 135497.

Meinnger,R.C.(2006). Aggregate for Concrete. in Portland Cement Association (PCA), *Engineering Bulletin*. Skokie, IL: Portland Cement Association.

Mohammed, G. A., & Al-Mashhadi, S. A. A. (2020). Effect of Maximum Aggregate Size on The Strength of Normal and High-Strength Concrete. *Civil Engineering Journal*, 6(6), 1142–1155.

Neville, A.M. and Brooks J.J. (2010). *Concrete Technology* (Second Edition). London:

Ndon, A. I., & Ikpe, A. E. (2020). Experimental study on the Effect of Different Coarse Aggregate Sizes on the Strength of Concrete. *International Journal of Engineering and Innovative Research*, 3(1), 1–10.

Ogundipe, O. M., Akinkurolere, O. O., Nnochiri, E. S., & Ale, P. O. (2018). Effects of Coarse Aggregate Size on the Compressive Strength of Concrete. *Civil Engineering Journal*, 4(4), 836–842.

Okereke, P.A. (2003). *Construction Materials: Testing and Quality Control in Tropical Climate*. Crown Publishers: Owerri, Nigeria.

Tam, V. W. Y., Le, K. N., & Butera, A. (2023). Advances in Concrete Aggregate Technology and Structural Performance. *Materials,* 16(4), 1458.

Udoeyo, Iron, and Odim (2006). Strength Performance of Laterized Concrete. Construction and Building *Materials*, 20(10), 1057-1062.

Umasabor, R. I., & Osayogie, E. O. (2020). Effect of coarse aggregate sizes on the compressive strength of concrete using response surface methodology. *NIPES Journal of Science and Technology Research*, 2(1), 34–44.

Wang, L., Zhang, Y., & Liu, H. (2024). Experimental Assessment of Coarse Aggregate Size on Concrete Mechanical Behaviour. *Case Studies in Construction Materials*, 20, e02931.

Waziri et al. (2011).Investigating the Effect of varying the Size of Coarse Aggregate on the Size of Coarse Aggregate on the Strength Development of Concrete

Zhang, P., Xu, S., & Wu, J. (2023). Aggregate Particle Size Effects on Concrete Microstructure and Strength Development. *Materials Today Communications*, 35, 106114.