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Engineering Characterization of Rocks from the Minna Granitic Formation as Pavement Construction Aggregates

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Abstract

Rocks from the Minna granitic formation were assessed for their suitability as aggregates in pavement construction. Eight rock samples were collected and subjected to petrographic, mechanical (Aggregate Impact Value, Los Angeles Abrasion Value) and physical (Water Absorption, specific gravity) tests. Petrographic studies revealed that the study area is made up of fine and coarse grained granites as well as schist. The granitic rocks have specific gravity of 2.44 – 2.67 with water absorption of 2.57% and 3.17% while the schist has specific gravity of 2.21 and water absorption of 3.63%. The granites have mechanical properties of between 17.46% - 20.89%, 19.40 - 21.00%, for Aggregate Impact Value and Los Angeles Abrasion Value respectively. The schist has aggregate impact value of 37.73% and Los Angeles Abrasion Value of 39.36. The results generally reveal that the aggregates derived from the granites are of fairly good engineering properties while that derived from the schist is considered as weak. The granite derived aggregates will produce pavements of fairly good quality while the schist should not be contemplated for the purpose of pavement construction.

Keywords: Granites, Pavement, Aggregate, Aggregate Impact Value, Minna

1. Introduction

Over 90% of Nigeria's paved roads are made of asphaltic mixture surface. These surfaces are composed of aggregates derived from different rocks as well as bituminous asphalt. Apart from being used in road construction, aggregates have also been consistently and greatly utilized in other construction work such as buildings, bridges, railroads and dams among other uses. They exist as the skeletal material that will fill the asphalt mixture and includes rubbles, gravels and machine made sands as well as crushed rocks (Wu et al., 2017). As a result of increase in infrastructural development and decreasing availability of natural aggregates, the demand for crushed rock aggregates have more than doubled over the past two decades. However, for an aggregate to be found suitable in road construction, it must be able to resist abrasion and degradation during the stages of its utilization. The quality of rocks used for aggregate production is influenced by alteration, weathering and deformation (Ng, 2011). This quality is assessed using a combination of mechanical (Aggregate Impact Value, AIV, Los Angeles Abrasion Value, LAAV) and physical (Water Absorption, Specific Gravity) tests. The petrographic makeup of the rock is also a determining factor of the aggregate property.

Egesi and Tse (2012) evaluated the suitability of basement rocks of the Bamenda Massif as pavement aggregate materials and concluded that the biotite-granites were considered the best because of their high strength and low water absorption. Jethro et al (2014) studied the engineering properties of selected granitic deposits from southern Nigeria with a view to assess their performance as aggregates in road construction.

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The rocks were observed to contain desirable mineralogical composition and mechanical properties that makes them good aggregate production materials. Factors such as mineralogy, rock type, grain size and rock texture have a major control on the mechanical behavior of rock aggregate (Jakob et al, 2017). There is an intricate interaction between these parameters and the resulting mechanical properties making it difficult to assess mechanical quality accurately only based on petrographic examination. The objective of this study is to determine the suitability of aggregates derived from granitic rocks from the north-central Nigerian basement as road construction materials vis-à-vis their petrography.

2. The Study Area

The studied rocks are located along the Minna-Paiko-Lapai road in north-central Nigeria. The area is bounded by latitude 9⁰26'.00"N to 9⁰32'.00"N and longitude 6⁰34'.00"E to 6⁰40'.00"E (Figure 1). It falls geologically within the Minna Granitic Formation, made up mainly of metasedimentary and metavolcanic rocks. Three rock lithologies dominate the area; schist which are lightly foliated and rich in amphibolites, coarse and fine grained granites making up 80% of the study area and composed of quartz, feldspars and biotite in hand specimen (Figure 2).

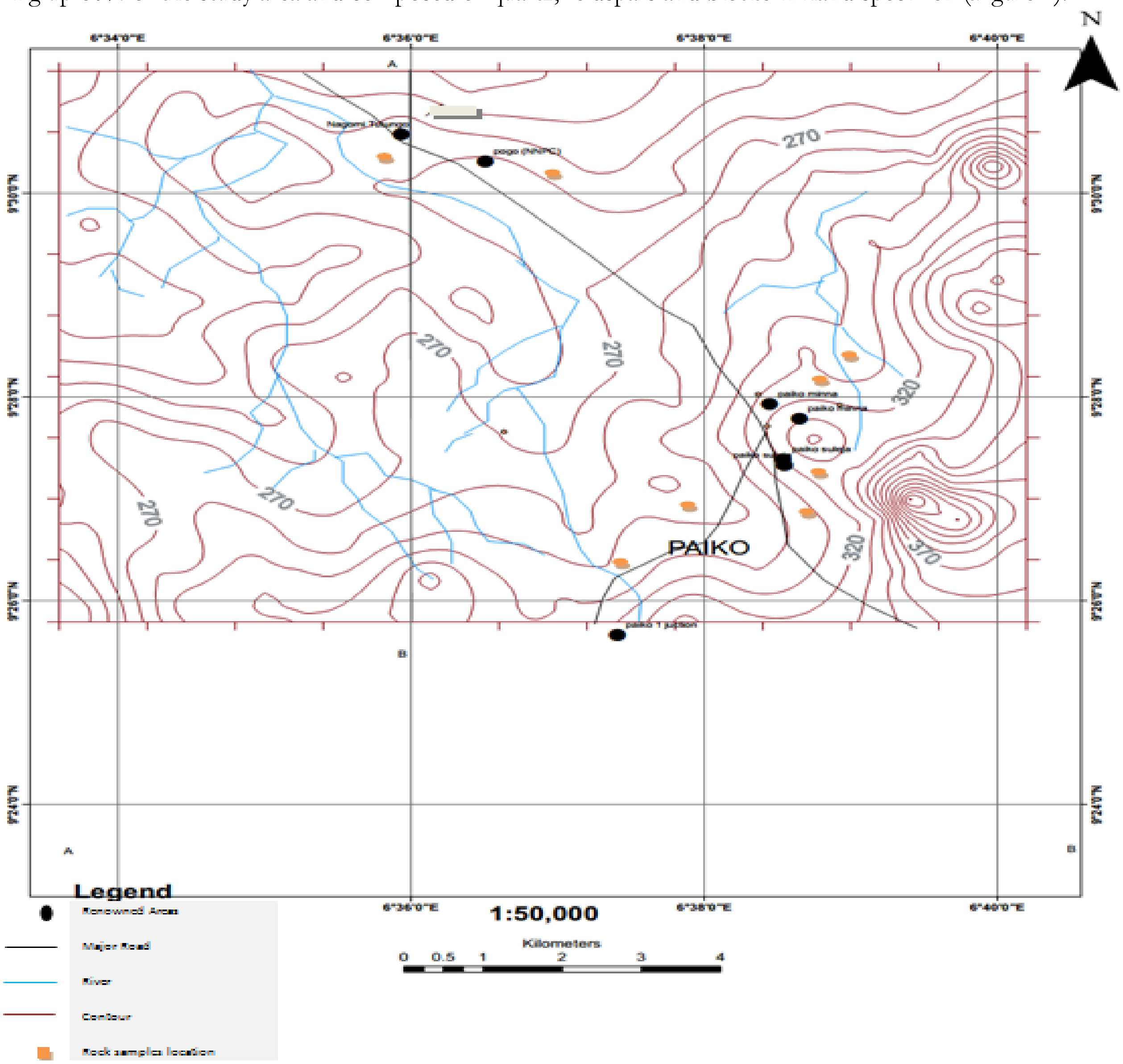


Figure 1. Location Map of the Study Area Showing the Sample Locations

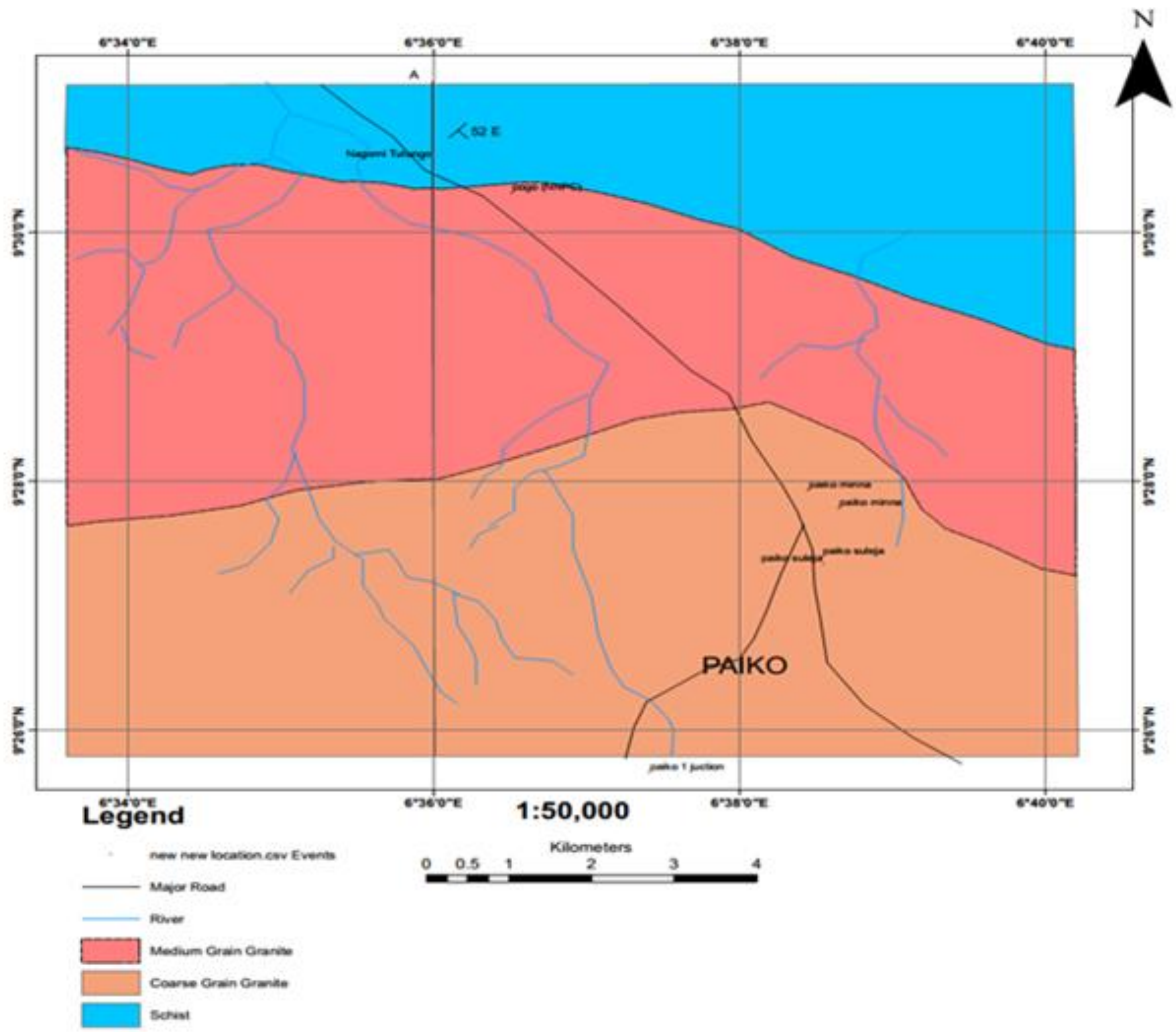


Figure 2. Geological Map of the Study Area

3. Methodology

A geological mapping exercise was first conducted in order to identify the rock types and their distribution as well as the structures within the study area. This was followed by collection of eight fresh samples; two from quarry faces and the other six from outcrops, ensuring that the samples are fresh. Two of the rock samples were selected for petrographic thin section study while mechanical (AIV and LAAV) and physical (water absorption and specific gravity) tests were run on all the samples in accordance to the British Standard Institution (1971), Nigerian Federal ministry of Works and Housing (1997) and American Society for Testing and Materials (1975) standards

3.1. Aggregate Impact Value Test

This test measures the resistance of aggregates to disintegration due to impact. Oven dried aggregates that pass through 13.2mm and are retained on 9.5mm British Standard Sieves were used for the test. A cylindrical cup of known weight is filled with the aggregates in 3 layers, with each layer receiving 25 gentle blows using the tamping rod. The weight of the cup and sample is noted after which the aggregates are transferred to the impact mould in one layer and then placed firmly in position at the base of the impact machine. The samples are then given 15 blows using the impact machine rammer. The crushed materials are removed from the mould and passed through a 2.36mm sieve. The fractions passing the 2.36mm sieve are weighed and the weight noted.

The impact value is calculated as the ratio of the weight of the fraction passing 2.36mm sieve to the weight of the sample expressed in percentage. The procedure is repeated a second time and the average taken.

3.2. Los Angeles Abrasion Test

This test is used to determine the resistance to wearing of aggregates. Oven dried aggregates were placed in a cylindrical drum and then mounted horizontally in the machine. A charge of 11 steel balls (4584±25g) is added to the drum and the drum is rotated at a speed of 20 to 33rpm until 500 revolutions is completed. The tumbling and dropping action of the aggregates and balls result in attrition and abrasion of the aggregates. The crushed aggregate is sieved using 1.70mm sieve with the fraction retained on the sieve washed, oven dried and weighed. The LAAV is calculated as the difference between the original weight and the final weight expressed as a percentage of the original weight of the test sample.

3.3. Water Absorption

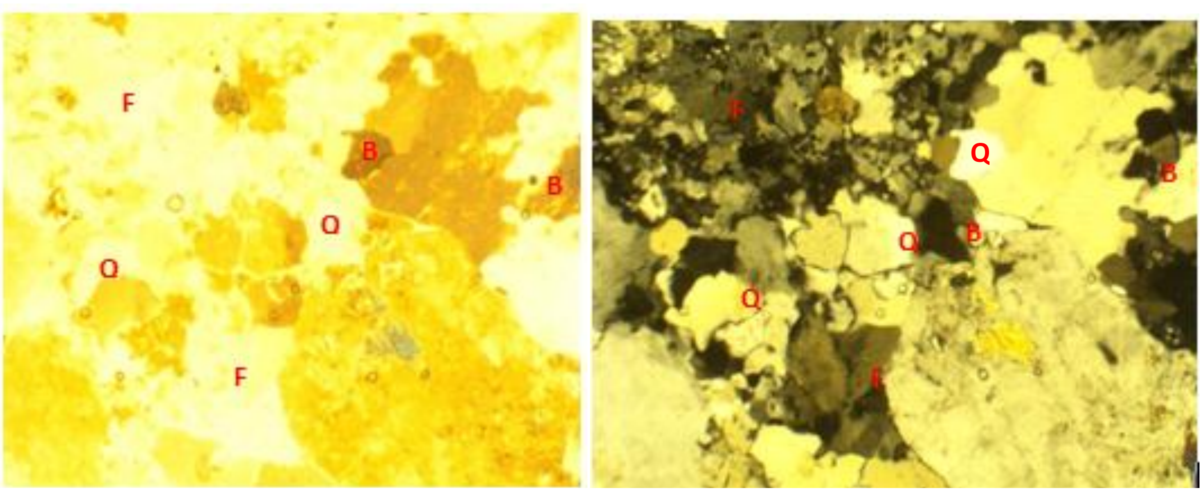
Water is added to a known weight of the aggregate retained on 1.75mm sieve in a vessel and allowed to soak for 24 hours. The water in the aggregate is drained and allowed to dry under room temperature. The aggregate is reweighed and oven dried for 24 hours and then reweighed again. The water absorption is calculated as the difference between the weight of the air dried aggregate and oven dried aggregate expressed as a percentage of the weight of the oven dried aggregate.

4. Results and Discussions

The results of the mechanical and physical tests are presented in table 1 while the thin section photomicrographs are shown in plates 1 and 2.

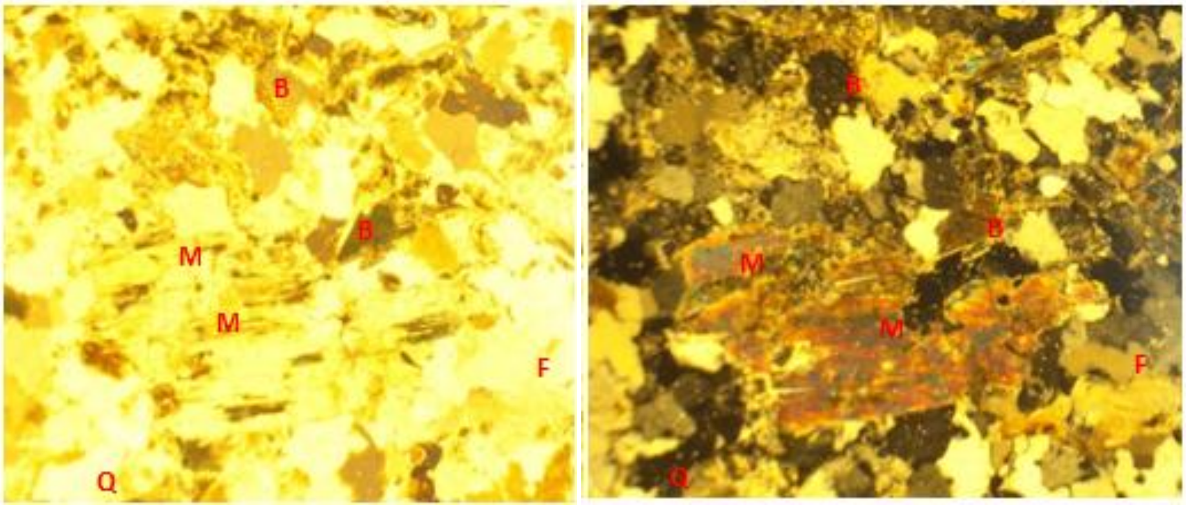
Table 1. Results of Mechanical and Physical Tests

SAMPLE NUMBER	Aggregate Impact Value (%)	Los Angeles Abrasion (%)	Water Absorption (%)	Specific Gravity
S1	17.46	19.40	2.65	2.63
S2	16.75	19.32	2.57	2.67
S3	22.45	24.12	3.09	2.56
S4	22.03	23.06	3.18	2.46
S5	19.81	19.92	3.25	2.51
S6	29.05	26.94	3.23	2.48
S7	20.89	21.00	3.17	2.44
S8	37.73	39.36	3.63	2.21



a b

Plate 1. Photomicrograph of sample S1 under Plane (a) and Crossed (b) Polarized Light



a b

Plate 2. Photomicrograph of sample S1 under Plane (a) and Crossed (b) Polarized Light Magnification=40

Under the petrographic microscope, the granitic rocks contain quartz, plagioclase feldspar, low concentration of biotite and accessory minerals. The quartz grains vary in size up to 2 cm and they occur mostly as anhedral isolated grains. Albite occurs as anhedral to subhedral grain with rare hornblende also observed during petrographic studies (Plate 1 a, b). The schist reveals a mineral assemblage of quartz, muscovite and plagioclase (albite). In plane polarized light, quartz occurs as irregular, subhedral body that displayed a low relief. Muscovite occurs as tabular crystal with an excellent cleavage which is brownish with marked absence of microcline, biotite and amphibole (Plate 2 a, b).

Specific gravity (SG) and water absorption of aggregates are important properties that determine their suitability for use in pavement construction. Most natural aggregates have a SG between 2.4 and 3.0 while aggregates for use in road construction have specific gravity range between 2.40 and 3.00. Aggregates derived from locations S1 to S7 have specific gravity within this range (2.44 – 2.67) while S8 has a lower value (2.21). The absorption of the aggregates range between 2.57% and 3.63% with sample S8 having the highest absorption. There are no maximum or minimum values for SG or water absorption for aggregates in pavement construction as available standards are meant only to help control aggregate quality. Aggregates to be used for asphalt mix production should however have water absorption of just above 0% and 5%. The higher the water absorption, the higher the quantity of asphalt binder required to account for the high aggregate absorption. Sample S8 will require a higher asphalt binder based on this property which will translate into high cost of pavement construction.

The ability of an aggregate to resist impact (AIV) or sudden shock determines its toughness. Such shock occurs as a result of traffic loads causing a thumping of the aggregates and resulting in their breakage. Aggregates for use in pavement construction should generally have a maximum AIV of 30%. Aggregate with AIV of <10% is considered strong while an AIV of >35% is considered to have a poor technical value and will be too weak for use in road construction. The aggregates from S8 (AIV = 37.73%) is the only sample that does not meet the required specification. All other samples have comparatively fair AIV.

An aggregates resistance to wear is an important index in the evaluation of its use in pavement construction. This resistance is evaluated based on the percentage loss of the aggregates due to a combination of impact and attrition as determined by the Los Angeles abrasion value test (LAAV). LAAV below 15% are regarded as good while values above 25% will pose poor resistance to wearing and fragmentation (Stalheim, 2014). Samples S6 and S8 have poor resistance while other samples have fair resistance values.

The results generally revealed that the granitic rocks from the Minna granitic formation are of fair mechanical and physical properties and can be selectively quarried and utilized as asphalt mix in pavement construction. Although aggregates from S6 will have a poor resistance to wear, they will provide fairly good toughness. Aggregates from the schistose rocks are considered to have poor engineering properties and should not be considered for use as asphalt mix materials in pavement construction.

5. Conclusion

The suitability of aggregates derived from the Minna granitic formation for use in pavement construction was assessed using mechanical and physical properties of the aggregates. The aggregates from the granitic rocks are generally of fairly good strength according to the BS, ASTM and FMWH standards and will produce pavements of fairly good quality. Aggregates produced from the schistose rocks are considered weak and capable of producing poor asphalt mix at high cost and should not be contemplated for pavement construction.

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