OPEN ACCESS World J of Engineering and Pure and Applied Sci. 2013;3(1):16 ISSN 2249-0582
Amartey et al. Evaluation of Natural Aggregate

Original Article
Basic Science

Evaluation of Natural Aggregate found in Zaria, Nigeria

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ABSTRACT [ENGLISH/ANGLAIS]

Aggregate are essential materials in civil engineering construction, their inclusion in concrete and asphalt mixes has always being economical. However, there are some physical and chemical properties of these aggregate particles, which make their acceptability of on the specific purpose for which they are used and the conditions surrounding their use. In this study, an attempt is made to study some of these physical properties of aggregate obtained in Zaria. Coarse (crushed gravel) and fine (sand) aggregate samples are obtained from eight different sources around Zaria. Series of laboratory experiments such as specific gravity, sieve analysis, aggregate impact value, silt and clay content tests, flakiness and elongation tests were carried out on the samples to ascertain there quality. After the tests were conducted it was found that the aggregate were generally sound and good for construction. Although the fine aggregate were found to contain some amount of harmful materials like clay lumps but are not excessive and can be treated before application in structural work, the coarse aggregate too were found to be deficient in particle shape to some extent and this can also be improved by regular monitoring and maintenance of the crushers.

Keywords: Aggregate properties, specific gravity, sieve analysis and crushed gravel

RÉSUMÉ [FRANÇAIS/FRENCH]

Les agrégats, dans le domaine du génie civil, sont des matériaux essentiels à la construction, leur inclusion dans les mélanges de béton et d'asphalte permet d'amoindrir les dépenses financières et de ce fait est économiquement rentable. Cependant, les éléments granulaires ont certaines propriétés physiques et chimiques qui dirigent leur utilisation dans des domaines spécifiques. Dans cette étude, il est tenté d'analyser certaines propriétés physiques des granulats obtenus à Zaria. Les grossiers échantillons granulaires (gravier concassé) et les fins (sable) sont provenus de huit différentes places situées autour de Zaria. Une série d'expériences de laboratoire telles que la recherche de la densité, l'analyse granulométrique, la valeur d'impact de l'agrégat, les tests mesurant la teneur de limon et d'argile, les tests de friabilité et d'allongement ont été effectués sur les échantillons dans le but de déterminer leur qualité. Une fois les tests réalisés, il a été démontré que les agrégats sont généralement solides et bon pour la construction. Bien que les granulats ont été signalés contenir certaines substances nocives comme des morceaux d'argile, qui sont néanmoins en quantité non excessive et peuvent être traitée avant l'utilisation pour la confection de charpentes, les gros granulats ont également présentés une déficience dans la forme des particules. Ce qui dans une certaine mesure peut être amélioré par le contrôle régulier et l'entretien des concasseurs.

Mots-clés: Propriétés des agrégats, densité, analyse granulométrique et gravier concassé

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Accepted/Accepté: September, 2012

Citation: Amartey YD, Otuoze HS, Sada BH, Modibbo I. Evaluation of Natural Aggregate found in Zaria, Nigeria. World Journal of Engineering and Pure and Applied Science 2013;3(1):16-20.

INTRODUCTION

Aggregate constitute the basic components to manmade environment. Civil engineering infrastructure such as roads, buildings, airports and dams, are built and maintained by use of large quantities of aggregate-sand, gravels and stones. It is therefore not surprising that the quality of these materials is of considerable importance and hence it is useful to establish the quality of aggregate from time to time in order to ensure quality control and be able to specify materials correctly and ensure materials will perform accordingly. This study investigated the quality of these essential materials used in civil engineering works; by evaluating the abundant natural aggregates obtained in Zaria. The aggregate impact value, aggregate crushing value, grading, specific gravity, aggregate clay and silt contents, flakiness and elongation indexes are some of the properties that indicate the soundness of aggregates and are the properties that were examined in this study.

Aggregates are readily obtained from river sources, from crushing of larger mass of rock or from suitable burrow pits. All aggregate particles originally formed a part of a larger mass and may have been fragmented by natural process of weathering or artificially by crushing. Thus, many properties of the aggregate depend entirely on properties of parent rock e.g. chemical and mineral composition, petrographic description, specific gravity, hardness, pore structure, colour etc. [5,6]. Other properties possessed by the parent rock: particle shape and size, surface texture and absorption, may also have considerable influence on the quality of the finished product. It may be reasonable to add that although these different properties of aggregate mentioned can be examined, it is difficult to define a good aggregate other than by saying that; it is an aggregate from which a good structure can result from.

MATERIALS, METHODS AND RESULTS

Materials

Fine Aggregate

The Fine aggregate used in this study consist of natural (river) sand which is obtained from three different river banks in Zaria. The samples are labelled; A, B and C respectively.

Coarse Aggregate

The coarse aggregate are crushed rock obtained from three different rock quarries with aggregate sizes ranging from 25.4mm to 9.52mm. They are labelled as Samples K, L and M respectively.

Methods and Results

Sieve Analysis

The sieve analysis was done in accordance with BS 812-1 [3].

Fine aggregate: One kilogram was taken from each sample; air-dried and sieved. The weight retained on each sieve was recorded and the percentage passing calculated.

Coarse aggregate: Three kilograms was taken from each sample and subjected to sieving. The weight retained on each sieve is recorded and the percentage passing calculated.

Specific Gravity

The specific gravity of aggregate is defined as the ratio of the mass of solid to the weight of an equal void-free volume of water at a stated temperature.

The specific gravity of three samples of fine aggregate was determined as described in BS 812:2 [8], which is given by:

$$\text{Specific gravity of aggregate} = \frac{c}{a-b}$$

Where a = mass of saturated surface dry aggregate in air,

b = mass of saturated surface dry aggregate in air,

c = mass of oven dry aggregate,

Two tests were carried on each sample and the mean value recorded (see table 1).

Table 1: This table shows specific gravity of fine aggregate

Test sample	Specific gravity
A	2.52
B	2.68
C	2.40
Average specific gravity = 2.53	

The specific gravity of four samples of coarse aggregate was also determined following the same procedure as described in BS 812:2 [8]. Two tests were carried out on each sample and the average recorded (see table 2).

Table 2: This table shows specific gravity of coarse aggregate

Test sample	Specific gravity
K	2.30
L	8.00
M	3.40
Average specific gravity = 2.53	

Aggregate impact value (AIV)

Basically, AIV is the percentage of fines produced from the aggregate sample after subjecting it to a standard amount of impact. It gives a relative measure of the resistance to sudden impact. The coarse aggregate samples which passes the 12.7mm sieve and is retained on the 9.52mm sieve was prepared (about 500g) and tested in a surface dry condition in accordance with BS 812:112 [9]. Two tests were carried out and the mean value recorded. The same procedure was adopted for each sample of coarse aggregate (see table 3).

Table 3: This table shows aggregate impact value of coarse aggregate

Test sample	AIV (%)
K	19.00
L	25.00
M	29.00
Mean AIV = 24.30%	

Crushing test of coarse aggregate

The crushing test generally indicates the ability of the aggregate to resist crushing under loading conditions. Sufficient quantity of aggregate was prepared, the material consist of aggregate passing the 12.7mm and retained on 9.52mm BS sieve. The experiment was carried out in accordance with BS 812:110 [10].

The residue obtained after crushing is sieved with 2.40mm sieve and the weight of fines passing is expressed as the percentage of the total weight of the aggregate used.

Two tests were carried out and the procedure was repeated for each sample of coarse aggregate. (See table 4)

Table 4: This table shows aggregate crushing value of coarse aggregate

Test sample	ACV (%)
K	23.00
L	28.00
M	34.00
Mean ACV = 28.33%	

Clay and Silt Content of Sand (Field Settling Test)

This test indicates the amount of silt and clay content in a sample of aggregate. In this study, the test is used on the fine aggregate samples only. Salt solution was prepared in a measuring cylinder and a sample of sand was then added. The cylinder containing the mixture was allowed to stand for three hours and the height (mm) of the clay and silt layer was recorded (see table 5).

The procedure was repeated for each sample of the fine aggregate.

Table 5: This table shows height of clay and silt layer

Test sample	Height		Percentage height of clay and silt to that of sand
	Clay and silt layer (mm)	Sand (mm)	
A	5	135	3.7%
B	3	137	2.1%
C	8	132	6.06%

Standard flakiness and elongation index tests

According to BS 812-105.2 [4], aggregate particles are classified as elongated when they have a length (greatest dimension) of more than 1.8 of their mean sieve size, this size being taken as the mean of the limiting sieve apertures used for determining the size fraction in which the particle occurs. The elongation index is found by separating the elongated particles and expressing their mass as a percentage of the mass of sample tested.

A sufficient quantity of coarse aggregate, an approximate minimum amount of 200 pieces was obtained on each of the sieves indicated in table 6. The flaky material on each fraction was separated by placing on the thickness gauge and the total weight passing the gauge of every slot is taken. The procedure was repeated using the length gauge. The same procedure was followed for each sample of coarse aggregate. Results are shown in tables 6 and 7.

Table 6: This table shows flakiness results for coarse aggregate samples K, L, and M

BS Sieve size (mm)	Weight of 200 Pieces (Kg)			Weight Passing (Kg)		
	K	L	M	K	L	M
25.40	6.2	5.8	6.5	1.10	1.30	1.6
19.05	2.8	2.6	3.0	0.30	0.50	0.7
12.70mm	1.4	1.6	1.9	0.08	0.06	0.1
9.52mm	0.6	0.5	0.5	0.04	0.02	0.03
6.35mm	0.2	0.3	0.2	0.05	0.08	0.05
Total	11.2	10.8	12.1	1.57	1.96	2.48

Table 7: This table shows elongation results for coarse aggregate samples K, L and M

BS Sieve size (mm)	Weight of 200 Pieces (Kg)			Weight Retained (Kg)		
	K	L	M	K	L	M
25.40	6.20	5.80	6.50	0.55	0.85	1.30
19.05	2.80	2.60	3.00	1.90	2.30	2.60
12.7	1.40	1.60	1.90	0.54	0.60	1.10
9.52	0.60	0.50	0.50	0.22	0.10	0.20
6.35mm	0.20	0.30	0.20	0.30	0.10	0.08
Total	11.2	10.8	12.1	3.51	3.95	5.28

DISCUSSION

Sieve Analysis of Fine and Coarse aggregate:

Fine aggregate

The gradation chart obtained as in Fig 1 shows that the fine aggregate used are almost gap graded. This means that nearly all the test samples contain few particles of intermediate size. The grading charts of fine aggregate are fitted into the ASTM C33-78 grading limits for fine aggregate

Coarse aggregate

The shape of the curve obtained (Fig 2) after plotting indicates the samples are uniformly graded. In other words there is a good distribution of aggregate sizes from the smallest to the largest. In Fig 2 the coarse aggregate grading curves are fitted into the BS 882 [11] grading limit for coarse aggregate. Samples K and M are within range, but Sample L falls slightly out of limit.

Figure 1: This figure shows grading chart for fine aggregates showing ASTM C33-78: grading limits for fine aggregate

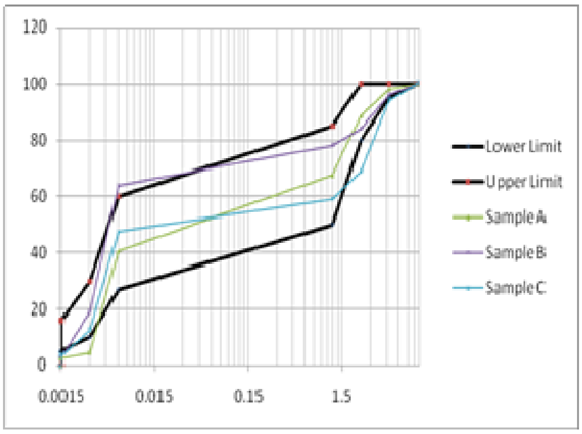
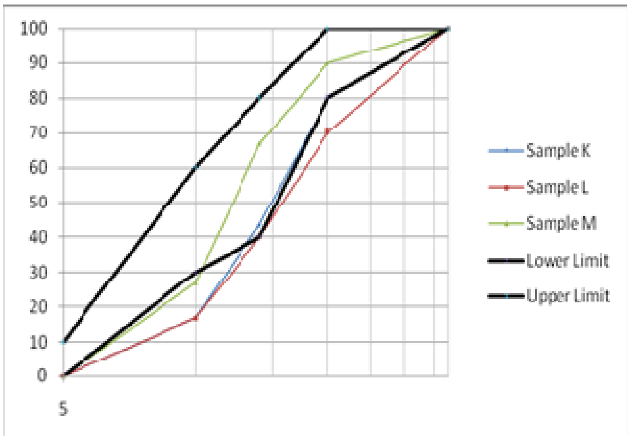


Figure 2: This figure shows grading limit for coarse aggregate with BS 882 1973 grading limits for coarse aggregate



Specific gravity

The results obtained from the specific gravity tests conducted shows a specific gravity of 2.53 for fine aggregate and a specific gravity of 2.48 for coarse aggregate (see table 1 and 2). This is satisfactory as both fell within the range of 2.5 – 3.0 for natural aggregates as coded by Neville [7].

Aggregate impact value (AIV)

The aggregate impact values obtained in this work range from 19% to 29% with a mean of (i.e. of the three samples) about 24.3% (see Table 3). Comparing these results to the permissible AIV, (which is 45% for use in ordinary concrete and 30% for concrete used for wearing surfaces) indicates that the aggregate are strong enough and has good abrading properties. They can be applied for ordinary concrete work and can also be used on wearing surfaces like paved walkways and highway pavement.

Crushing test of coarse aggregate

The laboratory test results obtained (Table 4) range from 23% to 34%. Comparing these with the permissible ACV (45% for ordinary concrete and 30% for concrete used on wearing surfaces) shows that the aggregate are good enough in resisting applied loading and can give optimum performance when used in pavement construction.

Clay and silt content of sand (field settling test)

The height (mm) of the silt and clay content obtained after the test (Table 5) conducted are slightly higher than the permissible 3% for natural sand (With Sample C being the severest of 6.06%)

Standard Flakiness and elongation index tests

The flakiness and elongation indexes obtained (Tables 8 and 9) from the test conducted on the coarse aggregate samples are slightly above the normal 10 - 15%, although there are no laid down rules for flakiness and elongation indexes [7].

CONCLUSION

After conducting fairly good survey, it was found that the aggregates obtained in Zaria are hard, dense and strong on observation.

Owing to the abundance nature of granite rocks in the area, crushed gravel (coarse aggregate) is readily obtained from the crushing of larger mass of rock

The fine and coarse aggregates investigated in this work can be said to meet the general requirement of grading as their grading falls within the limits of grading curves as specified in ASTM C33-78 [1] and BS 882 [11] standards

The various specific gravity obtained in this work are satisfactory; showing that the aggregates are dense can be used for mass construction work such as dams and construction of foundations for structures.

The organic matter, silt and crusher dust contained in the aggregates evaluated were found not to be excessive.

It was observed that due to poor maintenance, some crushers used in the industry are inefficient resulting in the production of flaky and elongated particles and often times with significant quantity of dust.

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ACKNOWLEDGEMENT / SOURCE OF SUPPORT

Nil.

CONFLICT OF INTEREST

No conflict of interests was declared by authors.