American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-9, pp-112-116
www.ajer.org
Research Paper Open Access

Effect of Aggregate Size and Gradation on Compressive Strength of Normal Strength Concrete for Rigid Pavement

*Ekwulo E. O[1]. and Eme D. B[2].
[1]*Department of Civil Engineering, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria*
[2]*Department Civil Engineering, University of Port Harcourt, Port Harcourt, Nigeria*
*Corresponding Author: *Ekwulo E. O*

ABSTRACT: *In road or most base constructions, uniform size and graded (mixed) aggregates of different sizes have been used without adequate consideration for its implications in terms of compressive strength. This study was carried out to investigate the effect of aggregate size and gradation on the compressive strength of concrete used for rigid pavements. The study investigated four concrete specimens made from aggregate size of 9.5mm, 12.7mm, 19.1mm and graded aggregate specimen made from a combination of 9.5mm, 12.7mm and 19.1mm aggregates. A concrete mix of 1:1.5:3 with a constant water-cement ratio (w/c) of 0.6 was used and tested for slump. Concrete cubes were produced from same mix, cured and tested for compressive strength at 14 and 28 days. The result showed that the concrete made from aggregate sizes of 9.5mm, 12.7mm and 19.1mm recorded slumps of 60mm, 50mm and 30mm respectively, while concrete made from the graded aggregates recorded the least slump of 20mm. Also, the concrete made from 9.5mm, 12.7mm, 19.1mm aggregates recorded mean compressive strengths of 18.2N/mm^2, 20.0N/mm^2 and 20.9N/mm^2 respectively at 28days while concrete made from the graded aggregates recorded mean compressive strength of 17.3N/mm^{2}at 28 days. It was concluded that workability (slump) of fresh concrete decreases with increase in aggregate size and that compressive strength increases with increase in aggregate size. The study also noted that grading aggregates using the Cement Treated Aggregate gradation procedure does not necessarily increase compressive strength of concrete for rigid pavements.*

Keywords: *Aggregate Size, Slump, Aggregate Gradation, Compressive Strength*

Date of Submission: 26 -08-2017 Date of acceptance: 09-09-2017

I. INTRODUCTION

Coarse aggregates play significant role in concrete production. Concrete is a composite material made of aggregates bonded together by liquid cement which hardens over time [1]. Concrete can be used as plain or reinforced concrete in civil engineering construction to build durable and long lasting structures. The major components of concrete are cement, water, and aggregates (fines and coarse aggregate) with coarse aggregates occupying over one-third of the volume of concrete. Research has shown that changes in coarse aggregate can change the strength properties of concrete. To predict the behavior of concrete under general loading requires an understanding of the effects of aggregate size. The compressive strength of concrete is one of the major properties that structural engineers take into consideration before erecting any structure [2]. 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. Unsatisfactory gradation of aggregates leads to segregation of mortar from the coarse aggregates, internal bleeding, need for chemical admixtures to restore workability, excessive water use and increased cement use [3]. Coarse aggregates constitute about 50 to 60% of the concrete mix depending on the mix proportion used. Research indicates that the larger aggregate percentage in concrete mix contributes to a lot to its strength [4]. Aggregates are the most mined material in the world. They are a component of composite materials such as concrete and asphalt concrete. Aggregates 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 [5].

There is much controversy concerning the effects of coarse aggregate size on concrete compressive strength. Tests by Zhou, Barr, and Lydon [6] show that compressive strength increases with increase in coarse aggregate size. However, most other studies disagree. Walker and Bloem [7] and Bloem and Gaynor [8] concluded that an increase in aggregate size results in a decrease in the compressive strength of concrete. Cook [9] showed that, for compressive strengths in excess of 69 MPa (10,000 psi), smaller sized coarse aggregate produces higher strengths for a given water-to-cement ratio. Walker and Bloem [7] studied the effects of coarse aggregate size on the properties of normal-strength concrete. Their work demonstrates that an increase in aggregate size from 10mm to 64 mm (3/8 to 2 ½ inch.) results in a decrease in the compressive strength of concrete, by as much as 10 percent. Bloem and Gaynor [8] studied the effects of size and other coarse aggregate properties on the water requirements and strength of concrete. Their results confirm that increasing the maximum aggregate size reduces the total surface area of the aggregate, thus reducing the mixing water requirements; however, even with the reduction in water, a larger size aggregate still produces lower compressive strengths in concrete compared to concretes containing smaller aggregate. Generally, in lower strength concretes, the reduction in mixing water is sufficient to offset the detrimental effects of aggregate size. However, in high-strength concretes, the effect of size dominates, and the smaller sizes produce higher strengths. Cordon and Gillespie [10] also reported changes in concrete strength for mixes made with various water-to-cement ratios and aggregate sizes. They found that, at water-to-cement ratios from 0.40 to 0.70, an increase in maximum aggregate size from 19 mm to 38 mm decreases the compressive strength by about 30 percent. They also concluded that, in normal-strength concrete, failure typically occurs at the matrix-aggregate interface and that the stresses at the interface which cause failure can be reduced by increasing the surface area of the aggregate (decreasing the aggregate size). If the strength of the concrete is sufficiently high, such as with high strength concrete, failure of the specimen is usually accompanied by the fracture of 5 aggregate particles; therefore, in high-strength concrete, compressive strength depends on aggregate strength, not necessarily aggregate size. Studies by Vilane and Sabelo [11] investigated compressive strength of concrete made from 9.5mm, 13.2mm and 19.0mm aggregates. Results indicates that compressive strength of concrete increased with increase in aggregate size.

Rozalija and Darwin [12] studied the effect of Aggregate type, size and content on concrete strength and fracture energy. The results indicates that compressive strength of both normal and high strength concrete is little affected by aggregate size. In fact, it is generally agreed that, although larger coarse aggregates can be used to make high-strength concrete, it is easier to do so with coarse aggregates below 12.5 mm *(1/2* in.) [13]. Aggregates for use as pavement material must meet specifications in terms of gradation [14]. In some developing countries like Nigeria, the use of single and/or graded aggregates for construction of rigid pavements is a common practice. In most cases for economic reasons, construction managers treat concrete for rigid pavement as Cement Treated Aggregate base (CTAB) in accordance with ASTM [15] hence producing concrete with combination of coarse aggregates of different sizes.

Objectives

The arbitrary use of uniform size and mixed aggregates for rigid pavement concrete with no consideration for the concrete compressive strength necessitated this research. This study attempts to investigate the effect of coarse aggregate size and gradation on compressive strength of normal strength concrete for rigid pavement.

II. MATERIALS, APPARATUS AND METHOD

2.1 Material

The selected materials to be used in this study are locally available and currently used in making concrete in Nigeria. They are:

(a) Ordinary Portland cement
(b) Fine river sand as fines
(c) 3/8 in. (9.5mm) river sand as coarse aggregate
(d) ½ in. (12.7mm) crushed stone (granite chippings) as coarse aggregate
(e) ¾ in. (19.1) crushed stone (granite chippings) as coarse aggregate
(f) water

The crushed stone was sourced from a quarry site at Akampka, in Cross Rivers State, Nigeria and in the desired sizes.

2.2 Apparatus

The equipment that were used in the study were: 150mm x 150mm x 1500mm steel moulds, tags sieves, retainers, brush, weighing instrument, trowel, spanners, electric table vibrator, electric concrete mixer, slump test cone, curing tank and concrete Universal Testing Machine.

III. METHODOLOGY

3.1 Experimental Design

The research involved experimental tests on four concrete specimen prepared with aggregate sizes of 9.5mm, 12.7mm, 19.1mm and graded aggregates comprising of a combination of 9.5mm, 12.7mm and 19.1mm coarse aggregates. The aggregates were blended in accordance with the Cement Treated Aggregate Procedure [13, 15]. The blending of the aggregates resulted concrete specimen comprising of 50% of 9.5mm aggregates, 30% of 12.7mm aggregates and 20% of 19.1mm aggregate and marked specimen “B”. There were three replications of each specimen using a constant mix proportion of 1:1.5:3 and water-cement (w/c) ratio of 0.6.

3.2 Concrete Batching, Mixing and Curing

Coarse aggregate, fine aggregate and cement were thoroughly mixed together with the electric concrete mixer, after which the required water estimated at 0.6 water-cement ratio (w/c) was added. The entire constituents were mixed until an even paste was obtained.

3.3 Slump Test

The slump mould was filled in three layers, each layer was compacted by a steel rod with 25 blows before pouring the next layer. The surface was leveled after filling the slump cone, and allowed for 2 minutes. The slump cone was then lifted off the concrete, thus allowing the pile of unsupported concrete to collapse. The difference between the initial and the final height of the concrete was measured and recorded as the slump.

3.4 Curing

For the four concrete specimen made from the uniform and graded aggregates, six (6) cubes were cast for each specimen making a total of twenty four cubes (24). The cubes were cast by filling each mould in small layers and compacting each layer by the electric vibrator before the next layer was poured. They were left in the mould for 24 hours to set at laboratory temperature, after which they were demoulded and transferred into a curing tank that contained clean water. For each specimen, three (3) cubes were cured for 14 days and the other three (3) for 28 days.

3.5 Compressive Strength Test

The cubes were removed from the curing tank, weighed and tested at 14 and 28 days with the Universal Testing Machine. The value of the load at which the test cube failed was recorded and used to calculate the compressive strength at each curing age. The compressive strength was calculated using equation 1.

$$f_c = \frac{P}{A} \text{ (N/mm}^2\text{)} \tag{1}$$

Where;

P = Failure load in N
A = cross-sectional area of test cube in m^2.

IV. RESULTS AND DISCUSSIONS

The results of workability (slump) and compressive strength test for the uniform size and graded (mixed) aggregates are as summarized in Table 4.1:

Table 4.1: Slump and Compressive Strength of Single and blended Aggregates

Aggregate Size/Content (mm)	Slump (mm)				Compressive Strength N/mm²							
					14 days				28 days			
	(1)	(2)	(3)	***Mean***	(1)	(2)	(3)	***Mean***	(1)	(2)	(3)	***Mean***
9.5	63	58	59	***60***	16.0	15.0	15.8	***15.6***	18.3	18.5	17.8	***18.2***
12.7	52	48	50	***50***	18.1	18,0	18.5	***18.2***	21.5	19.0	19.5	***20.0***
19.1	32	28	30	***30***	19.0	19.7	19.2	***19.3***	20.0	20.7	22.0	***20.9***
GRADED (MIXED) AGGREGATES “B”	19	21	20	***20***	10.9	10.7	10.5	***10.7***	16	18	17.9	***17.3***

The effect of aggregate size and gradation on workability (slump) is shown in Table 4.1. The result indicates that the workability (slump) of fresh concrete made from the various aggregates decreases with increase in aggregate size, aggregate sizes of 9.5mm, 12.7mm, and 19.1mm recording true slumps of 60mm, 50mm and 30mm respectively, while the concrete made from graded aggregates recorded the least slump of 20mm.

The effect of aggregate size on compressive strength of uniform size and graded aggregates is shown in Figure 4.2. The result indicates that compressive strength of the concrete made from various aggregate sizes increased with age from 14 to 28 days. The uniform aggregates sizes of 9.5mm, 12.7mm, 19.1mm recording compressive strengths of 18.2N/mm^2, 20.0N/mm^2, 20.9N/mm^2 respectively at 28 days while the graded aggregates "B" recorded the lowest strength of 17.3N/mm^2 at 28 days . The result also shows that the 19.1mm aggregates recorded the highest compressive strength of 20.9N/mm^2 at 28 days. This result indicates that compressive strength of concrete made from uniform size aggregates increases with increase in aggregate size and that aggregates mixed using the Cement Treated Aggregate gradation procedure does not improve the compressive strength of concrete used for rigid pavements.

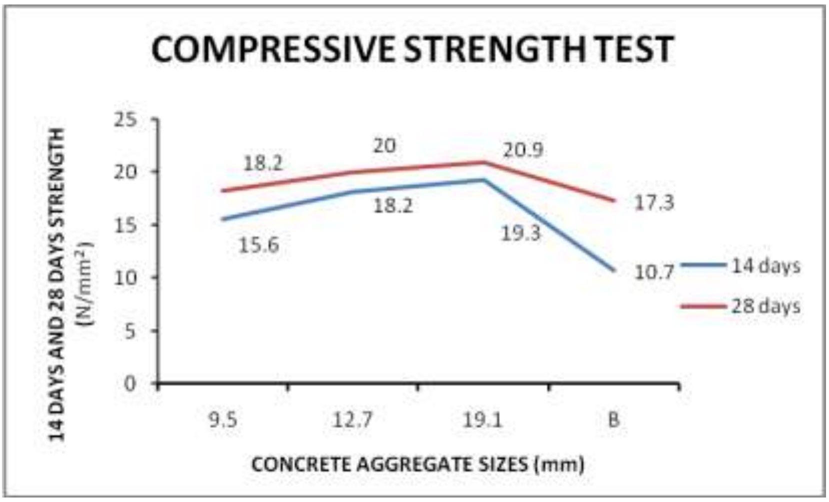

Figure 4.2: Variation of compressive strength with aggregate size/gradation

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the results of the study, the following conclusions are hereby made:

1. The aggregate size and gradation affect workability of fresh concrete and compressive strength of hardened concrete.
2. Workability of concrete made from uniform size aggregates decreases as the aggregate size increases.
3. Compressive strength of concrete made from uniform size aggregates increases with increase in aggregate size.
4. Blending aggregates using the Cement Treated Aggregate gradation procedure does not improve the compressive strength of concrete used for rigid pavements relative to concrete made from uniform size aggregates.

5.2 Recommendation

i. Further research be carry out to investigate the use of appropriate aggregate gradation procedure for blending aggregate for concrete used for highway pavement and its effect on compressive strength of concrete.
ii. Construction engineers should exercise caution in the use of arbitrarily graded (mixed) aggregates for design and construction purposes

ACKNOWLEDGMENT

The authors wish to acknowledge the good effort of Mr. Enos Enos Kpunueyirobe for the hardwork during the laboratory works that resulted in this research findings.

REFERENCE

[1]. Woodford, C. (2016). Concrete and reinforced concrete. http://www.explainthatstuff.com/steelconcrete.html. Accessed November, 2016.
[2]. Hollaway, L. C., 2010. A review of the present and future utilisation of FRP composites in the civil infrastructure with reference to their important in-service properties. Construction and Building Materials, 24 (12), pp. 2419-2445.
[3]. Loannides, M. A. and Mills, C. J. (2006). Effect Of Larger Sized Coarse Aggregates On Mechanical Properties Of Portland Cement Concrete Pavements And Structures: State Job No: 148030. Vol. 1. 2006: 30-31.
[4]. Waziri B. S.; Bukar, A. G and Gaji, Y. Z. (2011). Applicability of quarry sand as a fine aggregate. Continental J. Engineering Science.
[5]. Anonymous, (2012). Functions and requirements of ingredients of cement concrete. http://weebo.hubpages.com/hub/Functions-and-requirementsof- ingredients-of-cement-concrete. Accessed October, 2016.
[6]. Zhou, F. P., Barr, B. I. G., and Lydon, F. D. (1995). Fracture Properties of High Strength Concrete with Varying Silica Fume Content and Aggregates, Cement and Concrete Research, V. 25, No.3, pp. 543-552.
[7]. Walker, S. and Bloem, D. L. (1960) Effects of Aggregate Size on Properties of Concrete. ACI Journal, Proceedings V. 57, No.3, September, pp. 283-298.
[8]. Bloem, D. L. and Gaynor, R. D. (1963) Effects of Aggregate Properties on Strength of Concrete, ACI Journal, Proceedings V. 60, No. 10, October, pp. 1429-1456.
[9]. Cook, J. E. (1989) .I 0,000 psi Concrete, Concrete International, October, pp. 67-7 5.
[10]. Cordon, W. A. and Gillespie, H. A. (1963) Variables in Concrete Aggregates and Portland Cement Paste Which Influence the Strength of Concrete, ACI Journal, Proceedings V. 60, No.8, August, pp. 1029-1052
[11]. Vilane, B.R.T and Sabelo, N. (2016). The Effect of Aggregate Size on the Compressive Strength of Concrete. Journal of Agricultural Science and Engineering Vol. 2 No. 6 pp. 66-69
[12]. Rozalija, K and Darwin, David (1997) Effect of Aggregate Type, Size and Content on Concrete Strength and Fracture. The Reinforced Concrete Research Council, Project 56, The U.S Department of Transportation, Federal Highway Administration, SM Report No. 43.
[13]. ACI Committee 363. (1992) "State-of-the-Art Report on High-Strength Concrete (ACI 363R-92)," ACI Manual of Concrete Practice, 1997 Edition, Part I, Farmington Hills, MI.
[14]. Aggregate Gradation for Concrete Pavement Mixtures. CP Road Map, Map Brief, October 2014
[15]. AASHTO/ARTBA Guide Specification for Base Course or sub base. American Association of State Highway and Transportation Officials, Washington DC. 1988

*Ekwulo E. O "Effect of Aggregate Size and Gradation on Compressive Strength of Normal Strength Concrete for Rigid Pavement" American Journal of Engineering Research (AJER), vol. 6, no. 9, 2017, pp. 112-116