The Effect of Coarse Aggregate Shape on the Properties of Concrete

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Abstract

In plain concretes coarse aggregates amongst other constituents of concrete are known to contribute the highest in terms of strength and volume although its shape tends to affect the property of both fresh and hardened concrete. This paper investigates the effect of aggregate shape on properties of plain concrete.Four shapes of aggregates were considered- irregular, round, flaky and angular. Concrete cubes having dimensions of 150×150×150 mm were cast and cured for 7, 14, 21 and 28days and their fresh and hardened properties were determined. From the slump test results it was observed that the round shape aggregate has the highest work ability 36.67mm and also the compressive strength of the angular shape aggregate at 28 days is the highest with 20.60N/mm^2.

Key words: Concrete, Coarse aggregates, Aggregate shape

Introduction

Concrete is the most widely used man – made construction material in the world, and is second only to water as the most utilized substance on the planet. It is obtained by mixing cementitious materials, water and aggregate (and sometimes admixtures) in required proportions. The mixture when placed in forms and allowed to cure hardens into a rock-like mass known as concrete. The hardening is caused by chemical reaction between water and cement and it continues for a long time, and consequently the concrete grows stronger with age. Aggregate provide about 75 per cent of the body of concrete and hence its influence is extremely important. They should therefore meet certain requirements if the concrete is to be workable, strong, durable, and economical. The aggregate most be of proper shape (either rounded or approximately cubical), clean, hard, strong and well graded. It should possess chemical stability and, in many cases, exhibit abrasion resistance and resistance to freezing and thawing. (Gambhir,2000).

The strength of concrete is assumed to depend primarily on two factors: the water to cement ratio and the degree of compaction. Even so, the shape of aggregates has an influence on the concrete strength and this is the subject matter of this paper. It is known that the stress at which crack develops depends largely on the shape of the aggregate; smooth gravel leads to cracking at lower stress than rough and angular crushed rock. Also , a coarse aggregates act as crack arresters so that , under an increasing load , another crack is likely to open, the shape of the aggregate should influence the fracture energy of concrete(Rocco and Elices, 2009).

All those matters deserve to be evaluated, as there are few references on this subject. Effect of aggregate type on properties of hardened self-consolidating lightweight concrete (SCLC) was investigated by llker and Tayfun (2010)who reported that, replacement of crushed limestone aggregate with natural LWA in Self-consolidating concrete(SCC) causes an increase in absorption because of high water absorption ability of light weight aggregates compared with crushed limestone. Research along the same line was performed by Mohammed and Salim, (2010) on the effect of content and particle size distribution of coarse aggregate on the compressive strength of concrete;they reported that compressive strength of the normal concrete has shown to increase when increasing the maximum size of coarse aggregate. Up to 12% of a compressive strength increase was observed within the four combinations investigated. They also added that, at a given age, and for a given combination of granular fraction, the compressive strength of normal strength concrete increases as the MSA increases. On the contrary,the compressive strength of the high-strength concrete (HSC) increases as the maximum aggregate size(MSA) decreases. the objective of this paper include the following; to determine the physicalproperties of aggregate, to determine the slump of the concrete and to determin the compressive strength of the concrete made from different shapes of aggregate (Angular, Flaky, Irregular and Round shape).

Concrete is a three phases composite material including hardened cement paste, aggregate skeleton and interfacial zone. Compressive strength is known as to be significantly influenced by properties of those three components. Since coarse aggregate (CA)occupies an average of 45% of the total volume of the concrete mixture. It can be expected that this constituent has great influence on the properties of the hardened concrete. Grading limit, maximum aggregate size and shape have to be established and specified because gradation, shape and size affect the amount of aggregates used as well as cement and water requirements, workability, pump-ability, and durability of concrete. The main aim of this work is to achieve a better understanding of the effect of the shape of coarse aggregate on the compressive strength of concrete and hence arrive at the adequate shape that offer the best and higher compressive strength of a concrete.

Materials and Method

Materials used in this test:

Cement; The cement was bought from the cement depot located at Okada road Minna, Niger state, Nigeria. Were cement was kept on a raised platform and adequately protected from external damage by weather. The cement referred to in this work is the Ordinary Portland cement produced from Dangote group of companies in accordance with BS 12.

Sharp sand; The sharp sand was obtained from borrow pit located at, Minna Niger state Nigeria. The sand is clean and sharp, free from clay, loam, dirt or organic matters, and conforms, to the grading requirement of (BS 882:1978).

Coarse aggregate include different shapes which are: Angular shape, Flaky shape, Irregular shape, Round shape.The coarse aggregate was obtained from Tracta crushing plant also located at Makunkele in Minna Niger state, Nigeria.The aggregate were clean and sharp, free from clay, loam, clay, loam, dirt or organic matters and conforms to the grading requirements of (BS 882:19 78).

Water;The water used for mixing and curing was obtained from tap. The physical examination of the water revealed that it was clean, free from deleterious materials and fit for drinking as recommended by BS 3140.

Casting of Cubes

Wooden moulds of (150×150×150) mm3 were used. They were lubricated with engine oil in order to reduce friction and to enhance removing of cubes from the moulds.

They were then filled with concrete in three layers and each layer was tamped 25 times. The surface of each layer was then leveled properly with trowel and after sometimes were labeled. The mould containing the cubes were left for 24 hours under room temperature for the cubes to set before removing the mould. The cubes were remove after 24 hours and were taken to curing tank (BS1881: part 108:1983).

Curing of cubes

Curing is the process of keeping concrete under a specific environmental condition. Good curing is typically considered to be a moist environment which promotes hydration. More specifically, the object of curing is to beep concrete saturated, or as early saturated as possible, until the originally water filled space in fresh cement paste has been filled to the desired extent by the products of hydration of cement.

Power T.C showed that hydration is greatly reduced when the relative humidity within the capillary pore drops below 80%. . The method use for curing for the purpose of this work is by total immersion of the cubes in water for specific age of 7, 14, 21 and 28 days respectively from the day of casting(BS 1881: part 111: 1983).

Compressive strength Test

Compressive strength test on the concrete cube was determined using the standard procedure for concrete. The weight of each cube was always taken before the compressive strength test was conducted. Three cubes were crushed at each curing days (7, 14, 21 and 28 days respectively).

Results and discussions

Table 1. Physical properties of constituent materials

Parameters	Fine Aggregate(sand)	Different shape of Aggregate			
		Angular	Irregular	Flaky	Round
Moisture Content	0.31	0.47	0.34	0.52	0.53
Specific gravity	2.60	2.75	2.62	2.71	2.64
Bulk density(Loose)	1383.67	1383.58	1207.07	1194.56	1517.39
Bulk density(compacted)	1499	1499.63	1490.22	1463.04	1632.25
Void ratio		0.92	0.93	0.82	0.81
% Porosity		7.74	19.0	18.35	7.04
Average Slump		20.00	20.67	21.67	36.67
Types of Slump		Shear Slump	Shear Slump	Shear Slump	Shear Slump

Moisture content; The moisture content test results of both fine and coarse aggregate of (Angular, flaky, irregular, and round) are given in Table 4.1.1,4.1.2,4.1.3,4.1.4 and 4.1.5 respectively as 0.31,0.47,0.34,0.52 and 0.53 respectively. Since moisture content is the amount of water the aggregate contained, from the result its shows that the aggregate contain some certain amount of water which will result in their low absorption capacity.

Specific gravity; The results of specific gravity of both fine and coarse aggregate (Angular, flaky, irregular, and round) are given in table 4.2.1, 4.2.2, 4.2.3, 4.2.4 and 4.2.5 respectively as 2.60, 2.62, 2.75, 2.64 and 2.71 respectively. These fall within the specification of specific gravity of rock group which lies between 2.6 and 3.0 for natural aggregates. The angular shape aggregate have higher specific gravity follow by flaky which seem to have higher bound between concrete particle compare to the rest of the shapes. The specific gravity is of interest because it is used in the mix design of concrete.

Bulk density; The results of bulk density of both fine and coarse aggregate of different shapes obtained are given in Table 4.4.1, 4.4.2, 4.4.3, 4.4.4 and 4.4.5 respectively with the following: for loose and completed bulk density for angular, flaky, irregular and round are :1383.67kg/m^3 and 1499kg/m^3 ,1383.58kg/m^3 and 1449.63kg/m^3, 1194.56kg/m^3 and 1463.04kg/m^3, 1207.07kg/m^3, and 1490.22kg/m3 ,1517.39kg/m3, and 1632.25kg/m3 respectively.

The ration of loose bulk density to compacted bulk density of aggregate are 0.92 for sand and 0.92, 0.82, 0.81 and 0.93 for angular, flaky irregular and round shape respectively. Only result obtained for sand angular and irregular fell within the 0.87 and 0.96 standard as specified by Neville (1990).The result of round and flaky the it lie between the range. However, since bulk density depends on how densely the aggregate are packed together, therefore the flaky and round shape have lower bulk density which means that they cannot be easily packed together when compared to the other shape.

Void ratio and the percentage porosity; Porosity and void ratio have greater effect on durability of concrete. Result of void ratio of both fine and coarse (angular, flaky, irregular and round shape) are given in Fig 4.5 with the following value 0.92,0.92,0.82,0.93 and 0.81 respectively and for the percentage porosity are also given as 7.69% for sand 7.74%, 18.35%, 19.0%, 7.04% for angular, flaky, irregular and round shape respectively. These lie between (0-50) percent specified (Neville, 1990).

Slump test result of concrete made with different shapes of coarse aggregate,

The slump test primarily measures the consistency of concrete. Table 4.6.1 show the result of slump test with mix ratio of 1:2:4.From the result obtained concrete made with round shape aggregate have the higher workability has indicated in the graph of histogram. The results are 20mm,21.67mm, 20.67mm and 36.6mm for angular flaky,irregular and round shape respectively.

Table 4.7.5: Average compressive strength

Curing age(day)	Aggregate shape	Water/cement ratio	Average density (kg/m^3)	Average compressive strength (N/mm^2)
7	Angular	0.5	2402.96	14.47
	Flaky	0.5	2401.98	9.78
	Irregular	0.5	2344.69	14.02
	Round	0.5	2322.96	10.05
14	Angular	0.5	2498.76	17.65
	Flaky	0.5	2295.31	14.12
	Irregular	0.5	2272.59	16.95
	Round	0.5	2279.51	13.93
21	Angular	0.5	2346.67	17.77
	Flaky	0.5	2287.41	15.05
	Irregular	0.5	2390.12	18.67
	Round	0.5	2415.80	15.11
28	Angular	0.5	2431.61	20.60
	Flaky	0.5	2311.11	17.57
	Irregular	0.5	2322.96	20.24
	Round	0.5	2362.47	17.42

From the summary of comprehensive strength test results shown in Fig 4.65 it shows that at the end of 7 days curing, concrete had gain appreciable strength. This is more obvious with concrete made with angular aggregate followed by irregular aggregate has high has 14.47N/mm^2 and 14.02N/mm^2.These strength keep increasing as the curing days increase. At the end of 28 days the angular aggregate is say to have the highest strength of 20.60N/mm^{2}because of it bond existing between the aggregate body and the cement paste. The bond existing between aggregate and cement paste is one of the important aspect to be consider in terms of concrete strength.

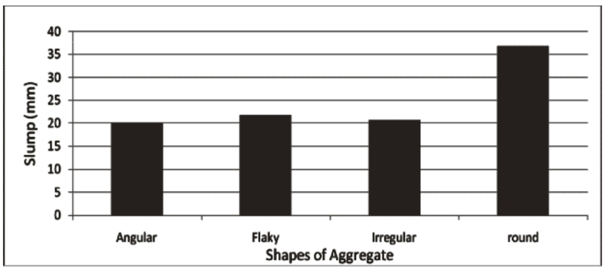

Fig. 4.8(e): Slump Test Chart

Sieve analysis; From the result of sieve analysis obtained above the graph of Fig 4.8(a) show a well graded particle size including fine, medium and coarse which produce a workable, durable concrete with minimum void space. The graph of coarse aggregate shown in Fig 4.8(b), 4.8(c), 4.8(d) and 4.8(e). These take similar shape of graph which indicates that they are relatively of the same size. This is particularly important since aggregate size also influence the strength of concrete.

Furthermore, from the graph it is seem that the majority of aggregate shapes fell within 20.00mm and 14.00mm this is due to the fact that, the samples used for the production of the concrete cubes where manually (hand) crushed. In addition to this, from Fig 4.3(d) the grading of the river gravel is not well distributed, this may be attributed to the fact that the aggregate is from natural source.

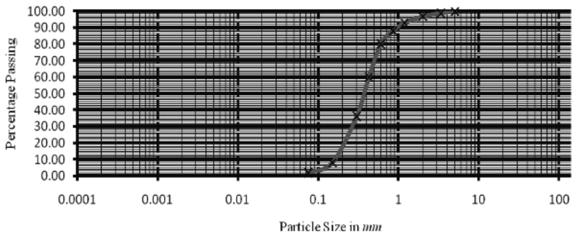

Fig. 4.8(c)ieve Analysis for Fine Aggregate

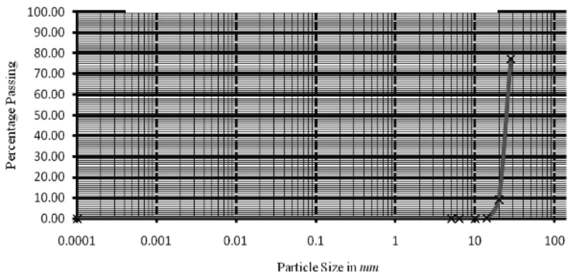

Fig. 4.8(B) Sieve Analysis for Angular Shaped Aggregate

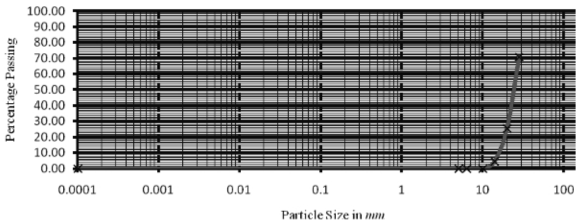

Fig. 4.8(d) Sieve Analysis for Flaky Shaped Aggregate

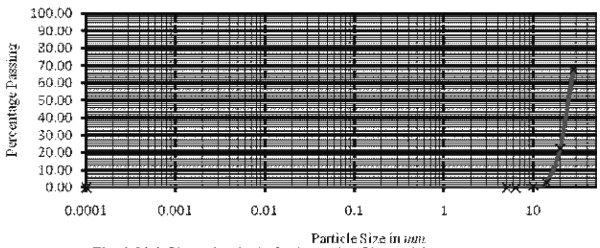

Fig.4.8(e) Sieve Analysis for irregular Shaped Aggregate

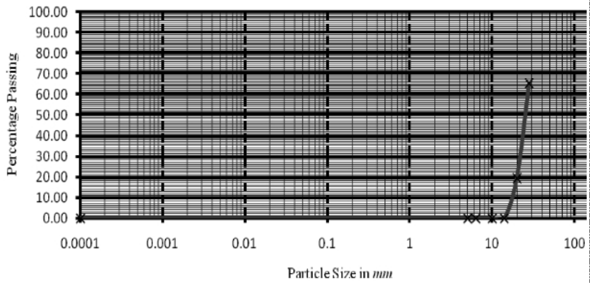

Fig. 4.8(e) Sieve Analysis for Round Shaped Aggregate

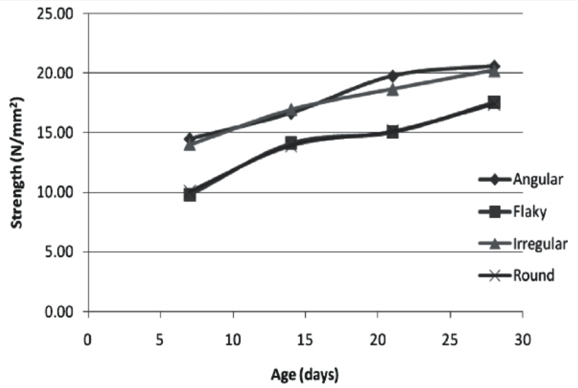

Fig. 4.8(i) Compressive Strength Graph

Conclusions

Having carried out tests and investigation of various shapes of aggregate in the production of concrete and results presented in the various sections of this work, the following conclusions are made.

1. Concrete made with angular aggregate have the highest compressive strength with the aggregate strength of 20.6N/mm^2.

2. The rate of absorption of aggregate is a function of the moisture content of the aggregate.

3. Concrete made with round shape aggregate have the highest slump with an average of 36.67mm when compared to the rest of the shapes.

4. The strength of concrete is directly proportional to the bond existing between the aggregate and the cement

paste.

5. All the aggregates used for the purpose of this work produce concrete of medium workability at water-cement ratio of 0.5.

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