IDENTIFICATION ON MINERALOGICAL AND MECHANICAL PROPERTIES OF ROCK

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IDENTIFICATION ON MINERALOGICAL AND MECHANICAL PROPERTIES OF ROCK

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled 'Thesis Title'. I also declare that it has not been previously submitted for the award of any degree and diploma or other similar title of this for any other examining body or University.

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Abbreviation	Term
UCS	Unconfined Compressive Strength
BTS	Brazilian Tensile Strength
PLT	Point Load Test

ABSTRAK

Sifat mekanikal batuan bergantung kepada sifat mineralogi. Sifat mekanikal batuan ini dikategorikan sebagai salah satu kriteria penting kepada ciri-ciri batuan dan penting dalam industri seperti pembinaan, perlombongan dan Kuari. Kajian ini dijalankan melalui pemerhatian keratan nipis dengan ujian mekanikal di makmal iaitu Schmidt Hammer, Ultrasonik halaju P-wave,Ujian kekuatan Mampatan Tidak Bertutup, Ujian Kekuatan Tegangan Brazilian dan ujian beban titik. Terdapat sembilan sampel yang disediakan untuk keratan nipis iaitu syal berfoliasi, Batu Kelodak, Batu Pasir, Batu Enapan Butiran Kasar, Kuartzit dan empat jenis batu kapur berbeza manakala tujuh sampel menjalani ujian mekanikal iaitu syal berfoli, Batu Kelodak, Batu Pasir, Enapan Butiran Kasar. batu, Kuarzit, dan sampel batu granit dari kawasan yang berbeza. Ujian mekanikal dijalankan dengan menyediakan sampel ke dalam saiz dan bentuk yang sesuai mengikut piawaian American Society for Testing and Materials (ASTM). Ujian mekanikal yang dijalankan menghasilkan nilai tegasan dengan graf beban dan sesaran. Sampel bahagian nipis diperhatikan di bawah mikroskop. Komposisi butiran dan mineral dianalisis apabila diperhatikan melalui mikroskop yang boleh dikaitkan dengan sifat mekanikal seperti kewujudan Kuarza dalam komposisi mineral batuan. Keputusan ujian mekanikal dihubungkaitkan antara mereka untuk mengenal pasti signifikan kekuatan batuan melalui ujian mekanikal yang berbeza. Selain itu, ujian mekanikal pada batuan adalah berkorelasi dengan pengenalpastian mineral daripada pemerhatian melalui bahagian nipis untuk mengklasifikasikan batuan sebagai batuan keras atau batuan lemah.

IDENTIFICATION ON MINERALOGICAL AND MECHANICAL PROPERTIES OF ROCK

ABSTRACT

Mechanical properties of rock depend on the mineralogical properties. Mechanical properties of the rocks categorized as one of important criteria to rocks characteristics and important in industry such as construction, mining and Quarry. This study is conducted throughout the observation of thin section with mechanical test in the laboratory which are Schmidt Hammer, Ultrasonic velocity P-wave, Unconfined Compressive Strength Test, Brazilian Tensile Strength Test and Point load. There are nine sample are preparing for thin section which are foliated shale, Siltstone, Sandstone, Coarse-Grain Sedimentary rock, Quartzite and four different type of limestone while seven sample undergoes mechanical test which are foliated shale, siltstone, sandstone, coarse-grain sedimentary rock, quartzite, and sample of granite rock from different area. Mechanical test is conducting by preparing the sample into the suitable size and shape according to American Society for Testing and Materials (ASTM) standard. The mechanical test conducted resulting the stress value with graph of load and displacement. The thin section sample is observed under microscope. Grain and mineral composition are analysed when observed through microscope and can correlate with the mechanical properties such as the existence of quartz in mineral composition of the rock. The result of mechanical test is correlated among themselves to identify the significant of rock strength through different mechanical test. Moreover, the mechanical test on rock is correlate with the mineral identification from observation through thin section to classify the rock as hard rock or weak rock.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Different textures of rock can be related to characterization. The rocks were seen in a microscope in a photomicrograph where the conditions required are that the rock must be prepared in thin slices, shown in plane-polarised light or between crossed polarizers, and the interference of light produce the colour. Liu *et al* state that the characterization on rock that have been measured are the perimeter of mineral phases and micro cracks. Although there are certain drawbacks, such as the challenge of obtaining the same amount of lightning and inclination, optical lens microscopy is acknowledged as one of the efficient approaches that offered the high image quality of the Normanski prism. Rock usually consists of pores in their composition. Bai *et al.* found the pores of Yanchang sandstone based on multi-scale 3D structure reconstruction on computerised tomography (CT) data in nanoscale and microscale. The picture of data including size, shape, distribution and connectivity. The rock samples were used and mineral composition consists of quartz, plagioclase, feldspar and biotite. When the rock consists of high-silica, it is usually recognized as crystal rock.

Plisson and Zotkina state the detail of rock-section by using a microscope is possible with a more resolute sensor and limits the increasing diffraction. The ability of a microscope to be imaged in three dimensions, the identification of cracks and failure are easily found (Pingitore et al. 1996). The rock needs to be cut and a thin section preparation must be made for analysis under microscope. The sample of rock is cut to get in about 30 μm thick and quartz is usually

used as a gauge to determine thickness since it is the most abundant mineral. Tetley & Daczko (2014), suggest the Virtual Petrographic microscope which provide static image and stage rotation for small areas of rock sample under petrographic microscope where thin-section must

be produced correctly to get available data since it is the basic procedure of petrographic analysis.

In terms of mechanical properties, hardness is one property that can be measured since every rock consists of different hardness. Since every rock formed depends on their composition, the most important criteria need to be considered is chemical bond and electrostatic bond. Calcite rock present as soft rock due to the reaction of carbonate ions and calcium ions are weak bonds beside acidic properties. Another criteria of hardness depends on the density of minerals in the rock which refer to moh's hardness from soft rock to hard rock. The specific hardness also referred to chemical bond, crystal size and grain boundaries which may change the hardness of existence rock. The process of rock formation also may affect the hardness such as sedimentary rock formed by lithification process show less hard than igneous and metamorphic rock due to the formation did not include high pressure and temperature.

There are two ways for identifying the mechanics of the rock which are non-destructive test and destructive test. Non-destructive test divided into ultrasonic, seismic, acoustic emission and hammer where the tests proceed to identify the defect on rock which are local defect and global defects. Menéndez (2016) did research on monumental stone conservation and suggests that non-destructive techniques are suitable for studying the cultural heritage which build and it is better to combine data on different non-destructive techniques for analysis of the building. Non-destructive test apparatus is made for measuring the vibration frequency or regular dimension on rock where the main component is elasticity which is related to weathering and important to the strength and hardness of the rock. Allison (1988) suggests that Non-destructive ways rock can be identified by using the velocity test to identify the hardness of the rock since hardness is one of the mechanical properties of rock. Non-destructive usually applied on rock bolts. (Beard & Lowe 2003), state that the use of waves in industry is complicated due to energy of ultrasonic travel in a different number of modes which the frequency component on rock

alter the signal as the wave propagates with different speed. Another study suggested pseudo-random signal as non-destructive testing to identify the quality of rock bolt on slope stability. The method of velocity test is by using ultrasonic pulse velocity test where high velocity shows the high strength of rock. The concept of velocity of rock also known as seismic velocity where the velocity of propagation waves through the rock medium. Palmström (1996) suggests that the seismic wave velocity is measured by the time travel versus distances which are affected by the properties of rock and in situ of rock mass conditions. Seismic wave velocity which identifies the hardness of the rock since the rock exists in rigidity where it consists of many minerals and sometimes there is pore present in the rock. The major component of the wave is P-wave and S-wave which are known as body waves while there are surface waves which are Rayleigh wave and love wave. P-wave, where the particle of rock propagates in terms of compression and dilation. S-wave is the wave propagated perpendicular to the wave moving. A research done by Carcione et al. (2007), the P-wave velocity decreases when there is high porosity on rock based on a few models due to the bulk modulus being less than the grains of rock. Another research made by Kassab & Weller (2015), found that the p-wave and s-wave velocity decrease when the porosity increases where the rigidity of rock is reduced with considering another parameter such as permeability, grains density, dry bulk density, wet bulk density and pressure on skeleton lithology. Gaviglio (1989), made a research that found that the rocks that are high density produce high velocity of rock due to high percentage of mineral content but also must consider pressure-solution for the nature of rock forming substances (Coal, clays, calcite).

Another non-destructive test is the Schmidt rebound test which measures the strength, hardness and consistency of the rock and applies to geological and engineering study. Aydin & Basu, (2005) suggest a few components are important on Schmidt hammer test such as operational principle, Hammer type, Normalisation of rebound values, specimens' requirement,

weathering and moisture content, test requirement, data gathering, reduction and correlation with unconfined compressive strength. Research made by Demirdag et al. (2009) found that Schmidt rebound hardness is easy, inexpensive and quick and state that the dimension of the rock is important in predicting the rock strength.

Destructive test is the test that results in the fracture of the rock. The test is proceeded to identify the failure point and the resulting rock cannot be reused for the next. One of the destructive tests on rock is the Unconfined Compressive Strength test. The load is applied on the surface of the drill core sample where the rock sample is prepared with required parameters which are the ratio of length of core to surface diameter is two. Applying the load in the test between 2 to 15 minutes produces the stress rate and strain rate. There are many ways to analyse and predict the hardness of the rock by using the Unconfined Compressive Strength test. Alvarez Grima & Babuška (1999), made a research to predict the Unconfined Compressive test on rock by using TS Fuzzy Model which resulted in the potential to model complex, non-linear and multivariable engineering geological systems. The main important component in uniaxial Compressive Strength is Stress and strain. Nazir et al. (2013) state that Unconfined Compressive Strength test can be visualised as stress-strain and lead to axial strain, where stress occurs at failure as strain. Clout & Manuel (2015) made a research on iron ore for mining crusher by using Unconfined Compressive strength test on six rock type and found that Cliffe Hill Diorite has the high value of Unconfined Compressive Strength while Friable hardness iron ore has the lowest value of Unconfined Compressive Strength. Hassan et al. (2021) state that the correlation of the Uniaxial Compressive test and other tests depend on porosity, water content, weathering of rock sample and quality of rock sample.

Another destructive test is the Brazilian Tensile strength test. Brazilian Tensile Strength test is the test where rock is compress in circular disc where the ratio of diameter and thickness is between 0.2 to 0.75. (Yuan & Shen 2017) Brazilian Tensile strength may provide a well-measure for heterogeneity when conducted properly especially on control of contact surfaces. There are few types of disc when applied on Brazilian Tensile Strength tests. Li & Wong (2013) introduce four types of disc used for loading the rock sample which are flat loading pattern, flat loading pattern with steel rod, flat loading pattern with cushion and curved loading jaws.

Point load test is another destructive test to determine the rock strength index with the same concept as Unconfined Compressive strength test. Point load test can be done in four different methods which are diametral test, axial test, block test and Irregular lump. A research made by Au et al. (1991) found that different thickness of specimen provides a wide scatter result and standard thickness of rock sample is 50mm while the thickness of prismatic type suitable for 40-50 mm. Broch et al. (1972), suggest that shape and size must follow the limit to identify the point load strength index and the result is correlated with the Unconfined Compressive strength test which gives the least scatter data.

1.2 Area of Case Study

There are three types of rock which are Igneous, Sedimentary and Metamorphic located in Peninsular Malaysia. There are three classification of longitudinal belts in Malaysia which are Western Belt, Central Belt and Northern Belt where Western Belt includes the Northwest sector and a Kinta-Malacca Sector. Yal et al. state that Northwest sector consist of clastic, limestone and minor volcanic, Kinta-Malacca generally comprise of the deposition of argillaceous, calcareous sediments and limestone deposition while central belt consists of

Permian Triassic-clastic, volcanic and limestone and Northern Belt comprise of Carboniferous and Permian Clastic volcanic. Langkawi is one of the area that fall on northwest which comprised of sedimentary and granite rock formations. A research made by Roselee et al. (2018), in Kampung Awah, Pahang and Tasik Kenyir, Terengganu which falls on East Malaya Block under Central and Eastern Belt found that there are volcanic rocks which consist of basaltic to basaltic Andesite composition in the area. Ali Yusof did research on Crocker Formation Tamparuli, Sabah and recognized the formation of interbedded sandstone and Shale units in tropical climate weather.

1.3 Problem Statement

The study characterization of rock is where the existence of minerals on rock is based on their composition and depends on the geological and type of rock. The texture of the rock is the main component for identification to identify the composition of rock where this method is applied by scientists, ceramists, chemists and engineers. The study on mineral deposits is required before proceeding with mineral optical microscopy. Then, setting up the optical lens microscope tools which are charged-coupled devices and microscopy.

The test provided to measure hardness of rock is the Schmidt Hammer Test as non-destructive to analyse the rock whether the rock is suitable used for application such as building and construction where the hammer is held perpendicular and pushed toward on the rock surface until the hammer impact. The test is provided to estimate the hardness and strength of the rock samples. The rock samples must be located at a place which can prevent damage when applied to the hammer. The type of hammer depends on ratios of rebound value on different surfaces and higher impact energy which need to reduce scatter at rebound values. The rebound number is the output of rebound which is related to the surface number of rock. ISRM and ASTM set

that the range of strength on rock is 1-100 MPa where the weak rock is below than 10 Mpa but there are extremely strong rocks that may exceed more than 300 Mpa. Microstructure on poly-mineral rock due to weathering such as feldspar and quartz may affect the rebound value. Theoretically, coarse-grained igneous rocks are expected to provide high rebound value due to comparable size of plunger tip. ASTM standard proposed that it is compulsory for the impact point to be separated by at least one-plunger diameter. After applying the impact hammer on rock, the author can predict the relationship between weathering grade, grain size and rebound impact. The impacts at some point may be a good indicator of weathering grade. Schmidt rebound hammer is suitable to correlate with Unconfined Compressive strength test which can be expressed by power, linear function and exponential. Therefore, the Schmidt Hammer Rebound is a reliable device for estimating the hardness and strength of rock.

Unconfined compressive strength test is the destructive test to identify the mechanical properties of rock which are measure the shear strength on rock core (cylindrical sample) under unconfined condition and the concept same as Uniaxial Compression Test where the stress is applied on longitudinal axis. The rock core sample is placed in the loading machine between lower and upper plates. The upper plate is adjusted which contacts the upper part on the rock core sample and sets the deformation as zero. Record The load and deformation values after applied load to get complete load deformation curve. Continue the loading until the reach the lower value or remain constant of load with high strain value. The result of stress and vertical strain provided lead to further analysis on graph Another test to identify the mechanical properties of rock is the Brazilian Tensile Strength test which is also important in geotechnical projects. The Brazilian Tensile strength test is widely used to identify the tensile strength of rocks where the procedure is efficient where the strength in the tips of micro-cracks exceed and propagation of cracks cause the specimen to fail. The rock is prepared as a disk specimen also by using a drilling machine and hard rock cutter machine same as unconfined compressive

strength test but difference in parameters which are diameter and thickness but difference in ratio. Based on ASTM standard, the ratio of thickness-to-diameter of rock sample 0.2-0.75 or the thickness is half of diameter. The Brazilian test Cell consists of 2 steel parts where the disk specimen of rock is placed. The steel parts contact with the rock disk specimen in two opposite ends. The Brazilian Tensile Strength machine applies load on rock by pushing the steel parts toward the rock disk specimen until failure occurs in a period of time. The load and the time of specimen to fail are recorded which lead to calculation of the tensile strength. The failure is valid if the rock disk specimen is cracked below 30 second.

Lastly, point load test where the failure of rock occurs between two conical steel plates. The main objective of using point load test in rock mechanic is to identify the rock index which correlate point load test index with uniaxial (Is_{50}) compressive strength. The rock specimen can be prepared in the form of rock cores (same as unconfined compressive strength Test sample preparations), irregular lumps or blocks.

1.4 Objective

- To study mineral composition on a rocks sample.
- To investigate the mechanical properties of rock.
- To study of the correlation between the Strength of rocks with mineral composition.

1.5 Thesis Outline

This thesis was made by the author to identify the difference of three types of rock which are igneous rock, sedimentary rock and metamorphic rock based on their composition and mechanical properties. There are five main chapters highlighted in this thesis which are introduction, literature review, Methodology, Result and Discussion and Conclusion. Chapter one in this thesis is introduction which comprises background study, problem statement, objective of the thesis and thesis outline. Chapter 2, literature review comprises

geological study of rock including mapping and theories of the rock formation. Chapter 3, Methodology of the thesis project explained the details of all tests mentioned above that have been conducted thin section preparation for microscopic observation on rock. Result and discussion on chapter 4 are data provided based on methods that have been conducted including the detailed analysis based on the result provided. Lastly, the analysis data and tests carried are summarised in the final chapter which are conclusions which lead to application used and correlation for future development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

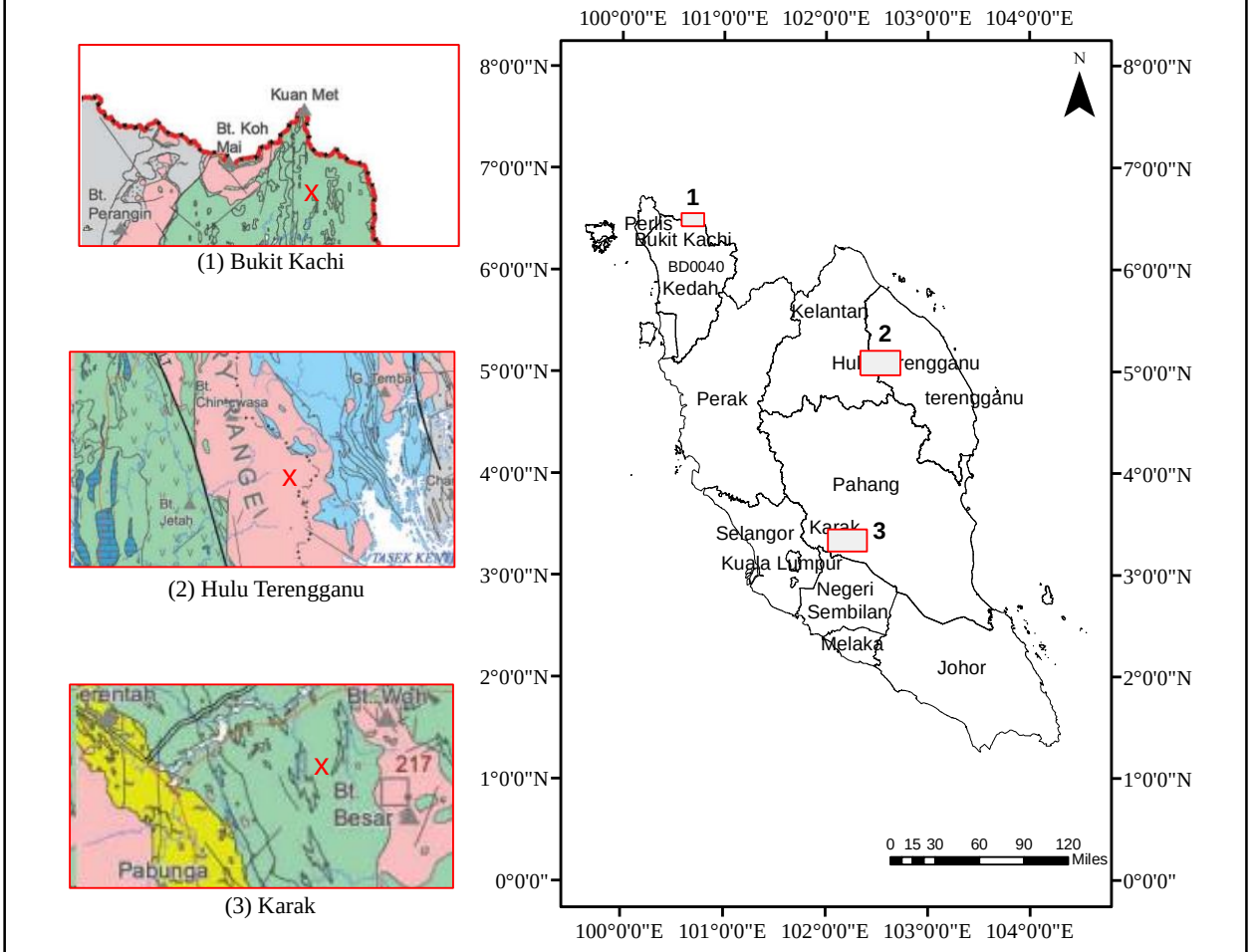
Thin sections are used to identify the properties of the rocks and to analyse their mineral content. One of the mechanical characteristics associated with rock mineral analysis is hardness. Boutrid et al. (2015), state that hardness of the rock is an important parameter to identify the strength of rock by providing some test including referring to the parameter elastic moduli and density. Zou et al. (2020), also agreed that the hardness of rock is an important factor in the mechanical behaviour of rock which considers the strength test such as unconfined compressive strength test and Brazilian tensile strength test. Yaşar & Erdoğan (2004) also state the hardness is mechanical properties of rock which important to determine in construction sector by using Schmidt hammer. Hardness can be identified by the rock when resist to the deformation when applied load on the surface. Tumac et al. (2007) state that the resistance of rock through deformation can be determined by using Shore hardness where the percentage of deformation changes is known as coefficient deformation. Shalabi et al. (2007), provide that the correlation between hardness and deformation can be identified by the relationship of poisson's ratio and Shore Scleroscope hardness especially for dolomitic marble and shale. Yilmaz (2013) suggests that the method of combination rebound hardness and ratio deformation provide hybrid dynamic hardness (HDH) where the value of hybrid dynamic hardness can be correlated with another strength test such as Uniaxial Compressive strength test. Singh et al. suggest that determine the strength and deformation parameter of rock for geotechnical study to perform any project or application such as mining project during feasibility study which the important parameter is index testing technique for intact rock including all the tests, sample size and further detail on surveying.

The structure, texture and mineral composition is one of the important factors of rock strength which correlate the hardness and rock mass based on geological topography. Jiang et al. (2014), employ the Tianshan slope rock mass (TSMR) system to apply the rock mass classification on cold region by collecting the data including the field geological survey and rock hardness before compute in geological strength index (GSI) and modification of original slope mass rating (CSMR) in slope stability study. Sapigni et al. (2002), employ the rock mass survey by using tunnel-boring machine (TBM) including the hardness data to construct a tunnel. Hustrulid et al. (2001), state that the joints may be cemented with minerals with different strength where in a high-stress environment may affect the strength of rock mass. The correlation of hardness of the rock with mineral composition depend on the formation of the such as igneous rocks form by molten lava with high pressure and temperature which cause the rock is considered hard rock while sedimentary form by compacting and cementing of sediments by action of water, wind or glacier which the rock may be considered weak rock. Li et al. (2021), state that the way to recognize the mechanical properties is by mineral composition of the rock, the sample collected to carry out tests including the preparation of thin section for microscopic observation and strength test and abrasivity. Yang et al. provide that the strength test for weak rock such as shale due to easily fractured which identify the brittleness of the rock by consider the lithology and mineral composition of rocks while Rahimi et al. state provide that the strength test which is Schmidt Rebound Hardness Test (SRHT) is suitable to identify the hardness test of sulphate rocks especially when the rock exists with clay.

2.2 Geology of Study area

Based on geological area in Malaysia, Limestone contributes as one of the rocks that provide benefits in Malaysia industry such as plastic and paper production. Boon-Kong state that major

sources of Limestone are Klang-Valley at Lembah Kinta, Pahang, Kedah-Perlis and Kelantan which usually deposited in unique landforms and karstic features and form on a few condition such as steep, subvertical limestone cliff, bedrock and on the ground surface. Another research made by Norsyafina Roslan (2017), Shah Alam which falls on Kenny Hills comprises interbedded shales, sandstone, mudstone and Conglomerate where shale and Mudstone may be phyllitic. Geological areas are being studied to identify the types of rocks that exist in Malaysia and to provide information on any actions, like blasting, that are controlled by quarry companies and take into account the local rock's mechanical qualities. Latif et al. (2016) made a study on the Flyrock accident in Johor Bahru and found that 4 sets of fracture exists at the blast site and new cracks form from previous explosions. In this case, local geology is important to identify the joint orientation, extended crack and unfavourable orientation. Besides, the study of rock characterization on geological areas may provide benefits to communities such as granite in the construction project. Latif et al. (2016) suggest the Topographic Wetness Index (TWI) to predict and identify the failure and landslide may occur based on wetness and hydrological area. Ashaar et al. did a study on slope field mapping on Ulu klang and suggest that geological factors are the main component in slope mapping such as type of rock and soil, discontinuities, weathered grade percentage, Geological features including faults, uniformity and joints and potential failure. The samples used in this study's thin section and strength tests were from Bukit Kachi, Hulu Terengganu, and Karak which are shown in the figure below. Shale, siltstone, and sandstone are interbedded in the rock of Bukit Kachi. Slate and Phyllite are found in some areas, while undifferentiated acid intrusive is found in other areas. The geology of Hulu Terengganu is similar to that of Bukit Kachi, but it differs in that the sandstone and schist are subordinate to the slate, shale, and phyllite, and certain areas are covered with extremely thick limestone. Argillaceous, slate, phyllite, schist, pelitic hornfels, calc-silicate facies, and calc-silicate hornfels are a few of the geological formations found in the Karak area.



Legend

Study Area

X Sampling Point

Lithology

Interbedded sandstone, siltstone and shale; widespread volcanics, mainly tuffs of rhyolitic composition.

Acid Intrusive (Undifferentiated).

Phyllite, slate, shale and sandstone; argillaceous rocks are commonly carboneceous.

Phyllite, Slate, Shale with subordinate Sandstone and Schist.

Pure light colour thick to very thickly bedded limestone.

Mainly argillaceous, slate, phyllite, schist, pelitic hornfels, calc-silicate facies and calc-silicate hornfels.

Figure 2-1 The study of geological area of Bukit Kachi, Hulu Terengganu and Karak

2.2.1 Igneous rock in Malaysia

Malaysia is rich with the source of igneous rock. Igneous rock is made up of magma activity and divided into two classifications which are volcanic rock and Plutonic rock. Volcanic rock or extrusive rock formed when magma is kept inside the earth and solidifies in thousands of years while plutonic rock or intrusive rock formed when magma reaches out and cools on the earth surface. Volcanic rock is generally present as coarse grained and Plutonic rock present as fine-grained. Moniruzzaman SHIRAZI et al. (2015) did research on Malacca state and state that granite and intrusive rock are the second major rocks that exist in Malacca. A research made by Roselee et al. (2016) on petrographic of 19 samples of Southern part of Tioman-Island and found that Biotite granite which are Plutonic rock consist of K-feldspar (Orthoclase), Plagioclase, and Biotite with traces of hornblende while Plutonic rock such as Rhyolite consists of quartz, Plagioclase and K-feldspar, then conclude that both rock consist of overlapping mineral composition and trend on Harker diagram are petro-genetically related. In Semporna Sabah which located at Northern Borneo comprise of Andesite which consist of fine-grained and porphyritic texture with Plagioclase, clinopyroxene, hornblende and biotite, which also same textural with Dacite and Rhyolite but Secondary Mineral in Rhyolite have more cavities which show that those Andesite, Rhyolite and Dacite in Semporna formed by volcanic lava with tectonic environment (Petrologi dan Geokimia Batuan Volkano Semporna ,2021). Granite in Gunung Raya, Langkawi are covered along 100 km square area which formed at late Triassic in age and exist in faults intrusion of granite with consist of some coarse and fine grained including large crystal on groundmass (Porphyritic granite) that show the amazing features of granite. Yusoff et al. (2016), found that limestone existed which intruded by the igneous rock in Kuala Lumpur. Hatta (2014), made a research on Volcanic rock Teluk Ramunia, southeastern Johor, Peninsular Malaysia which are Rhyolite, Diorite and Trachydacite. Diorite consists of most plagioclase composition, Mafic minerals are biotite and hornblende and there

are alteration minerals with little amount of micro granophyric. Rhyolite also contains porphyritic but there are other main minerals which are quartz and K-feldspar and few minor components which are ferromagnesian minerals. Trachydacite exists in light and dark grey colour which also consist of the same mineral composition as Diorite with a major amount of K-feldspar. Bignell & Snelling (1977), made a research on igneous rock in Terengganu found that Dolerite which is form after granitic batholiths have been crystallise basic magma undergoes assimilation of granitic material resulting the various of dykes rocks. Kosaka did research on the Mamut Porphyry Copper Deposit on Sabah and found that there is volcanic rock present in a very thin bed between sequences of clastic rock. F.Tongkul (1991) did a research on Tectonic activity in Sabah on igneous rocks and state that Andesitic pyroclastic intrusion of granite occur at Semporna and Mount Kinabalu, Intrusion of Basalt occur in occur in Lubuk Valley and Andesitic of pyroclastic occur at Semporna. A study made by Omang & Sains Bumi (1996), state that island arc on Lahad Datu Sabah made from tectonic environment and resulting the formation of volcanic rock from volcanic activity where the volcanic rock consists of clinopyroxene, plagioclase, olivine and Fe-Ti. A study to predict terrestrial gamma dose rate which depend on soil type and geological formation by Saleh et al. in Johor state, Malaysia to identify the radioactivity of the and state that intermediate intrusive made by formation of igneous rock resulting high dose rate based on the one-way analysis on variance (ANOVA).

2.2.2 Sedimentary Rock in Malaysia

Sedimentary rock formed from the deposition or accumulation of minerals, sediments or organic materials near the earth surface with high pressure due to the weathering, dissolution, erosion, lithification and precipitation. Sedimentary rock falls into 3 type which are clastic sedimentary rock which formed weathering debris undergoes lithification and accumulation, chemical sedimentary rock where solution form dissolved material through precipitation and

Organic Sedimentary where plant or animal debris. Malaysia land also comprise with the source of sedimentary rock such as sandstone, siltstone and limestone. F.K. Yee (1983) did a research on rock in Peninsular Malaysia and provide the formation of Sedimentary rock based on four areas which are Northwestern area, Western zone, Eastern zone and Central zone. Northwestern area such as Machinchang formation of siltstone in Langkawi, shale sandstone and limestone based shelf deposit on deltaic facies. The Western zone is divided into two stratigraphic groups which are lower Palaeozoic Bentong Group such as limestone formation in Kuala Lumpur and Baling Group such as Setul formation which also consist of limestone formation and two clastic belts. Central zones such as Gua Musang formation consist of crystallised limestone and subordinate sandstone including the formation of grey shale or black shale when it undergoes carboniferous. Eastern zones such as Kuantan formation consist of shale facies followed by volcanic facies, mudstone and siltstone formation. S.senathi (1979) did a research on Kinta Tinfield state that the alluvial tin deposits correlate with cut-off sedimentary rock such as bedding limestone, dolomitic limestone and dolomite .Sajid et al. (2020) study on sedimentary geology and deposition in Semanggol Formation, found the sandstone facies which consist of hard and fracture of sandstone with light colour and fine grained size. A research made by FCP Spiller (1998), on a few localities and the existence of sedimentary rock in Peninsular Malaysia. One of the localities is Genting Sempah Tunnel which is located between Kuala Lumpur and Karak Highway and there are sandstones, mudstones and Schistose mudstones matrix exist which the author suggested the rocks formed affect from hydrothermal alteration. Another locality is made on Bahau, where sandstone and siltstone exist which are covered with rounded clasts of conglomerate. Kasim et al. (2020) did a study on Onshore Cenozoic Basic in Peninsular Malaysia and found that the sediments are formed based on quaternary and Tertiary ages. Sedimentary rock formed from Quaternary ages such as Kempadang formation in Kuantan South and Simpang Formation in Kinta Valley

consist of sand, clay and silts while the rocks formed from Tertiary ages are seven basins (Batu Arang, Kluang Niyor, Enggor, Bukit Arang, Kampung Durian CHondong, Layang-layang and Lawin) which consist of limestone, calcareous shales, low-grade coal seams, sandstones and conglomerate. The density of sedimentary rocks is different based on rock type. Nursalam et al. (2019) did research on rock Type on Maluri site, Kuala Lumpur and found that Dolomite has the highest density and the density sandstone is low but not the lowest density. The author suggests that the difference density value affects the gravity anomalies on the Maluri which are correlated to the voids and inhomogeneity type of the rock. Another research made on Semantan Formation by Ismail et al. (2007) found that the facies of Semantan formation are siltstone, shale, sandstone and conglomerate which are discovered between middle to upper Jurassic. Sedimentary rock also exhibits different characteristics. Tan et al. made a research on Iskandar Puteri, Johor, Malaysia and found the existence of shale and sandstone where the size of rock is fine to medium, light-grey to yellowish reddish-brown with different weathering grade. The authors also found that shale and sandstone in Legoland were mostly highly-weathered. In terms of mineralogy, Nagarajan et al. (2014) made a study on sedimentary rock in Borneo Basin, East Malaysia found that sandstone consists of a major amount of quartz while a minor amount of clay mineral such as Kaolinite and Illite. Sedimentary rock may differentiate or derive to form soil.

2.2.3 Metamorphic Rock in Malaysia

The last type of rock to be discussed is Metamorphic rock, which form from other rock due to pressure and temperature with changes components from their original or parent rocks. Md Ali et al. (2016) found that Taku Schist produce from sedimentation of Gua Musang and recognize as high grade of metamorphism such as the existence of Phyllite which are folded and crenulated and connect with shale mudstone. The authors found that Shale, Slate and Phyllite formed in Carboniferous Permian age. A geometric analysis was made and author

found the composition of few sample of Schist consist garnet, Quartz ribbon and K-feldspar. Yusoff et al. (2016) state that the metamorphic rock exists in Kenny Hill, Kuala Lumpur are dolomite, schist, Phyllites and there are some correlated with metamorphism sandstone and shale. Surjono & Leman (2015) state that East Johor, Malaysia consist of low grade of metamorphic rock such as Phyllites, Schists, Meta-sandstones which subjected Quartzite and Schist where the rocks is suggested deposited in shallow marine and formed by metamorphism in carboniferous time. The unit of rock is elongate to northern Terengganu area. The authors also state that Quartzite in Mersing, Johor are arenaceous rock type which have light grey, white and buff-coloured and composed of little grains of Quartz and mica while Schist consist of black to dark grey colour which mineral exist on flaky foliation and layered orientation of granular mineral and exist in termixture grain. Omang & Barber did a study on metamorphic rock which associated with the Darvel Bay Ophiolite, Sabah, Malaysia and found the existence of hornblende and amphibolite. Amphibolite present with the banded gneiss which could form extensive outcrops as smaller body and explained the intrusive relationship with hornblende gneisses. Hornblende act as dominant rock which consist of centimetres to millimetres thick of black or dark greenish ferromagnesian band and define as mineral lineation which placed on plane schistosity where the band consist of parallel schistosity in local shear zone and folded into sheath folds. Amphibolite consists of different grain sizes where coarse grain size explains black or green ferromagnesian and white feldspar while fine grain consists of dyke and angular which correlate with the band of the gneiss. The metamorphic may be tested by using radionuclide to identify the concentration of Uranium. A research made by Alnour et al. in Johor state about radioactivity level in rocks and found that hornfels has the high value among in metamorphic rock group but lower with igneous and sedimentary rock which are 93 ± 6 Bq kg^{-1} of radium equivalent activity and 47 ± 3 nGy $h^{-1}$of dose rate. Some metamorphic rock exists in mine ore extraction minerals. Makoundi et al. (2013) found the existence of Phyllite

which is composed with mylonite, cataclasite and siltstone on the orebody of mine in the Cross-section of Selinsing Gold Mineralization which is located on the lower zone. Najla Mohamad et al. (2020) did a study on Kuching Zone Sarawak state that the oldest metamorphic rock formed at Pre-Upper Carboniferous age such as Schists while the younger Metamorphic formed at Late Mesozoic age which recognized with uncertain protoliths and origin which correlated with setting of Cretaceous-Cenozoic accretionary. Peucker-Ehrenbrink & Miller (2004) state that metamorphic rock exhibit 361149 km^2 with 1112 average Million year ago for low grade and 44537 km^2 with 2606 average Million years ago. The slope failure is always related to the geological condition of rock. Ballantyne (2008) states that the metamorphic rock such as schists on highland in Hebrides and Midland valley usually undergoes non-rotational failure. Based on Stead et al., the relationship between slope failure or landslide and metamorphic rock is dependent on the characteristics of metamorphic rock which are foliation, cleavage, deformation and metamorphic lithologies. Authors highlight the main important characteristic is Deep seated gravitational displacement which refers to topography which provides the movement of slope which occur in multiple rock-type and in metamorphic mountain terrain.

The hardness of the rocks depends on the rock formation which depends on the geology of the study area. The component factor affecting the formation of rock may also affect the hardness such as the presence of bubbles or the existence of high temperature and pressure during the formation. This thesis is made to study hardness of rock where the rock samples are taken from Bukit Kachi, Karak and Hulu Terengganu.

Hulu Terengganu consists of meta-sedimentary rock. Gasim et al. (2010) state that Eastern belt of Terengganu consist of Carboniferous-Permian meta-sedimentary rock, Triassic Igneous rock, Jurassic-Cretaceous continental rock and Quaternary deposits while South Eastern part of Terengganu consist of Carboniferous or older meta-sedimentary rock (such schist, Phyllite

and slate) which are exist in NNW axis of peninsular. Based on (Program Geologi, Pusat Pengajian Sains Kesekitaran, Universiti Kebangsaan Malaysia et al. (2006), also agreed the southeastern in Terengganu consist of meta-sedimentary rock such as schist, phyllite and slate which formed during Triassic granite and Quaternary-sediment along with sediment deposition which occur since late Palaeozoic and intrusion of granitic occur during early Triassic. Yusri et al. also agreed that the eastern belt of Peninsular Malaysia in Terengganu consist of Carboniferous meta-sedimentary rock, igneous rocks and Jurassic Cretaceous rock continental deposits including Kelantan and east of Johor. The meta-sediment rock acts as dominant rock deposition in this belt which consists of clastic-sedimentary rock with metamorphism process in low-grade. One of the places that consist of meta-sedimentary rock is Chukai which consists of Carboniferous Shale. Ooi et al. (2017), state that the existence of meta-sedimentary rock in Kuala Abang, Terengganu consist of carboniferous rock formation which are sandstone and siltstone to the south of Kuala Terengganu.

Karak is also rich with meta-sedimentary rock. State that the tunnel rock consists of granite batholith with less meta-sedimentary rocks of Karak formation. Madon et al. (2010), suggest that 'post-orogenic' continental deposits referred to Jurassic-Cretaceous Gagau group depend on unmetamorphosed nature and low structural dip with environment deposit on surrounding rock. The survey shows Karak consists of fluvial deposits which contain fining-upward channel fill sands and muds with floodplain mudstones. Rahim et al. also agreed that the rock in Karak formation consists of less meta-sedimentary rock in the main range of granite batholith in ranges from 25m to 1315m of tunnel route below the ground surfaces. Syed Zainal et al. (2015) , also employ the existence of meta-sedimentary rock and granitic in groundwater in tunnel by the understanding environmental isotope with complex hydrological system including determine the type of water with Deuterium ($\delta^2 H$) and oxygen-18 ($\delta^{18} O$) content. Jasin also

agreed that the suture in Karak highway and Bentong rich of meta-sedimentary rock including sandstone, limestone, conglomerate and interbedded sandstone.

Bukit Kachi contains various types of mineral deposits. Based on Geologist's annual report for the year 1923, mining in Bukit Kachi provides the source of tin and tungsten including different quartz-veins The Malaysian and Thai Working Groups Malaysia-Thailand Border Joint Geological Survey Committee (MT-JGSC), (2006) also state that the existence of Tin-tungsten next to granite bodies where the deposits occur either in veins type or surrounding hornfelsic rocks. Yai et al. state that Bukit Kachi contains parallel veins while cutting tourmaline schist.

Batu Tiga Quarry operate the extraction of Granite. Granite was commonly found in Peninsular Malaysia and made for human building and house. Granite compose of feldspar. An investigation made by Chu Ling Heng et al. about the extraction of feldspar from granite. Authors found that the recovery of feldspar exceed 60% at 1170 C^o to extract from central Belt Granites.

2.3 Introduction of three type of rock.

As mentioned earlier, major types of rocks are classified as igneous, sedimentary and metamorphic rock. Igneous rock formed when crystallisation and solidification of hot molten rocks either deep inside of earth (Intrusive igneous rock or plutonic) or above the earth's surface (Extrusive rock or volcanic rock). Naming and classifying the igneous rock based on petrology including their composition. Middlemost (1994), state that the volcanic rock is identify by TAS diagram where content of alkali minerals ($Na_2O + K_2O$) and silica oxide (SiO_2) are analysed. TAS is introduced by intrauterine gestational sac (IUGS) sub-commission which identifies the co-composition of mineral kalsilite (*Ks*), nosean (*No*), fayalite (*Fa*) and nepheline (*Ne*). In other ways, Davidson *et al.*, (2007) provide radiogenic isotopes ratio to analyse isotopic magma crystal in igneous rock. Generally, the concept of identifying the

mineral composition in igneous rock is similar to other rocks which are using an optical lens microscope.

Sedimentary rock formed by accumulation and lithification near rock surface by precipitation process at normal temperature. Sedimentary rock is usually produced by weathering of preexisting rock or erosion where weathering rocks are transported from the weathering site. The sedimentary rock is usually composed of mud, sand and gravel. Folk, (1954) proposed that three components which are gravel, sand and mud in sedimentary rock provide fifteen textural groups which are from 2mm coarser material to 0.0625mm fine material. In addition, Fedo *et al.*, trace the elements such Cobalt, Titanium and Nickel exist during formation of sedimentary rock in the upper crustal in fine and coarse grained clastic sedimentary rock.

Metamorphic rock formed by the deviation or alteration of pre-existing rock with high temperature and pressure. The new rock form may be different from parent rock. The rock is formed by a metamorphism process. Bucher & Frey (2002) state that there are a few types of metamorphism that formed metamorphic rock such as High-pressure limit metamorphism, contact metamorphism, Ocean-floor metamorphism and Burial metamorphism. In addition, there are Boron-isotopic compositions found in subduction of metamorphic rock such as blueschist, Mafic and Quartz schists.

In Malaysia, most of the rock is dominated by sedimentary rock such as limestone which formed during Palaezoic Era but half of peninsular Malaysia are covered by granite and others igneous rocks.

2.4 Physical and Mechanical Properties of rock

Study on this thesis consist of seven type of rock for mechanical test which are Foliated shale, Siltstone, Sandstone, Coarse-Grain Sedimentary rock, Quartzite and two sample of Granite.

2.4.1 Physical and Mechanical properties of Igneous rock

Igneous rock usually made for building due to its hardness in construction provides a strong condition for engineering projects such as dams and bridges. The example of igneous rock application is Basalts which act as foundation of structures and roads. Small grain size causes high mechanical strength of rock and can be reduced by alteration of mineral, joints, cavities, and faults which lead to the porosity of rock. Lavallée & Kendrick (2021) state that to determine to brittleness and ductile of volcanic rock based on the mechanical properties (compressive strength, tensile strength and Yound modulus) and physical properties (porosity) with another parameter, pressure and time.Salih & Alshkane (2018), employ the correlation of strength mechanical test for igneous and found that the good relationship of test is between uniaxial compressive strength test and Schmidt hammer test (UCS-Rn) which is better than uniaxial compressive strength test and point load test (UCS-I_{50}). The result of Unconfined compressive strength for 240 sample igneous rock is in range 60 MPa to 240 MPa with average 94 MPa, while the range for point load test is 1MPa to 13.2 MPa with average 4.32 MPa for 119 sample of igneous rock and the range for Schmidt hammer rebound test is 18 MPa to 72 MPa with average is 45.7 MPa for 119 sample of igneous rock. Aladejare (2021), provides the way to predict the model of Uniaxial compressive strength test (UCS), Young modulus and poisson's ratio of gabbro and granite (Otanmaki area, Finland) from a set of data. The data are collected Brazilian Tensile strength test (BTS), porosity, water content and density. The data provide the analysis of correlation among the variables but the correlation was deemed with T-test at p-value <0.05 in software. The empirical formula in data in matlab software shows the correlation between the independent and dependent variables which are limited to water content and porosity for Uniaxial compressive strength insignificant with Young's modulus and limited to poisson's ratio. In another way, Siratovich et al. (2014), employ that the mechanical test of Rotokawa Andesite rock in Taupo volcanic rock, New Zealand and state

that the rocks in the area are moderately strong based on mechanical properties of rock included some rocks which have different compressive strength values due to different physical properties which may affect the strength value of rock.

The strength of rock is recognized for further engineering study in mining. Arif et al. (2013) employ the mechanical properties which are Unconfined compressive strength test on igneous rock (alkali granite) and state that the value of Unconfined compressive strength test depends on the grains size. Different phenocrysts in alkali granite provide different strength values where fine-grained phenocrysts are between 35.849MPa to 39.622 MPa while coarse-grained phenocrysts are between 27.672 MPa to 30.817 MPa. The strength value shows that fine-grained phenocrysts are stronger than coarse-grained Phenocrysts.

Generally, the hardness of rock depends on empty spaces or porosity in rock such as volcanic rock is hard when it contains full solid glass but may be weak when there are bubbles during their formation. Yasir et al. (2018), state made a research on Sungai Tekai, Jerantut, Pahang found that sandstone which is exposed to sodium hydroxide and nitric acid solution with high strength contribute highly reactive and moderately reactive. Mechanical tests on rock exhibit any deformation when applied load. The deformation of rock depends on the young modulus and poisson ratio known as elasticity. M.S. Paterson & Teng-fong Wong state that either small-scale deformation by using hand-specimen to large-scale deformation through tectonic processes depend on plastic deformation of rock. Paterson states the mechanical properties are stress-strain of rock which results from the deformation and confining pressure on apparatus. The fracture and faults due to pressure and temperature begin with the growth of micro-cracks. Shiotani, Ohtsu and Ikeda state that Acoustic Emission is a suitable method to detect the crack due to effective and sensitive function when applied to rock, thus predicting the rock failure. These mechanics of rock refer to the hardness which is important in industries such as construction.