GEOTECHNICAL PROPERTIES OF MARL ASSOCIATED WITH EZEAKU FORMATION IN AFIKPO AREA, SOUTHEASTERN NIGERIA, IN RELATION TO AGGREGATE QUALITY ASSESSMENT

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Abstract

The use of marl deposit as construction material has recently attracted some attention to both government and construction companies, hence the evaluation of the geotechnical properties and aggregate quality assessment of the deposit in the Afikpo area was conducted to determine its suitability as aggregate for concrete and highway pavement. The Marl deposit belong to the Ezeaku Formation, this was confirmed from the field observations and description which shows that they are of dark grey to black shale, sandstone, subordinate limestone and siltstone deposited by shallow marine environment. Physico-mechanical properties of the rock shows that the specific gravity of the marl sample is 2.58 %, the water absorption is 1.90 %, the Aggregate Crushing Value (ACV) of the marl sample is 23.50%, the Los Angeles Abrasion Value (LAAV) is 42.70 % and Aggregate Impact Value (AIV) is 29.40 % while the Atterberg Limit Test are Liquid Limit 29.50 %, Plasticity Index 4.60% with Free Swell 10% and Linear Shrinkage 0.30 %. On these bases of low Atterberg Limit values and favourable physico-mechanical properties, the marl in Afikpo area is a good aggregate material for highway pavements and concrete.

Keyword: Marl deposit, Properties, Aggregate, Physico-mechanical, Atterberg limit, Highway pavement, Concrete.

1.0 Introduction

The increasing demand for construction aggregates has necessitated sourcing for alternative aggregates to the conventional granite and other igneous and metamorphic aggregates. The marl deposits of the Ezeaku Formation exposed around the Amasiri-Akpoha axis has been quarried both locally and commercially for its aggregate.

Studies have shown that properties of an aggregate such as mineral composition, texture, roughness, swelling potential and strength can affect the performance of the aggregate. Limestone is a good construction aggregate material owing to its low alkali-silica ratio and textural quality.

The depositional model for the Amasiri Sandstone of the Ezeaku Formation, southern Benue Trough has been controversial. The sandstones have been variously interpreted as tidal/subtidal shallow marine deposits (Banerjee, 1980), storm-dominated shallow shelf deposits (Amajor, 1987), shelf to deep water environment (Okoro and Igwe, 2014).

Marl has extensively been used as aggregates within the study area, it becomes imperative that since they are geological materials; hence, a study to investigate or understand the geotechnical properties and quality of aggregates.

The present study involves evaluation of geotechnical properties of the marl deposit associated with the Ezeaku Formation in Afikpo area, and assessment of the marl as rock aggregate for engineering purposes (concrete and highway pavement).

1.2 Location and Geology of the study Area

The study area covers approximately 461.2km^2 and is located between Latitudes $5^0 51^I$N and $6^0 009\ ^I$N, Longitudes $7^0 45^I$E and $8^0 00^I$E (Fig.2.1). The area includes the following communities: Amasiri, Akpoha, Ibii, Mgbom, all in Afikpo.

The study area lies within the Ezeaku Formation for which consists of feldspathic sandstones, laterally alternating with marine shales and limestone lenses (Reyment, 1965). In the Afikpo area, the dominantly shaley Ezeaku Formation changed facies to a sequence of sandstones interbedded with shales and minor limestones referred to as the Amasiri Sandstone (Whiteman, 1982).

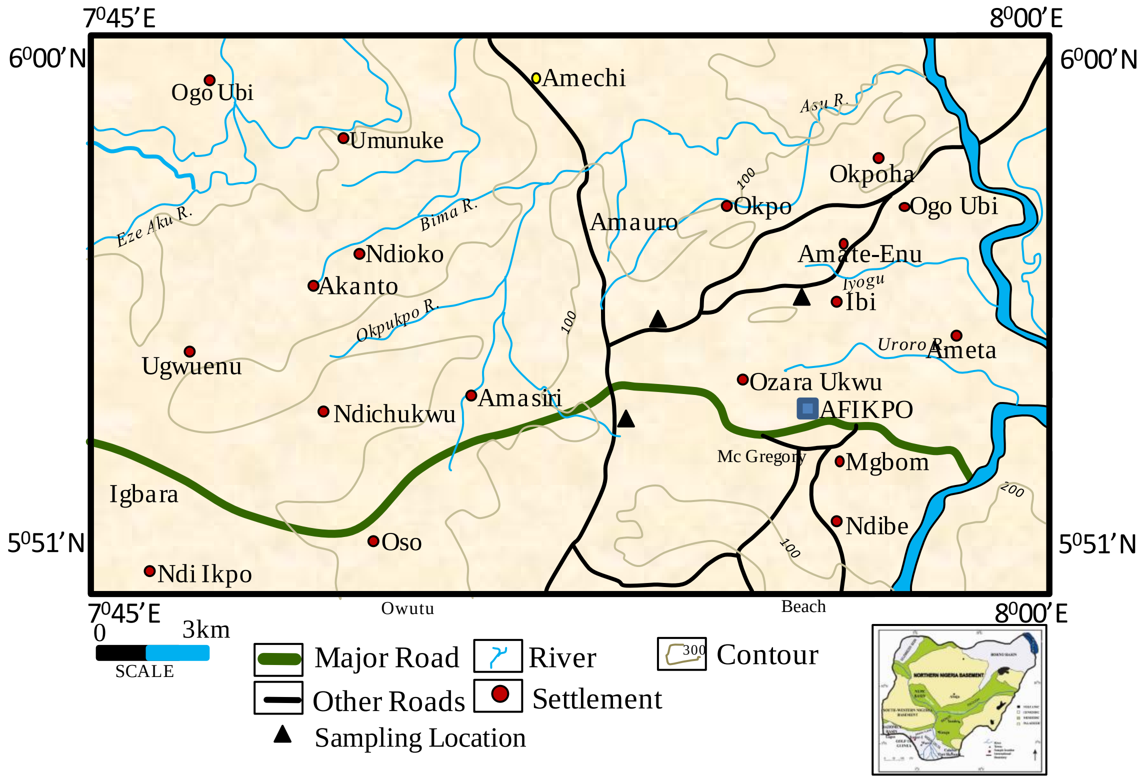

Fig 1: Location and topographic map of the study area

The geologic and tectonic evolution of the area can be traced to the Benue Trough. The Benue Trough is a northeast – southwest trending intracontinental basin that connects the east with the African rift system through the Bornu basin (Olade, 1975, 1978; Benkhelil, 1986).

The first mantle plume and associated events that led to the evolution of the Benue Aulacogen is believed to have taken place during Aptian times and was associated with the emplacement of the alkaline – mafic lavas and volcaniclastics (the Abakiliki pyroclastics) as well as the deposition of the Asu River Group (Olade, 1975). Temporary cessation or reduction in the Trough became the principal cause of deformation (folding) of the Albian sediments. This was accompanied by marine regression that led to the deposition of the Odukpani Formation only in the Calabar flank during the Cenomanian.

Mantle upwelling became reactivated during the Turonian and rifting along earlier lines of weakness allowed for unstable conditions that led to the deposition of the Eze-Aku Formation unconformably on the folded Asu River group (Nwachukwu, 1972; Ogbukagu, 1974; Olade, 1975). The final stage in the tectonic evolution of the Benue Rift/ Aulacogen occurred when the mantle upwelling ceased or there was an eastward migration of the plume relative to the continent in the Senonian. This led to sub – crustal contraction, final collapse of the Trough and a broad asymmetric downwarp (Ajakaiye & Burke, 1973) which led to a widespread compressive deformation of pre–Santonian rocks within the Trough.

Table 1: Correlation Chart for Early Cretaceous Tertiary Strata in the Southeastern Nigeria (After Nwajide, 1990).

AGE		ABAKILIKI - ANAMBRA BASIN	AFIKPO BASIN
m.y 30	Oligocene	Ogwuashi-Asaba Formation	Ogwuashi-Asaba Formation
54.9	Eocene	Ameki/Nanka Formation/Nsugbe sandstone (Ameki Group)	Ameki Formation
6.5	Paleocene	Imo Formation Nsukka Formation	Imo Formation Nsukka Formation
73	Maastrichtian	Ajali Formation Mamu Formation	Ajali Formation Mamu Formation
83	Campanian	Nkporo Oweli Formation/Enugu Shale	Nkporo Shale/ Afikpo Sandstone
87.5	Santonian	Agbani Sandstone/Awgu Shale	Non-deposition/Erosion
88.5	Coniacian		EzeAku Group (incl. Amasiri Sandstone)
	Turonian	Eze Aku Group	
93 100	Cenomanian -Albian	Asu River Group	Asu River Group

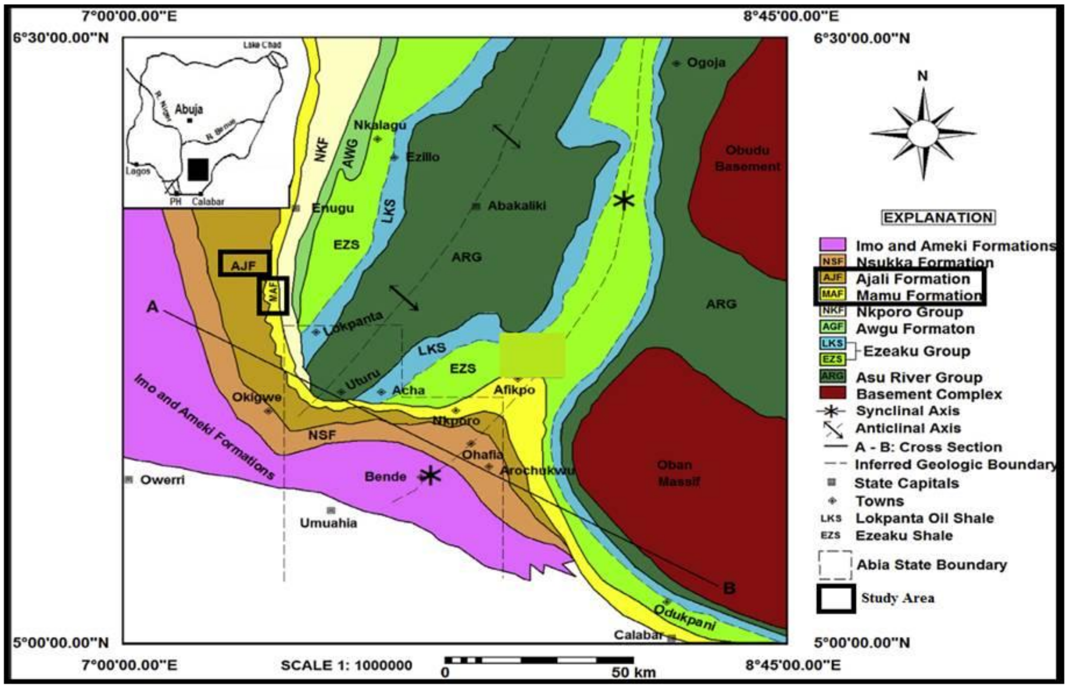

Fig 2: Regional geologic map of the southern Benue Trough (Modified after Okoro et al, 2016)

1.3 Materials and Methods

1.3.1 Field Studies and Sample Collection

The field study entailed a geological mapping of the study area. The mapping was completed within subsequent field trips for about four times and was basically aimed at examination of outcrop sections, the lithologic relationship in the outcropping profile, the nature of contacts, and the sedimentary structures. The attitude of the bed and other structural features were measured with the aid of Brunton/Silver compasses, while steel tape was used to measure the vertical thickness of the units. A geologic hammer was used for collection of samples followed by labeling and packaging.

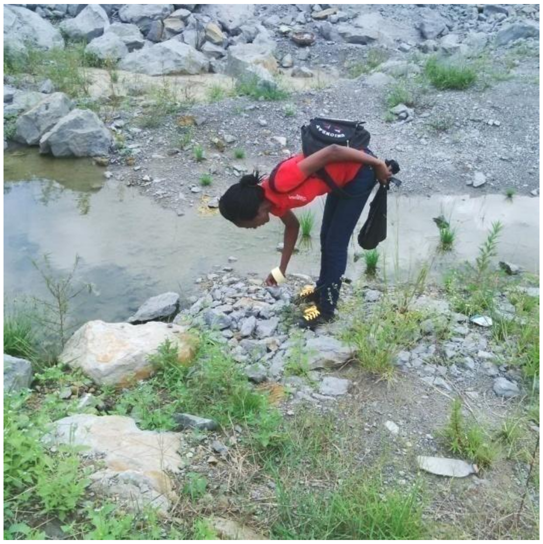

Fig 3: Sample Collection from Study Area

1.3.2 Laboratory Tests on Samples

1.3.2.1 Geotechnical Tests

The test consists of subjecting the specimen of aggregate ranging between 20 to 32mm in standard, dry aggregates (between 100 to 110^{0}c temperature) passing through IS sieve of size 32mm and 2.36mm. Retained 19.5 mm sieves are filled in a cylindrical measure of 11.5. The quarry dust for Atterberg Limit Test and Free swell.

It was done at Arab Constructors, Ulakwo, Imo State.

1.3.2.2 Specific Gravity Test and Water Absorption test

The test is performed by immersing aggregate sample (20 to 32mm) in distilled water and enclosed in a wire-mesh container for 24 hours. The container with the aggregate is weighed when immersed in water, thus giving it a buoyant weight. The material is then surface-dried and weighed in air, giving the saturated weight (M_S), thereafter the material is oven-dried at a temperature of 100-110^{0}c and dry weight is determines (M_D)**.**

The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. About 15 to 25 mm (348 g) of weight of aggregates sample, empty pyconometer and water were recorded as (m3). Weight of pyconometer and aggregates were recorded as (M2), weight of pyconometer and water recorded as (m4) while the weight of empty pyconometer was recorded as (M1).

1.3.2.3 Aggregate Crushing Value Test

The test consists of subjecting the specimen of aggregate ranging between 20 to 32mm in standard mould to a compression test under standard load conditions. Dry aggregates (between 100 to 110^{0}c temperature) passing through 32mm sieves and retained 19.5mm sieves are filled in a cylindrical measure of 11.5.

Load is then applied through the plunger at a uniform rate of 4 tonnes per minute, until the total load is 40 tonnes and then the load released. Then crushed aggregates are removed from cylinder and sieved through 2.36 mm sieve and weight of passing material (**W2**) is expressed as percentage of the weight of the total sample (**W1**) which is the aggregate crushing value.

1.3.2.4 Aggregate Impact value test

Aggregates may be air dried or oven heated at 100 to 110^{0}c for a period of hours and passed in 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal diameter 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material for about 350g is filled in 3 layers where each layer is tamped for 15 numbers of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 numbers of blows.

1.3.2.5 Los Angeles Abrasion test

About (5000) gm is (W1) of the aggregate ranging from 20 to 32mm in the oven for drying. Open the Los Angeles equipment and put the dried aggregate sample with the (10) balls in it and close it again.

After specified revolutions of about 30 per minute for 500 revolutions at the completion of the test, the material is sieved through 2.36 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.

1.3.2.6 Atterberg Limit Tests

I. <u>Liquid limit</u>

About 200 gm of quarry dust is mixed with distilled water to form a uniform paste, the dust should be that which passed through sieve No 425µm. A portion of the sample (wet) is placed in a casagrande cup half-filled, and the top bucked up pararell to the base. A groove of 2mm is cut through the center of the portion of the wet sample in the casagrande cup or dish with a grooving tool. The cup is lifted 10mm and dropped onto a rubber base until the bottom of the groove had closed over a length of 10mm, the number of blows at which the groove closes is recorded. This procedure is repeated to four times to obtain various numbers of blows, for each of the grooves in casagrande cup samples that was collected for moisture content determination.

II. Plastic limit

About 200 gm of quarry dust is mixed with distilled water to form a uniform paste, the dust should be that which passed through sieve No 425µm. A portion of the sample (wet) is placed in a casagrande cup half-filled, and the top bucked up pararell to the base. A groove of 2mm is cut through the center of the portion of the wet sample in the casagrande cup or dish with a grooving tool. The cup is lifted 10mm and dropped onto a rubber base until the bottom of the groove had closed over a length of 10mm, the number of blows at which the groove closes is recorded. This procedure is repeated to four times to obtain various numbers of blows, for each of the grooves in casagrande cup samples that was collected for moisture content determination.

1.3.2.7 Linear Shrinkage limit (Attimeyer, 1956)

This test was done by putting the moist sample in the linear shrinkage bar that is about 14cm in length and allowed for 24hours, if the water content is sufficient to fill the pores when the sample is at its minimum volume attained by drying.

1.3.2.8 Free Swell Test

Free swell determines the swelling potential and degree of expansion classification of expansive soils. The free swell test was determined in accordance with the method given by Krynine and Judd (1957) and Hardcastle (2003) for the clay content in a given rock. The Quarry dust put into the cylindrical tube and distilled water added. The same procedure is done for kerosene and kept for 24hours, to determine the clay content.

4.0 Results and Discussion

4.1 Atterberg Limit Test, Linear Shrinkage and Free Swell

Table 2: Result of Atterberg Limit, Linear Shrinkage and Free Swell Values

Sample no	Liquid limit %	Plastic limit %	Plasticity index%	Moisture Content %	Linear Shrinkage %	Free Swell
MA1	29.50	24.90	4.60	30.0	0.30	10

It is observed that all the samples gotten from the study are non plastic, meaning the soil has little or no plasticity. The plasticity index is also low.

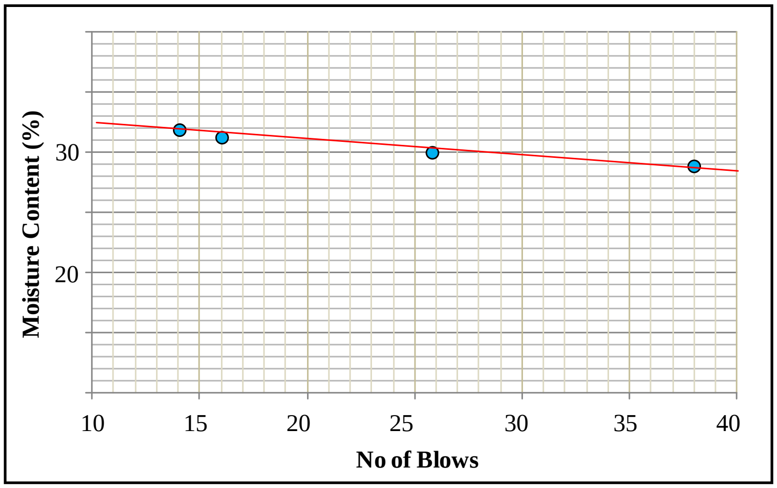

Fig 4. Plot of moisture content versus no. of blows

Table 3. Guidelines For Swelling Potential and Degree of Expansion Classification of Expansive Soil Based on Various Geotechnical Parameters.

Swelling Potential Classification					
S/NO	PARAMETER	VALUES	CLASSIFICATION	TEST RESULTS	
1	Plasticity Index (%) (Ola, 1981)	<15	Low	4.60%	Non plastic
		15 – 25	Medium		
		25 – 35	High		
		>35	Very High		
Degree of Expansion Classification					
2	Linear Shrinkage (%) (Attimeyer, 1956)	<5	Non – Critical	0.30%	Non critical
		5 – 8	Marginal		
		>8	Critical		
3	Free Swell (%) (Dawson, 1956)	<50	Low	10%	Low
		>50	High		

4.2. Physico-Mechanical and Engineering performance

Table 4

Parameters	**Test Results**
Specific Gravity (%)	**2.58**
Water absorption (%)	**1.90**
ACV (%)	**23.50**
LAAV (%)	**42.70**
AIV (%)	**29.40**

Table 5. Specification limit for Materials (Roads and Bridges) (F.M.W. Nigeria, 1997).

DISCUSSION

Parameters	**Test Results**	**Standard**	**Remark/Interpretation**
Specific Gravity (%)	2.58	<2.60	Good
Water absorption (%)	1.90	<3.0	Fair to good
ACV (%)	23.50	<30	Good
LAAV (%)	42.70	< 40	Good
AIV (%)	29.40	<30	Good

Suitability of rock aggregate for engineering purposes

The result of the physico-mechanical properties of marl samples from the study area shows that values are within the acceptable limits for highway pavement aggregates, building stones and facing/decoration stones respectively (BS 882, 1973; FMW 1997).

From this result, the water absorption and aggregate crushing values are within the acceptable limits for highway pavement aggregates, building stones and facing/decoration stones, since their values are less than 3% and 30% respectively (BS 882, 1973; FMW 1997).

Furthermore, the Los Angeles abrasion value from General Specification, FMW 1997 Nigeria and BS 882, 1973 suggested also that Los Angeles Abrasion should be equal to or less than 45% for road base material in lightly trafficked road. The aggregate crushing value of aggregate is a measure of the resistance of the aggregates to crushing under a gradually applied compressive load while Los Angeles abrasion value is a measure of the resistance of the aggregates to surface wear by abrasion (the lower the value, the greater the resistant) (Okeke & Agbasoga, 2001). The water absorption of the aggregates controls the amount of binder required in surface design (high water absorption value will need more binder materials after the ingredients have been mixed).

The specific gravity of the marl sample is 2.58. These values when compared with standard suggest that the marl posses the required specific gravity value required for highway aggregates. According to Akpokodge (1992), the specific gravity of aggregates is an important property that is 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 specified temperature. The higher the specific gravity, the denser the rock and stronger is the aggregate.

The results from the study area, for Atterberg Limit, Free Swell and Linear Shrinkage Limit indicate that due to the values gotten, it has low swelling potential (Dawson, 1956), it is non-plastic (Ola, 1981), and the favourable degree also of not expanding (Attimeyer, 1956) makes the marl deposit of Afikpo good material for highyway pavement.

Compared to natural gravels, in a study of the suitability of gravel deposits from Ihiagwa, Okeke and Agbasoga (2001) noted that the smooth texture of the gravels decrease bonding of the aggregates with cement in the concrete and is also responsible for the lower compressive strength of concrete made from Ihiagwa gravel aggregates.

5.0 Conclusion

The Marl deposits under study belong to the Ezeaku Formation, field observations identified sandstone ridges trending NE-SW with subordinate marl deposits exposed along the Amasiri-Akpoha axis.

Geotechnical tests confirmed that the rock has low swelling potential, non critical and low degree of expansion. The physico-mechanical strength characteristics also are within the acceptable limits. The Marl deposit in Afikpo Area, Southeastern Nigeria is therefore a good rock to be used as aggregate for highway or concrete pavement.

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