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Evaluation Of Suitability Of Natural Gravels Associated With Nsukka Formation In Owerre-Ezukala (Awka Area), Southeastern Nigeria,As Aggregates For Highway Pavement

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--***ABSTRACT:***--

The use of aggregates as roadstones depends on the strength and durability characteristics of the aggregates.The suitability of natural gravels associated with Nsukka Formation in Owerre-Ezukala (Awka area), Southeastern Nigeria as aggregates for highway pavement was investigated and evaluated. In this study, some gravelsamples were collected froma local quarry at Owerre-Ezukala (Awka area) and subjected tophysical and mechanical tests includingAggregate Crushing Value(ACV), Aggregate Impact Value (AIV), Los Angeles Abrasion Value (LAAV), SpecificGravity (SG) and Water Absorption (WA).Results of the physico-mechanical tests show thatthe samples associated with Nsukka Formation in Owere-Ezukala have an ACV of 31.30%, AIV of 33.70%, LAAV of 50.30%, SGof2.75 and WAof 11.70%.The ACV and SG are within the acceptable limit of <40.00% and> 2.50, respectively; while the AIV, LAAVand WAexceeded the acceptable limit of <30.00%, <35.00% and <3.00%,respectively.The natural gravels of Owerre-Ezukala do not meet up the requirements for highway pavement due to their high AIV, LAAV and WA values;hence, they are not suitable for use as aggregates for highway pavements. They will exhibit low resistance to abrasion caused by the wheels of automobiles.However, they can be used as gravel-pack materials in boreholes, fill-in materials at the toe of dams and as coarse aggregates in concretes.

Keywords*: Suitability, natural gravels, Nsukka Formation, Owerre-Ezukala,aggregates and highway pavement.*

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I. INTRODUCTION

Gravel is defined as a sedimentary formation that contains 50% of more of particles greater than 2mm in diameter (Rust, 1979; Lambe and Whiteman, 1979; Scot and Schoutra, 1968). Such gravel may of course be described as sandy, clayey or silty gravel, if the composition of the minor constituent is greater than 5% but less than 50% (Bell, 1992). Similarly, it can occur as a minor constituent in a soil mixture where clay, silt or sand constituent is greater than 50%. Gravelly silt, gravelly clay or gravelly sand may therefore occur provided the gravel content is greater than 5% but less than 50% (Okeke and Agbasoga, 2001).Gravels are used extensively as aggregates for concretes, highway pavements; drainages and gravel pack materials.

Aggregates are defined as inert materials which when bound together into a conglomerated mass by cement and water to form concrete or mortar (Krynine and Judd, 1957). Concrete is therefore a composite material formed by mixing cement, fine and coarse aggregates and water while mortar is a paste formed by mixing cement, fine aggregates and water.For Portland cement concrete, (rigid pavements) natural sand, gravel and crushed stone are widely used in pavement structures (BS 882, 1973).

Aggregates may be regarded as coarse (size greater than 5mm), fine (size less than 5mm) and all-in-varieties (comprising both fine and coarse aggregates) (Dhir and Jackson, 1980). Aggregates may also be classified in terms of natural and artificial aggregates. The natural aggregates are crushed rocks, gravels and sands. They are essential resources used extensively in the construction industries as aggregate for highway pavements, without the use of gravel aggregate our homes and cities would be what they are today. Gravels and crushed stones are the major sources of most pavement aggregates. Their angular shapes perform well in applications where inter particle friction adds to the pavement strength, such as granular bases and asphalt layers. The artificial aggregates include blast furnace slag, pulverized fuel ash, broken bricks and saw dust (Clustterbuick et al, 1982).Aggregates are also used as wearing surfaces and binders in flexible pavements (highways and runways).

Aggregates may also be defined as material either natural or manufactured that are either crushed and combined with a binding agent to form bituminous or cement concrete or treated alone to form products such as rail road, ballast, filter beds or fluxed material, treated and untreated aggregates are also used for local gravel roads or other aggregates surfaced roads, driveways and parking areas. In general, natural aggregates are mined from stone quarries, sand and gravel pits, increasingly however, agencies are using recycled reclaimed and alternative by-product materials such as blast furnace, slag which are artificial aggregates.

In this study physical and mechanical testwere performed on some samples of natural gravel aggregates associated with Nsukka Formation in Owerre-Ezukala. The tests performed on the aggregates include aggregate crushing value (ACV), aggregate impact value (AIV), Los Angeles abrasion value (LAAV), specific gravity (SG) and water absorption (WA). The results of these tests were used to evaluate the suitability of the soil samples as aggregates for highway pavements.

II. LOCATION AND GEOLOGY OF THE STUDY AREA

2.1 Location and Accessibility of the Study Area

The study area,Owerre-Ezukala is in Orumba South L.G.A of Anambra state, south-eastern region of Nigeria. It lies between latitude 5°45'- 6°5'N and longitude 7°15'- 7°35'E with an altitude of about 22m above sea level. The area shares common boundaries with some other states of the nation such as Imo, Abia and Enugu State.Owerre-Ezukala haseight villages Ihie, Isiafor, Iyiafor, Lete, Mkputu, Ogwuada, Okpoghuta and Okpu.The area can be accessed through Enugu-Onitsharoad,with other secondary and minor roads(see Fig.1).

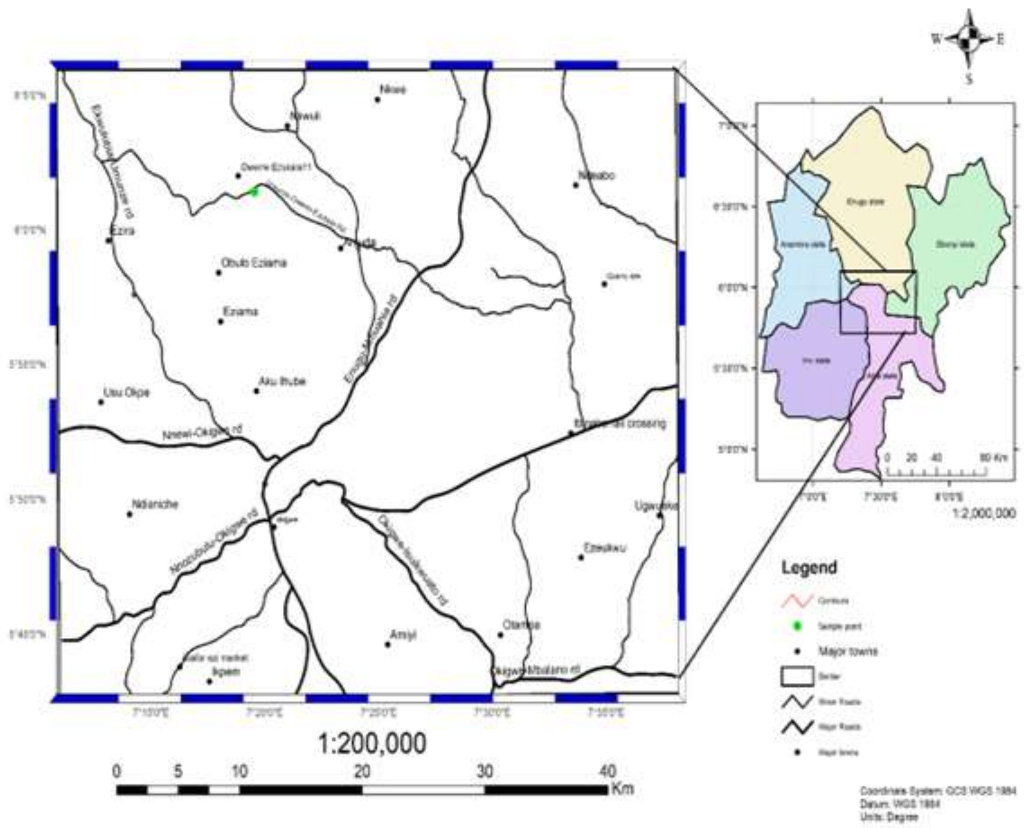

Fig 1: Accessibility map of the study area

2.2 Geology of the Study Area

Owerre-Ezukala, geologically, lies within the Anambra Sedimentary Basin, which constitutes a major depocenter of clastic sediments in the southern portion of the lower Benue Trough (Nwajide, 2005; Mode, 2004).The Benue Trough is a rift basin in Central West Africa that exceeds NNE-SSE from about 800km in length and 150km in width (Obaje et al., 2003). It is a major structural feature in Southeastern Nigeria and was developed during the separation of South America and opening of South Atlantic Ocean at the site of RRr triple junction (Burke et al., 1972; Olade, 1975;Peters 1978). The geologic formations of Anambra Basin are Nkporo Formation, Mamu Formation, Ajali Formation, Nsukka formation Imo Shale, Ameki Formation and Ogwashi Asaba Formation (Reyment, 1964 and 1965; Offodile, 1975; Hoque, 1977; Ofoegbu, 1985; Agumanu, 1986; Nwajide, 2005).Table 1 shows a generalized stratigraphic sequence of sedimentary rock in the study area.

Table 1: Generalized stratigraphic sequence in Okigwe Area (Modified from Reyment, 1965, Offodile 1975, Mode 2004 and Ofoegbu, 1985)

Age	Formation	Lithological Characteristics
Paleocene (55-65 m.y.)	Imo Formation (Imo Shale)	Blue to dark grey shales and subordinate sandstone member (Umuna and Ebenebe sandstone)
Maestricitian (65-68 m.y.)	Nsukka Formation	Alternating sequence of sandstone and shale with coal seams
Maestricitian (65-68 m.y.)	Ajali Formation	Friable sandstone with cross bedding. Alternating sequence of sandstone, siltstone, shale and claystone with coal seams
Campanian (68-78 m.y.)	Mamu Formation Nkporo Formation (Enugu Shale)	Shale and mudstone with sandstone lenses

The area of study and its environs are underlain by the Nsukka formation (as shown in Fig. 2) which lies conformably on the Ajalli sandstone. The formation was first described by Tattam (1944) as the upper coal measures; the lithology of Nsukka formation is very similar to that of the Many formation and the rocks consists of an alternating succession of sandstone, dark shale and Sandy shale, with thin coal seams at various horizons. The outcrops of the formation can be observed in the valley of the Nadu River and on road cuts along Enugu-Onitsha road.

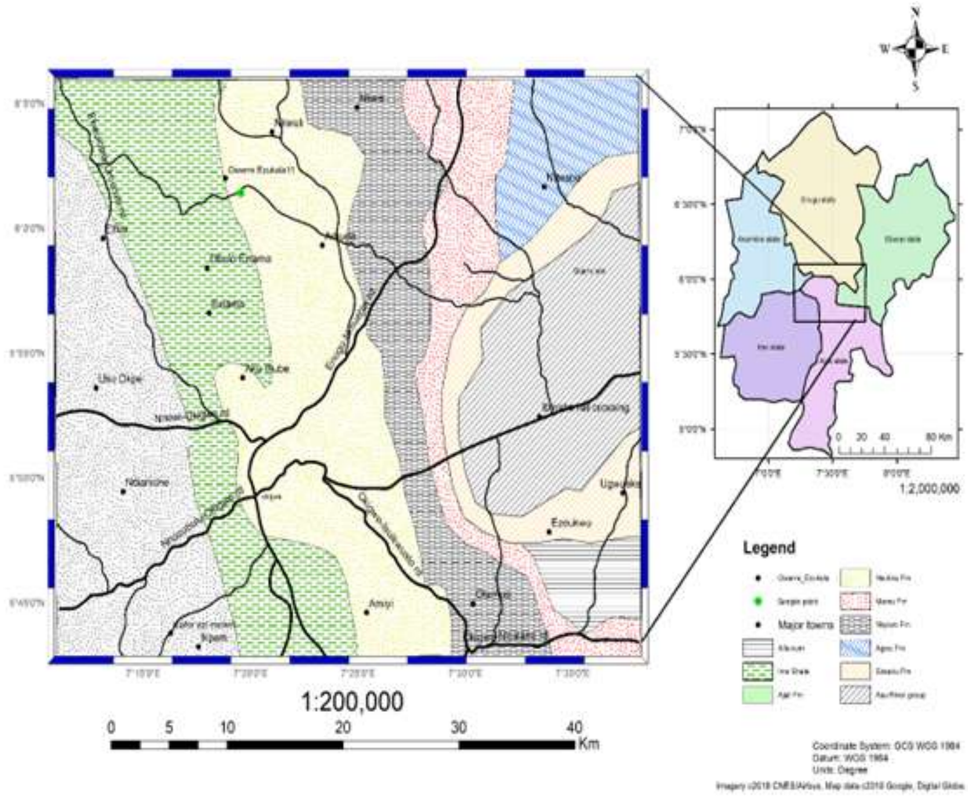

Fig 2: Geologic map of the study area
(Modified from Okeke and Igbarueo, 2003).

2.3 Climate

The climate of Owerre-Ezukala is tropical. In winter, there is much less rainfall than in summer. The average annual temperature is 270°c the rainfall averages 1828mm. The driest month is December with 7mm of rain. Most precipitation falls in September with an average of 306mm (as shown in Fig. 3).

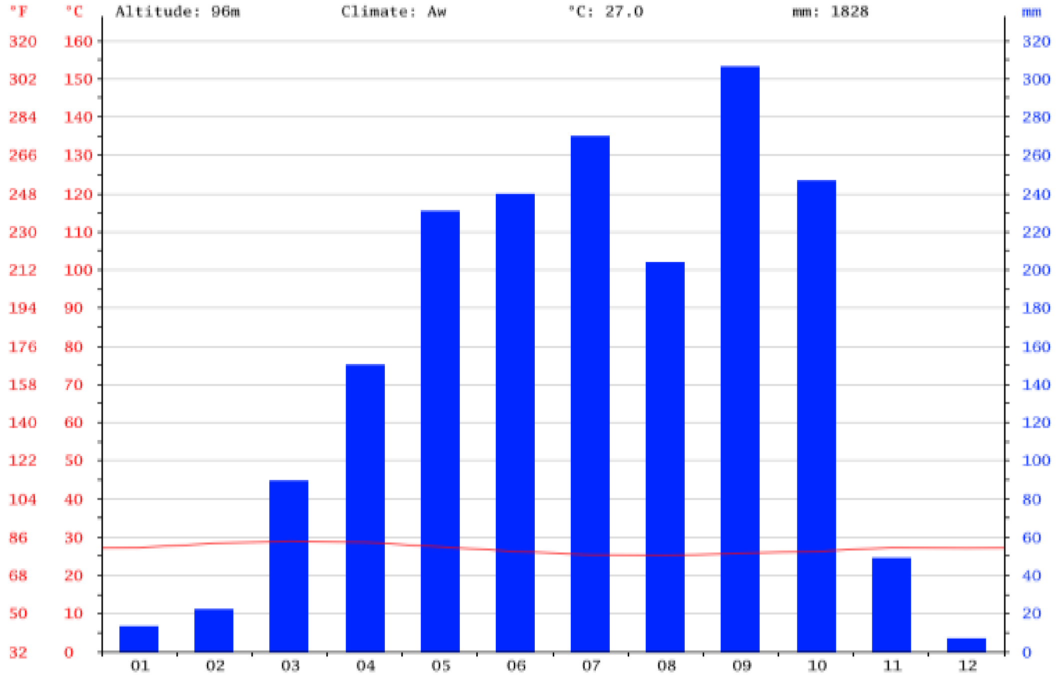

Fig 3: Climography of Owerre-Ezukala

2.4 Temperature

March is the warmest month of the year the temperature in March averages 29.0°c in august the average temperature is 25.2°c. It is the lowest average temperature of the whole year (see Fig. 4).

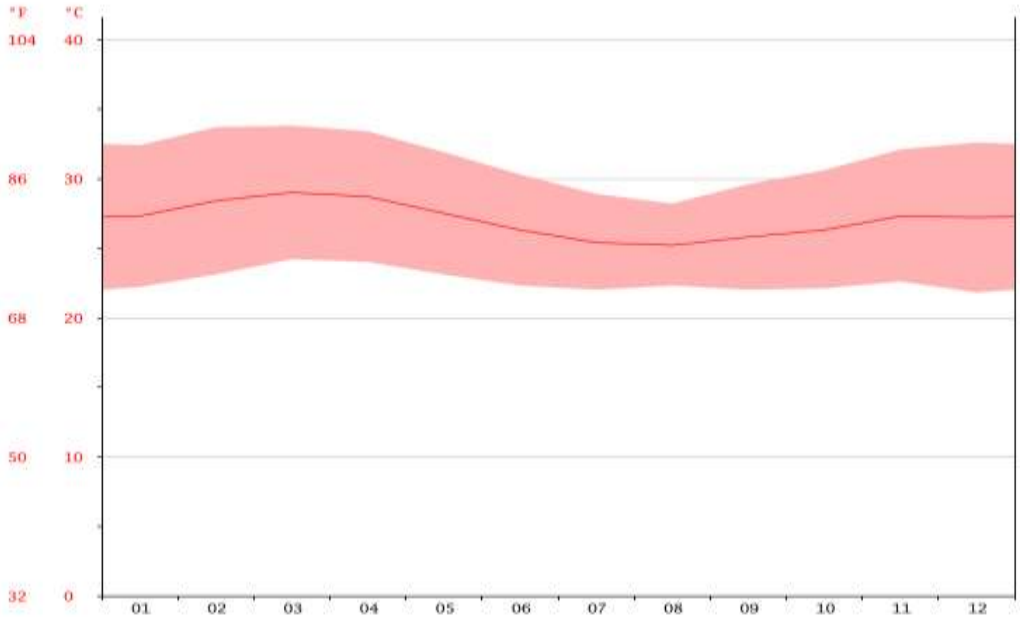

Fig 4: Temperature graph of Owerre-Ezukala

2.5 Rainfall

The area is characterized by the annual double maxima of rainfall. The annual total rainfall is above 1,450mm, concentrated mainly in 8months of the year.

2.6 Vegetation

It falls within the high forest zone and it comprises of tall trees with thick undergrowth and numerous timbers. Oil palm trees and raffin palm trees are the most common.

III. MATERIALS AND METHODS

3.1 Field Studies and Sample Collection

The field studies were carried out andgravel samples were collected from Owerre-Ezukala by shovels from the exposed outcrops, bagged in clean sample bags labeled and taken to the laboratory for various tests and analysis.

3.2 Laboratory Tests on Samples

3.2.1 Aggregate crushing value (ACV)

One of the models in which pavement material can fail is by crushing under compressive stress. The test was standardized by IS: 2386 and used to determine the crushing strength of the aggregates. The aggregate crushing value provides a relative measure of resistance of aggregates to crushing under gradually applied crushing load. About 3.00kg of the sample passing the 12.70mm and retained by 9.52mm BS sieve was placed in a standard mould, and then load of 450 tonnes was gradually applied to the material over a period of 10 minutes. The load was then removed and the amount of material passing the 2.36mm sieve was determined. This weight (W_2) expressed as the percentage of the total weight(W_1) of the material used in the test was the aggregate crushing value of the sample.

Aggregate crushing value (ACV) = $W_1/W_2 \times 100$

3.2.2 Aggregate impact value (AIV)

The aggregate impact test was carried out to evaluate the aggregate resistance to impact of repeated and sudden falls. Aggregates passing through 12.50mm sieve and retained in 10.00mm sieve was filled in a cylindrical steel cup of internal diameter 10.20mm and depth 5.00cm which was attached to ametal base of impact testing machine. The material was filled in 3 layers where each layer was tamped for 25 numbers of blows. Metal hammer of weight 13.50 to 14.00kg is arranged to drop with a free fall of 38.00cm by vertical guides and the test specimen was subjected to 15 numbers of blows. The crushed aggregate was passed through 2.36mm IS sieve.

3.2.3 Los Angeles Abrasion value (LAAV)

Los Angeles Abrasion test is a preferred one for carrying out the hardness property. The principle of Los Angeles Abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge. LAAV is the measurement of resistance to attrition. Abrasion test was carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. About 5.00kg of the sample passing 12.70mm but retained on the 9.52mm sieve was placed in a steel cylinder with 12 steel balls. The horizontally placed steel cylinder was rotated at 20-33 revolutions per minute for 500 revolutions. At the completion of the test, the sample was sieved over 1.77mm sieve and the weight passing was expressed as a percentage of the original weight (O'Flaherty, 1974).

3.2.4 Specific gravity and water absorption

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specific temperature. The pyconometer method was used in determining the specific gravity. The empty and dry pyconometer was weighed to the nearest 0.01g and recorded as weightW_1, after which about 100g of the sample was placed in the pyconometer. The pyconometer and the sample were then weighed to the nearest 0.01g and recorded as the weightW_2. Water was added in the pyconometer until about it was two-third filled.Gently and carefully, the mixture was agitated; more water was added in the pyconometer until the bottom of the meniscus was exactly as the volume marked. The pyconometer was weighed and recorded as W_3. Thepyconometer was emptied and washed then filled with water up to the mark and weighed as W_4. The above procedure was repeated three times, the temperature of the sample-water mixture was recorded by the thermometer.

Water Absorption test was carried out in conjunction with specific gravity test. Water for 24 hours, surface dried and weighed in air and then oven-dried and weighed in air again. The water absorption was obtained by expressing the difference between the weights of the saturated and oven dried samples in air as a percentage of the latter (O'Flaherty, 1974).

The specific gravity of aggregates normally used in road construction ranges from about 2.50 to 2.90. Water absorption values ranges from 0.10 to about 2.00 percent for aggregates normally used in road surfacing.

IV. RESULTS AND DISCUSSION

4.1 Results

The results of the physio-mechanical tests on the samples associated with Nsukka Formation which including aggregate crushing value (ACV), aggregate impact value (AIV), Los Angeles abrasion value (LAAV), specific gravity (SG) and water absorption (WA) are shown in the Table 2 below.

Table 2: Physico-mechanical properties of natural gravels from Owerre-Ezukala

Test Descriptions	Aggregate sizes (O'Flaherty, 1974)	Results	Federal Ministry of Works (1997)
Aggregate crushing value (ACV) %	10.00 -15.00mm	31.30%	<35.00%
Aggregate Impact value (AIV) %	5.00 -15.00mm	33.70%	< 30.00%
Loss Angeles Abrasion Value (LAAV) %	10.00 -25.00mm	50.30%	<40.00%
Specific Gravity (SG)	10.00 - 25.00mm	2.75	>2.50
Water Absorption (WA) %	10.00 -20.00mm	11.70%	<3.00%

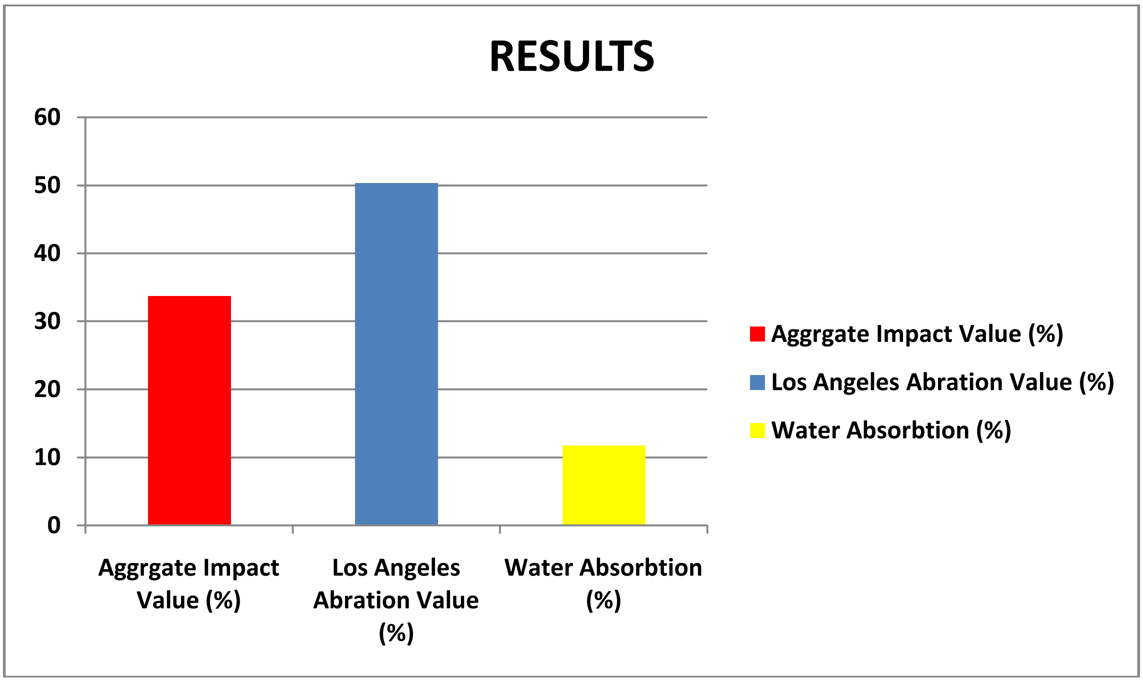

Figure 5: Results showing AIV, LAAV and WA values

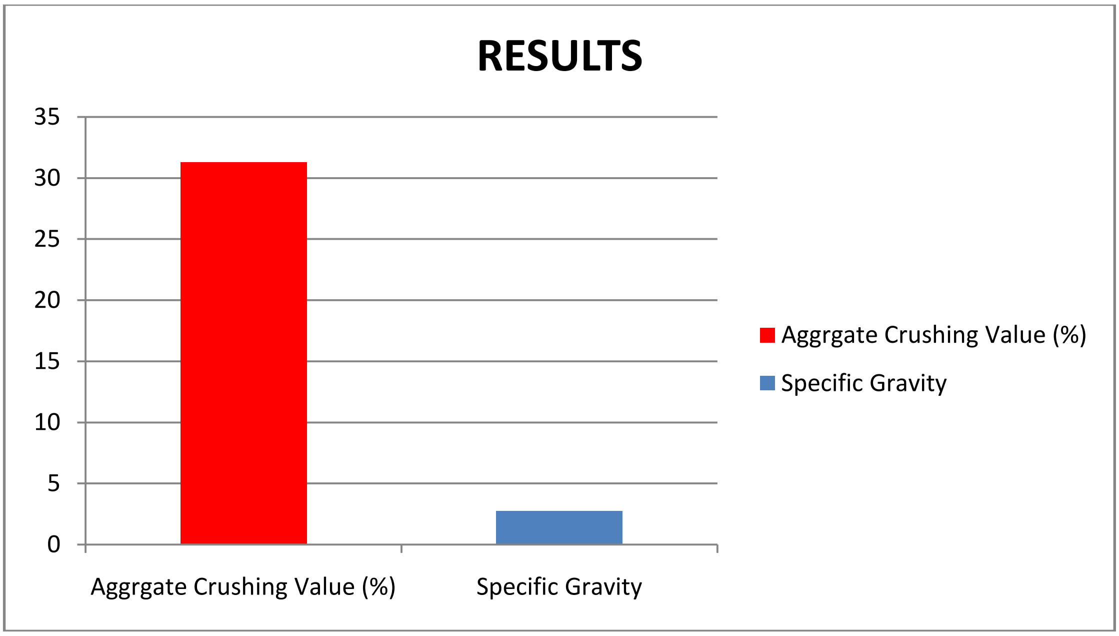

Figure 6: Results showing ACV and SG values

4.2 Discussion

Aggregates used in highway construction can experience strength failure if severe stresses act on their surfaces. Based on the method of measurements, materials with low aggregate crushing value are generally preferred to be used in high quality pavements. A value less than 10 signifies an exceptionally strong road stones while a value above 35 would normally be regarded as weak road stones. Aggregate to be used in road construction should therefore be though enough to resist friction from such impact.

The aggregate crushing value (ACV) and thespecific gravity (SG)are within the acceptable limits for highway pavement aggregates with values of less than 35.00% and greater than 2.50, respectively. The aggregate impact value (AIV) exceeds the acceptable limit for highway pavement since its value is 33.70% and itexceeded the acceptable limit of<30.00%.The Los Angeles Abrasion value (LAAV) exceeded the acceptable limit for highway pavement since its value is 50.30% and it exceeded the acceptable limit of <40.00%. The water absorption exceeded the acceptable limit of <3.00%, since its value is 11.70%.

The aggregate crushing value (ACV) of aggregates is a measure of the resistance of the aggregates to crushing under gradually applied compressive load while Los Angeles abrasion value (LAAV) is a measure of the resistance of the aggregates to surface wear by abrasion (the lower the value the greater the resistance). The water Absorption of the aggregates controls the amount of binder required in surfacing design (high water Absorption value will need more binder materials after the ingredients have been mixed).

The natural gravels of Owerre-Ezukala do not meet up the requirements for highway pavement; hence, they are not suitable for use as aggregates for highway pavements in terms of their low resistance to abrasion caused by the wheels of automobiles. However, they can be used as gravel-pack materials in boreholes, fill-in materials at the toe of dams and as coarse aggregates in concretes.

V. CONCLUSION

The results of physico-mechanical tests on samples of natural gravels from Owerre-Ezukala were used to evaluate their suitability as materials for highway pavements.The deductions from the laboratory analysis have yielded a good number of results which includes aggregate crushing value (ACV), aggregate impact value (AIV), Los Angeles abrasion value (LAAV), specific gravity (SG) and water absorption (WA).Although the ACV and SG are within the acceptable limits of < 35.00% and > 2.50, respectively, the AIV, LAAV and WA exceeded the acceptable limit of <30.00%, <35.00% and <3.00% respectively. Owerre -Ezukala natural gravels does not satisfy some of the requirements for good highway pavement aggregates. They are therefore not recommended for use as aggregates for highway pavements. However, they can be used as gravel-pack materials in boreholes, fill-in materials at the toe of dams and as coarse aggregates in concretes. This research work has in essence, provided data for engineers and geologists as it will help to prevent possible difficulties, delays and additional expenses during construction.

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