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The Suitability of Some Selected Granite Deposits for Aggregate Stone Production in Road Construction

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ABSTRACT
The investigation of the suitability of some selected granite deposits for aggregate stone production within the basement complex of Nigeria for road construction was studied. Aggregate samples obtained from the deposits were analyzed in the laboratory to determine their mechanical properties (aggregate crushing value and aggregate impact value). It was found out that the granite deposits possess certain desirable aesthetic and visual characteristic. Also, the percentage mineralogical compositions of the studied samples were examined. The results show that Beautiful Rock Company has the highest percentage composition of microcline content which reduces the rate of wearing and tearing. The results of the laboratory analyses on the aggregate sample indicated that the technical features of the deposit are suitable for aggregate stone for road construction when compared with the globally accepted standard. The result of the investigation will be useful and serve as database to prospective investors in aggregate stone quarrying.

Keywords*: Suitability, Deposit, Aggregate, Basement complex, Aggregate crushing value, Aggregate impact value, Microcline.*

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I. INTRODUCTION

Blasting operation, a major component of rock fragmentation, is a technique that is based on scientific principles derive from knowledge of action of explosives, mechanisms of fragmentation and the mechanical properties of rocks [1]. Therefore, it is imperatives to study and determine the mechanical properties of granite rock before carrying out the blasting operation. In order to achieve good and effective mine planning, development, design, equipment selection mechanism, type of explosive that is suitable for maximum output, the mechanical properties of granite rock have to be determined [2]. Well planned blasting operation will yield good fragmentation which is the result or outcome of the blasting operation fragmentation process is extremely important both economical and technical in mining and construction industry and its influence by various granites rock properties [3].

Moreover, many factors may affect blasting behaviour besides the characteristics of rock. It is very difficult and even impossible to control the entire factors, which could affect the behaviour of rock undergoing detonation. Dimitry and Evgeny [3] posited that blasting have some connections with geology or rock properties. The explosive energy level and distribution must be matched with geological conditions in order for rock fragmentation to be successful. The understanding of the geology of the area to be blasted will influence blasting design based on observation of fragments distribution.

In addition, experimental analysis such as crushing value, impact value, Abrasive resistance, Hardness and mineralogical characteristics of rock can dictate a load or energy that can be absorbed before failure of rock mass could occur [3].

Rock fragmentation can be described as the extent to which rock is broken into pieces by blasting or any other means. The geological factors that affect rock fragmentation are variable and non controllable, but with good engineering judgment, values can be placed on them to achieve the desire fragmentation. Explosives also played a major role in blasting operation for effective fragmentation and displacement of rock from in-situ position [4].

1.1 Locations of the Study Areas

The five deposits investigated are within Lokoja and Okene in Kogi State, North Central Nigeria. The coordinates of the areas are given in Table 1.

Table 1: Location of the Study Areas

S/N	Name of Company	Description	Co-ordinate:	
			Latitude	**Longitude**
1	Borini Prono (Bp) Nig. Ltd.	59km along Lokoja – Okene Highway, Okene.	$06^0\ 16^1\ 45^{11}$	$07^0\ 37^1\ 30^{11}$
2	Bulletine Construction Company (Bt)	Along Okene – Lokoja Highway, Felele, Lokoja.	$06^0\ 44^1\ 15^{11}$	$07^0\ 49^1\ 54^{11}$
3	Gitto Construction Company (Gt)	Opposite Bulletine Construction Company, Felele, Lokoja.	$06^0\ 44^1\ 17^{11}$	$07^0\ 42^1\ 15^{11}$
4	Beautiful Rock Quarry (Br)	Plot 626, Ganaja Street, along Ajaokuta - Lokoja Road, Lokoja.	$06^0\ 44^1\ 15^{11}$	$07^0\ 42^1\ 15^{11}$
5	Rock Bridge Quarry (Rb)	Plot 626, Ganaja Street, along Ajaokuta - Lokoja Road, Lokoja.	$06^0\ 43^1\ 00^{11}$	$07^0\ 40^1\ 30^{11}$

1.2 Geology of the Study Area

Generally, Kogi State has two geological formations; Basement complex and Sedimentary basin. Approximately, half of the state is covered by crystalline basement complex while the other half is covered by cretaceous to recent sediments [5].

Nigerian basement and ancient hard rocks predominantly underline the western flank of the state. They are made up of crystalline complex rock (gneiss and Migmatite) older metasediment (quartzite, marble calc-silicate and the pan Africa granites/older granites). The eastern flank of the state is on the alluvium (youngest and most recent sedimentary rocks) and other sedimentary rocks, which form part of cretaceous to recent sediments of Nigeria The crystalline complex contained economic minerals such as Iron-ore, gen-stone, quartz, feldspar and other associated minerals while the Pan Africa granite/older granite contained cassiterite, tantalite, columbite, gemstones and other associate minerals. [5].

According to Caen-Vachette Ekwueme [6], the migmataite and gneiss in the Lokoja – Okene area are Eburnean (+2500 ma) and Kibaran (+1000 ma), while the granite, pegmatite and quartz veins are Pan African (550+ 100 ma) in age.

Figure 1 is a Geological Map of Nigeria showing the study areas – Lokoja and Okene.

II. METHODOLOGY

Aggregate stones from five selected quarries – Borini Prono (Bp), Bulletine Construction Company (Bt), Gitto Construction Company (Gt), Beautiful Rock (Br) and Rock Bridge were tested for Aggregate Crushing Value (ACV), Aggregate Impact Value (AIV) and Petrographic Analysis. The ISRM [7] and Verwaal and Mulder [8] standards were followed.

2.1 Aggregate Crushing Value

The materials for the test consist of aggregates passing 14.0mm sieve and retained on a 10.0mm sieve. The samples were surfaced dried by heating to 100^0C for three hours and allowed to cool to room temperature before testing. The depth of the material was ensured to be 100mm after tamping.

The cylindrical measure was filled in three layers of approximately equal depth, each layer being tamped 25 times from a height of approximately 50mm.

The cylinder of the test apparatus was put on the base plate and test sample added in thirds, each third being subjected to 25 strokes from the tamping rod distributed evenly over the surface of the layer and dropping from a height approximately 50mm above the surface of the aggregate. The surface of the aggregate was carefully leveled and the plunger inserted so that it rests horizontally on this surface, taking care to ensure that the plunger does not jam in the cylinder.

The apparatus with the test sample and plunger were placed in position between the platens of the testing machine and loaded at a uniform rate and the required force of 400kN reached in 10 min.

The load was released and the crushed material removed by holding the cylinder over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. Fine particles adhering to the inside of the cylinder were transferred to the base plate and the underside of the plunger to the tray by means of a stiff bristle brush.
The whole of the sample on the tray was sieved on a 2.36mm sieve until no further significant amount passes in 1 min. The fraction passing the sieve was weighed and recorded as B.

Repeat the whole procedure, starting from testing, using a second sample of the mass as the first sample.

Calculations

The ratio of the mass of fines formed to the total mass of the sample in each test was expressed as a percentage; the result was recorded to the first decimal place as shown in Equation 1.

$$Percentage \quad fines = \frac{B}{A} \times 100 \quad \ldots\ldots\ldots\ldots \quad (1)$$

where

A is the mass of surface-dry sample (g)

B is the mass of the fraction passing the 2.36 mm sieve (g)

2.2 Aggregate Impact Value, AIV Test

The materials for the test also consist of aggregate passing a 14.0mm sieve and retained on a 10.0mm sieve. The sample was surfaced dried by heating to 100^0C for 3 hours and cooled to room temperature before testing.

The measure cup was filled for about one third by means of a scoop. The aggregate was discharged from a height of 40mm above the top of the cup. The aggregate was tamped with 25 blows of the rounded end of the tamping rod, each blow being given by allowing the tamping rod to fall freely from a height of about 50mm above the surface of the aggregate and the blows being evenly distributed over the surface.

A similar quantity of aggregate was added in the same manner and tamped with 25 blows. The measure cup was completely filled and tamped 25 times. The tamping rod was removed by rolling across and in contact with the top of the container, any aggregate which impedes its progress. Aggregate was added to fill any obvious depressions.

The mass of aggregate in the measure cup was weighed as Mass A.

The aggregate was put in the test cup. The cup was fixed firmly in position on the base of the machine and the whole of the test sample placed in it and compact by a single tamping of 25 strokes of the tamping rod as above. Test sample was subjected to a total of 15 blows from the aggregate impact test machine, each being delivered at an interval of not less than 1 second.

Crushed aggregate was removed by holding the cup over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. Fine particles adhering to the inside of the cup were transferred and the underside of the hammer to the tray by means of a stiff bristly brush.

The whole of the sample in the tray was sieved on the 2.36mm BS test sieve until no further significant amount passes in 1min.

Fractions passing and retained on the sieve were weighed to an accuracy of 0.1g as (mass B and mass C respectively). Where the total mass B + C is less than the initial mass (mass A) by more than 1g, the result is discarded and a fresh test made.

The whole procedure is repeated starting from testing using a second sample of the same mass as the first sample.

2.3 Mineralogical Characteristics of the Selected Deposits – Modal Analysis

Modal analysis is the method of determining the petrography of rocks by counting the different minerals thereby determining the mineralogical composition and the percentage of crystal formation of various minerals present in the samples of each rock type.

According to Jethro [1], "Percentage Mineral Composition" can be calculated using Equation 2

$$C_m = \frac{T_m}{T_{tm}} \times 100 \quad \ldots\ldots\ldots\ldots \quad (2)$$

where C_m = Percentage mineral composition (%) ;T_m = Total number of count for a mineral and T_{tm} = Total number of count for the entire mineral

III. RESULT

The results of aggregate crushing value, aggregate impact value and minerals composition of the various locations are presented in Tables 2, 3 and 4

Plates 1 to 5 and Figure 1 shows the results of the photomicrographs and the modal composition of the various locations examined in this work.

Table 2:Aggregate Crushing Value Test Results

PARAMETERS	LOCATIONS				
	Bp	**Bt**	**Gt**	**Br**	**Rb**
Weight of aggregate dry sample (g)	3463.4	3667.4	3565.2	3502.3	3558.2
Weight of fraction passing separating sieve	574.9	1037.9	1055.3	924.6	935.8
(ACV)%	16.6	28.3	29.6	26.4	26.3

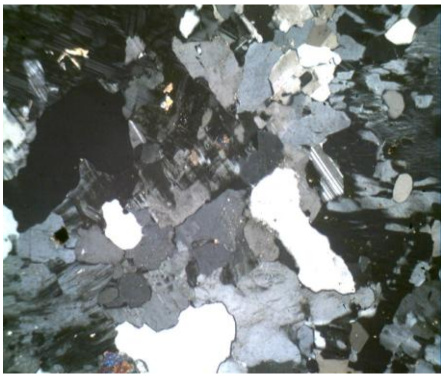
Table 3: Aggregate Impact Value Test Results

PARAMETERS	LOCATIONS				
	Bp	**Bt**	**Gt**	**Br**	**Rb**
Weight of aggregate dry sample (g)	328.9	352.7	352.7	360.2	355.4
Weight of fraction passing separating sieve	46.7	72.7	73.4	69.5	68.4
(AIV)%	14.2	20.6	20.8	19.3	19.2

Table 4: Mineral Composition of the Rocks Tested

Sample Locations	Q (%)	P(%)	B (%)	M (%)	H (%)	AM (%)	OM (%)	A (%)
Bp	31.9	8.5	12.8	21.3	19.14	4.25	2.19	-
Bt	28.6	10.7	16.07	21.43	19.6	3.57	0.00	-
Gt	19.23	13.46	11.54	26.92	23.08	3.85	1.92	-
Br	27.08	12.50	10.42	31.25	19.6	4.17	0.00	14.58
Rb	28.3	15.0	10.0	20.0	21.67	3.33	1.67	-

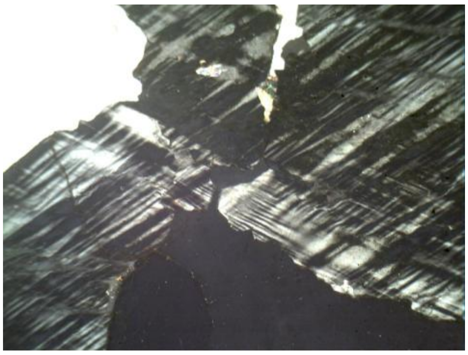
Q – Quartz; P – Plagioclase; B – Biotite; M – Microcline, A- Amphibole; H – Hornblende, AM- Accessories mineral and OM – opaque mineral.



a

b

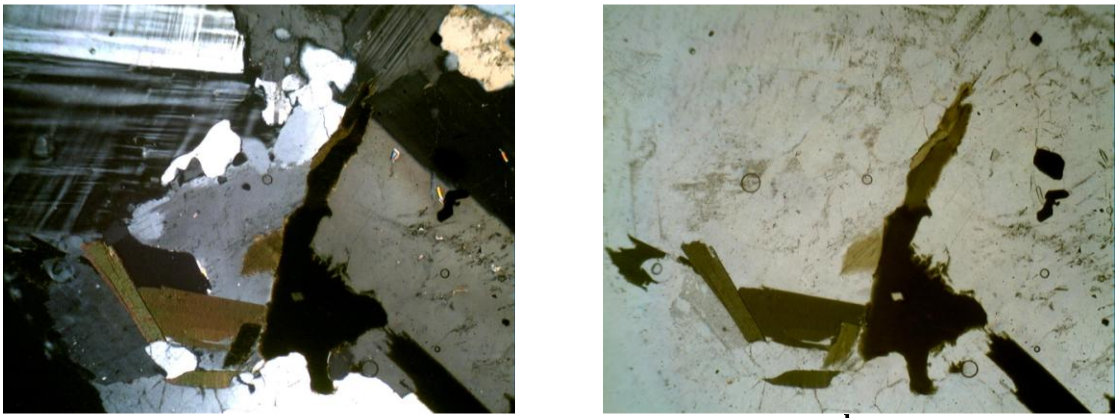
Plate 1: (a) Photomicrograph of Bp with (b) Crossed Nicols: mag. x 40



a

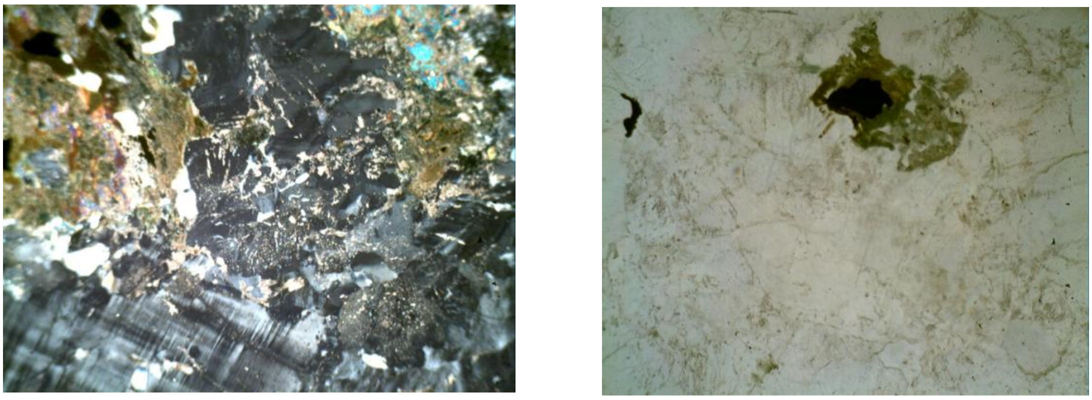
b

Plate 2: (a) Photomicrograph of Bt with (b) Crossed Nicols: mag. x 40



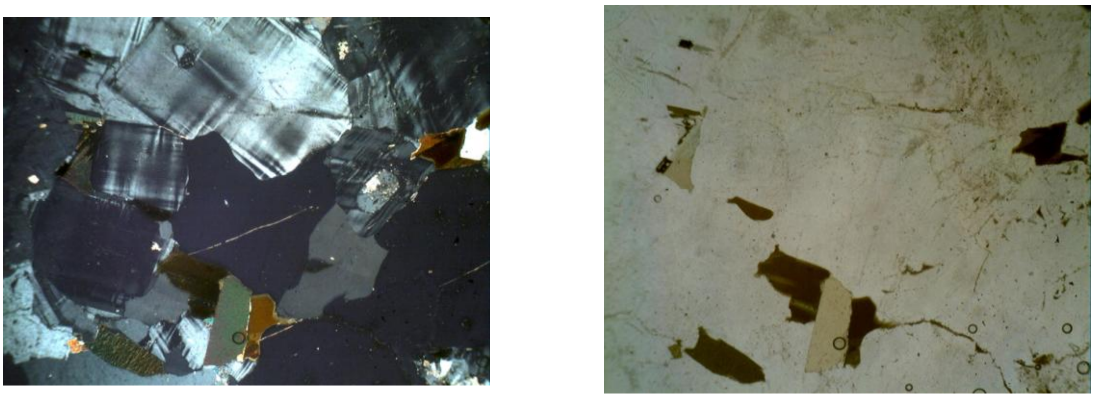
a b

Plate 4: (a) Photomicrograph of Br with (b) Crossed Nicols: mag. x 40



a b

Plate 5: (a) Photomicrograph of Rb with (b) Crossed Nicols: mag. x 40



a b

Plate 3: (a) Photomicrograph of Gt with (b) Crossed Nicols: mag. x 40

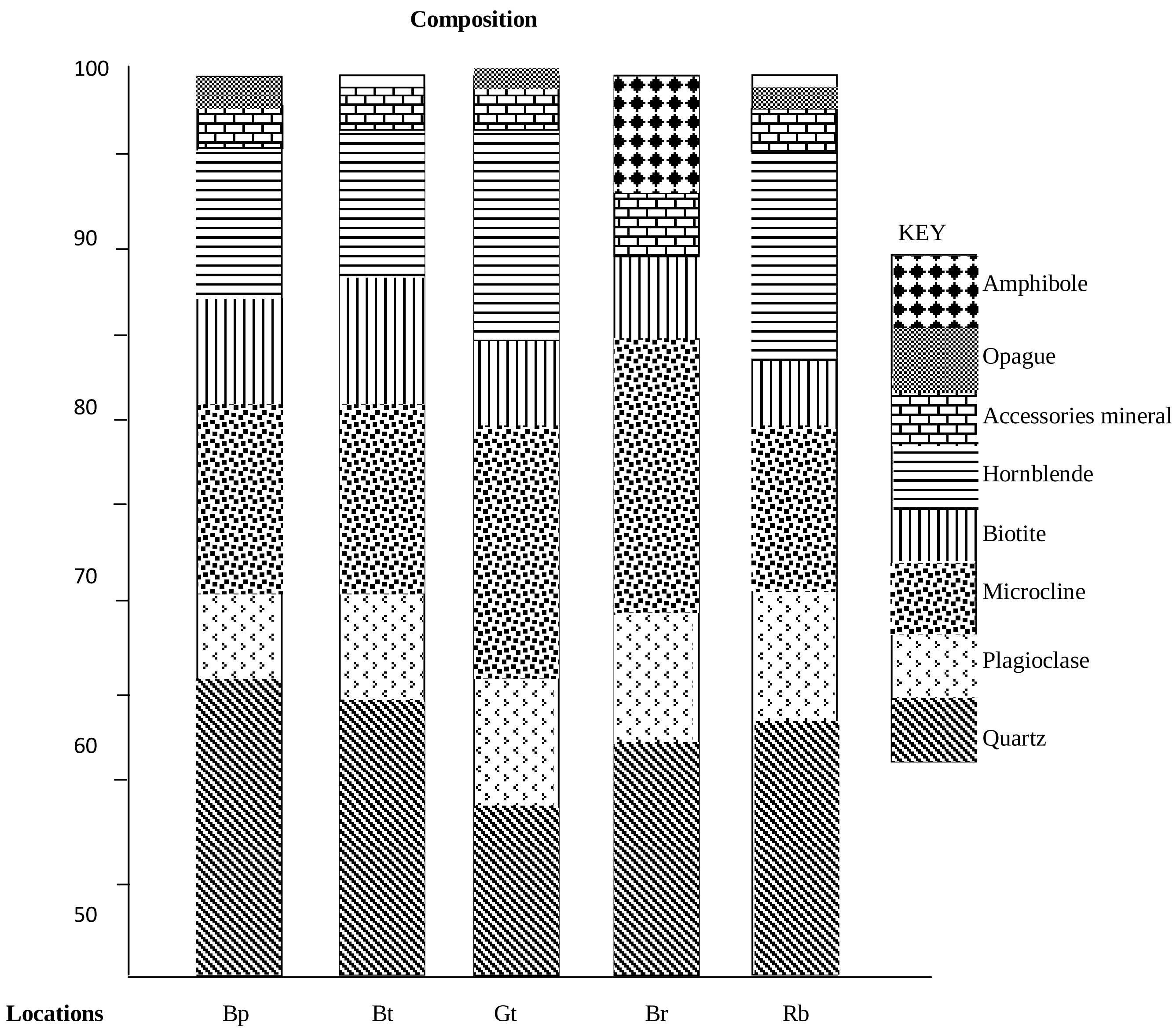


Figure1: Modal Composition of Rocks Studied as Determined by Analysis of Thin Sections

IV. DISCUSSION

4.1 Analysis of Strength Properties

The principal mechanical properties required in road stones are (i) satisfactory resistance to crushing under the roller during construction and (ii) adequate resistance to surface abrasion under traffic - Verwaal and Mulder [8]. Also, surface stresses under rigid tyre rims of heavily loaded vehicles are high enough to consider the crushing strength of road aggregate as an essential requirement in Nigeria.

Aggregate used in road construction, should be strong enough to resist crushing under traffic wheels loads if the aggregate are weak, the stability of pavement structure is likely to be adversely effected. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load [9]. In order to achieve a high quality of pavement, aggregate possessing low aggregate crushing value should be preferred.

IRC [9] suggested standard Aggregate Crushing Value of 23 – 30% for granites in road construction. Table 2 shows the aggregate crushing value of location Bp, Bt, Gt, Br and Rb with their values of 16.6, 28.3, 29.6, 26.4 and 26.3 respectively. Therefore, all the locations are suitable for road construction except Bp which is below the recommended standard despite its high quartz contents. It is advisable that when this aggregate (Bp) is used in road construction, more asphaltic bituminous should be used.

Toughness is the property of a material to resist impact. Due to traffic loads, the roads stoned are subjected to the pounding action or impact and there is possibility of stones breaking into smaller pieces. The road stones should therefore be tough enough to resist fracture under impact.

IRC [9] suggested standard Aggregate Impact Value of 17 – 21% for granites in road construction. The Aggregate Impact Values of 20.8, 20.6, 19.3 and 19.2 obtained for locations Gt, Bt, Br and Rb respectively (Table 3) are therefore suitable for road construction and other engineering work. The results indicate that Gt, Bt, Br and Rb are very good for road construction unlike Bp (4.2%) which is below the recommended standard.

4.2 Analysis of the Petrographic Characteristics

Quartz, microcline, hornblende, plagioclase and biotite are the main minerals in all the tested samples (Table 4). From the results, it can be concluded that Br has the highest percentage composition of microcline content of 31.25% as compared to Rb which is 20%. Thus Br has the highest strength value.

Plates 1 to 5 and figure 1 show the variation of the various mineral constituents and Gt contain the highest percentage of hornblende which adds to the high strength value as a result of the microcline and quartz content as shown in the modal composition. The slides were studied using the polarizing microscope and the exact percentage of each mineral composition is calculated. In location Bp, the texture ranges from fine to medium, coarse grained possessing gray colour and it forms varies from anhedral to subhedral. In location Bt, the texture is coarse grained, gray in colour and the form range from subhedral to anhedral. In location Gt, the texture is from fine to medium, the coarse is gray and form from anhedral to subhedal. In location Br, the texture is fine to medium grained and the colour is with a form of anhedral to subhedral. In location Rb, the texture is fine to medium and the colour is gray ranges from anhedral to subhedral. Since the texture of Br in fine to medium, this also confirmed the hardness of the rock as shown in result of aggregate crushing and aggregate impact values.

All the five deposits have the same texture and colour but slightly different forms despite the fact that they are gotten from close locations within the Kogi State – Lokoja and Okene.

V. CONCLUSION

The result of the investigation shows that the value of all the parameters determine on Bt, Gt, Br. And Rb location of granite deposit fall within the specified ranges of the globally accepted ISRM standard of aggregate stone production for road construction. The value of the crushing test results and impact test results depicts good quality and high durability of the expected product from the deposits. Consequently, granite aggregates from the studied locations are suitable for road construction, construction of ditching and building etc.

Exclusively, location Bp which has the aggregate crushing value of 16.6, and aggregate impact value of 14.2 that cannot be use for road construction but durable for other engineering work. The preparation and study of thin section of the rock samples by modal analysis shows that they comprise of the following minerals: plagioclase, quarts, Biotite, microcline, Hornblendes and accessories minerals. This indicates that the expected product from the deposits could freely gain entrance into, and attract interest in both local and international markets.

VI. RECOMMENDATION

More experimental works are recommended to be done on all granite quarry locations to ascertain their suitability in road construction.

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