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Influence of Aggregate Shape on the Workability and Strength Development of Concrete

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ABSTRACT: *This study investigates the effect of aggregate shape on the properties of concrete, focusing on key factors such as angular and rounded shaped coarse aggregates. The experiment involved preparing concrete specimens and analyzing the influence of the aggregates varying shapes on the workability and strength development through the slump and compressive strength tests respectively. The slump provided insight to measure the consistency and moisture content of fresh concrete before it is poured, which influences the workability. The compressive strength tests were conducted at 7, 14, and 28 days using a rebound hammer method to assess the load-bearing capacity of the concrete over time. The results indicated that aggregates with angular shapes contributed to higher slump value and compressive strengths due to improved interlocking between particles, leading to better load distribution. In contrast, rounded aggregates exhibited lower workability and compressive strength, likely due to a reduced ability to form stable particle networks. These findings underscore the importance of aggregate shape in optimizing concrete mix designs for enhanced structural performance. The study concludes that aggregate shape significantly influences the mechanical properties of concrete, with angular aggregates offering superior workable concrete and improved strength characteristics. The results have practical implications for construction practices, particularly in the selection of aggregates for concrete applications where improved mechanical credentials is critical*

Keywords: Concrete, Workability, Coarse Aggregates and Compressive Strength

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I. INTRODUCTION

Concrete is a composite that is widely used globally in the construction industry due to its strength, durability, and versatility and made of aggregates bonded together by liquid cement which hardens over time (Woode *et al.,* 2015). Research has shown that changes in coarse aggregate which makes up about 60-75% of the total volume of concrete can change the strength properties of concrete (Oseke, 2017). The aggregates are generally categorized into fine aggregates (sand) and coarse aggregates (gravel or crushed stone). To predict the behavior of concrete under general loading requires an understanding of the effects of aggregate size. Aggregates serve as a filler material but also play a crucial role in defining the properties of concrete. They influence the workability, strength, dimensional stability, and durability of concrete. The compressive strength of concrete is one of the major properties that structural engineers take into consideration before erecting any structure (Meyer & Baxter, 2018). Compressive strength of concrete can be affected by many factors including water to cement ratio, aggregate size, degree of compaction and shape. Aggregate gradation plays an important role in concrete mixing.

Aggregates are the most mined material in the world and are responsible for the unit weight, elastic modulus and dimensional stability of concrete because these properties depend on the physical characteristics (strength and bulk density) of the aggregate (Oseke, 2017). Accordingly to (Mehta & Monteiro, 2006), the shape, size, texture, and grading of aggregates significantly affect the behavior of concrete. However, among these factors, the shape of the aggregate is particularly critical as it impacts the mix design, mechanical properties, and overall performance of concrete (Woode *et al.,* 2015).Generally, in lower strength concretes, the reduction in mixing water is sufficient to offset the detrimental effects of aggregate size. While, in high-strength concretes, the effect of size dominates, and the smaller sizes produce higher strengths. The shape, size, texture, and grading of aggregates significantly affect the behavior of concrete. Among these factors, the shape of the aggregate is particularly critical as it impacts the mix design, mechanical properties, and overall performance of concrete (Mehta & Monteiro, 2006).

Aggregate shapes can be classified into different categories such as angular, sub-angular, rounded, and flaky. The shape of aggregates directly affects the concrete's strength and workability. Angular, elongated, or flaky particles interlock more effectively than smooth, rounded ones, resulting in a stronger but less workable mix. Conversely, rounded aggregates improve workability but may decrease the overall strength of the concrete due to less efficient particle interactions (Oseke, 2017). Angular aggregates, often produced by crushing rocks, have sharp edges and rough surfaces, which contribute to a better interlocking effect and increased strength of concrete (Faliang *et al.,* 20205). On the other hand, rounded aggregates, typically found in riverbeds, provide better workability due to their smooth surfaces but may reduce the strength due to less interlocking (Faliang *et al.,* 2025).

Several studies have been carried out to investigate the effect of types, proportions, physical and mechanical properties of aggregate on the compressive strength of concrete. However, researches focusing on the effect of the particle size distribution of coarse aggregate are still limited and its effect is not yet well established. According to Sahin *et al.* (2003), increase in strength for a given increase in cement content depends on the type of aggregate used and the cement content. Similarly, Faliang *et al*, (2025) have found that for the same properties of concrete paste with varying constituent such as shape, texture, mineralogy and strength may result in different concrete strengths.

As pointed out above, the aggregate properties depend on the properties of the parent rock (e.g., chemical and mineralogical composition, petrographic classification, specific gravity, hardness, strength, physical and chemical stability and pore structure). All these characteristics have an important influence on the properties of both fresh and hardened concrete (Li *et al.,* 2025). Whilst Golewski, (2023) have found that andesite and dolomite provide a highly stiffer concretes than granite or quartzite. Results of Li *et al.* (2023) have shown that concrete made with basalt has higher compressive strength than that made with triassic or limestone aggregate. Moreover Li *et al,* (2025) reports that crushed rocks are more suitable for high strength concrete production as compared to natural gravel and sand.

In this regard, this study presented herein is to achieve a better understanding of the effect of particle size distribution of coarse aggregates on the compressive strength of concrete, and hence, to propose a proper design of concrete with the adequate proportions of granular fractions depending on the type of concrete targeted and give better understanding into the relationship between aggregate shape and concrete properties is essential for optimizing mix design and achieving desired performance outcomes

II. MATERIALS AND METHODS

Cement

Portland limestone cement (PLC) with a specific gravity of 3.15 sourced from the Federal University Otuoke concrete laboratory conforming to provisions reported in Oseke, (2017). A precautionary measure to prevent the cement from lumps formation during the tests was done by keeping it away from moisture. Table 1 presents the chemical compositions of Portland cement as the binder materials used in this study, highlighting its complementary characteristics. Similarly, the major physical characteristic of Portland cement as the binder materials is provided in Table 2.

Table 1: Chemical composition (%) of Portland limestone cement

Constituents (wt %)	Portland limestone cement
CaO	61.49
MgO	3.54
SiO_2	18.84
Al_2O_3	4.77
Na_2O	0.02
P_2O_5	0.1
Fe_2O_3	2.87
Mn_2O_3	0.05
K_2O	0.57
SO_3^-	0.05
Loss of ignition	4.3

(Source: Extracted from Oseke, 2017)

Table 2: Physical properties of Portland limestone cement

Constituents (wt%)	Portland limestone cement
Insoluble residue	0.5
Bulk density(kg/m^3)	1400
Specific gravity(g/cm^3)	3.15
Glass content	-
Blaine fineness(m^2/kg)	365
Alkalinity value (pH)	13.41
Colour	Grey
Physical form	Fine

(Source: Extracted from Oseke, 2017)

Fine and Coarse Aggregates

The fine aggregates used was river sand and was locally sourced from within the Federal University Otuoke environment, with a fineness modulus of 2.7, while the coarse aggregates comprising the angular and rounded shaped aggregates were crushed granite with a nominal maximum size of 20 mm sourced from local dealers within Otuoke community, Ogbia Local Government Area f Bayelsa. Other properties of the coarse aggregates are listed in Table 3.

Table 3: Properties of coarse aggregates

Properties	Angular	Rounded
Specific Gravity	2.74	2.68
Bulk Density (kg/m^3)	1592	1568
Water Absorption (%)	0.15	0.11
Aggregate Crushing Value (%)	12.17	10.22

Water

The water was sources from the Federal University Otuoke water supply through an installed Tap within University Otuoke concrete laboratory with oxide composition meeting BS EN 196 requirements for mixing and curing purposes of concrete mixes.

Apparatus

The testing apparatus used for this investigation includes: 150 mm x 150 mm x 150 mm steel molds, tags sieves, retainers, brush, weighing instrument, trowel, spanners, shovel, slump test cone, curing tank and concrete rebound hammer.

Mixing Procedure

Concrete mixes were prepared using a pan mixer in accordance with BS EN 196 standards, as well the mixes was designed to ensure adequate workability and consistency, factoring in the effects of different aggregate shapes on the strength properties

Specimens Preparation and Program

The preparation involves categorizing the specimen into angular and rounded aggregates representing 6 different sets of concrete cubes. These categories were subjected to a testing program for compressive strength test at 7, 14, and 28 days of curing. Each specimen was prepared to ensure uniformity and accuracy in testing.

Proportion of Mixtures

The concrete proportion of mixture design was adopted from previous researches according Oseke (2017), and based on British standard (BS EN 196). However, it was modified for the current investigation with a water-cement ration of 0.65 and the ratio was maintained for all the same for all mixes.

Specimens Testing

The testing for compressive strength of the concrete specimens was done using a rebound hammer. The rebound hammer test, as per BS EN 196, measures the surface hardness of concrete. Multiple points were tested on each concrete specimen's surface, and the average rebound number was recorded. The compressive strength was calculated using Equation 1 as shown below. According to Li *et al.,* (2022), this equation is based on the rebound hammer (Schmidt Hammer) test, a non-destructive method for estimating concrete strength.

$$\text{Compressive Strength (N/mm}^2\text{)} = a \times R + b \quad (1)$$

Where:

I. R = Rebound number (average of multiple points tested

II. *a and b = Constants derived from the calibration curve specific to the concrete mix used.*

The rebound hammer results were validated by comparing them with the compressive strength tests conducted on the same specimens using the standard crushing test.

III. RESULTS AND DISCUSSION

Workability

The workability is tested using the slump value and its results presented in Table 4 while the graphical representation is shown in Fig. 1. The slump values increase as the coarse aggregate size increases for both angular and rounded aggregate at constant water-cement ratio. This proportional relationship is consistent with the results of other investigators (Woode *et al.,* 2015). Larger aggregates have less surface area to be wetted per unit mass and when the water-cement ratio is kept constant, more water will be available in the mix to increase workability and thereby increasing the slump values of the concrete mix. Consequently, larger aggregates will require less water to achieve high strength (Singh, & Siddique, 2019).

Table 4: Slump Test Results

Aggregate Size (mm)	Slump	
	Angular Shaped Aggregates	Rounded Shaped Aggregates
5.0	25	26
6.3	27	30
10.0	32	36
14.0	37	43
20.0	42	47
25.0	49	57

Therefore, it can be stated that slump values are indicators of compressive strengths of hardened concrete (Oseke, 2017).Concretes made with smaller coarse aggregates tends to have higher compressive strength than concretes produced with larger sized coarse aggregates, which is attributed to weak bonds in concretes with larger aggregates as a result of heterogeneity, internal bleeding and micro cracks development (Singh, & Siddique, 2019). Fig. 1 shows the relationship between slump values of concrete mix made with angular shaped coarse aggregates with those of concretes mix made with rounded coarse aggregates. Although slump values increase with increasing size of coarse aggregate for both angular rounded shaped aggregates, it has been observed that concrete mix produced with rounded coarse aggregate have higher slump values than concrete mix produced with angular coarse aggregate. This is due to the smooth surface texture of rounded aggregates that is responsible for improving workability

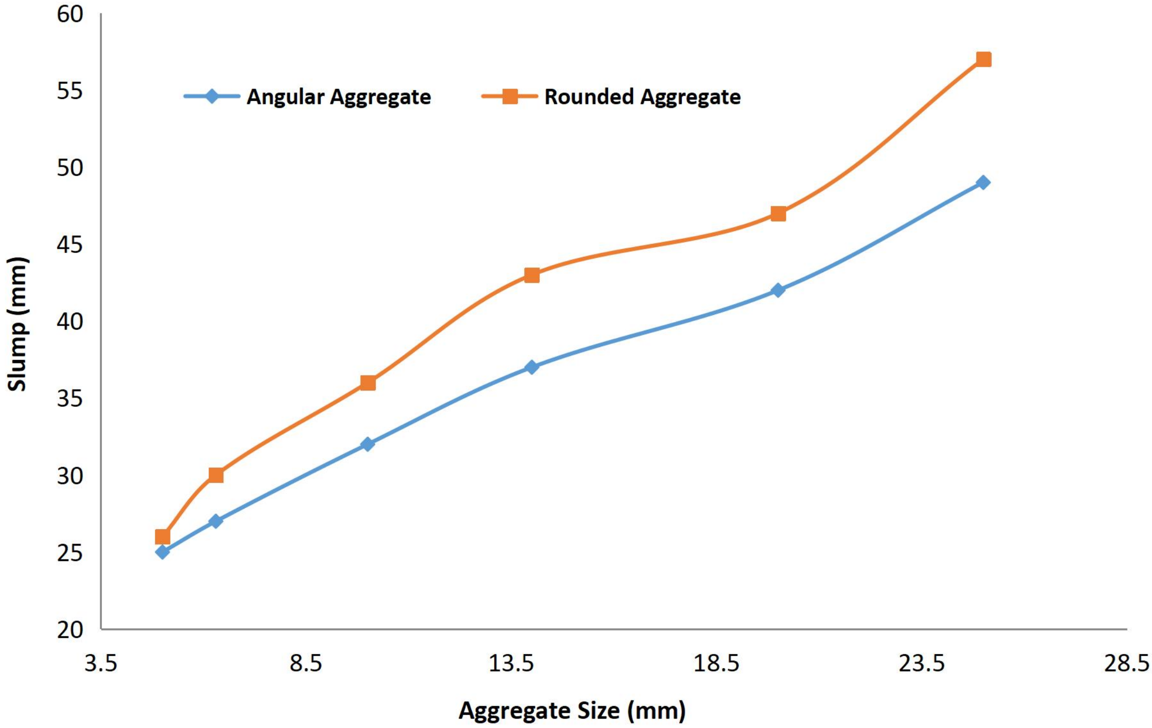

Fig. 1: Graphical presentation of slump of concrete for angular and rounded aggregates

Compressive Strength Test Results

The average compressive strengths result for the different concrete mixes with angular and the round shaped coarse aggregate sizes are presented in Table 5, using the rebound hammer method. Similarly, shown in Fig. 4, is the graphical representation of the combine averages compressive strength of concrete for angular and rounded coarse aggregates using the rebound hammer method**.** Higher strength were observed for the angular shaped aggregate and the rounded shaped aggregates at 14 days curing age with a slight decrease in the compressive strength values as the curing approach the 28 day days. The 7 days curing witnessed the lowest strength values for the angular and rounded aggregates respectively. This can suggest that strength development at curing between 14 day and 28 days may exhibit same trend as against the 7 day curing period. Regarding the results of the compressive strength obtained, it should be noted that in case of the strength development a roughly graded particle size distribution system is more advantage and provides a better compressive strength than the smoothly graded aggregate. The results agrees with Woode *et al.* (2015), who reported that compressive strength of concrete made with aggregates of higher angularity surfaces exhibits higher strength at all curing ages compared to more rounded aggregates indicating how particle size distribution of coarse aggregate influence the compressive strength of concrete.

Angular aggregates are generally rough in texture, while rounded aggregates are smooth in texture (Singh, & Siddique*,* 2018).According to Popovics (2004), rough surfaces of aggregates are believed to bond better to cement paste than smooth surfaces aggregates, although at microscopic level rounded aggregates have surfaces rough enough to form an adequate bond with cement paste since cement paste has particles sizes in the smaller range (Bala, and Aminullahi, (2014). The specific surface area of angular aggregates is higher than that of rounded aggregate, higher specific surface areas result in better surface adhesion, load distribution and coupled with better interlocking effects resulting in concrete with better compressive strength than rounded aggregates (Aginam *et al.,* 2013). These findings are in consistent with the expected behavior of concrete as it continues to hydrate and gain strength over time thereby collaborating findings of other researchers (Ogundipe *et al.*, 2018).

Summarizing the influence of the coarse aggregate on the compressive strength of concrete, it can be concluded that the angular shaped aggregates plays a predominant role within the concrete mixture regarding the development of mechanical properties such as compressive strength. It is believed that in order to improve the mechanical performance of concrete material, the angular shaped aggregates based concrete should be optimized as results have clearly shown that the compressive strength of concrete mixture is mainly influenced by the composition of the angular shaped aggregates.

Table 5: Compressive Strength Test Results

Days	Points	Rebound Number	Angular shaped aggregates Compressive Strength (N/mm^2)	Rebound Number	Round shaped aggregates Compressive Strength (N/mm^2)
7	Point 1	12.5	9.88	12	9.48
	Point 2	12	9.75	12.5	9.58
	Point 3	13.5	10.66	14.5	11.46
	Point 4	14	11.76	13	10.27
	Point 5	15	11.55	13	10.27
			Avg.=10.758		**Avg.= 10.212**
14	Points	F2 Rebound Number	Compressive Strength (N/mm^2)	Rebound Number	Compressive Strength (N/mm^2)
	Point 1	17	13.43	16	12.64
	Point 2	17	13.43	16	12.64
	Point 3	15	11.85	15.5	12.15
	Point 4	16.5	13.04	18	13.22
	Point 5	16.5	13.04	17	13.43
			Avg.=12.192		**Avg.= 12.816**
28	Points	F3 Rebound Number	Compressive Strength (N/mm^2)	Rebound Number	Compressive Strength (N/mm^2)
	Point 1	16	12.64	15	11.55
	Point 2	15	13.85	17	13.43
	Point 3	16	11.74	17	13.43
	Point 4	15	13.05	15	12.85
	Point 5	17	13.43	17	13.12
			Avg.= 12.142		**Avg. =12.876**

Note: Avg = Average

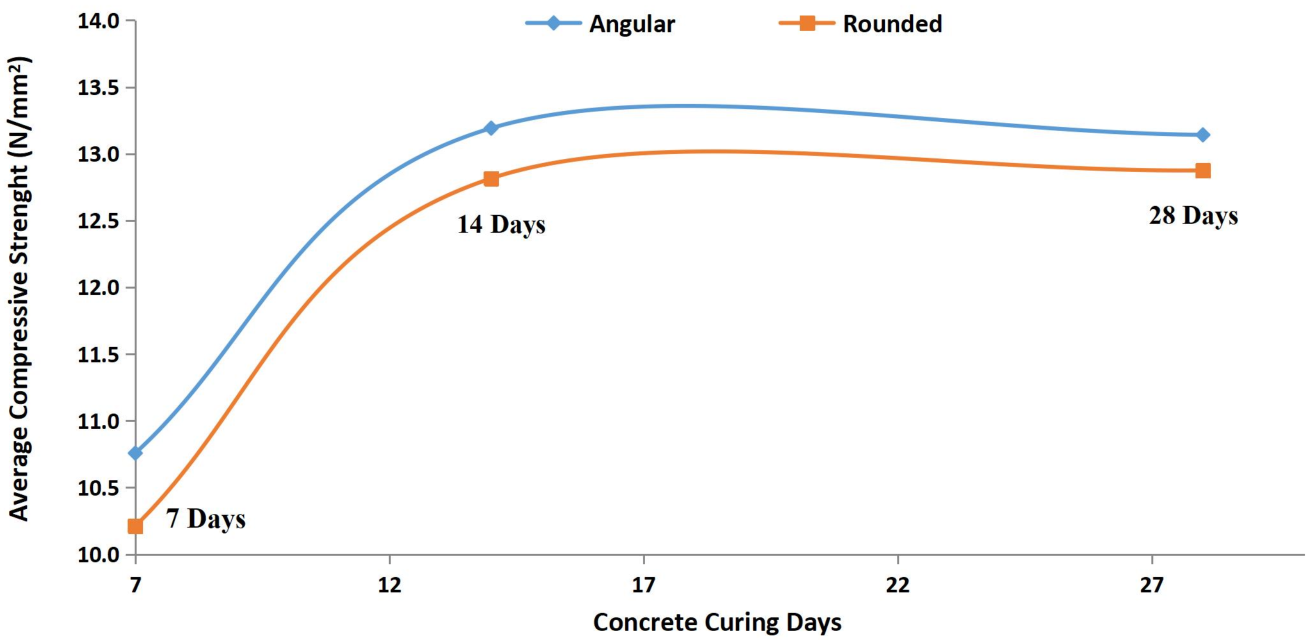

Fig. 2: Graphical representation of the combine averages compressive strength of concrete for angular and rounded coarse aggregates

IV. CONCLUSION

This research presented results of effect of the size and shape of coarse aggregate with a specific focus on the on the workability and compressive strength of concrete over time.

i. The findings of this research further suggest that the shape of aggregates is a key consideration when designing concrete mixes, particularly for applications where high strength is critical. Higher slump values were obtained in concrete with angular shaped aggregates

ii. Under the same curing conditions and the same water-cement ratio, aggregates with angular and rough surfaces contributed to higher compressive strength in concrete when compared to rounded aggregates.

iii. Angularity of the aggregates in concrete generally allows for better interlocking, which enhanced the load-bearing capacity of the concrete, as compressive strength increases steadily over the 28-day period which is typical of the hydration processes in concrete.

Based on the results of this research, it is recommended when producing concrete for load-bearing application, attention must be focus must be on the size and shape of the aggregate when selecting materials for concrete mix designs, as this can significantly impact the long-term durability and strength of the structure.

REFERENCES

Aginam, C.H. Chidolue C.A, and Nwakire, C. (2013): "Investigating the Effect of Coarse Aggregate on the Compressive Strength of Concrete," *International Journal of Engineering Research and Application.* ISSN: 2248-9622, Volume 3 (4), pp.1140-1144.

Bala, A and Aminullahi, O (2014): "The Effect of Coarse Aggregate Shape on the Properties of Concrete," *Nigeria Journal of Engineering and Applied Science*, Volume 1 (4).

BS EN 196: Methods of Testing Cements,' *British Standard Specification*, London, 2000

Faliang Gao, Zhi Ge, Huaqiang Yuan, Hanming Zhang and Hongzhi Zhang, (2025): Influence of aggregate characteristics on workability and rheology of self-compacting concrete, *Case Studies in Construction Materials*: Volume 22, ISSN 2214-5095, https://doi.org/10.1016/j.cscm.2025.e04595.

Golewski, G. L. (2023): Assessing of water absorption on concrete composites containing fly ash up to 30 % in regards to structures completely immersed in water, *Case Studies in Construction Materials*. Volume 19, e02337, ISSN 2214-5095, https://doi.org/10.1016/j.cscm.2023.e02337

Li, W., Cao, W., Ren, X., Lou, S., Liu, S., & Zhang, J. (2022): Impacts of aggregate gradation on the volumetric parameters and rutting performance of asphalt concrete mixtures. *Materials (Basel), 15*, Article 4866. https:// doi.org/ 10. 3390/ ma151 44866

Mehta, P. K., & Monteiro, P. J. M, (2006): Comparative Studies of Steel, Bamboo and Rattan as Reinforcing Bars in Concrete: Tensile and Flexural Characteristics, *Open Journal of Civil Engineering*, Vol.5 No.2.

Meyer, C., & Baxter, S. (2018): Utilizing SCMs to Enhance the Durability of Concrete with Rounded Aggregates. *Cement and Concrete Composites*, 91, 32-41.

Ogundipe, M.O. Olanike, A.O. Nnochiri, E.S, and Ale, P.O. (2018): Effects of Coarse Aggregate Size on the Compressive Strength of Concrete, *Civil Engineering Journal*, Volume 4-(4).

Oseke Ifie-Emi Francis (2017): Durability of Concrete Incorporating Ground Granulated Blast-furnace, *Nigerian Journal of Scientific Research, (*Online) Vol. 16(3):

Popovics, J. S. (2004): Aggregate Shape and Its Impact on Concrete Properties. *Journal of ASTM International*, 1(1), 100-114

Sahin R, Demirbog˘ RA, Uysal H, Gul R. (2003): The effect of different cement dosages, slumps and pumice aggregate ratios on the compressive strength and densities of concrete. Cement Concrete Research; 33(8):1245–9.

Singh, & Siddique, (2019): Influence of Aggregate Shape on Workability and Strength of Concrete. *Journal of Building Materials*, 22(3), 345-354.

Woode, A, Amoah, D.K Aguba, I.A, and Ballow, P. (2015): "The Effect of Maximum Coarse Aggregate Size on the Compressive Strength of Concrete Produced in Ghana," *Civil and environmental Research*. ISSN: 2224-5790 (Paper) ISSN: 2225-0514 (Online). Volume 7 (5)

