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A New Model of Microcracks Propagation in Granite Rock

Vahed Ghiasi, Husaini Omar, Zainuddin B. Md. Yusoff , Bujang K Huat, Ratnasamy Muniandy. Mohd Najmin Alias

Mountainous Terrain Development Research Center Department of Civil Engineering, and Faculty of Engineering, University Putra Malaysia 43400 Serdang, Selangor, Malaysia

Abstract: One of the most significant current discussions in legal and moral philosophy is a new model of microcracks propagation in granite rock. The objective of this research is to identify the parameter that controls the crack propagation and identification a model to show the microcracks propagation in granite rock. To conduct this research, the samples of granite rock was used. Laboratory test was conducted for this research was Uniaxial Compressive Test (UCT),Schmite hammer and microscopic study to detection more about Thin Section(TS) of granite rock. This model is based on laboratory and field investigation on weathered granite in tropical area.

Key words: Microcracks, Granite, weathering, Thin Section (TS).

INTRODUCTION

The main factor influence microcracking occurs in the granite rock dependants on the mineralogy, fabric, and microstructure of a given rock type. Crack indication and propagation will occur during uniaxial cyclic loading. Normally, granite has a well developed existing microcrack pattern. Cyclic loading caused new cracks to form and caused extension of existing microcracks. (U. Akesson *et al*, 2004). When the local stress exceeds the local strength, cracks are normally produced and may start at cleavage planes, grain boundary contacts or around intra-crystalline cavities. Intragranular and intergranular cracks appear to depend upon the mineralogy of the granite and the presence of secondary minerals. Under the compressive loads fracture wills occurs is a result of coalescence of many microcracks, and normally not the growth of a single crack. Initial formation of the crack does not depend on the minerals under the correlation between petrographical and morphological properties of mineral grains. A mineral type does impose a deforming factor as the crack propagates. (Yusoff, Z *et al*, 2007)

Granite is one of the rocks under igneous rock. Granite is a stone that have moderate to rough texture grain and usually are subhedron grain. This rock contains 20%-60% quartz from minerals like mica and feldspar; one over three of feldspar is alkali feldspar, which is either orthoclase or microcline. For most granite, its plagioclase’s composition is oligoclase. The biotite minerals are character most normal granite. Its color index which is the percentage of darks mineral compared to the total not more than 15. (Hamzah, 1993).

Granite rock comprises of many colors which are dependent on characteristic, some of the colors are white, gray, pink, and red. The color index is between 0-30. Granite is classified to many types; some of them are alkali granite, granite biotite, and granite grafit. Types of granite depends on its maximum mineral contains such as granite biotite which only contain biotite as it mafik mineral and granite alkali contains high mica. Granite which is strongly alkali contains amphibole and pyroxene minerals which are rich in natrium such asaegirin and riebekit beside quartz and orthoclase. (Hamzah, 1993).

The term of “granite” means “grain” in Latin word “Granum” because of its granular texture. Granite is an igneous rock. It is a very hard, crystalline and composed of three minerals and some other black minerals. These minerals are quartz, feldspar and mica. Granite forms as magma cools far under the earth's surface. Because it hardens deep underground, it cools very slowly. This allows crystals of the three minerals to grow large enough to be easily seen by the naked eye. Granite is visibly homogenous in texture.

Komoo *et al*., (2004) had done studies on the shear strength parameters of rock. Three important factors

Corresponding Author: Vahed Ghiasi, Mountainous Terrain Development Research Center Department of Civil Engineering, and Faculty of Engineering, University Putra Malaysia 43400 Serdang, Selangor, Malaysia
Email: Ghiasi_upm@yahoo.com

that influence the rock slope stability are the geometry of the rock mass behind the slope face, the shear strength of potential failure surface and the groundwater flow in rock masses. The determination of reliable shear strength values is a critical part of a slope design because relatively small changes in shear strength can result in significant shanges in the safe height or angle of a slope. Granites form extensive outcrops in the shield lands that form the ancient nuclei in each of continents, and also of orogens. They also protrude through the sediments of platform areas in small, but frequently notable, exposures. (C.R. Twidale *et al*, 2005)

The larger masses of granite, and especially migmatites, however, are metamorphic. They formed as a result of the transformation of other rocks, including argillites, by not fluids and gases spreading through the Earth's lithosphere. These processes have gone on throughout geological time, and they continue to operate. (C.R. Twidale *et al*, 2005)

In this research, we used granite rock to study the microcrack propagation when certain amount of load is exerted using Uniaxial Compressive Test (UCT). Figure 1 presents geological mapping of the peninsular Malaysia, which shows the location of igneous rocks.

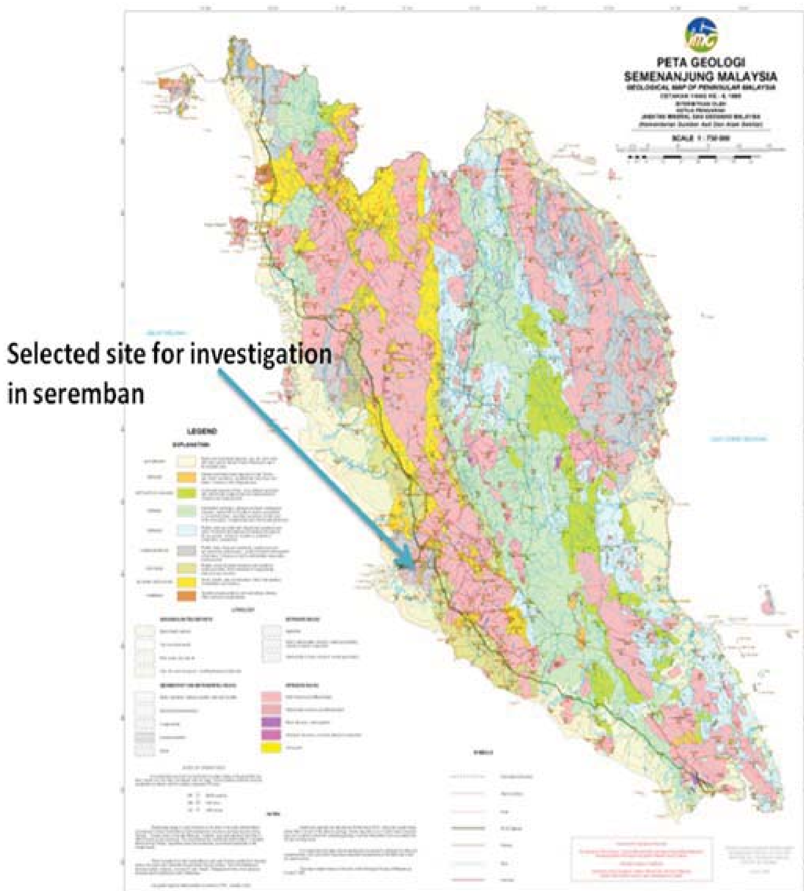


Fig. 1: Geological mapping of the peninsular Malaysia, which shows the location of igneous rocks (Mineral and Geosciences Department)

Scope of the Research:

The scope of this research covers the sample of granite rock (fresh rock) attained from Institute Kerja Raya Malaysia (IKRAM). The origins of these samples (borehole logging for soil investigation works) are from Seremban (Malaysia). The granite rocks sample can be classified the degree of weathering whether it is fresh rock, slightly weathered rocks, moderatelty weathered rock, highly weathered rock, completely weathered rock, and residual soil. In this research, the degree of weathering can be justified using the Schmidt Hammer.

Schmidt hammer can give the rebound reading and the degree of weathering can be classified according to weathering classification system for granite and volcanic rocks.

The test will be conducted to these granite rocks is uniaxial compressive test (UCT). Uniaxial compressive test (UCT) is the test where the granite rock sample will be exerted with certain amount of load before it crushed. The reason of this test is to create the microcracks propagation in granite rock. A thin section is prepared in order to identify mineral types in a rock, to help to reveal the rock's origin and evolution. Other than that, it can show the microcracks propagation in granite rock after that granite samples was exerted with uniaxial compressive test.

Through the thin section, what are the minerals contain in the granite rocks can be identified. What is the strong and weak mineral can be observed through microcracks propagation. Other than that, the microcracks propagation and microcracks types can be observed whether transgranular, intergranular, and grain-boundary cracks.

Problem Statement:

The common problems in granite rocks are microcracks propagation. When the granite rock is exposed to the small amount of weathering, the possibility of the microcracks to occur is very high. Just small amount of weathering, the propagation of microcracks will occurs. The growth of microcracks may affect not only mechanical strength of rock but also hydraulic properties like permeability. Further, depending on environmental conditions like humidity and temperature, sub-critical propagation of crack may appear leading to time dependent creep deformation and failure.

Cyclic loading caused new cracks to form and extension of existing microcracks. The extension of existing microcracks will be observed because the growth of microcracks may affect mechanical strength but also hydraulic properties like permeability. Lastly, what are the minerals that can improve crack propagation because of difference in mechanical strength and E-Modulus compare to rock forming materials. The microcracks will across the minerals if minerals boundary is very strong. The knowledge about behavior of granite is very important especially the composition of minerals and how the propagation occurs when certain amount of uniaxial compressive test was applied to the granite rock. The knowledge about microcrack propagation in brittle rocks is very important in construction of tunnel and underground mining. Microcracks can also be related to the engineering properties such as the shear strength parameters.

Damage by microcrack growth is commonly considered as the main mechanism of inelastic deformation and failure in brittle materials such as concrete and rocks. Many experiments investigations have shown different modes of iniation and propagation of microcracks in rock materials. Two dissipitation mechanisms, related to the size evolution of microcracks and frictional sliding in closed cracks, to be taken into account in modeling of damage. As a consequences of damage by microcrack growth mainly include nonlinear stress-strain relations, deterioration of elastic properties, induced anisotropy, irreversible deformation after unloading, dilatancy, hysteric response and unilateral effects. Induced damage can also affect transport and diffusion properties, in particular permeability. Propagation of microcracks and associated volumetric dilatancy can significantly increase rock permeability. (Q. Zhu *et al*, 2008).

Microcrack Propagation:

Microcrack propagation usually starts from initial crack which requires certain quantity energy to break the chemical bonds in a given cross section of material. The relaxation of strain energy in the surrounding material as a result of crack propagation in turn frees energy which stress concentration mechanism then translate into further growth. The understanding of this further growth or crack propagation are based on the relatives rates at which energy generated and concentrated during this problems not always equal.

Process of Microcrack Propagation:

An initially crack can propogate through the part by various mechanism depending upon a number of parameters, particularly;(i) the loading conditions, (ii) temperature, (iii) geometry of the crack, and (iv) nature of the environment. Regardless of the mechanism by which an initially existing crack propagates, once it reaches a critical size, the cross-sectional area of the intact part is reduced to the extent that the applied stress exceeds the ultimate strength of the material leading to the fracture. As a result of an overloading condition, the final separation or fracture of the cracked part always occurs. (Yusoff, Z. et.al, 2007).

Therefore, the characteristics of the final fracture crack surface are essentially the same regardless of the mechanism of crack propagation. It is extremely important to recognize the fact because it guides the failure analyst towards using the correct terminology in describing the importance of examining the entire fracture crack surface before the mechanism of crack propagation can be identified. Figure 2 presents Schematic diagram illustrating the process of fracture. An initial crack of size C_0 (a), Crack propagation under the influence of a tensile load P; the crack reaches a critical size C_c and the part becomes overloaded because of the corresponding reduction in cross-sectional area supporting the load (b), Final separation due to an overloading condition (c).

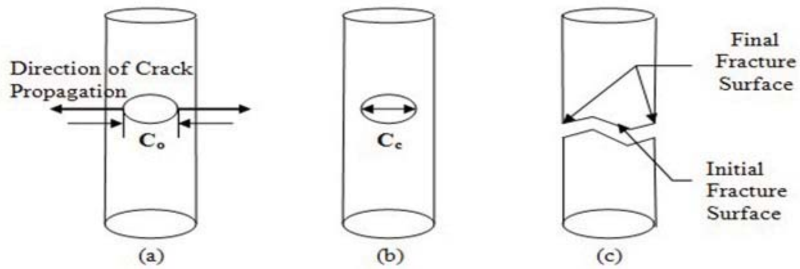


Fig. 2: Schematic diagram illustrating the process of fracture. (a) An initial crack of size C_0. (b) Crack propagation under the influence of a tensile load P; the crack reaches a critical size C_c and the part becomes overloaded because of the corresponding reduction in cross-sectional area supporting the load. (c) Final separation due to an overloading condition. (Hani *et al*., 2004).

Types of Microcrack:

There are two types of fracture on rock which is considered as brittle material. The first type of fracture is transgranular fracture. In transgranular fracture, the fracture travels through the grain of the material. The fracture changes direction from grain to grain due to different lattice orientation of atoms in each grain. In other words, when the crack reaches new again, it may have to find a new path or plane atoms to travel on because it is easier to change direction for crack than it is to trip through. Cracks choose the path of least resistance. The second type of fracture is intergranular fracture. Intergranular fracture is crack travelling along the grain boundaries, and not through the actual grains. Intergranular fracture usually occurs when the phase in the grain boundary is weak and brittle. Figure 3 shows the transgranular fracture and intergranular fracture of rock material.

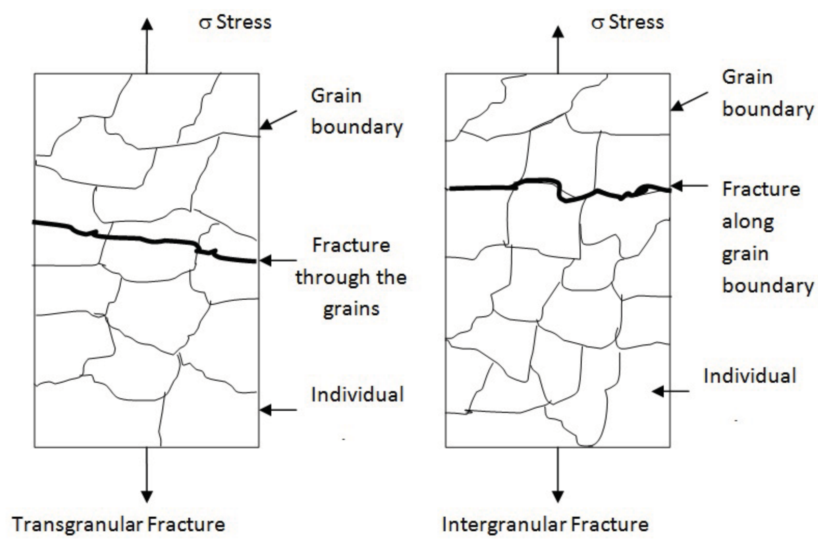


Fig. 3: Transgranular fracture (Pauzi, 2007)

Microcrack Mechanism in Granitic Rock:

As proposed by Ehlen (2002), the mechanism for microcrack of joint in granite rock starts from the weathering processes on the rock surface and in open joints within the rock mass. As weathering occurs in the rock material, small cracks first occur along grain boundaries and then, mineral grains themselves begin to crack, possibly due to thermal expansion. Within grain, micro-cracking occurs at different rates for the different minerals in the crack. Dark colored minerals, particularly biotite, tend to crack earlier and longer, compared to light colored minerals (Ehlen and Zen, 1986). These new cracks filled with weathered material, perhaps local or perhaps washed in from the ground surface along open joints. These filing materials are primarily clays, which contract themselves and expand under changing thermal and moisture conditions. This in turn causes more within-grain micro-cracking and more expansion in rock fabric as well as loading of joint edges on the rock surface due to erosion of the loosened fragments. The microcrack surfaces which occur on the dark colored mineral explain the presence of microcrack on the tested samples that are caused by shear mechanism because dark colored material are weaker compared to the light-colored minerals. (Yusoff, Z. et.al, 2007).

Brittle Rocks:

Damage by nucleation and growth of microcracks is an essential mechanism of deformation and failure in brittle geomaterials like rocks and concrete. The induced damage not only affects the mechanical properties of materials, but also the flow and conductivity properties. One of the most significant phenomena to be taken into account in many engineering applications for example, the storage of nuclear wastes, the stability of rock slopes and hydraulic dams, and the long term durability of concrete structure is the variation of permeability with the growth of microcracks.

A number of constitutive models have been proposed for the description of induced damage in geomaterials. It can be roughly separated into two classes: phenomenological models and micromechanical models. Remains in the possibility to account for physical mechanisms involved in material damage are the advantage of the micromechanical models. Numerical implementation of these models in view of engineering application is not easy and the associated computation is usually time-consuming. The phenomenological models provide with simple and unified mathematical formulations. These models can be easily implemented in a computer code and then give powerful tool for engineering applications.

Granite Rock:

Nowadays, the word granite is widely recognized in a general context, so much so that laymen commonly refer to any crystalline rock as granite. The rock itself is also familiar to the general public, for granite is beautiful ornamental stone sand and, polished, is widely used as a facing on major buildings and monuments. Many headstones of graves are also of granite. (C.R. Twidale and J.R. Vidal Romani, 2005). Figure 4 presents granite rock samples.

Fig. 4: Granite rock samples

Physical Characteristics:

Granite has an average specific gravity of 2.662. A cubic metre of granite weighs of the order of 2,658 kg, or almost 2 tonnes a cubic yard. Its physical hardness varies according to composition, and principally according to the proportion and type of feldspars present. Despite its crystallinity, granite at the surface is flexible in thin sheets. Like most rock fresh granite has a considerable compressive strength, but it also possesses a high tensile strength. Fresh granite is of low of porosity and permeability, but it is pervious because near the surface it is characteristically fissured and fractured. Porosity, also known as mass permeability, refers to the ratio of the volume of voids to the total volume of rock expressed as a percentage. Porosity depends on the shape of the constituent grains as well as their sorting, packing and cementation.

A mass of closely packed uniform spheres consists of 26% by volume of voids or pore space, but in crystalline medium such as fresh granite the value is commonly less than 1%. Permeability, also known as primary permeability, refers to the capacity of a medium to transmit fluids. It differs from porosity for voids may be unconnected, or be too narrow to allow transmission of fluids because of surface tension. Fresh granites are of low permeability but most weathered rocks allow ready passage fluids. (C.R. Twidale and J.R. Vidal Romani, 2005).

Minerals in Granite:

Granite is classified according to the QAPF diagram for coarse grained plutonic rocks (granitoids) and is named according to the percentage of quartz, alkali feldspar (orthoclase, sanidine, or microcline) and plagioclase feldspar on the A-Q-P half of the diagram. True granite according to modern petrologic convention contains both plagioclase and alkali feldspars. When a granitoid is devoid or nearly devoid of plagioclase the rock is referred to as alkali granite. When a granitoid contains <10% orthoclase it is called tonalite; pyroxene and amphibole are common in tonalite. A granite containing both muscovite and biotite micas is called a binary or *two-mica* granite. Two-mica granites are typically high in potassium and low in plagioclase, and are usually S-type granites or A-type granites. The volcanic equivalent of plutonic granite is rhyolite. Granite has poor primary permeability but strong secondary permeability.

Feldspar:

Feldspar is the most abundant mineral in rocks that are located at or near the earth's surface. Feldspar can have glassy white, blue, green, or red crystals. All feldspars contain silica and aluminum. When feldspars are exposed to the atmosphere they break down or weather easily. When they are broken down, feldspar forms other minerals, many of which are clay minerals. Feldspars also contain potassium, which is a major nutrient for plant growth. Pottery manufacturing plants use the clays formed by weathered feldspar. Kaolinite is the highest quality of the feldspar clays used by potters. Feldspar is number 6 on the Moh's scale of hardness

Mica:

Mica is a mineral that can be separate into very thin leaves and elastic. Layering in the divalent or brittle, micas also results in perfect basal cleavage; the greater bond strengths, however, makes them more brittle and less flexible. Mica can be clear, black, green, red, yellow, and brown**.** The important species of the mica group are: muscovite, common or potash mica, pale brown or green, often silvery including damourite; biotite, iron-magnesia mica, dark brown, green or black; lepidomelane, iron, mica, black; phlogopite, magnesia mica, colorless, yellow, brown; lepidolite, Lithia mica, rose-red, lilac (Maail, S., Huat & Jamaluddin S. 2004).

Quartz:

Quartz is a common mineral, which found in many different types of rocks. The chemical formula is silicon oxide (SiO2). One type of quartz is easily identified by its hexagonal crystals, but it can also be found in a large mass. Quartz can be broken into the tiny pieces (sand). Regarding to Mohs hardness scale, Quartz locate at number seven. Quartz is also chemically stable, which means that it weathers very slowly, yellow, milky white, rose, smoky (brown or black), and the best known of the colored crystals amethyst, which is purple. Impurities in the rock at the time of formation cause the quartz crystal to have these different colors. Table 1 presents Mohs' scale of Hardness.

Chemical Composition:

A worldwide average of the average proportion of the different chemical components in granites, in descending order by weight percent, is:

- SiO_2 — 72.04%
- Al_2O_3 — 14.42%

- K_2O — 4.12%
- Na_2O — 3.69%
- CaO — 1.82%
- FeO — 1.68%
- Fe_2O_3 — 1.22%
- MgO — 0.71%
- TiO_2 — 0.30%
- P_2O_5 — 0.12%
- MnO — 0.05%

Table 1: Mohs' scale of hardness

Hardness	Minerals
1	Talc
2	Gypsum
3	Calcite
4	Fluorspar
5	Apatite
6	Orthoclase Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Occurrence:

Granite is currently known only on earth where it forms a major part of continental crust. Granite often occurs as relatively small, less than 100 km² stock masses (stocks) and in batholiths that are often associated with organic mountain ranges. Small dikes of granitic composition called aplites are often associated with the margins of granitic intrusions. In some locations very coarse-grained pegmatite masses occur with granite.

Origin:

Granite is an igneous rock and is formed from magma. Granitic magma has many potential origins but it must intrude other rocks. Most granite intrusions are emplaced at depth within the crust, usually greater than 1.5 kilometers and up to 50 km depth within thick continental crust.

Geochemical Origin:

Granitoids are a ubiquitous component of the crust. They have crystallized from magmas that have compositions at or near a eutectic point (or a temperature minimum on a cotectic curve). Magmas will evolve to the eutectic because of igneous differentiation, or because they represent low degrees of partial melting. Fractional crystallisation serves to reduce a melt in iron, magnesium, titanium, calcium and sodium, and enrich the melt in potassium and silicon - alkali feldspar (rich in potassium) and quartz (SiO_2), are two of the defining constituents of granite.

Alphabet Soup Classification:

The 'alphabet soup' scheme of chappell & white was proposed initially to divide granites into I-type granite (or igneous protolith) granite and *S-type* or sedimentary protolith granite. Both of these types of granite are formed by melting of high grade metamorphic rocks, either other granite or intrusive mafic rocks, or buried sediment, respectively.

M-type or mantle derived granite was proposed later, to cover those granites which were clearly sourced from crystallised mafic magmas, generally sourced from the mantle. These are rare, because it is difficult to turn basalt into granite via fractional crystallisation.

A-type or anorogenic granites are formed above volcanic "hot spot" activity and have peculiar mineralogy and geochemistry. These granites are formed by melting of the lower crust under conditions that are usually extremely dry.

Granitization:

An old, and largely discounted theory, granitization states that granite is formed in place by extreme metasomatism by fluids bringing in elements e.g. potassium and removing others e.g. calcium to transform the metamorphic rock into a granite. This was supposed to occur across a migrating front. The production of granite by metamorphic heat is difficult, but is observed to occur in certain amphibolites and granulite terrains. In-situ granitisation or melting by metamorphism is difficult to recognise except where leucosome and melanosome textures are present in gneisses. Once a metamorphic rock is melted it is no longer a metamorphic rock and is magma, so these rocks are seen as a transitional between the two, but are not technically granite as they do not actually intrude into other rocks. In all cases, melting of solid rock requires high temperature, and also water or other volatiles which act as a catalyst by lowering the solidus temperature of the rock.

Ascent and Emplacement:

The ascent and emplacement of large volumes of granite within the upper continental crust is a source of much debate amongst geologists. There is a lack of field evidence for any proposed mechanisms, so hypotheses are predominantly based upon experimental data. There are two major hypotheses for the ascent of magma through the crust:

- Stokes Diapir
- Fracture Propagation

Based on these two mechanisms, Stokes diapir was favoured for many years in the absence of a reasonable alternative. The basic idea is that magma will rise through the crust as a single mass through buoyancy. As it rises it heats the wall rocks, causing them to behave as a power-law fluid and thus flow around the pluton allowing it to pass rapidly and without major heat loss.Granitic magma must make room for itself or be intruded into other rocks in order to form an intrusion, and several mechanisms have been proposed to explain how large batholiths have been emplaced:

- Stopping, where the granite cracks the wall rocks and pushes upwards as it removes blocks of the overlying crust
- Assimilation, where the granite melts its way up into the crust and removes overlying material in this way
- Inflation, where the granite body inflates under pressure and is injected into position

Most geologists today accept that a combination of these phenomena can be used to explain granite intrusions, and that not all granites can be explained entirely by one or another mechanism.

Natural Radiation:

Granite is a natural source of radiation. Granite contains around 10 to 20 parts per million of uranium. By contrast, more mafic rocks such as tonalite, gabbro or diorite have 1 to 5 ppm uranium, and limestone and sedimentary rocks usually have equally low amounts. Many large granite plutons are the sources for palaeochannel-hosted or roll front uranium ore deposits, where the uranium washes into the sediments from the granite uplands and associated, often highly radioactive, pegmatite's. Granite could be considered a potential natural radiological hazard as, for instance, villages located over granite may be susceptible to higher doses of radiation than other communities. Cellars and basements sunk into soils formed over or from particularly uraniferous granites can become a trap for radon gas, which is heavier than air.

However, in the majority of cases, although granite is a significant source of natural radiation as compared to other rocks it is not thought an acute health threat or significant risk factor. Various resources from national geological survey organisations are accessible online to assist in assessing the risk factors in granite country and design rules relating, in particular, to preventing accumulation of radon gas in enclosed basements and dwellings. (Radiation and Life).

Weathering:

Weathering may be defined as the disintegration or decay of rocks in *situ* and in the range of ambient temperature found at and near the Earth's surface (Winkler, 1965). Some weathering processes are physical or mechanical in the break down or fragmentation of the rock. Others are chemical and involve the alteration of one or more of the constituent minerals. Biota also make important contributions to both types of weathering, and indeed, several processes, of various kinds, commonly work together to produce a weathered mantle or regolith, which with the addition of organic materials becomes a soil. The lower limit of significant or detectable weathering is called the weathering front.

Weathering is an essential precursor to erosion: without preliminary weathering of the rock, there would be little erosion. Some weathering processes, however, result not in the weakening of the rock but rather in its cementation and induration, through the development of concentrations of minerals called duricrusts of which laterite, ferricrete, bauxite, silcrete, calcrete and gypcrete are well-known and widely developed examples. None, however, is peculiar to granitic terrains. On the other hand, many of the minerals forming the duricrusts are allochthonous, being transported in groundwaters, in rivers, or on the wind, so that, combined with locally derived contributions, laterite and silcrete, for example, are well represented in granite landscapes. Where the duriscrusted surface is dissected, plateau forms are characteristic. Where intact, the duricrust forms a protective carapace, as for example on northern Eyre Peninsula, South Australia, where the rolling granite plain carries a veneer of calcrete which has not only stabilized the surface but has induced a weal karst. (C.R. Twidale and J.R. Vidal Romani, 2005).

The process of weathering varies with the depth or exposure of the soils. The intensity of the weathering generally reduces with increasing depth as weathering proceeds from the surface down and inwards from joint surfaces and other percolation paths. As rock goes through the weathering processes to form residual soils, generally, the higher weathering grades would have soil with higher finer particles. (Bujang et al, 2005).

Types of Weathering:

There are three (3) types of weathering which may occur in the fresh rock until it totally changes to soil. In geology, the soil recognized as residual soil. Weathering in rock is caused by physical disintegration, chemical decomposition affects and biological effects (Vahed *et al* 2009).

Physical/mechanical Weathering:

Physical or mechanical weathering is a breakdown process of the rocks without marked changes in the nature of the mineral constituents. This disintegration process leads to the formation of a residual soil comprising mineral and rock fragments virtually unchanged from the original rock. This is due to temperature, rainfall and wind. The properties of the new fragments are the same as the original rocks. Some types of mechanical weathering are frost wedging, thermal expansion and contraction, mechanical exfoliation, wetting and drying and abrasion (Singh H. & Huat B.K, 2004).

- Frost wedging is a process of expanding of water when it freezes.
- Thermal expansion and contraction is a process of heating and cooling which always repeating daily. Heating may cause expansion while cooling may cause contraction of the fragments.
- Mechanical exfoliation happens when the rocks breaks into flat sheets along joints that parallel the ground surface as the rock is uncovered.
- Wetting and drying or known as slaking occurs when the accumulated layers of water molecules in the mineral grains of a rock due to their increasing thickness push the rock grains apart with great tensional stress.
- Abrasion is the physical grinding down of rock fragments. It occurs when rock surfaces come in contact with mechanical weathering or grinding of their surfaces.

Chemical Weathering:

Weathering process included the reaction of minerals in the original rock/soil with water, oxygen and acid organic at the soil surface which the decomposition of the internal structure can produce new phase and some of the products are easily dissolve in water. The reaction occurs due to chemical agents, those are wind, water, ice, and dependent on the surface area that available for reaction and presence of active fluids. Processes involved are decomposition, oxidation, reduction, hydration, hydrolysis, and ions exchange. In chemical weathering, only the mineral composition of rocks will change.

Biological Weathering:

Biological weathering is the combination of disintegration and decomposition induced by bio-physical and bio-chemical agencies. It is generally of less important than physical or chemical weathering, except perhaps in the upper few terms of millimeters of the earth’s crust.

Weathering Process:

Commonly, rocks were formed at high pressure and temperature. Then, weathering process will occur under the lower temperatures and pressures present at the earth’s surface in the presence of air and water. Two main ways that rocks will weather are by chemical decomposition and physical disintegration. In chemical decomposition of granite, quartz generally remains unchanged. Then biotite is bleached and transformed to chlorite and other clay minerals, the discharge of iron will lead to general brown staining of the rock.

Weathering Classification:

Weathering is classified into six grades according to their level of weathering process. The grades consist of fresh rocks, slightly weathered, moderately weathered, highly weathered, completely weathered and residual soil. The descriptions of all of the grades are simplified below in Table 2 and also typical weathering profile in granitic rocks is illustrated in Figure 5.

Table 2: The classification of the weathering profile (McLean & Gribble, 1979)

Term	Grade	Description
Residual soil	VI	All rock material is converted to soil which the mass structure and material fabric are destroyed. There is a large change in volume but the soil has not been significantly transported.
Completely weathered	V	All rock material is decomposed and/or disintegrated to soil but the original mass structure is still largely intact.
Highly weathered	IV	More than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a discontinuous framework or as core stones.
Moderately weathered	III	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a discontinuous framework or as core stones
Slightly weathered	II	Discoloration indicates weathering of rock material and discontinuity surfaces. Weathering may discolor all the rock material.
Fresh rock	I	No visible sign of rock material weathering. Perhaps slight discoloration on major discontinuity surfaces.

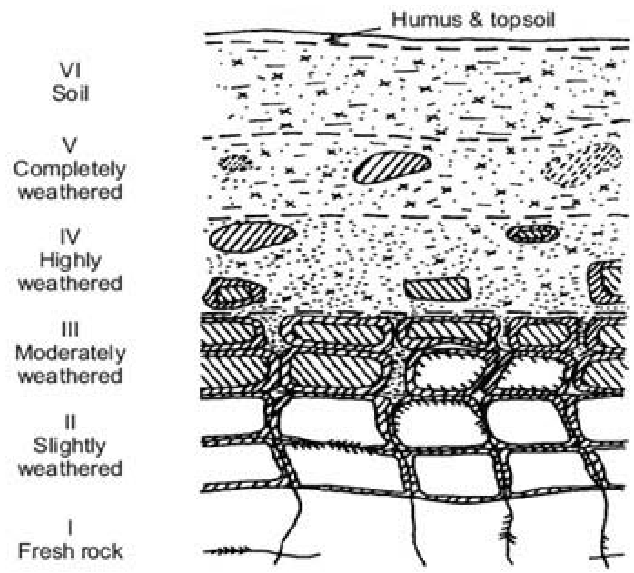


Fig. 5: Typical weathering profile in granitic rocks (Little, 1969)

MATERIALS AND METHODS

This part explain the methodology of this research such as finding the information (source of data), testing, acquiring the data, obtaining laboratory report and analyzing which depends on objectives and scope of research. To conduct this research, the sample of granite rock was used. The origins of these samples (borehole logging for soil investigation works) are from Seremban (Malaysia). The grade of weathering for this granite rock will be measured using Schmidt Hammer(SH). The number of "Rebound" from Schmidt Hammer(SH) can be used for identification of degree of weathering. Laboratory test was conducted for this research is Uniaxial Compressive Test (UCT). Uniaxial Compressive Test (UCT) is conduct to the ten samples of granite rock until it crushed. The reason of (UCT) is to create the microcracks propagation in the granite rocks. All of these ten samples were tested until it crushed and the average peak strength of the granite is recorded. Sixty percent of the granite rock (average peak strength) will be testing using (UCT) for the three samples. Strain gauge was attached to these three samples of granite rocks. The reason strain gauges are attached at these granite samples because to get the reading of strain for every sample.

After the Uniaxial Compressive Test (UCT) was done, the next procedure for granite sample is Thin Section (TS). Through Thin Section (TS), the minerals contents in the rock sample can be identify, to help to reveal the rock's origin and evolution. Thin section was prepared to these three samples of granite rock. Every samples of granite rock (after we applied 60% of the peak strength using Uniaxial Compressive Test) are sent to Thin Section(TS) works. There are two types of microcracks that will be observed, intragranular fracture and transgranular fracture. The observation can be making during this test like what is the strong minerals and weak minerals in granite rock. After the Thin Section(TS) was done, all of the information of microcracks propagation was analyzed. The flow chart shows the methodology of the research in Figure 6.

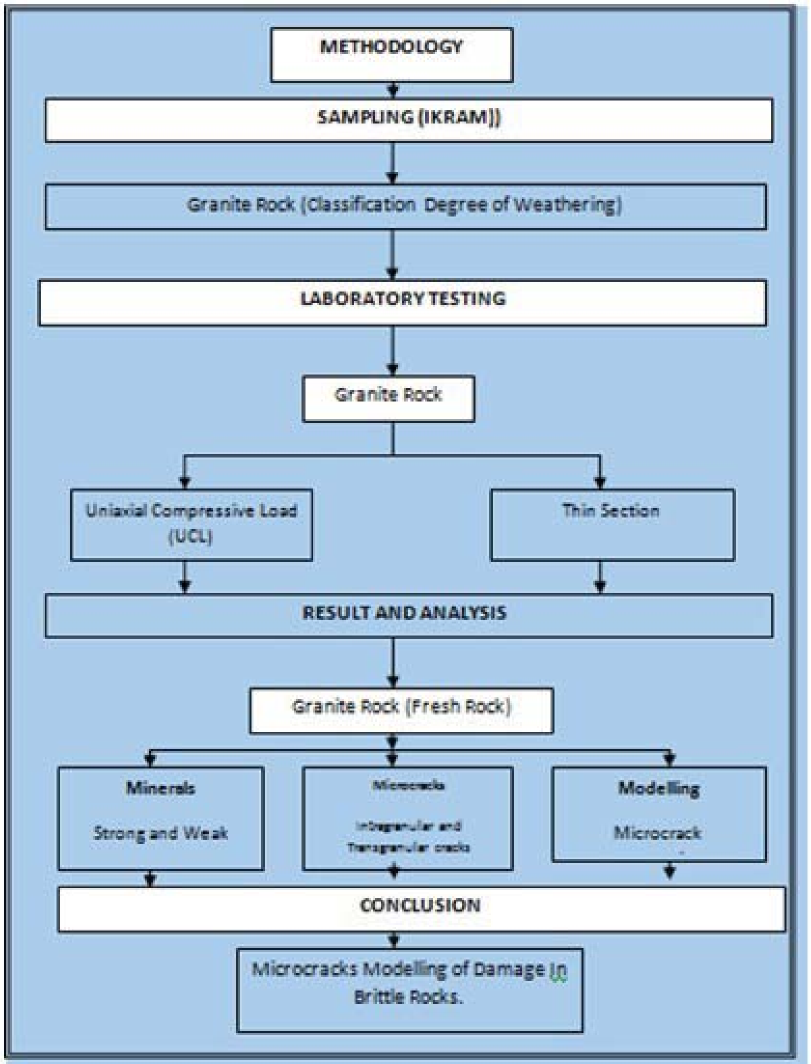


Fig. 6: The flow chart shows the methodology of the research

Background of Study:

This part involves the study of the geological maps to determine boundaries of Kuala Lumpur granite. The Seremban granite is also in Kuala Lumpur granite formation. Site investigation refers to procedure of determining surface and subsurface condition in a particular or proposed area while soil investigation is essential to obtain the details information about the soil types, properties and ground water profiles. Observation of the microcracks propagation in granite rock is very important. The study of microcrack propagation is very important in the construction of tunnel and underground mining.

Through the Thin Section (TS), the microcracks propagation and minerals contain will be observed. All of these microcracks propagation are analysed and the microcrack propagation can be observed. The granite rock investigation is essential to obtain the details information about the minerals contents, microcracks propagation, and types of microcracks propagation.

Sampling:

For this research, the dimension of granite rock is 5 cm for diameter and 15 cm for height. The granite rocks used for this test will be cut to a length of 15cm in order to have the length to-diameter ratio between 2 and 3. To cut the granite rock, Diamond Cutter Machine (DCM) is used to get the dimension wanted. All the information like weight for every samples, dimension is recorded for the calculation work. The Site location for site sampling is illustrated in Figure 7.

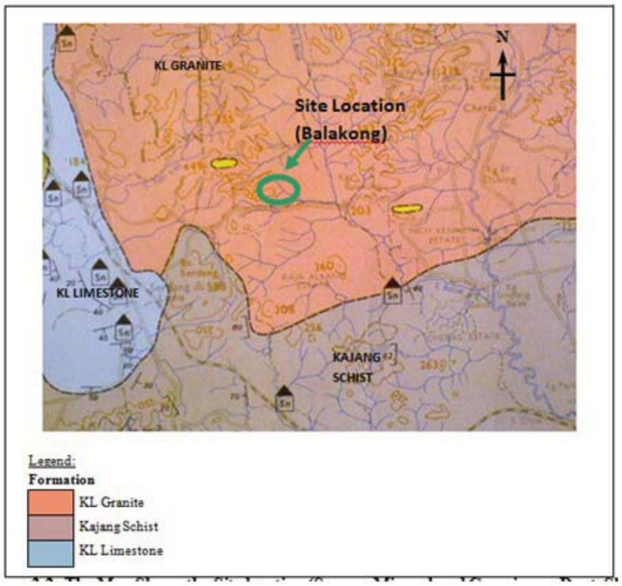


Fig. 7: The site location (Source: Mineral and Geosciences Dept, Sheet 94).

(a) **(b)**

Fig. 8: (a) Diamond cutter machine (b) cutted granite rock 5 cm diameter and 15 cm height

(a) (b)

Fig. 9: (a) Weight of granite sample (b) Measurement of granite sample

Schmite Hammer:

The Schmidt Hammer(SH), developed in the late 1940s as an index apparatus for non-destructive testing of concrete in situ, has been used in rock mechanics practice since the early 1960s, mainly for estimating the uniaxial compressive strength and Young's modulus (Et) of rock materials. Considering its long history and widespread use, the standard methods for the Schmidt Hammer(SH) test might be expected to ensure consistent and reliable values and reproducible correlations for a given rock type. Much of the published work has focused on improving data gathering procedures and developing new correlations for different rock types.
To identify the degree of weathering for this granite sample, Schmidt Hammer (SH) will be used. Figure 10 (a, b) shows Schmidt Hammer (SH) and its reading's respectively and also weathering classification system for granite and volcanic rocks are presented in Table 3.

(a) (b)

Fig. 10: (a) Schmidt Hammer(SH) (b) Schmidt Hammer(SH) reading

Uniaxial Compressive Test (UCT):

Uniaxial Compressive Test (UCT) will be conducted to the granite rock sample. Ten samples of granite rock are test using (UCT) until it crushed. The reason of (UCT) is to create the microcracks propagation in the granite rocks. All of these ten samples are test until it crushed and the average peak strength of the granite is recorded. Sixty percent of the granite rocks (average peak strength) are test using (UCT) for the three samples. Strain gauges will be attached to these three samples of granite rocks. The reason strain gauges are

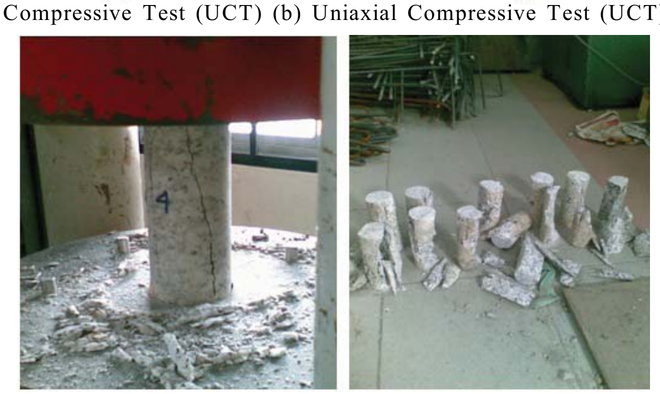
Table 3: Weathering classification system for granite and volcanic rocks (Hencher and Martin, 1982)

Grade	Description	Typical Distinctive Characteristic
VI	Residual soil	A soil formed by weathering in place but with original texture of rock completely destroyed.
V	Completely weathered rock	• Rock wholly weathered but rock texture preserved • No rebound from N Schmidt hammer • Slake readily in water • Geological pick easily indents surface when pushed
IV	Highly weathered rock	• Rock weakened so that large pieces can be broken by hand • Positive N Schmidt rebound value up to 25 • Does not slake readily in water • Geological pick cannot be pushed into surface • Hand penetrometer strength index greater than 250 kPa • Individual grain may be plucked from surface
III	Moderately weathered rock	• Completely discolored • Considerably weathered but possessing strength such that pieces 55mm diameter cannot be broken by hand • N Schmidt rebound value of 25 to 45 • Rock material not friable
II	Slightly weathered rock	• Discolored along discontinuities • Strength approaches that of fresh rock • N Schmidt rebound value greater than 45 • More than one blow of geological hammer to break specimen
I	Fresh rock	No visible signs of weathering or discolored

attached at these granite samples because to get the strain value for every sample. Figure 11 (a, b) Uniaxial Compressive Test (UCT) and its results respectively and also Figure 12: (a, b) Sample is test until crushed to obtain peak strength and ten samples of granite rock after tested respectively.

(a) (b)

Fig. 11: (a) Uniaxial Compressive Test (UCT) (b) Uniaxial Compressive Test (UCT) result



(a) (b)

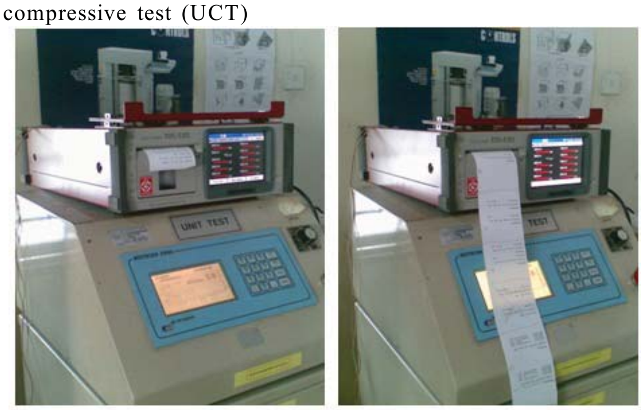
Fig. 12: (a) Sample is test until crushed to obtain peak strength (b) tested granite rock samples

Radial Strain Gauge:

After the average peak strength for ten samples obtained, the Uniaxial Compressive Test (UCT) will be conducted to the other three samples. This time, only 60 % of the average peak strength of granite rock is applied. The reason only 60% of the average peak strength is applied to these three samples because to create the microcrack propagation in granite rocks. Radial strain gauge was attached at these three samples of granite to get the strain reading. Strain reading can be obtained from strain device. Figure 13 presented (a, b) radial strain gauges are attached to granite samples and 60% of average peak strength is applied using Uniaxial Compressive Test (UCT) respectively. Figure 14 represented (a, b) radial strain gauge device and radial strain gauge reading respectively.

(a) (b)

Fig. 13: (a) Radial strain gauges are attached to granite samples (b) 60% of average peak strength is applied using uniaxial compressive test (UCT)



(a) (b)

Fig. 14: (a) Radial strain gauge device (b) radial strain gauge reading

Thin Section (TS):

Thin Section (TS) was done in order to study the petroghraphic of the sample. Minerals in rocks and soils are usually studied by using thin section. A thin section is a hair-thin slice of rock and soil particle that mounted on a microscope slide. The samples are trimmed to a small wafer and then polish one face of it on an iron lap wheel covered with carbide grit. The face is then fixed to a glass slide with hard resin. Then, the other side is grinded down to about 30 micrometers (30 μm) thickness, fix a thin glass cover slip on it with more resin.

In a laboratory setting, thin sections are prepared manually and it takes years of experience to become proficient in the technique. Part of the art of thin section preparation is the skill of judging the thickness of a rock slice, as it is being ground down and the surface finish (it is very easy to miss the correct thickness and in turn ruin the thin section). This is commonly done by examine the section under a polarizing microscope and looking for the interference colours that are related to the thickness of known mineral grains.

Figure 15(a, b) shows Thin Section Slide (TSS) is put under the microscope and the image of the minerals is observed through the computer respectively.

(a) (b)

Fig. 15: (a) Thin Section Slide (TSS) under the microscope (b) observation of the minerals through the computer.

RESULTS AND DISCUSSION

Objective of the laboratory tests was to study the microcrack propagation in granite rocks and classify the degree of weathering for granite rock at Seremban area.

Granite Geological Section:

The study is located at Seremban (Malaysia). Area, Seremban (approximate location is E 101° 44' 09.12", N 3° 02' 07.43"). The study is focused to analyze:

- Microcracks propagation in granite rock
- Types of mineral in granite rock
- What is the strong and weak minerals when microcracks occur
- How to model the microcrack propagation

Referring the weathering classification system for granite and volcanic rocks, the grade of weathering for sample no 1-13 can be classified as shown in the Table 14.

Table 4: Grade of weathering for granite sample

Sample No	Average Schmidt Hammer	Grade of Weathering Weathering Classification System for Granite and Volcanic Rocks, (Hencher and martin, 1982)
1	38	III (Moderately Weathered Rock)
2	32	III (Moderately Weathered Rock)
3	31	III (Moderately Weathered Rock)
4	39	III (Moderately Weathered Rock)
5	31	III (Moderately Weathered Rock)
6	38	III (Moderately Weathered Rock)
7	34	III (Moderately Weathered Rock)
8	36	III (Moderately Weathered Rock)
9	31	III (Moderately Weathered Rock)
10	32	III (Moderately Weathered Rock)
11	32	III (Moderately Weathered Rock)
12	35	III (Moderately Weathered Rock)
13	34	III (Moderately Weathered Rock)

Uniaxial Compressive Test (UCT):

According to Table 6, there are same reading where the peak strength is too high and some too low. The higher reading of peak strength shows the sample is still fresh and the lower peak strength shows the sample is weathered at certain grade. The higher and lower peak strength was excluded from this calculation because it will contribute the bigger percentage of error.

- Diameter of granite sample (d) = **5 cm**
- Length of granite sample (l) = **15 cm**
- Area of granite sample (Pressure Area) = $(3.142*d^2)/4$
  $= (3.142*5^2)/4$
  $= 19.6375\ cm^2$
- Volume = $(3.142*d^2)/4*$ (l)
  $= (3.142*5^2)/4*$ (15)
  $= 294.5625\ cm^3$

Table 5: Peak strength for 10 samples of granite rock

Samples	Peak Strength (kN)	Area (cm^2)	Stress σ= F/A	Mass (kg)	Volume (cm^3)	Density ρ/1000=M/V
1	164.7	19.6375	8.387015	0.837	294.5625	0.0028415
2	155.3	19.6375	7.908339	0.825	294.5625	0.0028008
3	150.8	19.6375	7.679185	0.82	294.5625	0.0027838
4	166.9	19.6375	8.499045	0.824	294.5625	0.0027974
5	151.7	19.6375	7.725016	0.829	294.5625	0.0028143
6	164.5	19.6375	8.37683	0.836	294.5625	0.0028381
7	158.3	19.6375	8.061108	0.806	294.5625	0.0027363
8	159.2	19.6375	8.106938	0.812	294.5625	0.0027566
9	155.5	19.6375	7.918523	0.83	294.5625	0.0028177
10	150.23	19.6375	7.650159	0.823	294.5625	0.002794
	∑ 1577.13					

- Average Peak Strength $= \frac{\sum \text{Peak Strength for sample 1-10}}{10}$
  $= \frac{1577.13}{10}$
  $= \mathbf{157.713}$

Figure 16 shows the graph peak strength Vs stress for 10 samples of granite rock. All these 10 samples were applied with Uniaxial Compressive Test (UCT) until it crushed to obtain the average peak strength. As we can see, the stress were increase when the peak strength increasing.

Table 6: Peak strength and stress value

Samples	Peak Strength (kN)	σ=F/A
1	164.7	8.38701464
2	155.3	7.908338638
3	150.8	7.679185232
4	166.9	8.499045194
5	151.7	7.725015913
6	164.5	8.376830045
7	158.3	8.061107575
8	159.2	8.106938256
9	155.5	7.918523234
10	150.23	7.650159134

Uniaxial Compressive Test for 60% of Average Peak Strength:

To create microcrack propagation in this granite rock, 60% of average peak strength will be applied using Uniaxial Compressive Test (UCT). Three samples of granite rock were used for this reason. Table 7 shown the 60% of average peak strength were applied to three samples no 11, 12, and 13.

- 60% of average peak strength = 60%* average peak strength
  = 60%*157.713
  = **94.6278 ≈ 95 kN**

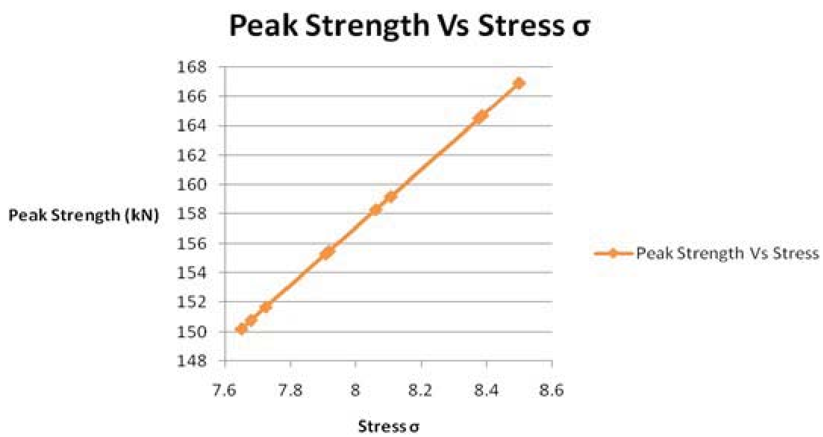


Fig. 16: Peak strength Vs stress (σ) for samples 1-10

Table 7: 60% of vverage peak strength of granite rock

Sample	Peak Strength (kN)	Area (cm^2)	Stress σ= F/A	Weight (kg)	Volume (cm^3)	Density ρ1000=M/V	Radial Strain ε=με	Modulus of Elasticity E= σ/ε
11	5	19.6375	0.254615	0.813	294.5625	0.0028	-85	0.003
11	10	19.6375	0.50923	0.813	294.5625	0.0028	-230	0.00221
11	15	19.6375	0.763845	0.813	294.5625	0.0028	-425	0.0018
11	20	19.6375	1.01846	0.813	294.5625	0.0028	-515	0.00198
11	25	19.6375	1.273074	0.813	294.5625	0.0028	-645	0.00197
11	30	19.6375	1.527689	0.813	294.5625	0.0028	-833	0.00183
11	35	19.6375	1.782304	0.813	294.5625	0.0028	-974	0.00183
11	40	19.6375	2.036919	0.813	294.5625	0.0028	-1086	0.00188
11	45	19.6375	2.291534	0.813	294.5625	0.0028	-1121	0.00204
11	50	19.6375	2.546149	0.813	294.5625	0.0028	-1199	0.00212
11	55	19.6375	2.800764	0.813	294.5625	0.0028	-1245	0.00225
11	60	19.6375	3.055379	0.813	294.5625	0.0028	-1273	0.0024
11	65	19.6375	3.309994	0.813	294.5625	0.0028	-1315	0.00252
11	70	19.6375	3.564609	0.813	294.5625	0.0028	-1366	0.00261
11	75	19.6375	3.819223	0.813	294.5625	0.0028	-1384	0.00276
11	80	19.6375	4.073838	0.813	294.5625	0.0028	-1399	0.00291
11	85	19.6375	4.328453	0.813	294.5625	0.0028	-1410	0.00307
11	90	19.6375	4.583068	0.813	294.5625	0.0028	-1422	0.00322
11	95	19.6375	4.837683	0.813	294.5625	0.0028	-1450	0.00334
12	5	19.6375	0.254615	0.835	294.5625	0.0028	-67	0.0038
12	10	19.6375	0.50923	0.835	294.5625	0.0028	-219	0.00233
12	15	19.6375	0.763845	0.835	294.5625	0.0028	-397	0.00192
12	20	19.6375	1.01846	0.835	294.5625	0.0028	-483	0.00211
12	25	19.6375	1.273074	0.835	294.5625	0.0028	-592	0.00215
12	30	19.6375	1.527689	0.835	294.5625	0.0028	-806	0.0019
12	35	19.6375	1.782304	0.835	294.5625	0.0028	-920	0.00194
12	40	19.6375	2.036919	0.835	294.5625	0.0028	-1005	0.00203
12	45	19.6375	2.291534	0.835	294.5625	0.0028	-1110	0.00206
12	50	19.6375	2.546149	0.835	294.5625	0.0028	-1166	0.00218
12	55	19.6375	2.800764	0.835	294.5625	0.0028	-1215	0.00231
12	60	19.6375	3.055379	0.835	294.5625	0.0028	-1244	0.00246
12	65	19.6375	3.309994	0.835	294.5625	0.0028	-1305	0.00254
12	70	19.6375	3.564609	0.835	294.5625	0.0028	-1322	0.0027
12	75	19.6375	3.819223	0.835	294.5625	0.0028	-1345	0.00284
12	80	19.6375	4.073838	0.835	294.5625	0.0028	-1380	0.00295
12	85	19.6375	4.328453	0.835	294.5625	0.0028	-1392	0.00311
12	90	19.6375	4.583068	0.835	294.5625	0.0028	-1400	0.00327
12	95	19.6375	4.837683	0.835	294.5625	0.0028	-1404	0.00345
13	5	19.6375	0.254615	0.826	294.5625	0.0028	-52	0.0049
13	10	19.6375	0.50923	0.826	294.5625	0.0028	-181	0.00281
13	15	19.6375	0.763845	0.826	294.5625	0.0028	-293	0.00261
13	20	19.6375	1.01846	0.826	294.5625	0.0028	-366	0.00278

Table 7: Continue

13	25	19.6375	1.273074	0.826	294.5625	0.0028	-483	0.00264
13	30	19.6375	1.527689	0.826	294.5625	0.0028	-591	0.00258
13	35	19.6375	1.782304	0.826	294.5625	0.0028	-670	0.00266
13	40	19.6375	2.036919	0.826	294.5625	0.0028	-877	0.00232
13	45	19.6375	2.291534	0.826	294.5625	0.0028	-939	0.00244
13	50	19.6375	2.546149	0.826	294.5625	0.0028	-1062	0.0024
13	55	19.6375	2.800764	0.826	294.5625	0.0028	-1091	0.00257
13	60	19.6375	3.055379	0.826	294.5625	0.0028	-1128	0.00271
13	65	19.6375	3.309994	0.826	294.5625	0.0028	-1154	0.00287
13	70	19.6375	3.564609	0.826	294.5625	0.0028	-1185	0.00301
13	75	19.6375	3.819223	0.826	294.5625	0.0028	-1197	0.00319
13	80	19.6375	4.073838	0.826	294.5625	0.0028	-1250	0.00326
13	85	19.6375	4.328453	0.826	294.5625	0.0028	-1278	0.00339
13	90	19.6375	4.583068	0.826	294.5625	0.0028	-1310	0.0035
13	95	19.6375	4.837683	0.826	294.5625	0.0028	-1314	0.00368

Figure 17 presented volumetric strain measured during Uniaxial Compressive Test (UCT). It can be seen that the volume of the sample has increased during the test.

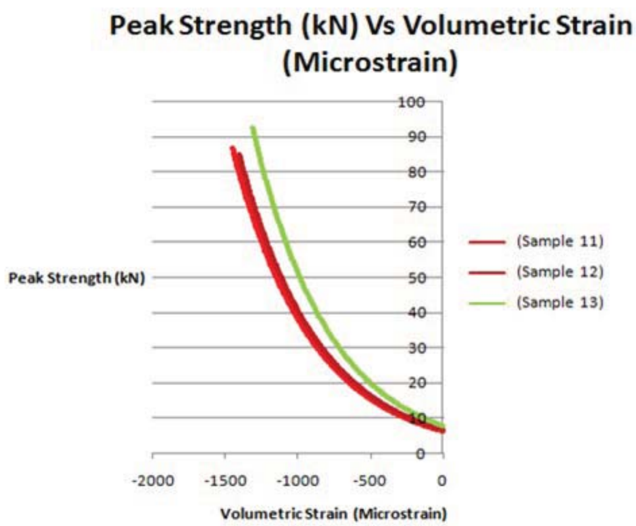


Fig. 17: Volumetric strain measured during uniaxial compressive test.

From Figure 18, it can be seen that the stress (σ) has increased linearly with the increasing of peak strength for granite sample no 11, 12, and 13.

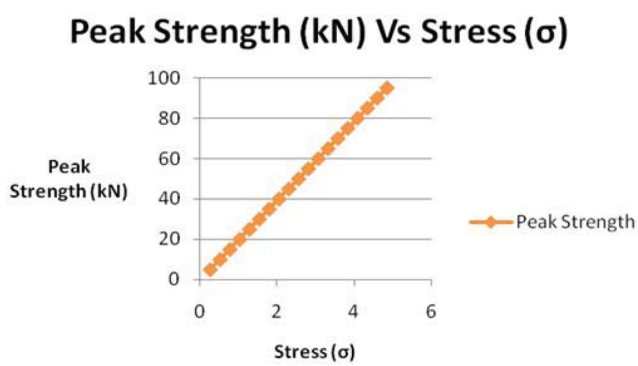


Fig. 18: Peak Strength Vs Stress for sample 11, 12 and 13

Thin Section:

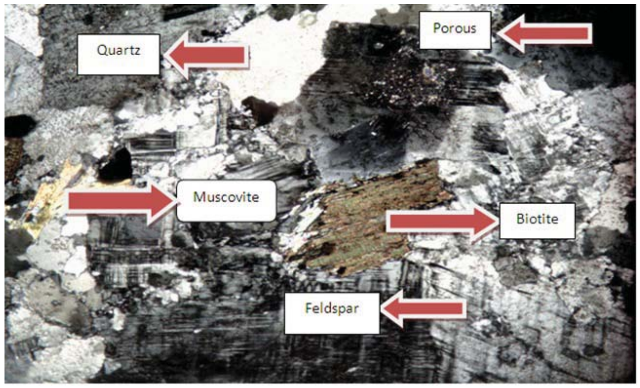


Fig. 19: The result for cross-polarised microscope (Sample-11)

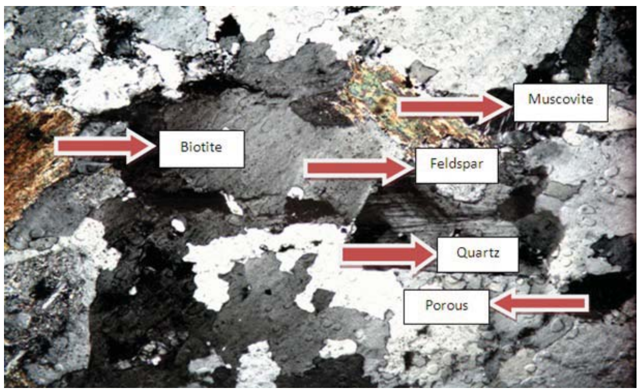


Fig. 20: The result for cross-polarised microscope (Sample-12).

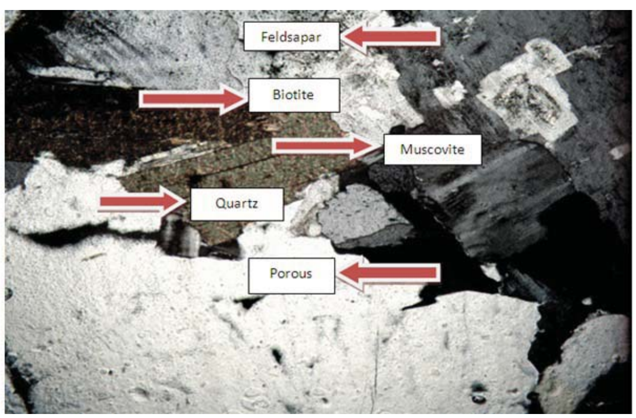


Fig. 21: The result for cross-polarised microscope (Sample-13)

The pOctober 6, 2010hotographs of the thin section image for sample 11, 12 and 13 are taken by using cross polarised of light for the microscope (Figure 19, 20 and 21). Based on the results, it can be summarized that, the minerals presence in the granite are Quartz, Feldspar, Boitite and Muscovite. In general, the results are explained below. The percentage of every mineral are just estimated value because the point centre machine are not available.

Therefore, the percentage of Quartz in the granite sample is more than 40%, Feldspar is about 40%, Biotite present less than 10% and Muscovite presence about 5%.

Analysis:

Based on the interpretation of the thin section of the granite, we can see that the major minerals consist in are Quartz and Feldspar (80%), while the minor minerals are biotite and muscovite. Therefore, the granite is a hard rock because Quartz is number 7 in the Moh's scale of hardness and feldspar is number 6 in the scale.

The weathering of biotite will form chlorite and then weathering of chlorite will form muscovite. In this sample, the percentage of muscovite is very low. This means that, the sample is slightly weathered. Biotite and muscovite are mica minerals. Mica minerals make some rocks sparkle because the light is reflected on their flat surfaces. The existence of cleavage will cause the minerals are easily to break along. Therefore, these minerals are weak and tend to break especially when Uniaxial Compressive Test (UCT) was applied to granite sample.

Besides that, the cross-polarised microscope for sample 11, 12 and 13 also shows the existence of porous, which is black in colour. The percentage of the porous is about 5%. Porous is a permeable surface and instead incorporates void spaces that allow for infiltration.

Conclusion and Recommendation:

These parts summarize the result for testing on granite, minerals observation and microcrack propagation to achieve the objective of this research. Two types of microcracks show the engineering properties of granite in Seremban. Therefore, the result can be considered as guidance to observe the types of microcracks of the granite rock in Seremban for future purposes. Cracks are normally produced when the local stress exceeds the local strength and may start at the cleavage planes, grain boundary contacts or around intra-crystalline cavities. A study on crack propagation was conducted by applying Uniaxial Compressive Test(UCT) to create the microcrack propagation in granite rock. Intragranular and intergranular cracks developed developed appeared to depend upon the mineralogy of the granite and their presence, and does not depend on minerals colour, as Quartz, being a hard mineral controls the propagation of the crack as the Uniaxial Compressive Test (UCT) increase. It uses the easiest route and the presence of Feldspars (in huge amount) will create the easier route for the propagation. Therefore, this presence of Feldspar grains will increase the risk of having a higher amount of microcracks. Quartz, being hard mineral controls the propagation of the crack as the Uniaxial Compressive Test (UCT) increases.

Recommendation:

Some insufficient were found during implementation of the research. Therefore, in order to get more accurate result during (Uniaxial Compressive Test), the ratio of the length over diameter of the granite sample should be one or two. Even though for this research the length to diameter ratio was three, it still follows the justification from the researchers.

The thin section was taken at the fewer microcracks from granite sample. The mistake was the thin section was taken parallel to the granite height. It should be taken parallel to the granite diameter because the microcrack propagation can be seen clearly at this direction when Uniaxial Compressive Test (UCT) was applied to the sample. Because of this mistake, not many microcrack can be observed. Transgranular and intergranular cracks are very hard to observe and only a few cracks appeared.

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