Engineering and Technology Journal e-ISSN: 2456-3358
Volume 08 Issue 02 February-2023, Page No.-1992-1996
DOI: 10.47191/etj/v8i2.05, I.F. – 7.136

Effects of Coarse Aggregates Gradings on the Properties of Concrete

Okonkwo V. O.[1], Nwogu C. P.[2], Obiora J. I.[3], Njotae B. A.[4]
[1,2,3,4]Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Nigeria.

ABSTRACT: Coarse aggregates gradings have varying effects on the properties of concrete. Coarse aggregates of sizes 10mm, 20mm and 25mm were used for this study. Sieve analysis was conducted on these aggregates. Their coefficients of curvature (C_c) ranged between 1.01 and 1.19, while the coefficients of uniformity (C_u) ranged between 1.24 and 1.73, showing that they are all uniformly graded. 10mm and 25mm coarse aggregates were mixed in various proportions to produce five different concrete mixes (concrete C1, C2, C3, C4 and C5). Concrete C6 was produced with 100% 20mm and was used as a check. Slump test was performed for each mixture, C1 gave the highest slump height of 88mm. Compressive strengths of the cast concrete cubes were determined after 7- and 28-days curing periods. C4 gave maximum compressive strength of 26.33N/mm^2 at 28 days. Increase in the percentages of 25mm aggregates resulted in higher compressive strength and decreased workability.

KEYWORDS: coarse aggregates, gradation, concrete, slump, workability, compressive strength.

1. INTRODUCTION

As a mixture of water, binders/cement and aggregates, concrete is one of the most generally used construction materials [1]. Several factors such as type, size and source of aggregates influence the characteristic strength of concrete [2] [3] [4] [5]. Other factors which influence the strength of concrete include their batch ratios, processes, aggregate texture and shape as well as the nature of other constituent materials [6].

At least, about three-quarter of the volume of normal weight of concrete is made up of aggregates [7] and they are cheaper than cement and also confer a considerable better durability in concrete than the ordinary cement paste. The aggregates are divided into two major divisions by size namely: fine and coarse. The fine aggregates are sizes not larger than 5 mm while the coarse aggregate are sizes of at least 5 mm [7].

Over the years, there has been concern about the best aggregate sizes to be adopted in the manufacturing of concrete in various construction industries. Effect of aggregate properties on concrete like grading of aggregates depends on proportions the coarse aggregate is varied or also the proportions of coarse aggregate and fine aggregate. If grading of aggregate is varied, it also changes cement content (cost economy), workability of the mix, density and porosity. Aggregate characteristics like shape, texture, and grading influence workability, finishing, bleeding, pumpability, and segregation of fresh concrete and affect strength, stiffness, shrinkage, creep, density, permeability, and durability of hardened concrete [8]. All these characteristics have an important influence on the properties of both fresh and hardened concrete [9] [10].

Coarse aggregates grading is an important factor and has a maximum influence on workability. Well graded aggregates result in the least number of voids in a given volume. Less voids result in excessive paste availability in a unit volume, hence, more lubrication. As a result, the mix will be cohesive and devoid of segregation.

2. METHODOLOGY

The utilization of three sizes (25mm, 20mm, and 10mm) of commercially available coarse aggregates (chippings) for concrete work was investigated. Normal concrete was produced from these different sizes of aggregates. The selected aggregates were spread out for few days before use, to dry, in order to keep the aggregates at surface dry condition.

Normal mix (1:2:4) and water – cement ratio of 0.55 was adopted for this work. Mix composition was obtained by weight method.

The workability and compressive strengths of five different concretes made by using two different coarse aggregates (25mm and 10mm) in various mix proportions were investigated. The third size which is 20mm was used as check.

Materials

The basic components of concrete (cement, fine aggregates, coarse aggregates and water) were used at their stipulated proportions.

Commercially available ordinary Portland cement (BUA Portland cement) was used for this research. The fine aggregate used is sharp river sand obtained from a local dealer in Awka, Anambra state, Nigeria. The three sizes of commercially available chippings (25mm, 20mm, and 10mm) which were used as coarse aggregates were also obtained from a local dealer. Clean water was obtained from Civil Engineering laboratory, Nnamdi Azikiwe University, Awka.

Methods

A total of six concretes were produced. Five were made using the 25mm and 10mm sizes of coarse aggregates at various proportions while the sixth was produced using only 20mm aggregates. The various mixes are designated as follows: Concrete C1 [100% of 10mm + 0% 25mm coarse aggregates], concrete C2 [75% of 10mm + 25% of 25mm coarse aggregates], concrete C3 [50% of 10mm + 50% of 25mm coarse aggregates], concrete C4 [25% of 10mm +75% of 25mmcoarse aggregates], concrete C5 [0% 10mm + 100% 25mm coarse aggregates], and concrete C6 [100% of 20mm coarse aggregates].

3. RESULTS

Gradation Test

The grain size distributions of the fine and coarse aggregates used in this study are shown as plotted in the log graphs in Figure 1(a – d). The coefficients of curvature and uniformity (Cu and Cc) were evaluated for the four aggregate samples.The produced concretes were subjected to slump test and compressive strength test.

Slump Test

A concrete slump test is a measure of the behaviour of inverted cone of concrete under gravity. It measures the consistency or wetness of a concrete which eventually gives a suggestion about the workability condition of the mix. It not only observes the consistency between different batches of concrete, but it also detects defects in a concrete mix, giving room for adequate amendment.

Compressive Strength Test

The compressive strength of concrete is its ability to withstand loads before failure. Among all the tests performed on concrete, compressive test is the most important, since it gives an idea about the characteristics of concrete. The compressive strength is calculated by dividing the failure load with the cross-sectional area of the resisting load. It is reported in units of pound-force per square inch (psi) in US Customary units or megapascals (MPa) in SI units.

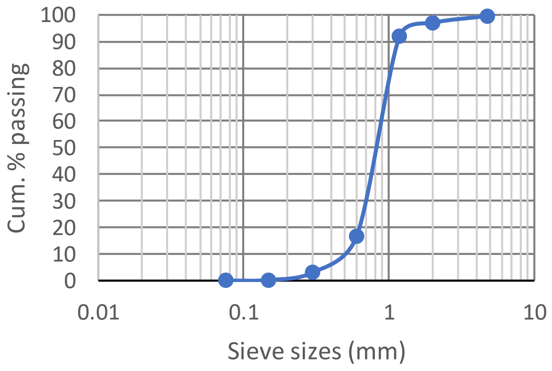

Figure 1(a): Gradation Graph for Fine Aggregate

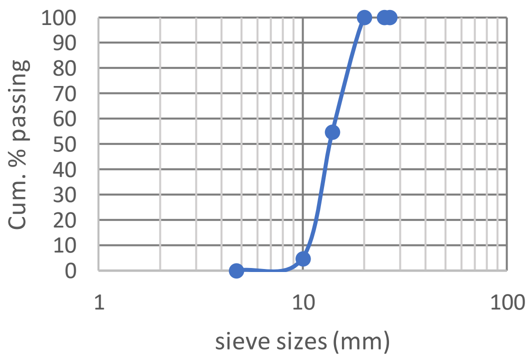

Figure 1(b): Gradation Graph for 10mm Coarse Aggregate

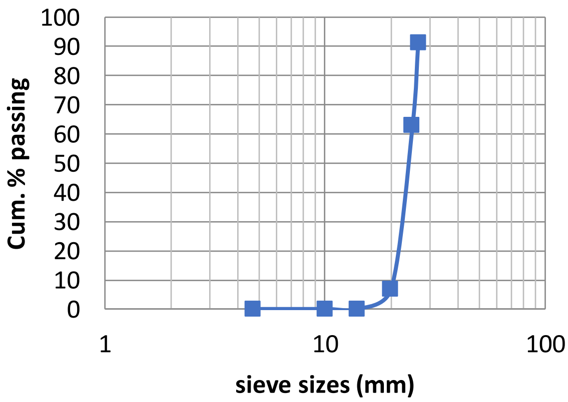

Figure 1(c): Gradation Graph for 20mm Coarse Aggregate

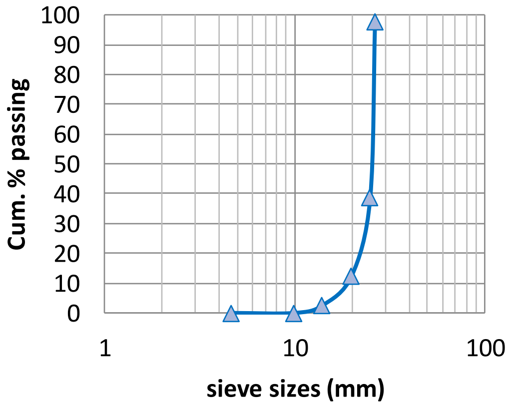

Figure 1(d): Gradation Graph for 25mm Coarse

Soil particles with coefficient of curvature (C_c) between 1 and 3 shows that the particles are well graded. The soil is poorly graded when its coefficient of curvature is less than 1; if it is 1, then the soil is uniform. The coefficients of curvature of the fine and coarse aggregates, as evaluated from the gradation graphs ranged between 1.01 and 1.19. This implies that they are all well graded particles.

The coefficient of uniformity (C_u) is a dimensionless ratio of the diameters of particles of soil which is used to differentiate between well-graded and poorly-graded soils. When the value of the coefficient of uniformity is greater than 4 to 6, the soil can be classified as well graded. But if the C_u value is less than 4, the soil is classified as poorly or uniformly graded. The C_u of the fine and coarse aggregates used in this study ranged between 1.24 and 1.73. This implies that the soils are uniformly graded.

For a soil to be well graded, the coefficient of curvature has to fall between 1 and 3 as long as the coefficient of uniformity is greater than 4 for gravels and 6 for sand. Therefore, judging form the values of the C_c and C_u of these aggregate, they are all uniformly or poorly graded. This is in line with findings of [11].

Concrete Slump

The concrete slump test estimates the consistency of a freshly mixed concrete before it gets set. It helps to check the workability of a freshly mixed concrete, thus, the ease at which it flows.

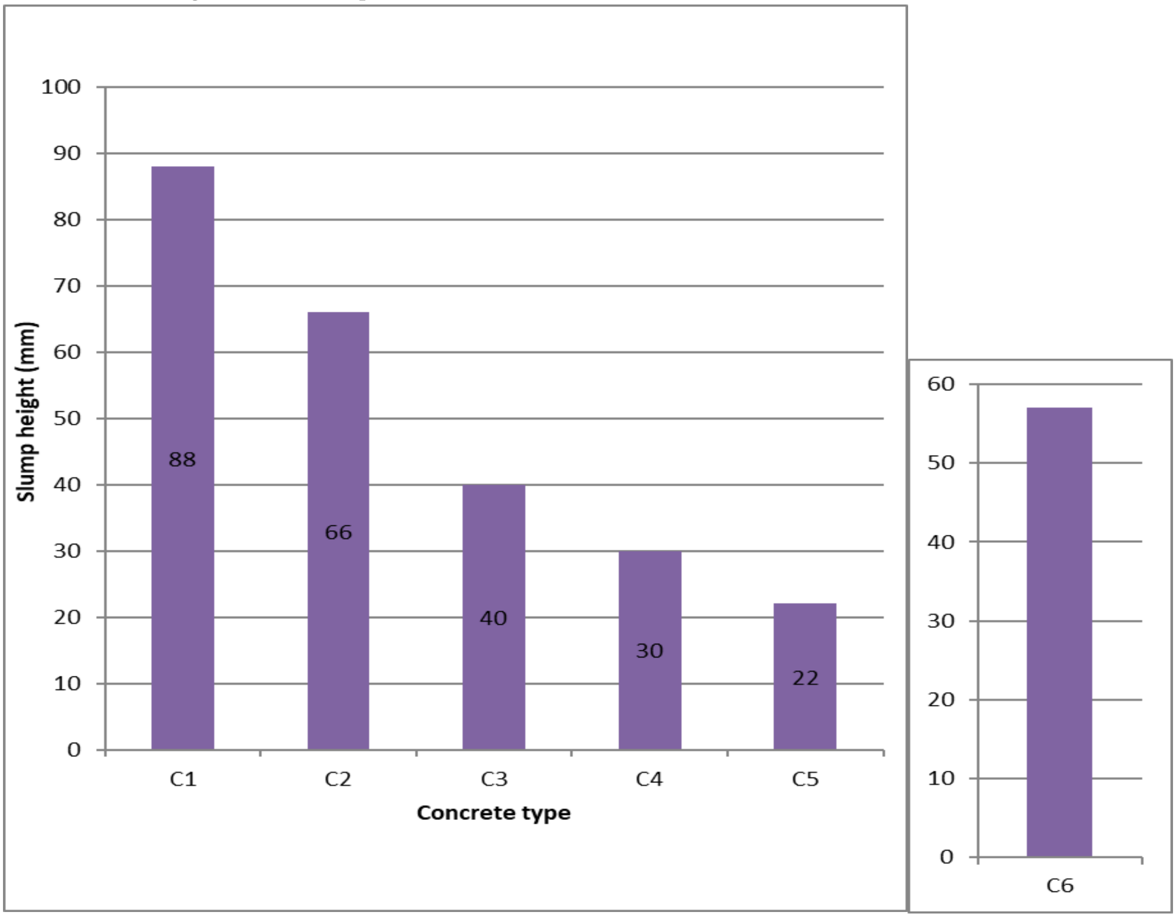

Figure 2: Slump Values of the Concretes

Generally, workability decreases with the increase in the sizes of aggregates. From Figure 2, C1 (100% 10mm) is found to have the highest slump height; this shows that it is more workable than others. The workability keeps decreasing as the ratio of 25mm aggregates increases in the concrete mixes. This conforms to the general principles and with findings of some previous research outputs [12] [13] [14] [15] and Chandwani *et al*, 2014.

Compressive Strength of Concrete

The compressive strength of concrete, which is its ability to withstand loads, ranges between 15MPa and 30MPa in residential structures. Higher values of up to 70MPa can be used for commercial and other special purposes. Concrete achieves about 99% of its strength within 28 days. Variations of the values of compressive strength of the different concrete mixes used in this study are as displayed in Figure 3

.

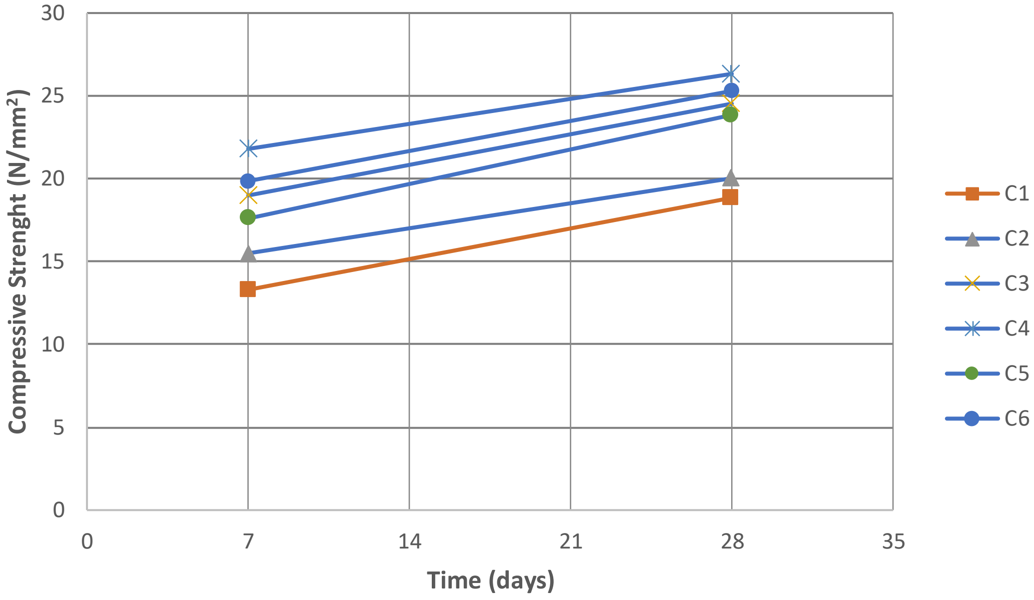

Figure 3: Compressive Strength of the Concretes at 7days and 28 days.

The graph in Figure 3 shows that the compressive strengths increased with the increase in the number of curing days. The 28 days curing gave higher strengths than the 7 days curing for each of the various concrete mixes (Rahman, 2020). Also, as the ratio of the bigger aggregates (25mm coarse aggregate) increases, the compressive strength of the mixture increases.

However, the compressive strength decreased at 100% of 25mm, having a value of 23.85N/mm^2. Concrete 6 (C6) which is composed of 100% of 20mm coarse aggregate and which is used as a control in this study has a compressive strength of 25.3N/mm^2. Concrete 4 (C4), composed of 25% of 10mm and 75% of 25mm coarse aggregates, has the maximum compressive strength of 26.33N/mm^2 at 28 days.

4. CONCLUSION

The study examined the influence of coarse aggregate gradings on the compressive strength of concrete. Three different sizes of coarse aggregates (10mm, 20mm, 25mm) were selected and after working with them, their individual concretes properties were recorded. The gradation of these aggregates, the workability of the produced concrete as well as their compressive strengths were determined through sieve analysis, slump test and crushing respectively.

The results showed that the compressive strength increases as the percentage of 25mm increases in the concretes, while reverse is the case for workability. Therefore, depending on the property desired at any time in a concrete, different percentages of 25mm and 10mm coarse aggregates can be used. For workability, 100% 10mm + 0% 25mm gave the best result, while 25% 10mm + 75% 25mm gave the best result in terms of strength. The usage of an appropriately sized aggregate will significantly reduce the low compressive strengths obtained when poorly sized coarse aggregates are used in concrete mix. It also increases a structure’s durability, reduces unnecessary expense encounters at times for usage of more cement (for an increased workability through lubrication by the cement paste) and unnecessary extra compaction for elimination of voids when poorly graded aggregates are used.

REFERENCES

1. Barritt, C. M. H. (1984). Advanced Building Construction Vol. I, 2nd Edition, J. W. Arrowsmith Ltd, Bristol.
2. Abdullahi, M. (2012). Effect of aggregate type on compressive strength of concrete. International journal of civil and structural engineering; Volume 2, No 3; Pg. 791 – 800.
3. Hassan, K., Reid, J. M., & Al-Kuwari, M. B. (2015). Use of recycled and secondary aggregates in Qatar - Guidance document.
4. Aginam C., Chidolue C., and Nwakire C. (2013). Investigating the effects of coarse aggregates types on the compressive strength of concrete. International Journal of Engineering 3(4):1140-1144.
5. Jimoh and Awe S. S. (2007). A study on the influence of aggregate size and type on the compressive strength of concrete. Department of civil Engineering, University of Ilorin, Nigeria. Journal of Research Information in Civil Engineering, Vol. 4 p. 02.
6. Woode, A., Amoah, D. K., Aguba, I. A., & Ballow, P. (2015). The effect of maximum coarse aggregate size on the compressive strength of concrete produced in Ghana. Civil and Environmental Research, 7, 7.

7. Neville, A. M. (1995). Properties of Concrete, 4th Edition. Addisson Wesley Longman, England.
8. Lafrenz, J. (1997). Aggregate grading control for PCC pavements improving constructability of concrete pavements by assuring consistency of mixes. Austin, Texas: Fifth Annual International Center for Aggregates Research Symposium.
9. Neville, A., & Brooks, J. (2010). Concrete Technology (2nd.). London: Prentice Hall.
10. Donza, H., Cabrera, O., & Irassar, E. (2002). High strength concrete with different fine aggregate. Cement and Concrete Research. 32 (11), 17551761.
11. Onyelowe K. C. and Shakeri J. (2021): Intelligent prediction of coefficients of curvature and uniformity of hybrid cement modified saturated soil with NQF inclusion. Clear Engineering and Technology 4 (2021) 100152; Pg.1-16.
12. Hoang N. and Pham A. (2016). Estimating concrete workability based on slump test with least squares support vector regression. Journal of Construction Engineering. https://doi.org/10.1155/2016/5089683
13. Yeh I. C. (2007). Modeling slump flow of concrete using second-order regressions and artificial neural networks. Cement and Concrete Composites, vol. 29, no. 6, pp. 474–480.
14. Chine W.-H., Hsu H.-H., Chen L., Wang T.-S., and Chiu C.-H. (2010). Modeling slump of concrete using the artificial neural networks. Proceedings of the International Conference on Artificial Intelligence and Computational Intelligence (AICI '10), pp. 236–239, Sanya, China.
15. Chandwani V., Agrawal V., and Nagar R. (2015). Modeling slump of ready-mix concrete using genetic algorithms assisted training of Artificial Neural Networks. Expert Systems with Applications, vol. 42, no. 2, pp. 885–893.
16. Chandwani V., Agrawal V., and Nagar R. (2014). Modeling slump of ready-mix concrete using genetically evolved artificial neural networks. Advances in Artificial Neural Systems; vol. 2014, Article ID 629137, 9 pages.
17. Rahman S. (2020). Analysis on compressive strength of concrete using different sources of fine aggregates. Proceedings of 2nd International Conference on Research and Innovation in Civil Engineering (ICRICE).