DETERMINATION OF THE MINIMUM STRESS REQUIRED TO FRACTURE AN IGNEOUS ROCK SAMPLE IN OKPILLA VILLAGE (EDO STATE, NIGERIA)

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Abstract— This paper was designed to determine the minimum stress required to fracture samples of igneous rock in Okpilla village in Edo State.An igneous rock sample was broken into different sizes by the application of force and various readings were obtained from the the different sizes when the forces were applied. A graphs of force against areas of different sizes of the rock were plotted and the minimum stress required to fracture the igneous rock sample was obtained.The result revealed that the stress required to fracture the igneous rock sample is in the order of 8.82 x 10-6 Nm-2.Therefore, the knowledge of this minimum stress should as a matter of principle be applied in any Engineering and construction work, such as subsurface Geology, construction of roads,houses tunnels canal or dams etc.

Keywords—fracture, igneous rock, Okpilla, minimum, stress

Introduction

Analysis of problems in the geosciences requires knowledge of the failure processes in rock. These include tunnel design and other engineering applications as well as geophysical problems such as predicting earthquake. In the 1960s, many of the advances in the theory of fracture and friction in rocks have had their origin in metallurgy.

The earth's crust consists of rocks. A rock is one of the mineral materials of the earth. All the rocks differ from one another in texture, structure, colour, permeability, mode of occurrence and degree of resistance to denudation. All rocks are classified into three major types:

(i) Igneous rock (ii) metamorphic rock (iii) Sedimentary rock

Igneous Rock

Igneous rock (derived from the Latin word igneous meaning of fire from ignis meaning fire) is one of the three main rock types. Igneous rock is formed through the cooling and solidification of magmas or lava. It may form with or without crystallization, either below the surface as intrusive (plutonic) rock or on the surface as extrusive (volcanic) rocks.

Igneous rocks are characterized as follows.

(a) They are crystalline in structure
(b) They non-stratified (i.e they do not occur in layers)
(c) They do not contain fossils
(d) They are usually hard and impervious.
(e) They are resistant to erosion and other element of climate.

Intrusive igneous rocks are formed from magma that cools and solidifies within the crust of a planet. Surrounded by pre-existing rock (called country rock) the magma cools slowly, and as a result these rocks are coarse grained. The mineral grain in such rock can generally be identified with the naked eye. This type of rock can also be classified according to the shape and size of the intrusive body and its relation to the other formations into which it intrudes. Typical intrusive formations are batholiths, stocks, laccoliths, sills and dikes.

Coarse grained intrusive igneous rock which form at depth within the crust are termed as abyssal;

those formed near the surface are termed hypabyssal. Hypabyssal igneous rocks are formed at a depth in between the Plutonic and volcanic rocks. Hypabbyssal rock are less common than Plutonic or volcanic rock and often appear like sills and laccoliths.

Extrusive igneous rocks are formed at the crust's surface as a result of the partial melting of rock within the mantle and crust Extrusive igneous rock cool and solidify quicker than intrusive igneous rock. Since the rock cool very quickly, they are fine grained. It is much more difficult to distinguish between the different types of extrusive igneous rock with the naked eye, because the minerals in extrusive igneous rock are mostly fine-grained. Generally, the mineral constituent of fine-grained extrusive igneous rock can only be determined by examination of thin sections of the rock under a microscope.

Magma which is melted rock with or without suspended crystals and gas bubbles rises because it is less dense than the rock from which it was created. When it reaches the surface, magma extruded onto the surface either beneath water or air which is called Lava. Eruptions of volcanoes into air are termed sub aerial whereas those occurring underneath the ocean are termed submarine. Black smokers and Mid-Ocean- Ridge basalt are examples of submarine volcanic activity.

Igneous rocks are classified according to mode of occurrence, texture, mineralogy, chemical composition, and the geometry of the igneous body. The classification of many types of igneous rocks can provide us with important information about the condition under which they formed.

Two important variables used for the classification of igneous rocks are particle sizes which largely depend upon the cooling history, and the mineral composition of the rock.

Feldspars quartz or feldspathoids, olivine, pyroxene, amphiboles and micas are all important minerals in the formation of almost all igneous rocks, and they are basic to the classification of these rocks. All other mineral are regarded as non-essential and are called accessory minerals.

For example, rocks containing quartz (are silica in composition; are solica –over saturated while rocks with field spathord's are silica- under saturated because feldspathords cannot coexist in a stable association with quartz.

Igneous rocks which have crystals large enough to be seen are called phanerites which implies intrusive origin; those with crystals too small to be seen are called aphanites, which implies extrusive origin. An igneous rock with larger clearly discernible crystals embedded in a finer-grained matrix is termed porphyry. Porphyritic texture develops when some of the crystals grow to considerable size before the main mass of the magma crystallizes as finer-grained uniform mineral.

For most magmas only entirely melts form small parts of their history. They are mixes of melt and crystals and sometimes of gas bubbles. Melts, crystals and gas bubble usually have different densities, and so they can separate as magmas evolve .magma composition can be determined by process other than practical melting and fractional crystallization. For instance, magmas commonly interact with rocks they intrude, both by melting those rocks and by reacting with them. Magmas of different composition can mix with one another. In rare cases, melts can separate into two immiscible melts of contrasting composition.

Factors Affecting Rock Strength

In this section, the paper examined some of the variables that affect rock strength. Their relative importance can be summarized in the following way. That is if one considers a 'typical' granitic rock saturated with water at room temperature and confining pressure of 100 MPa, the following changes should result in a reduction in strength of approximately 10%: a decrease in confining pressure of 24 MPa or are increase in more pressure if 24 MPa, a decrease in strain rate of 3+ 0.5 orders of magnitude; an increase in temperature of 190+ 40oc, or an increase in sample diversion of 50-110%. Each of these effects is considered separately.

Confining pressure affects brittle fracture strength by suppressing the growth of dilatant micro cracks. Micro cracks, tend to grow parallel to or when a sample is loaded in compression by locally overcoming the ambient compressive stress field near crack tips and developing a localized region of tensile stress. Pengs and Johnson[1] (1972), asserted that this processes requires some specialized mechanism such as slip along grain boundaries or bending a rigid grain that is adjacent to an open pore or more compliant grain. Such mechanisms are generally enhanced by deviatoric stress and suppressed by mean stress.

Ismail and Murrell[2] (1990), have observed that the failure envelope in general is concave towards the normal stress axis and the difference between inpact shear strength and frictional shear strength vanishes at high pressure.

The majority of strength measurements have been conducted under uniaxial or 'triaxial' stress conditions in which, a limited number of true triaxial measurements have been performed to explore the effect of intermediate principal stress on failure mode. Mogi[3](1967) and Amadei et al[4] (1987), have stressed that the most commonly used failure criteria (eg Mohr – Columb), assume that failure is interdependent of intermediate stress, but experimental evidence demonstrates that this assumption is not strictly true. Effective pressure law: pore fluid can affect fracture strength through a direct pressure effect as well as through chemical interactions with the rock matrix. According to Hubbert and Rubey[5] (1959) mechanically, pore pressure reduces the normal stress throughout the rock mass according to the effective pressure law.

MATERIALS AND METHOD

Sample of the igneous rock, was collected from Okpilla in Edo State, Nigeria

The sample was broken into smaller pieces of six different sizes. The diameter of the different sizes was measured using a micrometer screw gauge as shown in table 1. From which the values of the diameter the radius were also calculated, subsequently the areas of the different sizes of the sample rock was calculated using the formula below;

Where = a constant whose value is 3.142.

After the measurement of the different areas, the six different sizes of the sampled rock were individually fractured by adding different weights. At the end of the fracturing process, the weights that brought about the fracture was read and recorded correspondingly together with the measured area. The instrument used for fracturing of the rock samples is called the cracker, it comprises of a hanger that was capable of taking various weights. See figure (a) as shown below

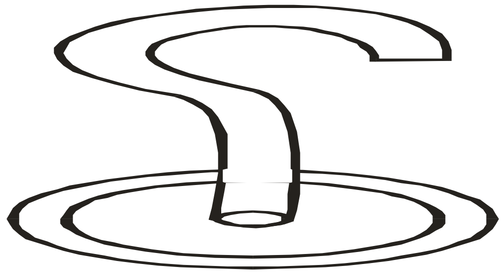

figure (a) -The cracker

Six different readings of force (weight) capable of fracturing different sizes of rock sample were obtained for each sample Table 1.

RESULTS

At the end of the experiment the table of values obtained for the various rock types are stated below.

The table of reading collected from igneous rock – granite is as shown in table 1 below:

Table-1: Sampled rock sizes, Diameter, Radius, Area and Weights

Size	Diameter (cm)	Radius (m)	Area (m^2)	Mass (kg)	Force (N)
1	0.200	$1.00x10^{-3}$	$2.142x10^{-6}$	3.00	30
2	0.203	$1.02x10^{-3}$	$3.24x10^{-6}$	3.50	35
3	0.230	$1.15x10^{-3}$	$4.16x10^{-6}$	5.00	50
4	0.290	$1.45\ x10^{-3}$	$6.16x10^{-6}$	6.00	60
5	0.305	$1.53x10^{-3}$	$7.31x10^{-6}$	7.00	70
6	0.3111	$1.56x10^{-3}$	$7.60x10^{-6}$	8.00	80

From the reading recorded in table 1, a graph of weight (force) measured in Newton (N) was plotted against area (A) measured in metre squared (m2). The graph as obtained by mathematics 6 software is as shown in figure (b) below.

ListPlot[{{3.142,30.0},{3.24,35.0},{4.16,50.0},{6.61,60.0},{7.31,70.0},{7.60,80.0}}]

IGNEOUS Rock-GRANITE

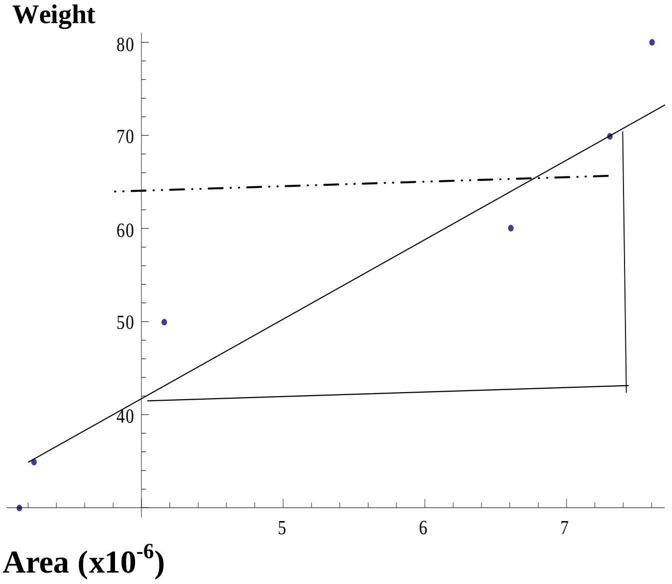

FIGURE 2 : Graph of weight (force) plotted against area (A)

From the plotted graph, the slopes, was calculated in order to obtain the minimum stress necessary for the fracture of rock slope,

Slope = Tensile Stress = 8.82 x 106 Nm-2

DISCUSSION

From the results obtained, it is observed that the minimum stress required to fracture a sample of an igneous rock (granite) is 8.82 x 106 Nm-2. The results obtained from the empirical research showed that granite from igneous rock required large stress for it to be fractured.

It is thereby recommended that geologists, engineers, and other disciplines in the Earth's sciences, such as geology, geomorphology, geochemistry should put into consideration the knowledge about the minimum tensile stress required to fracture an Igneous rock sample before using this type of rock for any engineering work such as construction of roads, bridges, tunnels, canals, sculpture work, houses, excavations e.t.c.

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