QUALITY ASSESSMENT OF CRUSHED ROCK AGGREGATES FROM LOKPAUKWU/UMUCHIEZE IN OKIGWE AREA, SOUTHEASTERN NIGERIA, FOR ENGINEERING CONSTRUCTION

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Abstract

The strength and durability of crushed rock aggregates depends on the physico-mechanical characteristics of the rock. Result of andesite aggregate from Umuchieze Lokpaukwu indicates that the aggregate possess mean aggregate crushing value (ACV) of 14.8%, mean aggregate impact value (AIV) of 12.6%, mean los Angeles abrasion value (LAAV) of 24.6%, mean water absorption value of 0.33% and mean bulk density of 2.4g/cm^3. All parameters analyzed falls within the acceptable limits, except for bulk density of mean value of 2.4g/cm3 which is below the acceptable limit of more than 2.6g/cm3. It is therefore deduced that crushed rock aggregates from Umuchieze Lokpaukwu is of good quality and can be used in engineering construction.

Keywords: Crushrock Aggregates, Strength and Durability, Physico-mechanical characteristics and engineering construction.

Introduction

Crushed-rock aggregate is the sized, or crushed and sized rock material used in rigid and flexible highway pavements. They are also materials that form concrete, motar or asphalt when mixed with appropriate proportions of water and a binding agent like cement or bitumen (Clutterbuck et al., 1982). The use of crushed-rock aggregates for engineering construction depends on the strength and durability characteristics of the aggregates (Okeke, 2005). Aggregates range in size from large boulders (rip rap) used as fill in large construction projects to finely-ground flour-sized particles used in paint, glass, plastic, medicine, agricultural feed and soil conditioners, and many other industrial and household products.

Most crushed stone is used as construction aggregate, commonly in the form of asphalt or concrete. In many cases it is required for use in asphaltic concrete, because the angular surfaces provide the needed intergranular strength. One km of a four-lane interstate highway requires nearly 50,000ton of aggregate (Langer and Glanzman 1993). Aggregates are essential not only as a foundation for pavements, but also constitute the cement that makes the road itself. When a road is finished, the upper layers provide protection for the sub-base. Nevertheless, water can freely pass through the open structure, so the constituent rock must be able to maintain its properties when in the wet state.

The properties of crushed rock result from the origin and mineralogy of the source rock and its subsequent alteration and weathering. Some important properties of a rock are the type, size, shape, orientation, and proportions of mineral grains; the type of contacts between the mineral grains; the layering of minerals; and the presence and interconnectedness of voids (Dolar-Mantuani 1983). The strength of the aggregates refers to the ability of the aggregates to resist compression due to external static or dynamic load (Prentice, 1984). During the construction process, the sub-base is used as track along which heavy construction machinery can run; it must therefore be able to withstand the weight and impact of such vehicles.

Selecting the right aggregate material is imperative to overcome the frequent problem of pavement failure. In the various ways in which aggregate is used, it is exposed to a variety of stresses, and the response of the structure in which it is used will largely depend upon the properties of the aggregate. It needs to resist heavy loads, high impacts and severe abrasion, and it needs to be durable in the prevailing environmental conditions. These properties will need to be tested and assured before the road is built. Similarly, after the initial trafficking and removal of any surface bituminous coating, vehicle will be traveling on the actual aggregate used in the mixture for the bulk of the life of the road surface. Thus they undergo substantial wear and tear throughout their life. In general, they should be hard and tough enough to resist crushing, degradation, and disintegration from any associated activities. About 52% of all construction aggregate is crushed stone, while 48% of the remaining is sand and gravel (AASHTO, 2001).

The durability of the aggregates is directly related to the strength of the aggregates and indirectly refers to the life of engineering structures constructed with them. In this paper, the physico-mechanical properties of the aggregates used in describing their strength and durability include aggregate crushing value (ACV), aggregate impact value (AIV), Los Angeles abrasion value (LAAV), water absorption, bulk density and specific gravity.

Location and Geology of the study area

Lokpaukwu Umuchieze is located within the Lower Benue Trough of Nigeria and it accommodates discontinuous exposures of eroded volcanic and hyperbyssal features (Adighije 2009). It lies between latitude $6^o\ 10^1$ to $6^o\ 30^1$N and longitude $8^o\ 40^1$ to $9^o\ 00^1$E. The Benue Trough formed as a result of series of tectonism, accompanied by magmatism and repetitive sedimentation in the Cretaceous during the separation of South America from Africa. This separation left the Benue Trough as an aulacogen, a failed arm of an RRR Triple Junction (Burke, 1972; Olade, 1975). A reconstruction by Murat (1972) shows the southern part of the Benue Trough as longitudinally faulted, with its eastern half subsiding preferentially to become the Abakiliki depression. During the filling of the Abakiliki-Benue sector of the Benue Trough in the Albian-Santonian times, the proto-Anambra Basin was a platform that became only thinly sediment-draped (Etuk et al., 2008). Basin subsidence in the southern Benue Trough was spasmodic. It was at a high rate in pre Albian time, low in lower Cenomanian, and very high in Turonian; the latter was an important phase of platform subsidence (Ojoh, 1990). This is thought to be the actual time of initiation of the Anambra Basin; a process that gained momentum in the Coniacian and climaxed during the Santonian thermotectonic event (Nwajide, 1990). The area is underlain by the Ezeaku and Awgu Formation (Fig 1).

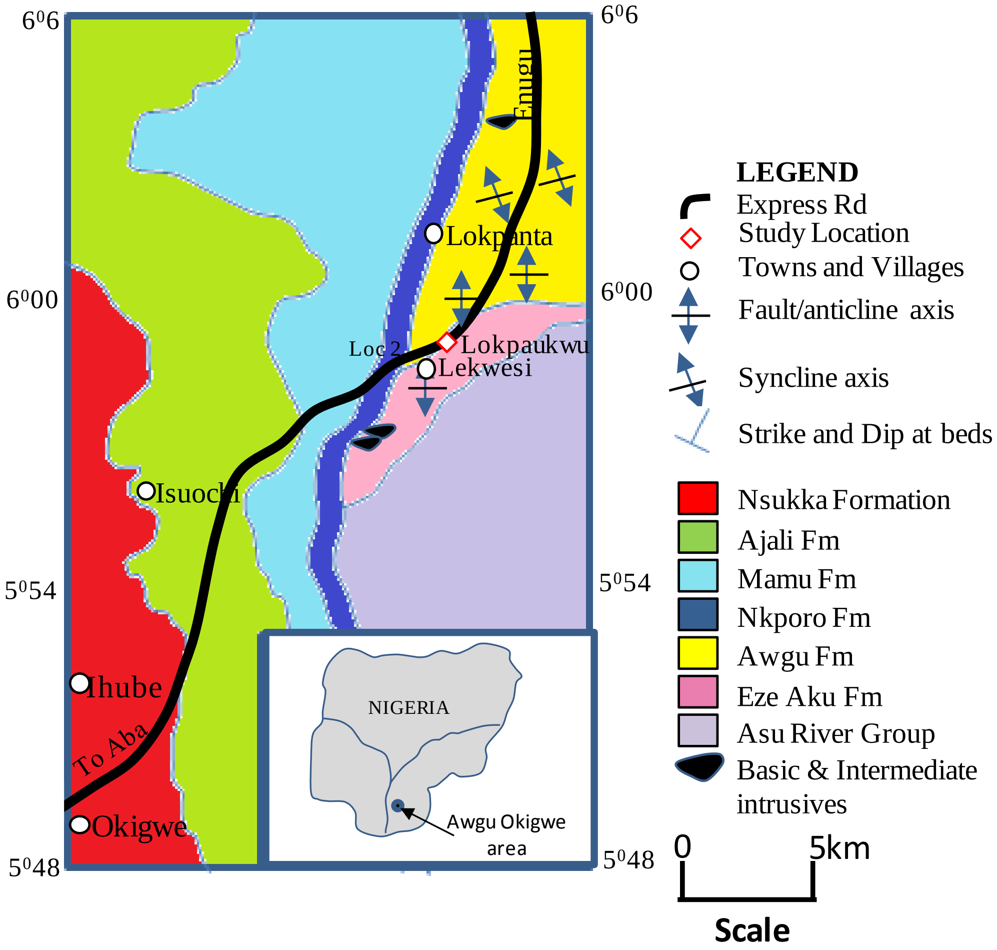

Fig 1. Geological map of study area and environ, modified from Udeyi et al, 1994

The Awgu Shales are fissile, finely laminated, dark bluish grey to black carbonaceous, richly fossiliferous, pyretic, and gypsiferous shales (Reyment, 1965). The Nkporo Shales consist of dark shales and mudstone with occasional thin beds of sandy shales and sandstone (Reyment, 1965). The area is drained by the Cross river system. This system may be related to structural controls, inequalities in rock hardness/texture, recent diatrophism, and the geology/geomorphic history (Igbozurike 1975). The stratigraphic sequence of the study area is presented in table 1.

Table 1. Stratigraphic Sequence in Anambra Basin (Modified from Nwajide, 2005)

Age	Basin	Stratigraphic Units						
Oligocene-Recent	Niger Delta	Ogwashi-Asaba Fm	Benin Formation					
Eocene		Ameki/Nanka Fm/Nsugbe Sandstone (Ameki Group)	Agbada Formation					
Thanetian		Imo Formation	Akata Formation					
Danian	Anambra Basin	Nsukka Formation						
Maastrichtian		Ajali Formation						
		Mamu Formation						
Campanian		Nkporo Fm	Nkporo Shale	Enugu Fm	Owelli Ss	Afikpo Ss	Otobi Ss	Lafia Ss
Santonian	Southern Benue Trough	Agwu Formation						

Materials and Methods

About 10kg of crushed rock aggregates (andesite) from different point location were collected from Umuchieze Lokpanta quarry site (Fig 2). The samples were bagged in polythene bags, labeled and taken to Arab Contractors Nigeria Laboratory in owerri, Imo State for various test. The test performed on the sample (A and B) with different size fraction 10-15mm and 15-20mm respectively include aggregate crushing value, aggregate impact value, Los Angeles abrasion value, water absorption, bulk density and concrete compression test (BS 812, 1975 and AASHTO T96-92 2001).

Fig 2. Crushed rock aggregates (Andesite)

Results and Discussion

Table 2 represents the result of the test for strength and durability characteristics on samples A and B of crushed rock aggregates from Umuchieze Lokpanta Anambra Basin, Southeastern Nigeria while table 3 represents acceptance limits for test results of roadstone (after BS 882, 1973 and Govt. of East Central State of Nigeria, 1972).

Table 2. Strength and Durability features of crushrock aggregates from Umuchieze Lokpanta

Parameters	A (10-15mm)	B (15-20mm)	Average
ACV (%)	14.7	14.9	14.8
AIV (%)	11.9	13.2	12.6
LAAV (%)	22.4	26.8	24.6
WA (%)	0.32	0.34	0.33
Bulk Density (Mg/cm^3)	2.39	2.4	2.4
Compressive Strength (N/mm^2)	19.6	25.2	22.4

Table 3. Acceptance limits for test results of roadstones (after BS 882, 1973 and Govt of East Central State of Nigeria, 1972).

Test	Acceptance Limits
Aggregate crushing value (ACV) (%)	Maximum 30
Aggregate impact value (AIV) (%)	Maximum 30
Los Angeles abrasion value (LAAV) (%)	Maximum 40
Water absorption (%)	Less than 3
Bulk density (Mg/m^3)	More than 2.6
Specific gravity	2.6-2.9

Crushrock aggregate is one of the major constituents for construction of highway pavements. However, the quality of the pavement depends on the quality of the aggregates used in the construction and hence the need to test the suitability of the crushrock aggregates to be used. Aggregate used in the surface course (running surface) of roads must be resistant to the polishing action of vehicle tyres, otherwise the road can become slippery, especially when wet. It is essential that aggregates used in construction purposes are strong and durable.

The Aggregate Crushing Value is a value which indicates the ability of an aggregate to resist crushing under a gradually applied compressive load (a California Bearing Ratio (CBR) machine or concrete crushing apparatus) over a period of 10 minutes, after passing through sieve 14.0mm, and retained on 10.0mm sieve. It ranges from 14.7% to 14.9% with average value of 14.8% 9Table 2). Materials with low aggregate crushing values are generally preferred to be used in high pavements (Kadiyali, 1989). Aggregates with values less than 10% are considered very strong, values between 10-20% are considered strong, and values between 20-30% are just good enough for roadstone (Singh, 1991). Relationship between pairs of physico-mechanical properties shows that aggregate crushing value is directly related to water absorption and inversely related to bulk density fig 2.

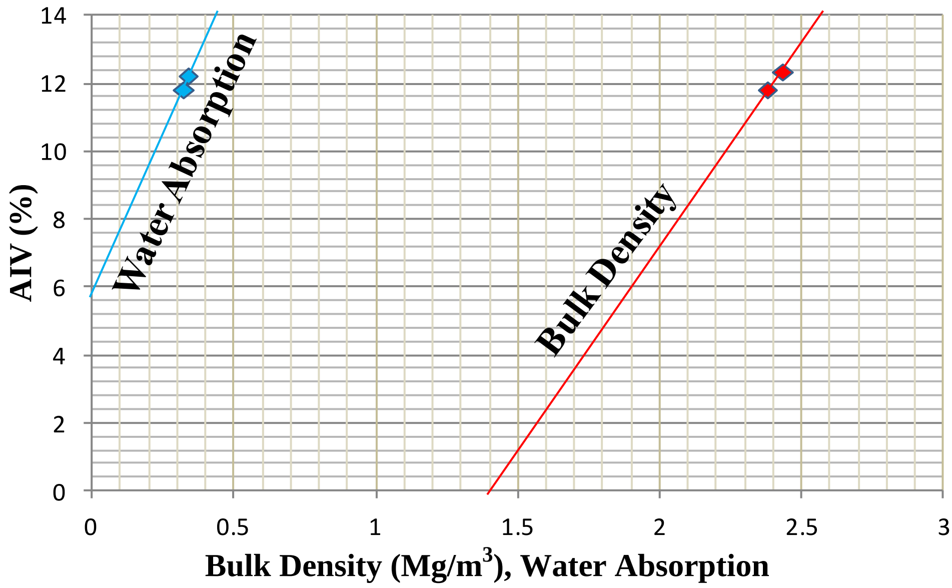

Fig 2. Relationship between aggregate crushing value and water absorption and bulk density.

Impact from traffic movement on aggregates develop as a result of irregularities in road surfaces. This impacts tend to break the aggreagte into smaller pieces. It is necessary that aggregates to be used in construction should be tough enough to resist friction from such impact. Aggregate impact value of roadstones is therefore another way of evaluating the strength of the aggregates to be used in road construction. Aggregate Impact Value (AIV) is the percentage of fines produced from an aggregate sample after subjecting it to a standard amount of impact. It ranges from 22.4% to 13.2% with mean value of 12.6% (Table 2). Aggregates with values less than 10% are considered very strong, aggregates with values between 10-20% are considered strong, and aggregates with values between 20-30% are just good enough for road surfacing (Singh, 1991). Comparing the properties of the rocks, it is however observed that aggregate impact value is influenced by water absorption fig 3.

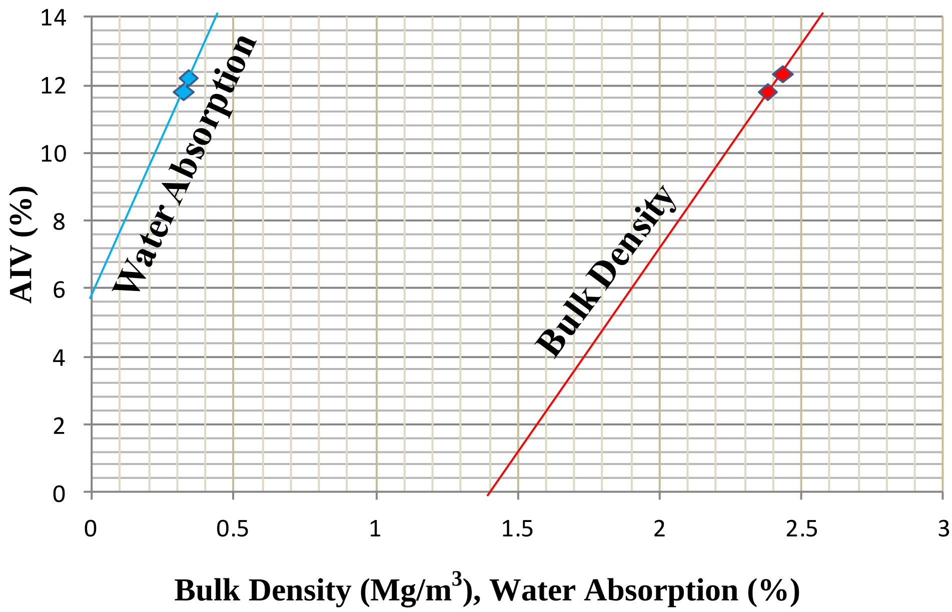

Fig 3. Relationship between aggregate impact value and water absorption and bulk density.

The percentage of wear caused by traffic load on roadstones is termed Los Angeles abrasion value. It ranges from 22.4.4% to 26.8% with mean value of 24.6% (Table 2). Rock materials with Aggregate Abrasion Values below 30 percent are regarded as strong, while those above 35 percent would normally be regarded as too weak for use in road surface. This implies that roadstones with lower Los Angeles values will have greater resistance to wear. Such roadstones are also said to possess long life or be very durable. Los Angeles values for good quality roadstones may be up to 40% (Govt. of East Central State of Nigeria, 1972). Los Angeles abrasion value is also influence by water absorption fig 4.

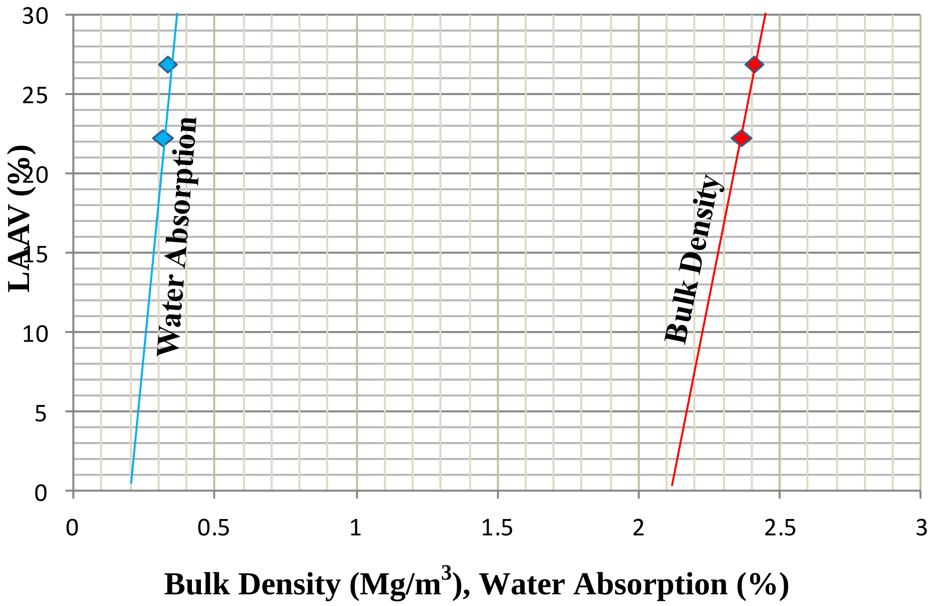

Fig 4 Relationship between Los Angeles abrasion value and water absorption and bulk density.

The water absorption of the aggregates controls the amount of binder required in highway surfacing design (high water absorption value will need more binder materials after the ingredients have been mixed). It ranges from 0.32% to 0.34% with mean value of 0.33% (Table 2). Water absorption values allowed for aggregates used in roadstones normally range from 0 to about 3% for materials used in road surfacing (BS.882, 1973). The bulk density of the aggregates is indirect measurements of the strength and quality of the roadstones. It ranges from 2.39Mg/m^3 to 2.4Mg/m^3 with average value of 2.4% (Table 2). Dense aggregates with high specific gravity values are generally strong. Aggregates with values of density greater than 2.6mg/m^3 are good for road construction.

The compressive strength of aggregate is the load at failure divided by the cross sectional area of one side of the aggregate. It ranges from 19.6N/mm^2 to 25.2N/mm^2 with mean value of 22.4N/mm^2 (Table 2). The compressive strength of concrete for engineering structures depends 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). Compressive strength of aggregates depends mostly on the size of the aggregates. Bigger sizes (10-15 and 15-25mm) are generally good roadstone while smaller sizes (5-10mm) are generally poor roadstones (O'Flaherty, 1974).

Conlusion

Results of physico-mechanical tests on crushed rock aggregates (andesite) Lokpaukwu Umuchieze in Okigwe area Southeastern Nigeria were used to evaluate their strength, durability and suitability characteristics as materials for engineering construction. The comparative study of results from analysis and reference standard limit, showed that the parameters falls within the acceptance limit except for bulk density value of 2.4g/cm^3 which is lower than the acceptance limit of more than 2.6g/cm^3. Bulk density does not have any influence on aggregate crushing value, aggregate impact value and loss angles abrasion value but rather, they are influence by water of absorption which falls within the acceptance limit. It can therefore be deduced that the aggregates are good material for engineering construction.

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