Investigation On the Suitability of Metamorphosed Granite In Ilorin Nigeria For Road Construction and Polished Rock

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Article

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Abstract

The suitability of metamorphosed granite for road construction and polished rock were investigated. Three samples A, B and C were handpicked from Man Hardi Quarry Ilorin using random sampling method. The samples were subjected to different test namely, chemical analysis, polish value, oxidation properties, compressive strength and hardness test. The chemical analysis shows the silica contents for samples A, B and C are 67.73%, 73.62% and 72.40% respectively, specific gravity obtained are 4.52, 4.80 and 3.60 for sample A, B and C. The oxidation properties test reported with no peeling was observed, the polish stone value (psv) test for the samples resulted in good abrasiveness and produce attractive colour. The values for samples A, B and C are 90.88, 97.36 and 93.71 while respectively compressive strength test estimation obtained were 142.37, 201.62 and 164.62 for sample A, B and C. The Hardness test values are 85.59, 96.84 and 88.11 respectively. Hence, the value obtained from the investigation on the suitability of metamorphosed granites for road construction and polish rock shows that they are good for constructional and polished stonework.

Introduction

Granite is a very hard natural igneous rock formation, it possesses visibly crystalline texture formed essentially of quartz and ortho close or microline and used especially for building and for monuments. It is used for architectural focades, construction materials ornamental stone and monument, more than 40% of dimension stone quarried is granite (Helsinki, 2015).

Granite rock formed by the molten magma deep within the earth under great heat and pressure, made available in large slab sizes and kinds are available from different parts of the world (Hay, 1963).

Granite is the hardest rock, it is also composite made of feldspar and quartz, with a hardness of 6 and 9 respectively. This make granite a fairly tough materials. The mineral ranked on a scale of 1 to 10; the higher the number the harder the mineral because it was a liquid (Hoffman and Masson, 1994).

Polished value is the only parameter relating to the micro texture properties of an aggregate which can be measured in a standardized manner, and which has been related to traffic and site condition (Alpha, 1993).

The compressive strength is the maximum load per unit that stone can bear without crusting. A higher compressive strength indicates that the stone can withstand a higher crushing load (Baar, 1972).

Oxidation in stone paving occur due to porosity of the stone and mineral contained within, some types of natural stone paving, such as granite contain iron, or iron ore, which can be drawn to surface when subjected to moisture (Ishihara, 1981).

Granite rocks are termed felsic, hence have a relatively low specific gravities, most should fall in the 2.7 to 2.8 range 1 use 2.75 as a good range (ISRM, 1978).

The study was carried out to determine the suitability of rock from Man Hardi Quarry for construction of roads and polished stone production.

Materials And Methods

Description of the study Area

MAN HARDI Nig. Ltd. Quarry is situated on Latitude N008^{0}34.291, Longitude E004^{0} 34.771 in Ilorin South Local Government Area of Kwara State. The Quarry has a land area of about 4000m^{2} and is at about a distance of 2.4km from Kangile, the nearest village. The site overview comprises of granite deposit, and it is surrounded by thick bushes, trees and stream. A fire boundary clearance separates the mining area from the surrounding vegetation. Figure 1 shows the map of Kwara State, Nigeria indicating the studied site.

Sample Preparation

Granite samples obtained from the MAN HARDI Quarry were brought to laboratory for further analysis. The granite samples were carefully selected for the following analysis: XRF, Hardness, Polish value, compressive strength, oxidation properties, specific gravity of granites.

X-ray Fluorescence (Xrf)

X-Ray Fluorescence is used to analyze the elemental composition of samples which is based on surface analysis. It is the emission of characteristic 'secondary' (or fluorescence) X-rays from a material that has been exited while bombarding with high energy X-rays or gamma rays. The method employed in this analysis is the energy-dispersive analysis (ED-XRF) and the machine model used to determine the basic chemical composition of the sample is the Shimadzu EDXRF-702HS

The sample is irradiated with X-rays within the instrument. If an X-ray photon is absorbed by the sample of sufficient energy then an electron is emitted via the photoelectric effect resulting in an electron hole in the atom. An inner shell electron will then fall back to fill this hole resulting in the release of electromagnetic energy with a frequency characteristic of the element present.

A metallic filter, which was 100-m-thick titanium or 50-m-thick zirconium, was attached to the Rh x-ray tube. The aluminum collimators of inner diameters of 6 mm and 3 mm were attached to the x-ray tube and the detector, respectively. The x-ray tube and the detector were tilted to 45 degrees. The detector and the sample holder were placed on a Z-stage and to adjust the distance from the point of the detector to the sample surface. The external diameter of the sample holder was 44.5 mm (inside diameter: 40.5 mm) and height was 25.5 mm. The thickness of sample could be changed depending on the volume put in the sample holder

All measurements were carried out on an energy dispersive X-ray fluorescence spectrometer Shimadzu EDXRF-702HS operated at 40 kV and 18 mA. The current was automatically adjusted (maximum of 1 mA). A 10 mm collimator was chosen. The counting time was 100 seconds for all measurements. The intensity of element $K\alpha$ counts per second (cps/μA) was obtained from the sample X-ray spectrum using the Shimadzu EDX software package.

Weighing Of The Samples

The Ohaus Digital weighing balance (model Ohaus AX22021 E-US) is a standard laboratory applications to ensure solid weighing performance and accurate repeatable results. It has a capacity of 2,200grams and a readability of 0.01gram (10miligrams).

The Form Test Seidner (Model GMBHD7940) is a system which produce high quality, high degree of accuracy and reproducibility of text results. It is used to determine the compressive strengths of materials.

Rock Well Hardness Testing

The Rock well hardness testing machine (Model: GMBH3806) is a device that indicates the hardness of a material usually by measuring the effects on its surface of a localized penetration by a standardized rounded or pointed indenter of diamond carbide or hard steel.

Rock Polish

The Road Wheel polishing machine is a great machine for grinding, smoothing and polishing process, it produce a high quality, repeatable finishing solution to achieve a highly polished results.

The Syno-electro –magnetic machine corporation (FMC) is a machine used to repolished materials with oxidized surface with variable speed of 250rpm (maximum) after the materials are removed from the machine, cleaned with oxygen damp paper of grade one and dried with pressurized air.

Chemical Analysis By Xrf

The sample was ground to a fine powder (to obtain a homogenous sample) using a vibration grinding mill with a steel milling. It was sieved through a 200-mesh sieve and dried to constant weight in a furnace at 110°C.

XRF was performed on sample prepared in the form of glass disks with a sample/melt ratio of 0.5/5; Li_2B4O_7 was used as the melt. The reference materials GSS8 and BCS-CRM 354 were used to produce standards; mixtures of these with an oxide content including that of the samples to be analyzed were used to produce a calibration curve. The reference materials were mixed with a 5% Au/Pt ZGS glass rod and melted in a furnace at a temperature of 1100°C for 15 min. The melt was taken from the furnace and stirred after 10 min and then replaced to eliminate bubbles. It was then poured into a Pt/Rh 30-mm diameter mold to form a glass disk, of 30 mm diameter and 9 mm thickness were used for the analyses.

Determination Of Percentage Loss On Ignition

Approximately 1.0g of sample was weighed in a platinum crucible at a temperature of 25°C, this material was heated at a temperature between 900-1,000°C, cooled and weighed, W_1. The loss in weight was checked by a second heating at same temperature for 5 mins and the content reweighed. This process was repeated until a constant weight was attained, and recorded as W_2. The loss in weight was recorded as the loss in ignition. Percentage loss on ignition was calculated as follows:

$W_3 = W_1 - W_2$,

% loss of ignition = $(W_3 \times 100)/W$,

Where:

W = weight of sample taken.

W_3 = Loss in weight.

plastics or stainless steel.

Hardness Test

The hardness test was carried out on the sample of dimension 20mm x 20mm x 20mm using a Rockwell Hardness Testing Machine (Model: GMBH3806) with steel ball as the indenter. The indentation was carried out on five randomly selected points on the surface of each sample, average of the hardness value was taken and reported.

Polish Value (Pv) Test

The polish Value test was carried out on the samples to determine the display of good abrasiveness and yielding attractive color tints.

Compression Test

Compression stress was measured using form test seidner, model GMBH D7940 compression machine, Riedlingen - West Germany. Compressive stress was applied uniaxially to sample of dimension 20mm x 20mm x 20mm with a crosshead speed of 20 mm per minute to determine the behavior of the composites under a compressive load.

Oxidation Test

The oxidation test was carried out to determine the rate of decomposition or break down of the rock samples surfaces when exposed to air, heat, and acidic solvent before and after polished. The procedure used for the test includes cutting of sample A, B and C of dimensions 20mm X 20mm X 20mm were polished before exposed to prepared solution of tap water, dilute hydrochloric acid (HCL) and oil. These samples were then left exposed to atmospheric condition for four days. After this the samples were then re-introduced into a synon-electro-magnetic machine corporation (FMC) with variable speed of 250rpm (Maximum) to allow re polishing of the oxidized surface. Finally, the samples were removed from the machine, cleaned with Oxygen damp paper of grade one and dried with pressurized air. The dried samples were then observed under a Nikkonophiphot polarized microscope for any damage to the already polished surface such as peeling due to the corrosive nature of the solution of acid, air and oil.

Specific Gravity Determination Of Samples

20 g of sample A was weighed (W) using Ohaus Digital Weighing Balance (Model: Ohaus AX2202/E- USA) and was charged into 100 ml measuring cylinder of known volume of water refers to as initial volume (Volume (V_2) of water was measured and the difference in the initial volume and final volume of water was noted as the displacement. Specific gravity was calculated using equation (ISRM, 1981)).

$$\text{Specific Gravity} = \frac{\text{Mass of sample (g)}}{\text{Displacement value}} \times \text{Density of water}$$

$$\text{Specific Gravity} = \frac{W}{V_2 - V_1} \times \text{Density of water}$$

These were repeated for other samples

Results And Discussion

Tables 1, 2 and 3 show the chemical composition of selected samples

Table 1 shows the Chemical Composition of Selected Sample A

Table 1
Chemical composition of selected sample A

S/N	Basic Oxides	Formulae	% Composition
1	Silicon Oxide	SiO_2	67.73
2	Aluminum Oxide	Al_2O_3	13.39
3	Ferric Oxide	Fe_2O_3	4.16
4	Calcium Oxide	CaO	0.37
5	Magnesium Oxide	MgO	0.12
6	Sodium Oxide	Na_2O	4.81
7	Potassium Oxide	K_2O	6.00
8	Sulphide	SO_3	0.02
9	Manganese Oxide	MnO	0.09
10	Lead Oxide	Pb_2O_5	0.02
11	Titanium Oxide	TiO_2	0.33
12	Loss of Ignition	LOI	2.95

Table 2 shows the Chemical Composition of Selected Sample B

Table 2
Chemical composition of selected sample B

S/N	Basic Oxides	Formulae	% Composition
1	Silicon Oxide	SiO_2	73.62
2	Aluminum Oxide	Al_2O_3	14.23
3	Ferric Oxide	Fe_2O_3	0.26
4	Calcium Oxide	CaO	0.62
5	Magnesium Oxide	MgO	0.02
6	Sodium Oxide	Na_2O	5.04
7	Potassium Oxide	K_2O	3.92
8	Sulphide	SO_3	0.04
9	Manganese Oxide	MnO	0.08
10	Lead Oxide	Pb_2O_5	0.04
11	Titanium Oxide	TiO_2	0.46
12	Loss of Ignition	LOI	1.63

Table 3 shows the Chemical Composition of selected Sample C

Table 3
Chemical composition of selected sample C

S/N	Basic Oxides	Formulae	% Composition
1	Silicon Oxide	SiO_2	72.40
2	Aluminum Oxide	Al_2O_3	16.10
3	Ferric Oxide	Fe_2O_3	1.42
4	Calcium Oxide	CaO	0.18
5	Magnesium Oxide	MgO	0.06
6	Sodium Oxide	Na_2O	3.67
7	Potassium Oxide	K_2O	4.28
8	Sulphide	SO_3	0.03
9	Manganese Oxide	MnO	0.08
10	Lead Oxide	Pb_2O_5	0.04
11	Titanium Oxide	TiO_2	0.30
12	Loss of Ignition	LOI	1.40

Silica content are 67.73, 73.62 and 72.40. These are closer to the value of 70–77% silica contents state by Nature (2016).

Hardness Value Of The Samples

Table 4 shows the Hardness Value

Table 4
Hardness Value

Sample	Hardness Value (%)		
	1	2	Average hardness
A	86.00	85.17	85.59
B	97.16	96.51	96.84
C	88.06	88.15	88.11

Table 4 is the result of the hardness test, which shows that sample A, B, and C have high hardness value of 85.59, 96.84 and 88.11, but sample B has the highest maximum hardness value of 96.84. The highest value was 96.84 (average) (Ojo and Olaleye, 2004). Hence, this, shows that the sample is hard enough for a road constructional work.

Polish Value Of The Sample

Table 5 shows the Polish Value

Table 5
Polish Value

Sample	Polish Value (%)		
	1	2	Average polish value
A	90.00	91.75	90.88
B	97.40	97.32	97.36
C	93.41	94.00	93.71

Table 5 shows the result of the polish value of sample A, B and C of good abrasiveness and yielding of 90.88, 97.36, 93.71, but sample B has the maximum abrasiveness and yielding value of 97.36 and thus shows that the sample is good enough for construction of roads. (Abuqubu, et al., 2016).

Compressive Strength Of The Sample

Table 6 shows the Compressive Strength

Compressive Strength

Table 6
shows the compressive strength test result of the three samples under study. Where samples A, B and C show good compressive strength of 142.37, 201.62 and 164.62 MPA respectively, this is comparable to Broch and Franklin, (1972) which state the range of compressive strength of granite to be 146.63Mpa to 197.00Mpa. However, sample B has the maximum compressive strength.

Sample	Maximum compressive Load (MPa)		Compressive Stress (MPa)		Mean compressive strength
	1	2	1	2	
A	5.35	5.40	142.74	142.00	142.37
B	8.62	8.50	202.71	200.53	201.62
C	6.34	6.91	151.88	177.35	164.62

Oxidation Properties Of The Sample

The samples show no peeling, making them good for road construction. **Specific gravity of selected samples**

Table 7 shows the Specific Gravity

Table 7
Specific Gravity

Sample	Mass (g)		Initial volume V_1 (ml)		Initial volume V_2 (ml)		Displacement V_2 -V_1 (ml)		Specific gravity		Average specific gravity
	1	2	1	2	1	2	1	2	1	2	
A	20.00	20.00	45.00	45.00	49.50	49.35	4.50	4.35	4.44	4.60	4.52
B	20.00	20.00	45.00	45.00	49.35	49.00	4.35	4.00	4.60	5.00	4.80
C	20.00	20.00	45.00	45.00	50.50	50.62	5.50	5.62	3.64	3.56	3.60

Table 7 gives the results of the specific gravity of the metamorphosed granite samples, from this it can be deduced that both sample A, B and C have almost uniform specific gravity 4.52, 4.80, and 3.60 respectively. These are heavier than specification of Will, (2006) for granite which is 2.2.

Conclusion And Recommendation

The result of the study shows that the three tested granite rocks samples possessed a very high engineering properties as well as chemical properties to be used for engineering application such as structural, building and road constructions and polished rocks.

It is recommended that the metamorphosed granites can be used for road construction and polished rocks. Further studies are to be carried out to check for the possible variability in the rock body.

Declarations

Conflict of Interest

The authors declare no conflict of interest.

Availability of Data and Materials

The dataset used and/or analysed during this study available from the corresponding author on reasonable request.

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Figures

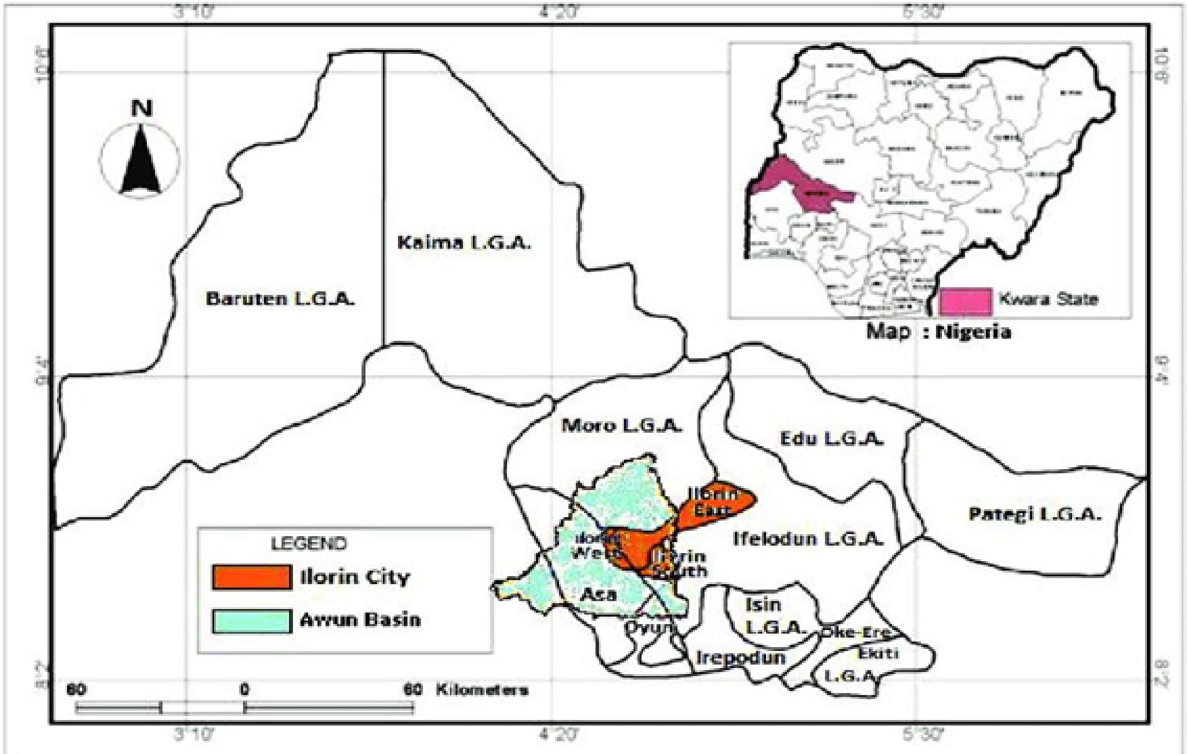

Figure 1

Map of Kwara State, Nigeria showing the Study Area.

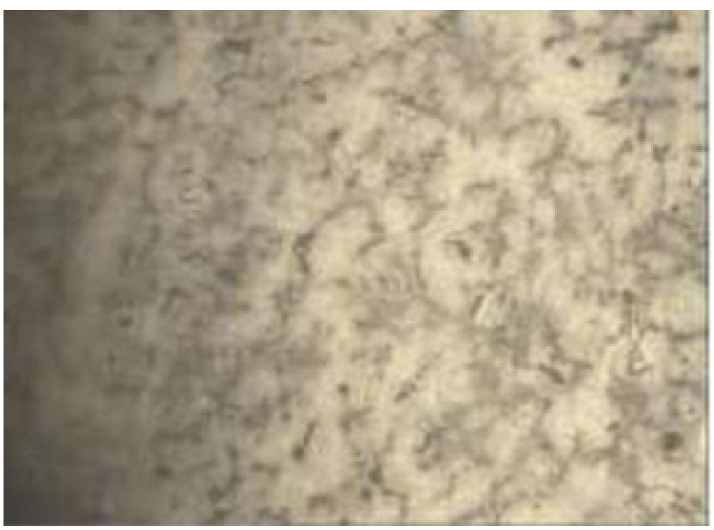

Figure 2

Photograph of Sample A after oxidation test was carried out.

Figure 3

Photograph of Sample B after oxidation test was carried out

Figure 4

Photograph of Sample C after oxidation test was carried out