

## EFFECTS OF AGGREGATE GRADATION ON THE PROPERTIES OF CONCRETE MADE FROM GRANITE CHIPPINGS.

Okonkwo V. O<sup>1</sup> and Arinze Emmanuel E<sup>2\*</sup>

<sup>1</sup>Department of Civil Engineering  
Nnamdi Azikiwe University, Awka, Nigeria  
odinakao@gmail.com

<sup>2</sup>Department of Civil Engineering  
Michael Okpara University of Agriculture, Umudike, Nigeria.  
[emmanuel.arinze@mouau.edu.ng](mailto:emmanuel.arinze@mouau.edu.ng)

\*corresponding author

### Abstract

Aggregate shape, size and grading can influence concrete workability. The volumes of water and cementations materials are commonly increased to accommodate poorly shaped or poorly graded aggregates. In this work the properties of concrete in fresh and hardened stage using different aggregate sizes and mix design was investigated. This was done using coarse aggregate of sizes 25mm, 20mm, 12mm and 6mm with mix ratios 1:2:4, 1:1.5:3 and 1:3:6. The experiments were conducted and it was found that concrete with coarse aggregate size 20mm had the highest compressive strength for any mix ratio. But the mix ratio 1:1.5:3 produced the highest compressive strength and density.

Keywords: aggregate size, concrete workability, compressive strength, granite chippings, concrete properties.

### Introduction

Concrete is a mixture of water, cement or binder and aggregates and is a commonly used material for construction. (Barritt, 1984). The strength of concrete depends on aggregate type, size and source (Abdullahi, 2012; Hassan, 2014; Aginam et al 2013; Jimoh and Awe 2007). Aggregates amount to at least three-quarter of the volume of normal weight of concrete (Neville 2003) and they are cheaper than cement and also confers a considerable better durability in concrete than the ordinary cement paste. The aggregates are divided into two major divisions by size- fine and coarse. The fine aggregates are sizes not larger than 5 mm while the coarse aggregate are sizes of at least 5 mm (Neville, 2003). There has been concern about the best aggregate sizes to be adopted in the manufacturing of concrete in the Nigerian construction industry. Compressive strength of concrete is the value of test strength below which not more than a prescribed percentage of the test results should fall (Kong and Evan 1987).

It is found to depend on the water to cement ratio, degree of compaction, ratio of cement to

aggregate, bond between mortar and aggregate, and grading, shape, strength and size of the aggregate (Rocco and Elices, 2009; Elices and Rocco, 2008).

Neville (1981) in his research findings published that entirely smooth coarse aggregates lowered the strength of concrete by 10% than when the aggregates were roughened. He reaffirmed the works of Bloem and Gaynor (1963) and Stanon and Bloem (1960) which reported that at equal water/cement ratio, irregular shaped smaller sized aggregates without coatings achieved a better strength than smooth rounded large sized aggregates. However, Young and Sam, (2008) stated that smooth rounded aggregates was more workable but yielded a lesser compressive strength in the matrix than irregular aggregates with rough surface texture. They were also of the opinion that a fine coating of impurities such as silt on the aggregate surface could hinder the development of a good bond and thus affects the strength of concrete produced with the aggregates.

### Materials and Methods

The materials used for this study include Portland cement, granite chippings, fine aggregate (sharp sand), and water. The aggregate used were of sizes 25mm, 20mm, 12mm and 6mm. The fine aggregate was sharp river sand. Dangote Portland cement (a popular Nigerian brand of cement) was used. Clean water was used in all the experiments. The freshly mixed was tested for workability (slump test) according to BS EN 12350-2:2009. The was carried for concrete of aggregate sizes 25mm, 20mm, 12mm and 6mm and for concrete mixes 1:2:4, 1:1.5:3 and 1:3:6 by volume. The hardened concrete was thereafter test for compressive strength according to BS EN12390-3:2009.

**Results and Discussion**

The results of the experiments are presented in tables 1 and 2 below. They were also plotted in Figures 1 and 2 for clarity.

**Table 1:** Slump test results

Aggregate Size (mm)	Slump(1:2:4) (mm)	Slump(1:1.5:3) (mm)	Slump (1:3:6) (mm)
6	20	50	0
12	60	161	10
20	100	118	20
25	90	114	0

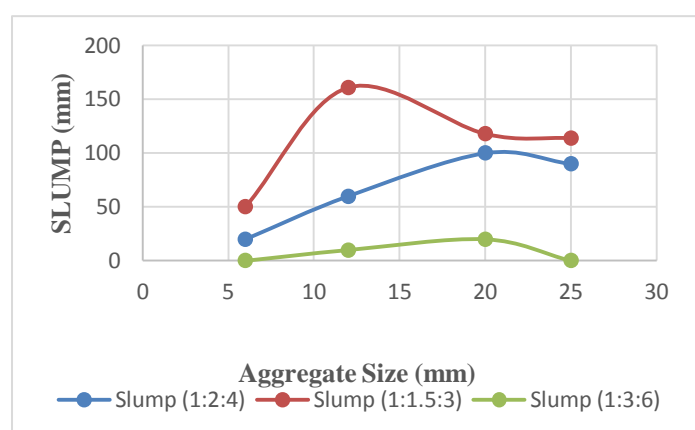


Figure 1: Comparison of slump for various mix ratios

From table 1 and Figure 1 the concrete mix ratio of 1:1.5:3 had the highest slump. This is followed by the concrete mix 1:2:4 while the concrete mix 1:3:

6 has the lowest slump. It will be imperative to say that size of aggregates just like the mix design affected the slump value of the concrete. At the same w/c ratio, the concrete mix ratio of 1:2:4 with coarse aggregate 20mm had the highest slump result while for 1:1.5:3, the concrete mix with coarse aggregate 12mm has the highest slump.

**Table 2:** Compressive strength Test Result

Aggre gate size (mm)	Average Strength(N/mm <sup>2</sup> ) (1:2:4)	Average Strength(N/mm <sup>2</sup> ) (1:1.5:3)	Average Strength(N/mm <sup>2</sup> ) (1:3:6)
6	12.29	13.63	10.07
12	17.18	18.67	13.78
20	21.92	27.11	17.63
25	20.14	20.59	16.74

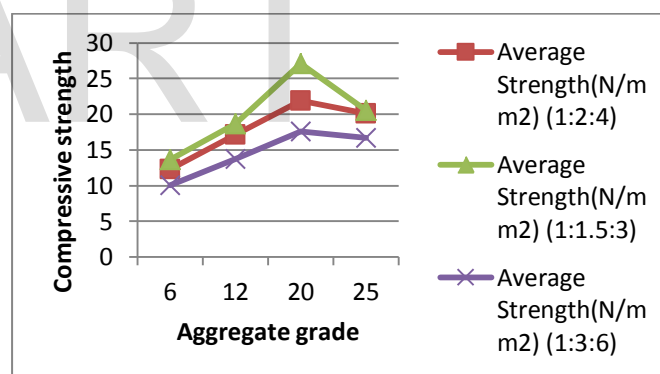


Figure 2 : Graph of Comparison of compressive strength for different mix ratios.

Figure 2 above shows the compressive strength test results of all the mix ratios employed in this work. It is observed that concrete mix ratio of 1:1.5:3 has the highest compressive strength value compared to other mix ratios. This is followed by the mix ratio of 1:2:4 while that of 1:3:6 have the lowest strength apparently because of its lower cement content. The result of the experiment also shows that the concrete mix with aggregate size 20mm maximum has the highest strength while that of 6mm has the lowest strength.

Below is the density table in accordance with concrete age for mix ratio 1:2:4, 1:1.5:3, and 1:3:6 respectively.

Table 3: Density Test results

Aggregate Sizes(mm)	Mean Density (1:2:4)	Mean Density (1:1.5:3)	Mean Density (1:3:6)
6	2131.36	2176.79	2126.42
12	2404.94	2396.05	2388.15
20	2414.81	2438.52	2409.88
25	2454.32	2427.65	2403.95

Compressive strength of concrete is the most important property of concrete used in the design of construction works. It is influenced by varying conditions ranging from mix proportions of the concrete constituents to type and size of aggregate used. Based on the results of this investigation carried out, the following conclusions can be drawn:

- a. 20mm coarse aggregate performed best for slump test for mix ratio 1:2:4 while 12mm coarse aggregate performed best for 1:1.5:3 mix ratio.
- b. 20mm coarse aggregate gave the highest compressive strength during crushing for all the mix ratios.
- c. 1:1.5:3 mix ratios gave the maximum compressive strength for the experiment conducted which is in line with the findings of Kozul and Darwin (1997).

**RECOMMENDATIONS:**

Based on the above conclusion, the following recommendations can be made;

- i. Concrete with aggregate sizes of 20mm should be adopted in the manufacturing of concrete in Nigeria and this aggregate size gave the overall best result in workability and strength for all the tested mix ratios.
- ii. Mix ratios with higher cement ratios as expected produced higher compressive strength.
- iii. There is a strong relationship between concrete density and concrete strength hence technology for measuring concrete density can easily be modified to measure concrete strength.

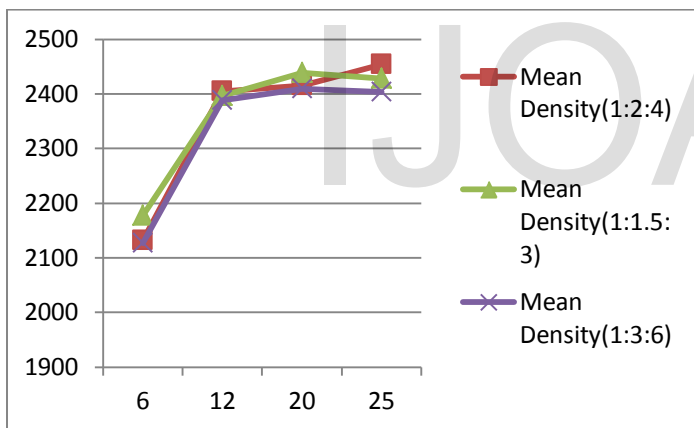


Figure 3: Comparison of the density of the different mix ratio against aggregate grade

Table 3 above and Figure 3 show the result of the density test carried out on the hardened concrete. It is seen that the density of the hardened concrete increases with respect to increase in compressive strength. The mix ratio of 1:1.5:3 gave the highest density while that of 1:3:6 gave a lower density. The density of the coarse aggregate of 20mm is slightly higher than that of the 25mm. The graph shows a good correlation between concrete density and strength.

**Conclusion and Recommendation**

## REFERENCES

- Aginam CH, Chidolue CA, Nwakire C. Investigating the effects of coarse aggregate types on the compressive strength of concrete. *International Journal of Engineering Research and Applications*. 2013;3:1140-1144.
- Barritt, C. M. H. (1984), *Advanced Building Construction*, Vol. I, 2<sup>nd</sup> Edition, J. W. Arrowsmith Ltd, Bristol.
- Bloem, D. L. and Gaynor, R. D. (1963) Effects of Aggregate Properties on Strength of Concrete, *ACI Journal*, Proceedings Vol. 60, Issue 10, pp. 1429-1456.
- BS EN 12350-2:2009: Testing Fresh Concrete: Slump Test
- BS EN 12390-3:2009: Testing Hardened Concrete. Compressive Strength of Test Specimens.
- Elices, M., and Rocco, C.G., (2008), Effect of Aggregate Size on the Fracture and Mechanical Properties of a Simple Concrete, *Engineering Fracture Mechanics*, 75(13), pp 3839-3851.
- Hassan NS. Effect of grading and types of coarse aggregates on the compressive strength and unit weight of concrete. Accessed on 10th September, 2014: Available:<http://www.iasj.net/iasj?func=fulltext&id=29047>
- Jimoh AA, Awe SS. A study on the influence of aggregate size and type on the compressive strength of Concrete. *Journal of Research information in Civil Engineering*. 2007;4(2):157-168.
- Kong, F.K. and Evans R.H. (1987) *Reinforced and Prestressed Concrete*. Pitman Publishers, London, UK.
- Kozul, R and Darwin, D (1997) "Effects of Aggregate Type, Size and Content on Concrete Strength and Fracture Energy" *Structural Engineering and Engineering Materials SM Report No.43*. University of Kansas Center for Research, Inc. Lawrence, Kansas
- Neville, A. M. (2003), *Properties of Concrete*, 4th Edition, Pearson Education, Delhi.
- Neville, A.M. (1981) *Properties of Concrete* (Third Edition) Longman Group Ltd. London, UK.
- Rocco, C.G., and Elices, M., (2009), Effect of Aggregate Shape on the Mechanical Properties of a Simple Concrete, *Engineering Fracture Mechanics*, (2009), 76(2), pp 286-298.
- Stanon, W. and Bloem, D.L. (1960) Effects of Aggregate Size on Properties of Concrete, *Journal of American Concrete Institute*. 57 pp. 203 – 290.
- Young, T.L. and Sam, A.R.M. (2008) Performance of Concrete Containing Engine Oil, Thesis Submitted to the University of Technology, Kuala Lumpur, Malaysia. compressive strength of concrete. *International Journal of Civil and Structural Engineering*. 2012;2(3):791-800.