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Petrography and Physicomechanical Characteristics of Iyuku Granite, Southwestern Nigeria

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Abstract

Petrography and physicomechanical characteristics of Iyuku granite from southwestern Nigeria were investigated. Rock and aggregate samples were obtained from five different quarry sites for thin-sectioning and physical and mechanical tests. The rock slides were subjected to petrographic analysis, while the aggregates were tested for the parameters of specific gravity (S.G), water absorption, aggregate impact value (AIV), aggregate crushing value (ACV), Los Angeles abrasion value (LAAV), and flakiness and elongation indices in accordance with the British Standards (B.S), American Standards for Testing Materials (ASTM) and Federal Ministry of Works Standards (FMWS). The petrographic, physical, and mechanical characteristics were described by bar charts and linear graphs. The results revealed that the rocks are of medium to coarse interlocking grains, with no evidence of weathering influences, and quartz content ranging from 17% to 35%. The aggregates showed appreciable high S.G. values, very low water absorption values and low maximum permission limits for AIV, ACV and LAAV when compared with different standards. All the aggregates are adjudged to be generally strong and durable for road construction, but those with higher quartz contents are more preferable. Significant statistical correlations were established among both physical and mechanical tests conducted.

Keywords: Iyuku Granite, Physicomechanical Characteristics, Road Construction

Introduction

Rock aggregates are important raw materials for the construction industry. As a nation develops, there arises the need for increased infrastructural development, especially in the construction of roads. Rock aggregates are therefore vital for achieving massive road construction projects. Aggregates can be obtained from quarries through drilling, blasting, and crushing processes.

To ascertain the suitability of rock aggregates for any engineering construction purpose, it is mandatory to subject them to various tests according to local and international standards. Siegesmund and Torok [1] opined that rock aggregates must be of high quality for optimum utility in the engineering construction industry. Egesi and Tse [2] noted that rocks respond differently to a variety of stresses according to usage in construction projects and this largely depends on the properties of the aggregates. Since rocks are aggregates of minerals, the petrography of the rocks is vital in their evaluation for construction purposes. Mineral composition and petrological characteristics largely determine the strength and durability of aggregates [3-5]. Lindquist *et al.* [6] postulated that texture and mineralogy are vital factors for the assessment of mechanical properties of rocks.

Furthermore, Ajagbe *et al.* [7] posited that mechanical properties can be significantly influenced by texture and mineralogical composition of rocks. Sajid and Arif [8] noted that differences in textures and modal mineralogic compositions accounted for variations in mechanical properties of rocks. Raisanen [9] stated that the plethora of fine-medium grained minerals, distribution of grain size, and

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degree of interlocking of grain boundaries of minerals greatly influence mechanical properties of rocks. Fabric and weathering states also affect the mechanical properties of rocks [10]. Thus, performance of aggregates in road construction will likely be greatly influenced by the variations in rocks properties.

In Nigeria, there is a high demand for quality aggregates to cope with massive construction of roads that link up the various oil producing communities. Iyuku granite has been chosen because it is quite massive and extensive, spanning more than 70km^2. This huge deposit, if fully tapped, will sustain the massive construction activities presently going on in the Niger Delta terrain. This study, therefore, focuses on the petrography and physicomechanical characteristics of the vast Iyuku granites to determine their suitability as road construction aggregates for the mangrove swamp terrains of the oil-rich Niger Delta region.

Location and Geology of Study Area

The study area is at Iyuku in Etsako East Local government area in Edo State, Nigeria. It is located between latitude 07^o 08^1 22^1 N to 07^o 10^1 00^1 W and longitude 06^o 14^1 18^1 E to 06^o 161 00^1 E Figure-1. The study area is part of the southwestern Nigerian Basement Complex. The entire Precambrian Basement Complex of Nigeria is polycyclic in nature [11]. The Basement Complex rocks of Nigeria are part of the African crystalline shield within the Pan-African mobile belt which lies between the West African and Congo cratons and south of the Tuareg shield affected by the Pan-African orogeny. [12]. Iyuku granite represents the youngest group of rocks of Precambrian age in the southwestern Nigeria Basement Complex. The granites are syn-to-late tectonic and most of their activity took place during the waning phase of the Pan African orogeny. Iyuku granite occurs as massive ridges and fragmented boulders [13].

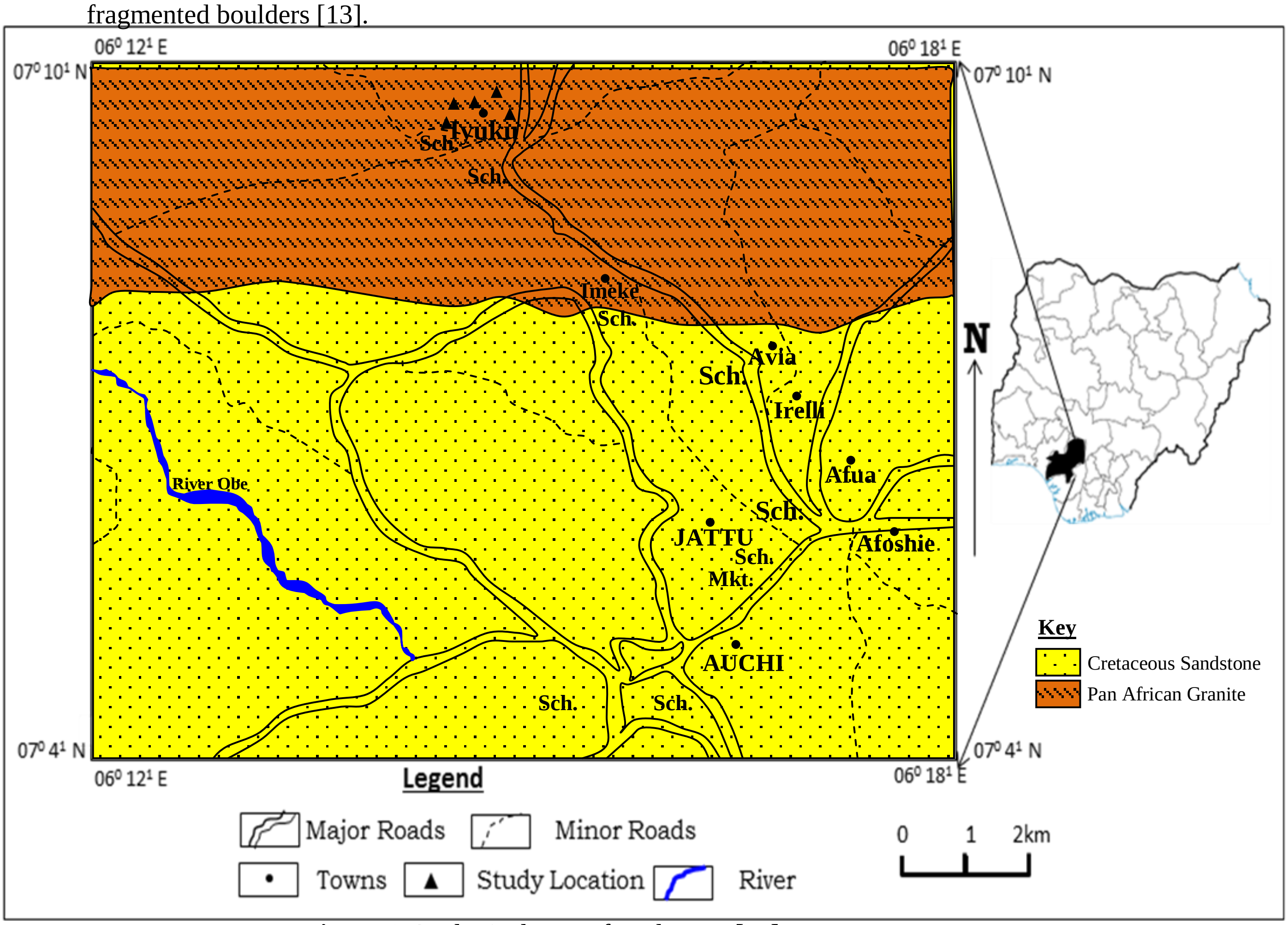


Figure 1-Geological map of study area [14]

Materials and Methods

Two rock samples were collected from each of the quarry sites, making up ten rock samples altogether. The rock slides were prepared in the Department of Geology, thin section laboratory, using the Lagitech thin section rock cutting machine (model GT51). Thereafter, the rock slides were viewed under the Meiji polarizing microscope (ML 9000). With the aid of the camera attached to the polarizing microscope, the photomicrographs of the rocks were obtained under cross and plane polarized light.

Aggregates of different sizes were collected from the different quarry sites and subjected to physical and mechanical analyses in accordance with British Standards (BS), American Standards for Testing Materials (ASTM) and Federal Ministry of Works Standard (FMWS) [15-20]. The tests carried out in the Department of Geology, Geotechnical laboratory, included the aggregate crushing value, Los Angeles abrasion value, aggregate impact value, specific gravity, water absorption, elongation index, and flakiness index.

Results and Discussion

The results of the physical and engineering properties of the aggregates are shown in table 1. The specific gravity (S.G) of all the samples ranges between 2.66 and 2.80. Bell [21] opined that rock samples with S.G greater than 2.55 are suitable for heavy construction work. The values of water absorption range between 0.3% and 0.80%. Generally with low water absorption and appreciably high S.G, the aggregates will be suitable for heavy construction work and this is consistent with the outcomes of previous works [4, 22]. The relatively low values of water absorption also suggest that the aggregates will be suitable for road construction in the mangrove swamp areas that characterize the Niger Delta region of Nigeria. Also the high values of S.G suggest very little or no noticeable weathering of the rocks.

Table 1-Physical and Engineering Properties of Coarse Aggregates

Physical and Mechanical Properties	S1	S2	S3	S4	S5
Aggregate Crushing Value (%)	24.6	25.5	27.2	28.7	29.1
Los Angeles Abrasion Value (%)	24.2	25.6	26.1	27.3	27.8
Aggregate Impact Value (%)	8.8	9.7	10.8	12.3	12.8
Specific Gravity	2.66	2.67	2.80	2.70	2.68
Water Absorption (%)	0.5	0.6	0.3	0.7	0.8
Elongation Index (%)	25	26	15	20	22
Flakiness Index (%)	16.3	18.2	14.7	17.4	16.8

Both flakiness index and elongation index are used to deduce the quality of the particle shape. A graph of the shape indices of the rock aggregate is presented in figure 2. The value of the flakiness index ranged between 14.7% and 18.2% whereas that of the elongation index ranged between 15% and 26%. These values are below the maximum permissible limit of 30%, recommended by the FMW [20]. When flakiness and elongation indices exceed the maximum permissible limits, the aggregates become inimical to effective workability and stability of mixes because they will not interlock well, which results in weak stone base in road construction, especially in areas like the swamp terrain of Niger Delta.

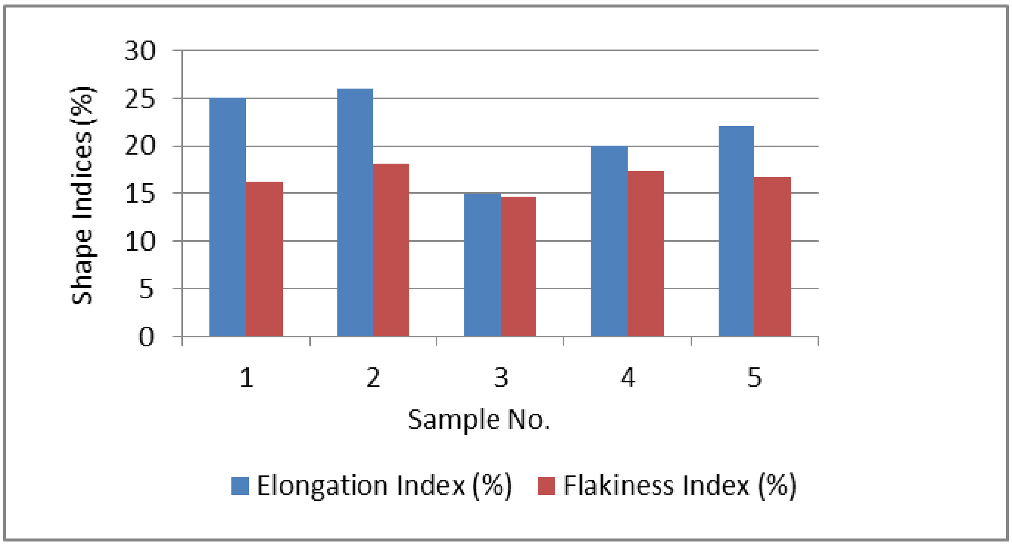


Figure 2- Shape indices of the rock aggregates.

Aggregate strength characteristics are used to evaluate the suitability of the aggregate for use in road construction. The aggregate impact value (AIV) ranged from 8.6% to 11.2%. These values are far below the maximum permissible limit of 35% recommended by the BSI [18]. Singh [23] noted that the lower the AIV, the stronger the aggregate, implying that they are quite strong for road construction. Aggregate crushing value (ACV) ranged between 24.6% to 29.1%. These values fall below the maximum permissible limit of 30% recommended by the BSI [17]. The aggregates are therefore suitable for road construction and these results are consistent with those of an earlier work [24]. Los Angeles abrasion value (LAAV) ranged between 24.2% to 27.8%. These values are below the maximum permissible limit of 35% recommended by [19]. The low values of LAAV indicate that the aggregates possess good quality for use in highway pavement construction because they are likely to be more resistant to wear, even under heavy traffic load.

Petrographic studies were carried out on the rock slides to identify the minerals, grain size and modal composition of the consistent minerals. Sample S1 has inequigranular coarse grained crystals. It consists of perthite and quartz phenocryst in a coarse grained groundmass of the same minerals. The modal mineral composition is 20% quartz, 52% feldspar (microcline + plagioclase), 18% biotite, 4% hornblende, and 6% muscovite, as shown in table 2 and figure 3. Sample S2 has inequigranular medium grained crystals. The modal mineral composition is 22% quartz, 52% feldspar (microcline + plagioclase), 66% biotite, 4% hornblende, and 6% muscovite, as shown in table 2 and figure 4. Sample S3 has equigranular fine grained crystals. The modal mineral composition is 35% quartz, 45% feldspar (microcline + plagioclase), 14% biotite, 2% hornblende, and 4% muscovite, as shown in table 2 and figure 5. Sample S4 has inequigranular and coarse grained crystals. It consists of perthite and quartz phenocryst in a coarse grained groundmass of the same minerals. Its modal mineral composition is 21% quartz, 53% feldspar (microline + plagioclase), 14% biotite, 6% hornblende, and 6% muscovite, as shown in table 2 and figure 6. Sample S5 has equigranular fine grained crystals. The modal mineral composition is 27% quartz, 50% feldspars (microcline + plagioclase), 12% biotite, 5% hornblende, and 6% muscovite, as shown in Table-2 and Figure-7.

Generally, none of the samples showed any evidence of alteration of the feldspars, both megascopically and microscopically.

Table 2- Average Modal Composition of Rocks from the Studied Quarries

Minerals	S1	S2	S3	S4	S5
Quartz	20	22	35	21	27
Microcline	32	35	30	33	29
Plagioclase	20	17	15	20	21
Biotite	18	16	14	14	12
Hornblende	4	4	2	6	5
Muscovite	6	6	4	6	6

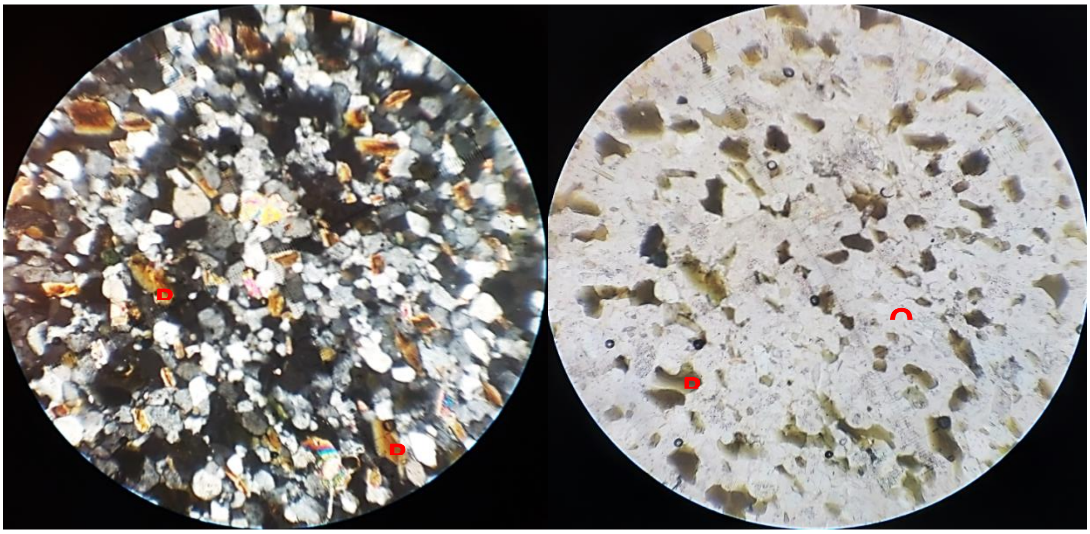


Figure 3- Photomicrograph of sample S1 under cross and plane polarized light (Mag ×40).

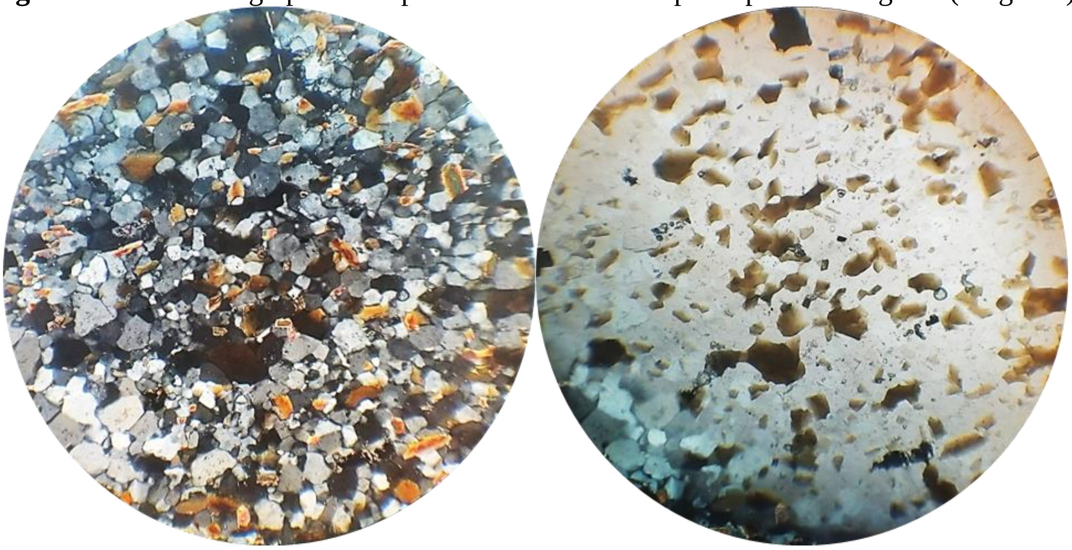


Figure 4- Photomicrograph of sample S2 under cross and plane polarized light (Mag ×40).

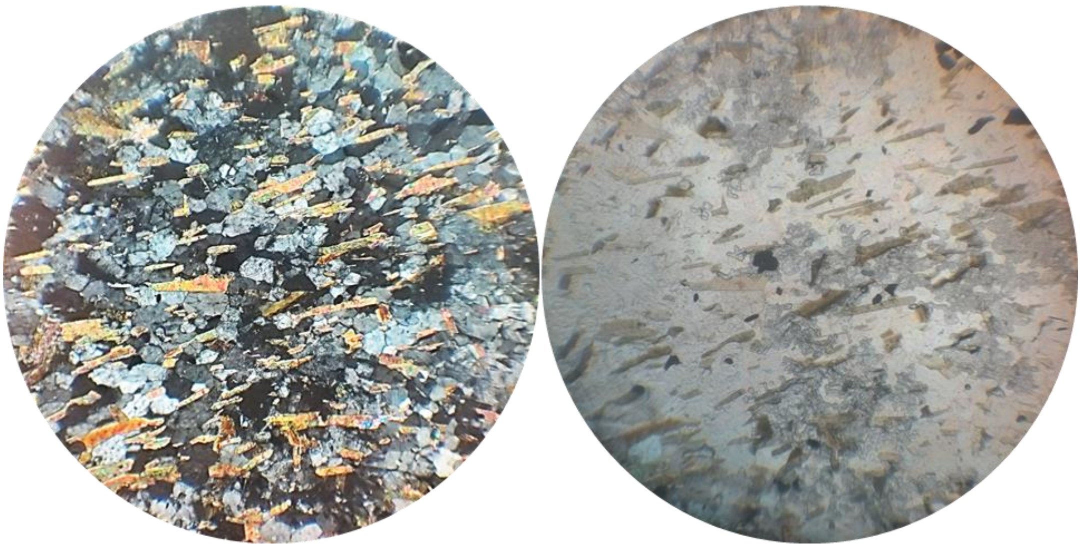


Figure 5- Photomicrograph of sample S3 under cross and plane polarized light (Mag ×40).

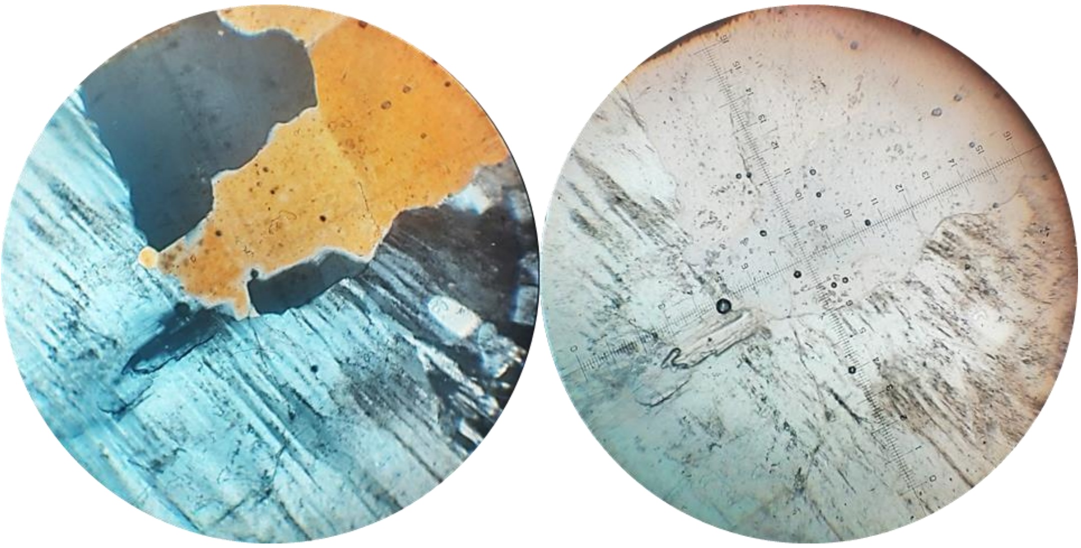


Figure 6-Photomicrograph of sample S4 under cross and plane polarized light (Mag ×40).

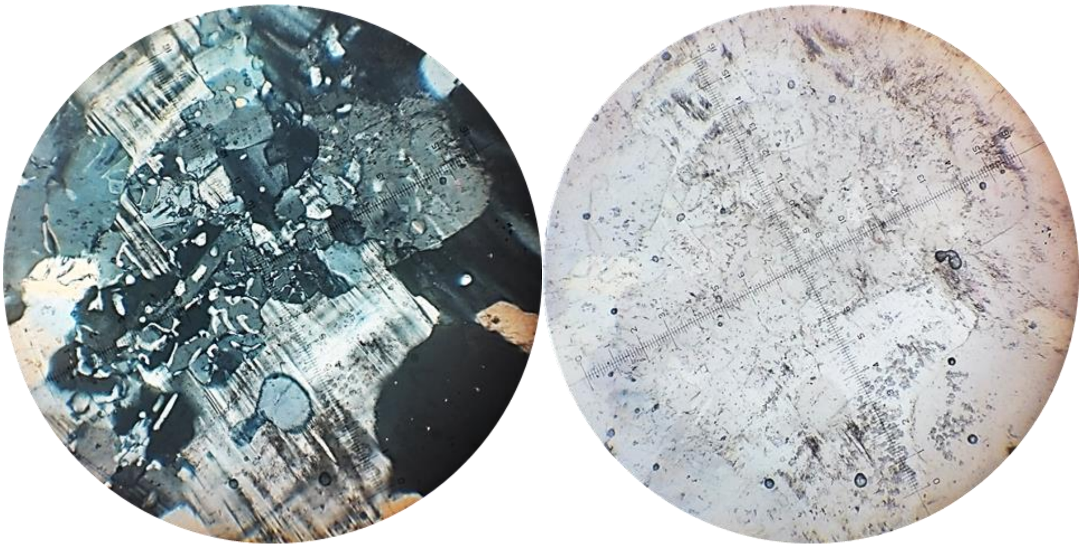


Figure 7- Photomicrograph of sample S5 under cross and plane polarized light (Mag ×40).

The utility potential of the rock is determined by their strength which usually depends on physical and mechanical properties. Both modal composition and texture of rocks define their petrographic characteristics. Samples S3 and S5 were found to be fine grained, S2 is medium grained while S1 and S4 are coarse grained.

All the samples have low AIV, ACV and LAAV. This indicates that all the aggregates, irrespective of their texture, could be suitable for road construction purposes. However samples S3 and S5 are most preferred because of their fine-grained texture and higher quartz content. This is consistent with previous reports [3,7,8] which noted that quartz content and texture have profound effects on the strength of rocks of same mineralogy.

The relationship between mechanical strength of aggregate and water absorption, as shown in figure 8, indicates low water absorption values, which resulted in low values of ACV, LAAV and AIV, generally suggesting greater strength as reported previously [2]. Figures 9, 10 and 11 illustrate the relationship between the percentage of minerals and AIV, LAAV and ACV. All the samples have low AIV and LAAV, but samples S3 and S5 have the highest percentages of quartz of 35% and 27%, respectively. Although all the samples are adjudged suitable for road construction, samples S3 and S5 are better preferred because of their higher quartz content and fine grained textures. Sample S3 is the most preferred because the aggregate has the lowest water absorption, low flakiness and elongation indices, and the highest S.G.

Figure-12 indicates a negative correlation between water absorption values and specific gravity. This is consistent with the outcomes of a previous work [25], indicating that aggregates of high specific gravity generally exhibit low water absorption.

The relationships between AIV and ACV, LAAV and AIV, as well as ACV and LAAV show positive correlations, as shown in figures 13, 14 and 15. Generally, the result of positive correlations among the strength properties is consistent with that of an earlier published study [26].

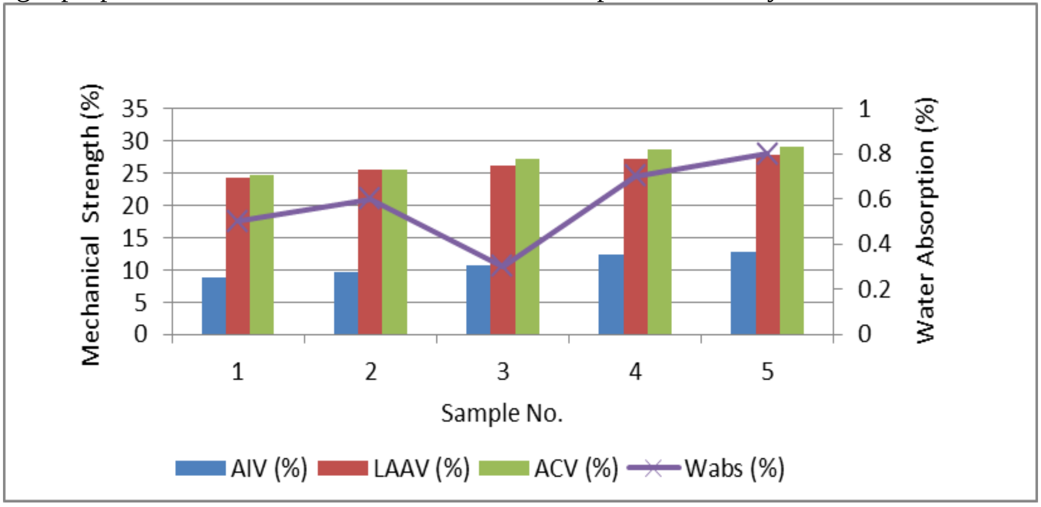


Figure 8- Relationship between mechanical strength properties (ACV, LAAV, AIV) and water absorption.

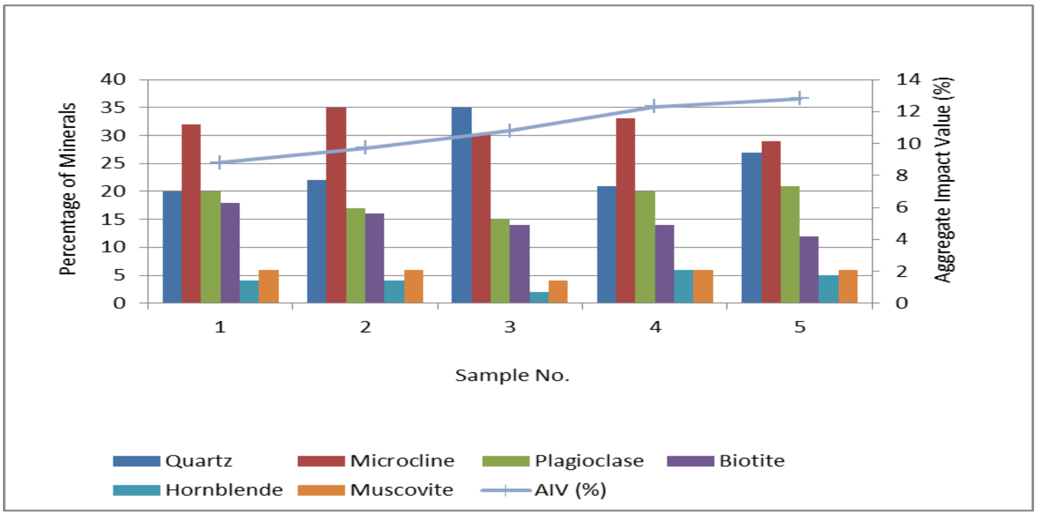


Figure 9- Relationship between the percentage of minerals and aggregate impact value (AIV).

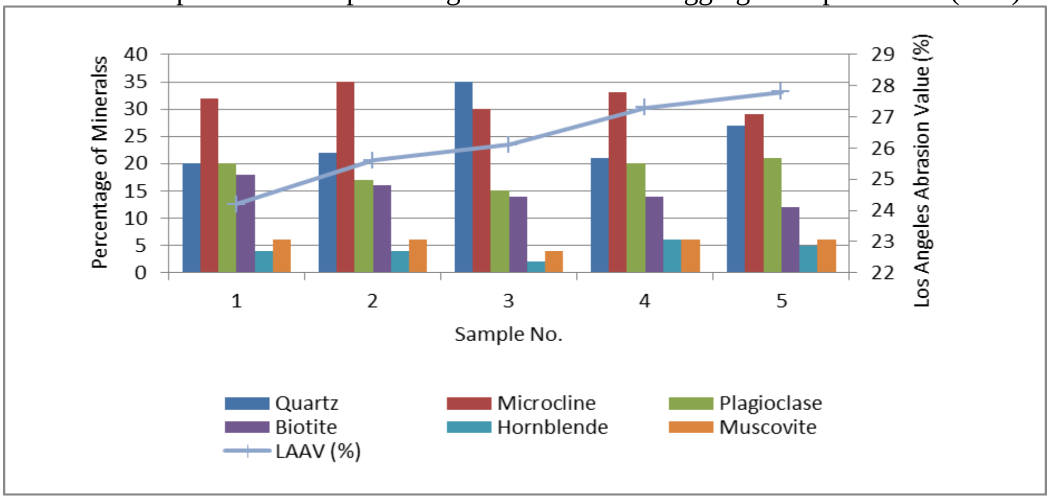


Figure 10- Relationship between percentage of minerals and Los Angeles abrasion value (LAAV).

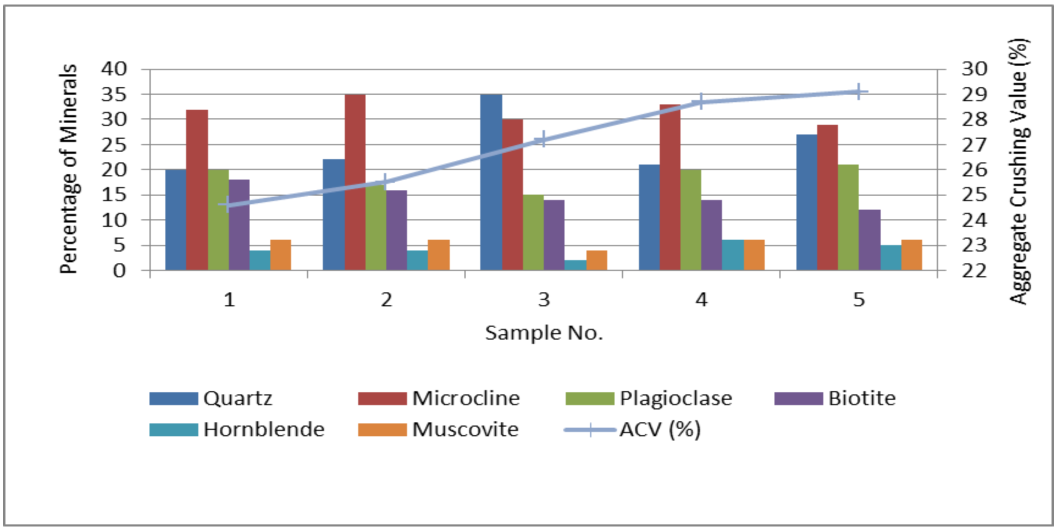
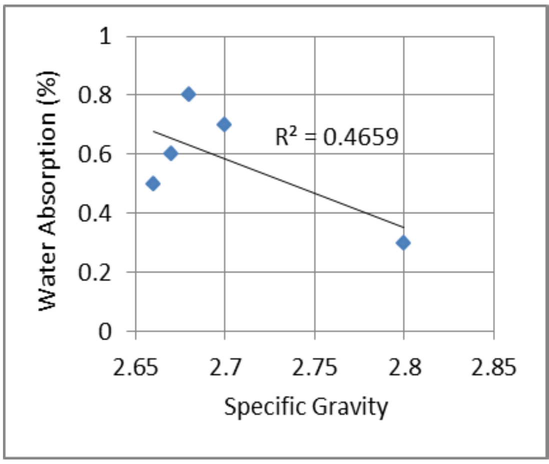


Figure 11- Relationship between percentage of minerals and aggregate crushing value (ACV).



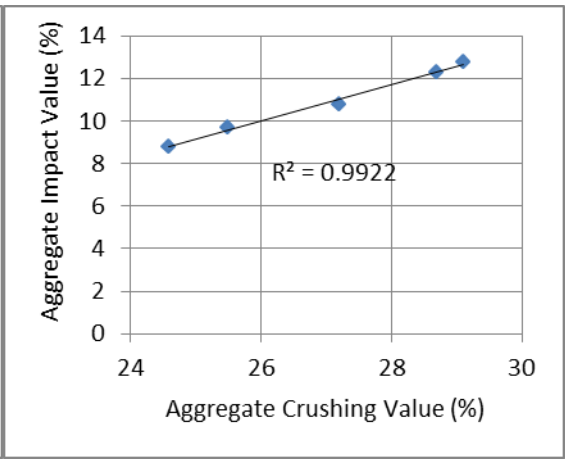
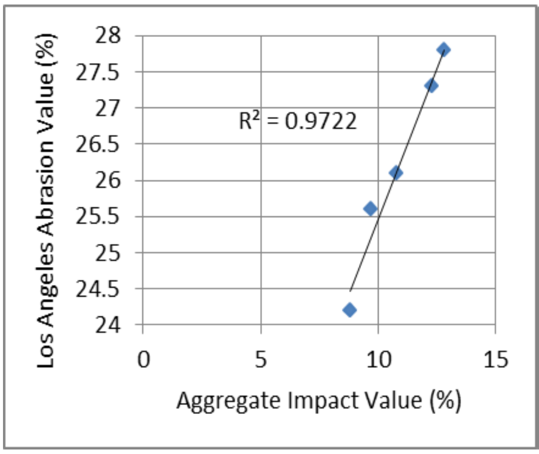


Figure 12- Relationship between Specific Gravity And Water Absorption.

Figure 13-Relationship between Aggregate Crushing Value and Aggregate Impact Value.



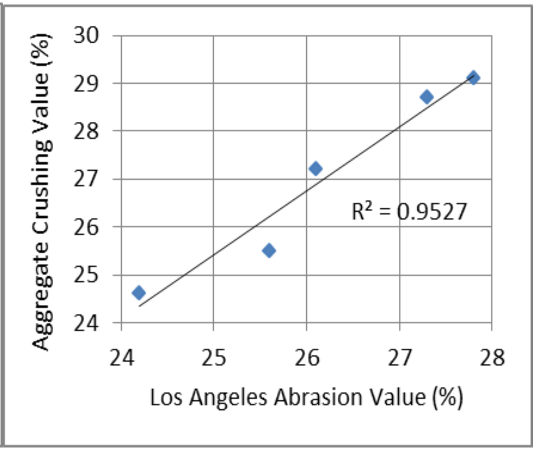


Figure 14- Relationship between Aggregate Impact Value and Los Angeles Abrasion Value.

Figure 15- Relationship between Los Angeles Abrasion Value and Aggregate Crushing Value.

Conclusions

The study showed that quartz content and texture of the rocks have profound effects on their geomechanical properties. This study therefore suggests a decreasing orders of strength for the aggregates (S3 S5 S2 S4 S1) for the studied samples. This study also revealed that there is a strong relationship between physical, mechanical, and petrographic characteristics of rock aggregates, rendering them strong and durable for road construction in accordance with BS, ASTM and FMW standards.

Significant statistical correlations were found between water absorption and specific gravity, ACV and AIV, as well as LAAV and AIV. The findings in this work will guide the selection of rocks of appreciable higher strength within the same rock type for better and more durable road construction aggregates.

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