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RHEOLOGICAL PROPERTIES OF SELECTED GRANITES FORM JOS PLATEAU, NIGERIA

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***Abstract*— Granites are sourced for construction aggregates viz, rock flour, crushed stones. They are also cut and polished for floor and wall tiles and other building accessories. Larger pieces of granites are used as surcharge materials to stabilize construction sites like petrol-filling station. In Nigeria, granites are sought for completion of road pavements and airport run ways. Varieties of granites having different textural characteristics and mineralogical composition are found on the Jos Plateau Nigeria. This paper presents data of engineering/rheological investigation of selected granites from Jos Plateau, The Jos-Bukuru and the Ropp complexes were studied and sampled between 2003 and 2006. Selected granite samples were cut with diamond studded saw blades into cubes (size 40mm x 40mm x 35mm). The cubes were subjected to imaxial/compression with the mechanized and computerized UTM machine model 50KN. The specimens were compressed to failure, marked by cracks/partings on the specimen surface(s) several rheological parameters viz, stress @ peak, load @ peak, strain @ peak and others were measured and recorded by another computer. The data collected are presented as tables and graphs in this report. The specimens exhibit data which show that they represent materials good for engineering construction and concrete aggregates. The granites may be classified by Deere and Miller criteria as high or very good for construction works.**

***Index Terms*— Geology, Mining Engineering, Granites.**

I. Introduction

Geologically, the studied area is dominated by the younger granites. A series of anorogenic intrusives with associated volcanics (rhyolites and basalts).

The Jos Plateau forms the local area of the younger granite province and is the principal centre of the associated tin and columbite mineralization. Early volcanic members largely rhyolite and acid tuffs are preserved through cauldron subsidence or deeply eroded vent, this was succeeded by granitic ring-dikes and plutons composed of hornblende, biotite and riebeckite - granites. Minor basic and intermediate rocks are also represented. The younger granites have recently been shown to be of Jurassic age.

A period of erosion followed the emplacement of the younger granites resulting in the formation of the major morphological units of the area.

Several factors affect the strength of rocks. Such factors include fabrics and flow pattern, size and strength gradient, rock forming minerals, pore and fluid pressure, temperature and anisotropy.

Rock fabrics as described by Turner and Weiss (1963) show that all rocks have different fabrics of some sort. Most consisting of aggregates of crystals and amorphous particles joined by varying amounts of cementing materials. The chemical composition of the crystals may relatively be homogenous as in limestone or greatly heterogeneous as in granites. Also, the sizes of the crystals may be uniform or they vary in dimensions in the order of inches or small fractions. These crystals largely represent the scale on which mechanical properties of the rock bodies are studied.

Jaeger and Cook (1976) found that homogenous rocks have their crystals aligned with short boundaries which represent a strong intra-planar bonding. Whereas, the long boundaries between heterogeneous crystals represent the weakness of the intra-planar bonding in the structure which is otherwise continuous.

On the other hand, large crystals with lesser cementing materials have weaker structure when compared with small sized crystals with high cementing materials Turner and Weiss (1968).

If the initial body is perfectly homogeneous and isotropic, then the state of stress with the body is perfectly correlated with any little force applied. More so, the resulting strain can be homogeneous (Hobbs et. al 1976). Here, the final fabric correlates with the stress and strain. Although the intact rocks are almost never isotropic nor homogeneous. Planar and linear discontinuities e.g. bedding and foliation, cause

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heterogeneous stress field when forces are applied Turner and Weiss (1968).

Strain resulting from this uneven state of stress is generally not homogeneous nor is it predictable. Means (1977) pointed that the strain distribution in metamorphic rock is a consequence of the pattern of the ductile flow but Turner and Weiss (1968) showed that there can be an infinite variety in flow pattern. In general, the ductile flow is reflected in the geometry of the final imposed fabric. Although strain and pattern of flow may not be directly correlated if the discontinuity in the body such as fabrication are closely packed and not mechanically significant Nicolas and Poirier (1966)

Sophisticated, correlation can be drawn between fabric flow pattern and strain with regards to their symmetries Turner and Weiss (1968).

Evans and Porneroy (1958); Evans, Porneroy and Bern Baum (1961) showed that a coal cube of various side length show a wide range strength which is distributed normally. Lund Borg (1967) also studied cylindrical granites of diameters ranging from 19-58mm and finds a range of 1750 - 2190Kg/m^2 in crushing strength. Evans (1961) finds a variation in the, tensile strength of coals with different specimen thickness in the Brazilian test.

Durelli and Parks (1962), described a small variation in the tensile stress with sizes for plastics. Obert et al (1946) concluded that the size effect or rock strength is small. This size effect is usually attributed to the presence of flaws, Robertson (1955). Durelli and Parks (1962) also noted that for each material with varied shapes and sizes, the stress gradient varies regularly with the stress at failure.

Bell (1980) showed that stress is present beneath the surface of the earth as a result of the weight of overlying rock as well as any load applied at land surface. The stress at any point can be resolved into maximum, minimum and intermediate components acting in mutually perpendicular direction at that point. Strain results from the application of stress to materials show that rocks exhibit complex deformational response to stress.

Deere and Miller (1966) explained that stress-strain behavior is utilized in the engineering classification of rocks. One component of the classification is the unconfined compressive strength. The modulus of elasticity (E) and the unconfined compressive strength (□*)* can be used to calculate the modulus ratio which is defined as MR = E/□.

Deere and Miller (1966) also showed that the strength of igneous rock is high when the rock is composed of a dense network of interlocking crystals. This condition is usually present in the intrusive rock, which had sufficient time for cooling and crystallization to develop a three dimensional network. The intrusive rocks generally have a high modulus of elasticity and a modulus ratio. The extrusive igneous rocks have a much wider range in strength and modulus properties that are similar to the intrusive rock but vesicular extrusive rocks are usually weaker. The pyroclastic rocks extend the field of the extrusive rocks into the area of low strength and modulus because of their low density and high porosity caused by their formation from flow processes. Most extrusive rocks fall into the medium modulus ratio category.

II. METHODOLOGY

A. Field Procedure

The representative samples of the rocks used for this study were collected form outcrops from the Rop complex and the Jos-Bukuru complex. The procedure is presented in Table 1 below.

TABLE I: TABULATION OF SAMPLE DESCRIPTION AND DIRECTIONAL READINGS AT ROPP AND JOS-BUKURU COMPLEXES

S / N O	SAMPLE LOCATION	SAMPLE DESCRIPTION	GPS READINGS
1 .	L 1-2 Location- Ropp complex. Opposite Nding Block making industry, Barkin Ladi. About 2m from Jos-Auchi high way.	Leucocratic medium grained granite. It mainly composed of Quartz, Kfeldspar in larger percentage. Other minerals include Biotite, muscovite, garnet and some mafic minerals.	Altitude - 1309m Longitude - N09°32 '163" Latitude - E008°54 '602"
2 .	L 1-3 Location Ropp - Complex. At the Nding Block Industry, Barkin-Ladi.	Mesocratic gray coloured porphyritic granite. Its phenocrysts are olivine and hornblende minerals 9majorly the mafic minerals).	Attitude - 1310m Longitudo- N09°32 '140" Latitude- E008°54 '997"
3 .	L 1-4 Location- Ropp Complex. This is about 2m Easterly from the block industry.	Leucocratic Coarse grained Granite	Altitude - 1304 Longitude - N09°32 '221" Latitude - E008°54 '949"
4 .	L1-7 Location- Ropp complex. Just behind the ridge	Pink Coloured Medium grained granites. This is primarily enriched in K- feldspar which accounts for its pink colouration.	Readings could not be taken because of unavailability of instrument.

	going to Mongono.		
5.	L2-1 Location - JosBukuru complex. Rayfield, Anglo-Jos, just within the mines.	Leucocratic - medium grained granites the dark coloured minerals more than those at the Ropp complex.	Altitude - 1296m Longitude N09°49 '806" Latitude E008°54 ‘586”
6.	L 2 - 2 Location- Jos-Bukuru complex. Within the Rayfield mines.	Medium grained leucocratic granite. Outcrop is highly fractured with cross joints.	Altitude - 1300m Longitude - - N09°49 ‘770” Latitude - EOQ8°54 ‘350”
7.	L3-1 Location- Jos-Bukuru complex. Jos-type 1	Porphyritic, coarse grained granites. This rock type is largely different from other rock types that have being sampled. It's distinct for it’s coarseness where each mineral grain can be visibly identified without an aid. The grains could. be described as “sugar-cube coarseness”.	Readings could not be taken because of unavailability of instrument.

B. Laboratory Procedure

In other to provide an accurate and detailed description of the minerals within the rock samples selected, petrographic sections were made, and thin section analysis (Table 2) were carried out at the geology laboratory, University of Ilorin. Figure 2 provides a photomicrograph of one of the samples.

Fig. 1. The Rocks samples Cut to a regular dimension and set for the compression tests.

C. Laboratory Testing of Samples

As earlier reported, the primary aim of this work is to test and determine the strength with relation to the texture of selected granites from the Jos-Bukuru and Ropp complexes of Jos Plateau under combined stress in a uniaxial compressive testing where in the strength of the outcrop can be inferred from the results gotten from a rock sample of known dimension. The known dimension in sample is preferred so that with a larger mass of rock, the strength can be inferred from the result of the representative sample.

Different samples, (Fig. 1 & 2) taken from same complexes were used so there can be comparism of strength between rocks of different grain sizes, different colors and different mineralogical composition.

Field samples were taken to a Mechanical Engineering Laboratory where they were first “cut” to a cube-like shape. The dimension was later reduced for uniformity of stress during loading. The new dimension used is given as: length-40mm; Breadth- 40mm; Width-35mm.

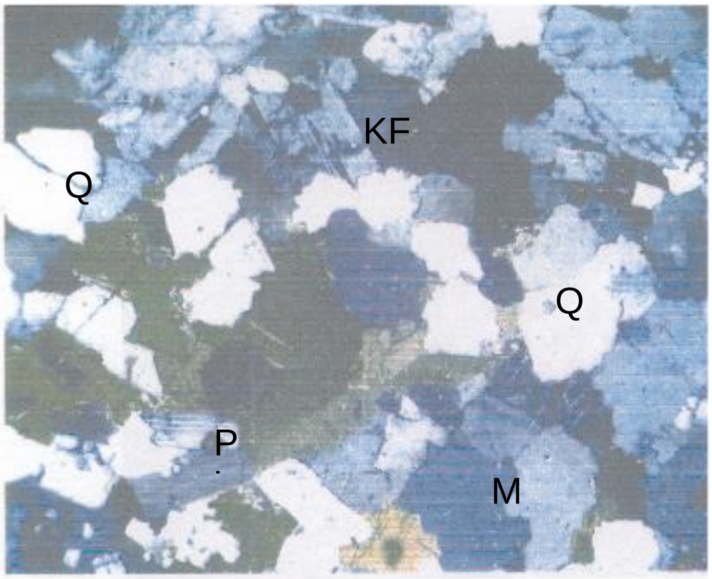

Fig. 2. Photomicrograph of granite from the Jos-Bukuru Complex

KEYS:

KF – Orthoclase

Q – Quartz

Pl – Plagioclase

O – Opaque

M – Mica

The Universal Testing Machine: A Universal Testing Machine known as EXTENSIOMETER of model AX M500 - 50 KN (Fig. 4) was used in the compression testing of the rock samples. The machine is called Universal because it’s used in the testing of different types of materials.

D. Procedure in the Testing of Samples

A collective photograph of all the samples to be tested is first taken then the samples are placed on the stage of the machine (Fig 5). The steps are given below:

(a) The adhesive tape wound round the sample is first removed.

(b) The compression Jaw is fixed and the sample is mounted on the stage, making sure the end is well flattened and smooth enough so the stress can be evenly distributed. The rig is then lowered and the machine is set by the operator and it starts to compress the sample to failure till it yields and the fractures. The point of yielding is therefore noted.

(c) The data gotten from the test done are noted and recorded.

(d) The steps are repeated for each of the other six (6) samples.

Sample 1

Sample 2

Sample 6

Sample 7

Fig. 2. Display of brittle failure in tested samples.

Test on intact or fractured rock with maximum confining stresses up to 50kN.

The machine has a cross head with an extensiometer which it uses in measuring extension. The Universal Testing Machine (UTM) uses the screw mechanism in its operation where the rig with different fittings for the various tests listed above is gently lowered at a particular compression rate, preferably 2.5mm per second. The equipment has a console which is its display unit.

The cell capacity is 50kN which is its maximum confining stress. If at this stress the material does not yield, the machine stops automatically.

To carry out a test, the compression jaw is fixed, sample is loaded and the machine is set up and testing starts. The machine is set to a sensor of 5 which is average and most appropriate sense for testing. Highest sense is 9.

At the console, data are presented and transferred to the connected computer system for constant monitoring and data storage.

III. PRESENTATION OF DATA

Results are gotten at three different stages during each test, which includes Load, Stress & Strain and Yield modulus.

Note that the stress - strain curve and the Load - Deflection curve indicates deflection at points of inflection.

The table above shows the locations at which the samples were collected and also summarized description of the samples collected and also the directional measurements. This gives the analysis of the data gotten from the field work.

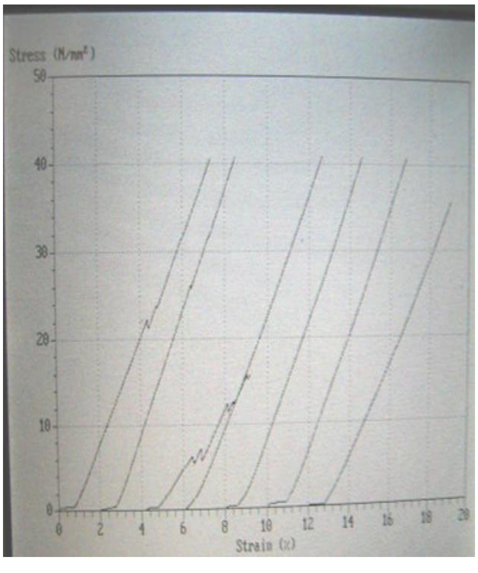

Fig. 3. The combined Stress-Strain curve for the seven samples.

IV. ANALYSIS OF LABORATORY RESULTS

In the presentation of results from the laboratory, some factors that help determine the strength of these rocks were calculated and have to be defined as given in the users manual of the Universal Testing Machine used in the compressive testing of the rock samples.

V. ANALYSIS AND INTERPRETATION OF DATA

A. Definition of Calculations

Load @ Peak

Definition: This is defined as the Maximum force reached during test. Its units are N, kN, Ibf, kgf, gf.

Stress @ Peak

This is defined as the maximum stress reached during the test. (Stress = force divided by cross sectional area). Its units are in N/mm^2, PSI, kg/mm^2,

Strain @ Peak

This is the strain at which maximum force .is reached. (Strain = distance traveled divided by sample length or distance traveled divided by sample height). Its unit is in %.

Load @ Break

This is the force at which maximum extension or deflection is reached. Its units are N, kN, Ibf, kgf, gf.

Deflection @ Break

This is the maximum deflection. It's measured in mm or in inch.

Stress @ Break

This is the stress at point of maximum extension or deflection. Its units are in N/mm^2, PSI, kg/mm^2, g/mm^2.

Strain @ Break

This is the strain at point of maximum extension or deflection. Its unit is in percentage (%).

Load @ Yield

This is the force at point of yield. (Yield is the point at which the initial strength line portion of the load/extension or load/Ideflection curve dips, i.e. drops off in load. The units are in N, kN, Jf, kgf, gf.

Deflection @ Yield

This is the distance at the point of yield. Its units are in mm or in inches.

Stress @ Yield

This is the stress reached at the point of yield. Its units are N/mm^2, PSI, kg/mm^2, g/mm^2.

Strain @ Yield

This is the strain reached at point of yield. The unit is in percentage (%).

VI. DISCUSSION AND CONCLUSION

In petrology, importance is on the mechanism of the rock response and the response of individual mineral grain to stress and strain. In unstrained crystals, the periodic array of atoms is maintained by inter atomic forces of attraction and repulsion. During elastic strain, the atomic bonds are distorted thereby shortening or lengthening the inter-atomic distances. If a non-hydrostatic stress applied exceeds the plastic yield strength, group atomic bonds can be systematically broken or rotated along perpendicular crystallographic directions into a new permanent equilibrium, wherein they remain upon relaxation of the stress Nicolas (1976). This permanent irreversible deformation is favored where continuing pressure is too great to permit brittle rupture or temperature are too high enough to facilitate rearrangement of atoms Paterson (1978). This cohesive type of response to a non-hydrostatic stress is an expression of the ductile behavior Nicolas and Poirier (1976). Rocks existing in areas where pressure and temperature are relatively low are subjected to very high strain, and respond in a very brittle manner to non-hydrostatic stress.

In summary, non-hydrostatic stress produce reversible elastic strain up to elastic limit or elastic strength. An applied stress which is greater than this limit produces permanent or irreversible deformation such as ruptures, faults and permanent ductile flows.

A rock is said to be brittle ruptured as a result of applied stress show no plasticity. This property is controlled by the value of elastic limit and the ultimate strength. If the elastic limit and the rock strength are not very different, the rock is said to be brittle and tends to yield by fracture, Remi (1997).

The samples tested in this research demonstrated brittle failure (Fig. 3).

RECOMMENDATION

Rock mechanics deal with the evaluation of engineering properties of rocks to their uses. This forms the basis of this research which has attempted to study intact granites from Ropp and Jos-Bukuru complexes of the Jos Plateau using representative samples.

It has being observed that the mineralogical composition of these intact rocks, the mineral grain sizes and corresponding colour which gives an inference to the origin of magma and mode of formation largely influence the result and strength of the materials.

From a critical study of the data Table 2 (Appendix), it can be observed that specimens with finer grains are more resistant to yielding when compared with samples with larger grain sizes. Also, samples with more ferromagnesian minerals are less resistant compared with those rocks with leucocratic mineral grains.

This study has shown that granitic rocks are fit for engineering construction and are therefore should be of economic importance.

Conclusively, we can deduce from this study, that these suites of rocks can be used for foundation, design, road construction, tunneling, building stones, freeways, dams and reservoirs construction.

Finally, this research has begun to provide preliminary data on the engineering properties of the Nigerian Jurassic younger granites which hitherto were absent in the geology literature.

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