SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

UNIVERSITI SAINS MALAYSIA

WEATHERING CLASSES IN RELATION TO PHYSICAL AND MECHANICAL PROPERTIES OF DECOMPOSED GRANITE

By

NORFATEHA BINTI AB HAN

Supervisor: Dr. Hareyani Binti Zabidi

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled “Weathering Classes in Relation to Physical and Mechanical Properties of Decomposed Granite”. I also declare that it has not been previously sent for the award of any degree or diploma and other similar title for any other examining body, Institution or University.

Name of student : Norfateha binti Ab Han Signature:

Date :

Witnessed by

Name of supervisor : Dr. Hareyani binti Zabidi Signature:

Date :

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SYMBOLS

W	Water content
G_s	Specific gravity
σ	Normal stress/ Direct stress
τ_f	Shear strength
c	Cohesion
ϕ	Friction angle of soil
D_e	Equivalent core diameter
I_s	Uncorrected point load index
$I_{s\,(50)}$	Size corrected point load index
C_u	Uniformity coefficient
D_{10}	Size which 10% particles passing
D_{60}	Size which 60% particles passing

ABBREVIATIONS

PL	Plastic Limit
LL	Liquid Limit
PI	Plasticity Index
XRF	X-ray Fluorescence
XRD	X-ray Diffraction
PSD	Particle Size Distribution
LOI	Loss of Ignition
ACV	Aggregate Crushing Value
UCS	Uniaxial Compressive Strength
PLI	Point Load Index

GRED LULUHAWA YANG BERHUBUNG KAIT DENGAN SIFAT- SIFAT FIZIKAL DAN MEKANIKAL BATUAN TERURAI GRANIT

ABSTRAK

Cabaran utama kajian ini adalah berkenaan kestabilan cerun, dasar pembukaan bawah tanah dan penggalian batuan yang dipengaruh oleh kadar luluhawa sesebuah jenis batuan. Profil luluhawa di sesetengah kawasan biasanya diklasifikasikan mengikut penglihatan dan observasi, kajian geologi dan sifat- sifat batuan sewaktu kerja lapangan. Kajian ini khusus untuk batuan terurai granit yang dikategori mengikut kadar luluhawa dan ciri-cirinya batuan itu. Mengikut kajian sebelum ini, terma batuan terurai granit merujuk dari gred II sehingga gred V kadar luluhawa batuan. Kajian ini menekankan hubungan antara ciri-ciri gred luluhawa batuan granit dengan sifat-sifat fizikal dan mekanikal. Pelbagai ujian fizikal dan mekanikal dilakukan untuk mengenal pasti sifat-sifat fizikal dan mekanikal batuan terurai granit. Ujian fizikal itu terdiri daripada agihan saiz zarah, kandungan kelembapan, limit atterberg, nilai graviti tentu manakala sifat mekanikal adalah ujian ricih terus, beban titik dan pecahan aggregate kasar. Analisis X-ray fluorescence (XRF) dijalankan untuk menganalisa komposisi kimia dalam setiap gred luluhawa yang memberi kesan penting kepada sifat- sifat granit. Data analisis dipadankan dengan kadar luluhawa batuan terurai granit dan sekiranya gred luluhawa berubah, sifat-sifat pada batuan juga berubah. Nilai R^2 untuk kandungan lembapan, limit cecair, beban titik dan pecahan aggregate kasar adalah 96.06%, 93.7%, 49.21% dan 92.74%. Komposisi SiO_2 dengan kekerasan 7 per 10 mengikut skala kekerasan Mohr berkurang, sekiranya kadar dan gred luluhawa bertambah. Konklusinya, gred luluhawa mempengaruhi dan memberi kesan terhadap sifat-sifat fizikal dan mekanikal batuan granit.

WEATHERING CLASSES IN RELATION TO PHYSICAL AND MECHANICAL PROPERTIES OF DECOMPOSED GRANITE

ABSTRACT

The main challenges in the study of slope stability, foundation, underground openings and excavation of rocks are by understanding the degree of weathering. The weathering profile at certain area are usually graded based on field observation, geological studies and material properties of the rocks. The research is on the decomposed granitic which are classified according to the degree of weathering and its properties. Based on earlier studies, decomposed granite is referring from grade II to grade V of weathering grade. This research focused on the relationship between the characteristics of weathering grade of granite and its properties. A series of physical and mechanical tests are carried out to identify the physical and mechanical properties of decomposed granite. The physical tests consist of the particle size distribution analysis, moisture content test, Atterberg limit test and specific gravity test which give result of 2.6 whereas mechanical test consist of direct shear test, point load test and aggregate crushing test. X-ray fluorescence (XRF) analysis are carried out to analyze the chemical composition in each weathering grade that significantly affect the properties of granite. The result from data analysis shows the correlation between the weathering grade of decomposed granite and as the weathering degree changes, the properties of granite changes. The R^2 coefficient for moisture content, liquid limit, point load index and aggregate crushing test was 96.06%, 93.7%, 49.21% and 92.74%. The composition of SiO_2 with hardness 7 out of 10 in Mohr hardness scale are decreased as the weathering rate of granite increase. To conclude, the weathering grade affected the physical and mechanical properties of granitic rock.

CHAPTER 1

INTRODUCTION

1.1 Project Description

The sample collected is located at Tanjung Rambutan which is a development area in Chemor district. The area is situated at North of Perak, Malaysia with coordinate of (4.666, 101.183). The studies mainly on the physical and mechanical properties of decomposed granite. Decomposed granite is a term used to define rock that has been weathered start from grade II to grade V.

Samples collected from the chosen area that represents different grades of weathering classes. The granitic rock properties identification will be primarily done during field work by observations before tested in laboratory. The sample collected is then tested in the laboratory to identify the physical and mechanical behavior of different grades of decomposed granite.

The weathering profile of rocks are the critical and important things need to be emphasized in every preliminary design and planning stages. Every profile has its own properties and need to be identified at the earlier stage to ensure the rock chosen is compatible with the application. The strength of the rock will determine the application and toughness of structure in geotechnical work.

1.2 Background of Study

Granite is a type of igneous rock that formed due to the cooling of molten rock underneath the Earth surface and the main components of typical igneous rocks are quartz, mica, feldspar and hornblende(Lu, 2002). Granite rock is very dominant in Peninsular Malaysia and that is why the Peninsular Malaysia is normally described as a land mass where intrusive core of solid granite is built. The granite located at three parallel belts in Peninsular Malaysia which is Western, Central and Eastern belts(Azman, 2008).

Granite displays a role as a full crystal grain structure with hard texture and uniform property. It can also withstand high compressive strength which in range of 120- 200 MPa. Granite surface easily cracks in the process of expansion and contraction due to the difference in expansion coefficient of quartz and feldspar almost doubled. Feldspar and mica exists joints, granite has three groups of primary joints and granite, commonly with coarse grain structure have high tendency to be weathered off easily(Wu, 2004).

Weathering happens when rocks are exposed to the atmospheric condition and slowly breaks down. It is a certain process of nature which will slowly alter rocks from its original with certain state to soil material. These changes will eventually change its engineering behavior(Gupta, 1998b). In some circumstances, the information collected by the geologist is not sufficient to predict the engineering behavior of rocks and rock masses. In general, rock behavior and rock masses are the physical, mechanical, hydraulic, thermal and in situ stress properties.

Weathering in rock is caused by physical disintegration, chemical decomposition affects and biological effects. Physical weathering is the physical breakup of a rock by mechanical processes before disintegration process take place. Disintegration happens

because of the physical or mechanical energy that acted upon the rocks either by abrasion, frost chattering, temperature drop and salt crystal growth(Ghiasi, 2009a). The process usually occurs close to the surface with the effect of wind, water and temperature.

Due to the different in physical and chemical properties of granite mineral composition, granite has been weathered in different degrees of weathering, and decomposed granitic soils are generally classified as weak weathering, weathering, strong weathering and residual(WCHEG, 2007). This research is focused on the decomposed granite which is a generic term of soils that belongs to grade II to grade V. The physical and mechanical features of weathered rock are affected by weathering condition and bed rock structures including the particle size(Kwon, 2011).

Decomposed granite soil properties to be differentiate from rock include the facts that it can be machine excavated and even though the appearance looks like a rock, it is decomposed during handling. To determine the behavior changes due to weathering process, test need to be conducted to evaluate the response of the rocks towards various kind of disturbance such as different atmospheric conditions including applied temperature that lead to the weathering process. Properties of decomposed granite are identified based on its physical and mechanical properties i.e. compaction and crushing ability, permeability and strength(Kwon, 2011).

Even though granite has high strength, other factors such as cracks, discontinuities and defects in granite itself need to be considered. The discontinuities will eventually affect the strength of the granitic rock and thus lead to failure. The failure of the structure is one of the failures in rock engineering project design. For weathered granite, each grade can be differentiating by a complete description and indication of material and mass features(Dearman, 1975).

1.3 Study area

The study area for this project is at the North of Perak. The location is situated at one of the town in Kinta district which is Chemor. It is located at 21 km from Ipoh North Exit Highway. Figure 1.1 shows location of the study area at latitude and longitude of (4.6663, 101.1828) and Figure 1.2 shows the photograph of the sample granite with various grade during field site.

Figure 1.1 Location of the study area

Figure 1.2 Photograph of weathered granite rock

1.4 Rock masses

A rock mass is a designed of system of rock blocks and fragments divided by the existence of discontinuities that form a material in which all elements in it act in mutual dependence as a unit. The material is identified by shape and measurements of rock blocks and fragments by their mutual arrangement within the rock mass, as well as by joint characteristics such as joint wall conditions and possible filling, as shown in Figure 1.3.

The complicated structure of rock mass with its defects and inhomogeneities cause challenges and problems in rock engineering and construction. The texture and mineral composition in the rocks will affect the rock strength.

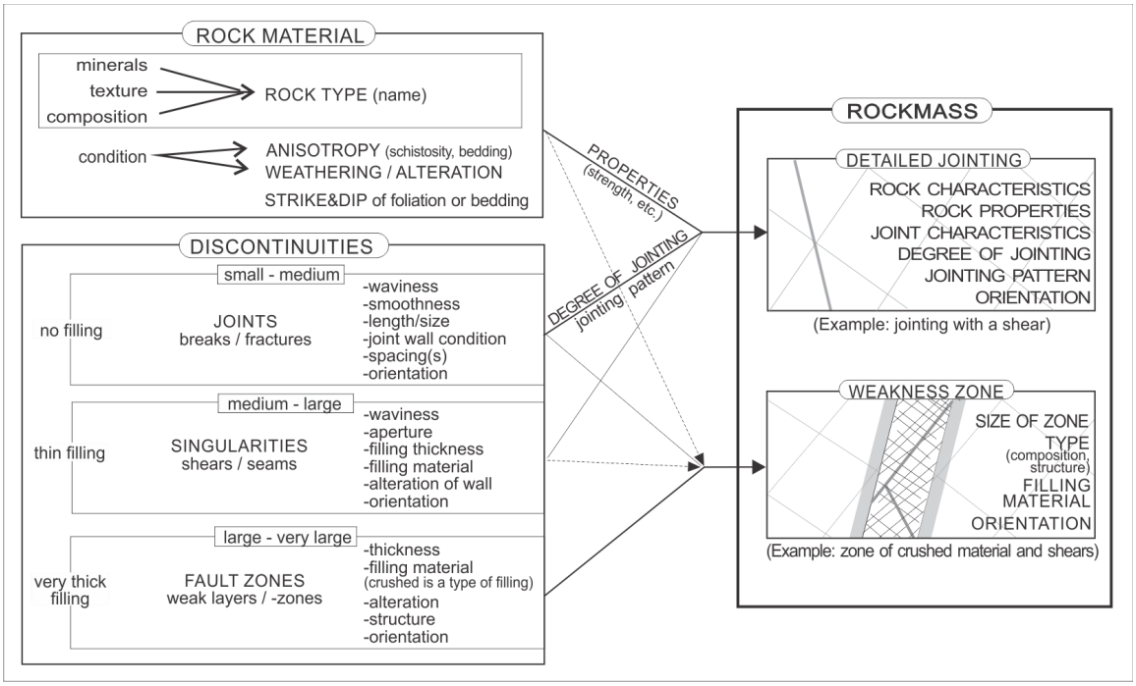

Figure 1.3 The main features constituting a rock mass

1.5 Problem Statement

Frequently, the collapse of tunnel, building, underground mining, cavern, dam andetc. occur due to the lack of attention to the properties of the rocks exist at that particular area. The collapses of these construction sites will cause trouble and nuisance to the people since many people die and injured when it happens. In addition, a lot of money needed to repair and fix the damage caused. Usually, the factor that caused the structure to collapse is because of the properties such as the discontinuities, strength and permeability of the rocks.

The properties of the rock depend on the weathering classes of the rock itself. Weathering classes of the rocks are divided into six levels which start from fresh rock, slightly weathered, moderately weathered, highly weathered, completely weathered, and residual soil. Each level might show different features of the rocks even though there are

very limited literature focusing on the relationship between weathering classes and the physical and mechanical properties of decomposed granite.

Based on the observations during field work, the existence and composition of the minerals in every level of weathering classes are different. Therefore, the test required to identify the physical and mechanical properties of the sample are different for every level of weathering classes of decomposed granite. The identification is needed to ensure the rock used suit the application.

The title that correlates the relation between the properties of the rocks and its weathering classes will be studied. The physical properties of decomposed granite that will be examined are particle size distribution, moisture content, porosity, specific gravity and permeability whereas for the mechanical properties, focusing more on the strength of the decomposed rock.

Physical properties and strength of the decomposed rocks are important to be identified because they will cause problems in design related to rock engineering projects, such as stability analyses of slopes and underground openings. Laboratory test will be done to prove that the weathering grade of granite affects the physical and mechanical properties. The weathering grade and properties of granite will help to determine the application of the rocks in real life.

1.6 Scope of Research

This thesis discussed on the decomposed granitic rock located at Chemor, Perak which represent different level of weathering grade. Throughout this research, the knowledge and assessment of geological engineering applied especially on rock mass

by site investigation and laboratory testing to identify the physical and mechanical properties of the rock mass itself.

Site investigation comprised a set of quantitative descriptions of geological condition which include the texture, color, minerals and hardness of soils and rock mass. Different description describes different weathering grade. Laboratory testing is mainly for the soil and rock recognition which includes rock mechanical and physical tests to correlate the result with the grade of weathering. This is to justify how it may affect each other and thus lead to different application depends on the requirement.

Sample of decomposed granite that shows different weathering grade were collected and tested in laboratory. Each grade has its own field identification description. During field work, by observing, the descriptions of the samples need to be written including the color, texture, mineral exist and location of the sample. The sample collected will be tested for their physical and mechanical properties such as particle size distribution, porosity, permeability, strength, etc. The correlation between the weathering grade and properties can be determined from the results from test.

1.7 Objectives

The physical and mechanical study of the decomposed granite is important to study the properties of the rocks after exposed to different level of weathering condition. The following are the objectives of conducting this research:

i. To study the characteristics of different weathering grades of decomposed granite rocks
ii. To determine the changes of physical and mechanical properties of decomposed granite

iii. To correlate the relationship between weathering grades and the physical and mechanical properties of decomposed granite

1.8 Outline of thesis

There are five main chapters contain in the thesis. The first chapter discuss mainly on the introduction on the project description, background of research and the objectives to achieve in the study. This is to ensure that we understood about the title on “Weathering classes in relation to physical and mechanical properties of decomposed granite” in Perak. Moreover, this chapter also contains the summarized of overview taken to finish the project given.

For the next chapter, chapter 2 is focusing more on the literature review where it is a critical part and need detailed evaluation on the previous research that related to the title. Literature review also can be a summary and synopsis of the research title. This chapter normally based on the previous studies and can be used to enhance the idea that relate with this topic. This chapter discussed about the geology of the granitic rock and their weathering classes and both physical and mechanical properties of each other.

The methodology or procedures in every laboratory testing are included in chapter 3. The procedures needed to study the physical and mechanical properties of the decomposed granite sample taken during work field. There are many tests conducted to identify the physical and mechanical properties of the rock such as moisture content, crushing test, specific gravity test, particle size analysis, etc. The results of each test for each weathering grade will be analyzed to relate with their properties and to correlate with each other. This chapter also includes the procedures taken to examine the composition of minerals in the rock by doing XRF.

In chapter 4, all the results will be presented and analyzed accordingly. The data present must be concise, clear and detailed. After that, discussion will be made to correlate the results with the objective of the project. The result will be analyzed and can be determine by plotting graph, calculation etc. In discussion, any new or unusual results must be explained and pointed out so that we can analyze the problems occur in this project.

The last chapter, chapter 5 will be the conclusion from the result of this research and future research will be suggested to study more about the problem related to this field. This is to enhance and improve the knowledge in engineering design study to develop new project related to the properties of the rock.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 discusses detailed on the previous studies related to this title. This chapter provides on understanding on the overall aspects of the research topic and explained on the geology of the granite rock in Malaysia and level of the weathering grade. The other aspects that will be discussed are the physical and mechanical properties of the granitic rock and the correlation between the physical and mechanical test result with the weathering grade of granitic rock.

In this project, the finding on the relationship between the strength, water content, plasticity and liquidity and the weathering grade of granite will be more useful for the industry to understand the behavior of this type of rock. This is because different mechanical properties of rock show different strength and quality of rock.

2.2 Geology of Study Area

Malaysia consists of a wide range of rock types, from the sands and silts of the coastal plains to the granite of the main range. Granite rock was chosen as type of rock to study because of its availability and easily be found in Peninsular Malaysia. Granite is the most well-known lithology due to the abundance amount and having outcrop over 40% of the land top. With that, they form the bedrock of the foremost mountain ranges

called Titiwangsa range and have been distinguished based on the mineralogy, geochemistry and radiometric ages (Vahid et al., 2009).

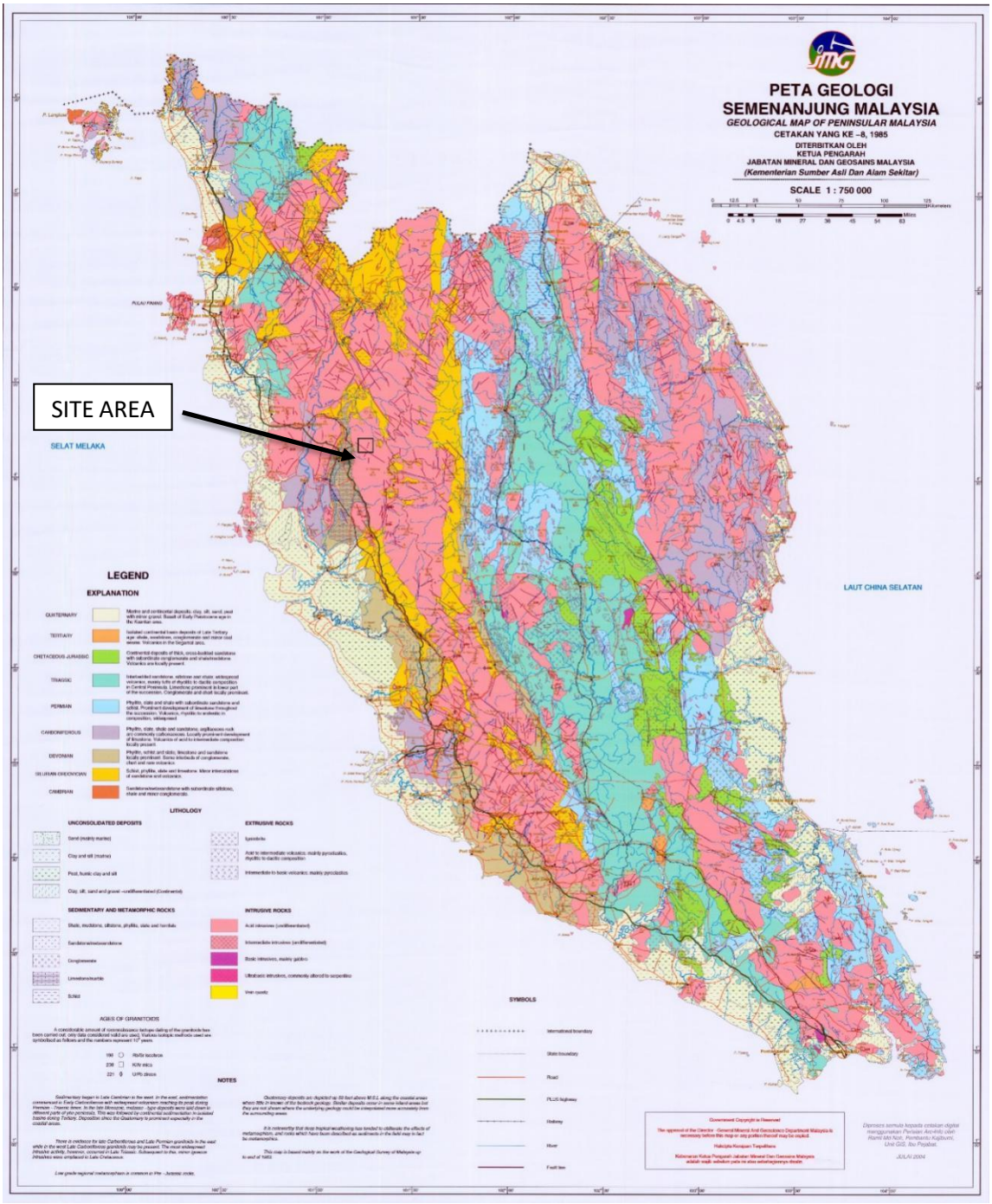

Figure 2.1 Geological map of Peninsular Malaysia

The study area was mapped in the geological map in Figure 2.1. The figure shows the general geological map of Peninsular Malaysia with different type of rocks i.e. igneous, sedimentary or metamorphic rock.

Peninsular Malaysia can be subdivided into four utmost tectonic regions which are the Western Stable Shelf, the Main Range Belt, the Central Graben and the Eastern Belt(Hutchison, 1977)**.** The Peninsular Malaysia granites have been classified into two granite regions called as Western and Eastern Belt of granite. The Western Belt granites of the Peninsular Malaysia cover from the Malacca in the south to Thailand in the north(Azman, 2000). The study area is part of the Western Main Range belt of Peninsular Malaysia that consist abundance of granitic rock.

2.3 Granite

Granite is a felsic intrusive igneous rock which having granular shape and phaneritic finish. Intrusive rocks are formed when the magma cool and solidify underneath the Earth's surface. Intrusive and extrusive rocks are described by their crystal sizes and intrusive rocks have larger and visible grain size compare to extrusive igneous rocks. This is because, when the magma cools at low speed and the cooling rate of intrusive rocks is longer, it permits the formation of larger and visible crystals. If the cooling rate is faster, the crystals growth is inhibited and thus, produces small crystals.

The visible crystals give the intrusive igneous rocks a phaneritic texture. Phaneritic texture means that the ability to be seen with naked eyes and by means of, it is possible to see the interlocking individual crystals between the rocks. These rocks mainly consist of feldspar, quartz, mica and amphibole minerals. Granite that consists of both muscovite and biotite micas is called binary or two-mica granite(Considine, 1995).

Figure 2.2 shows the mineral composition of common igneous rock for both intrusive and extrusive rock. From the figure, granites and rhyolites are having same

composition but the only difference is the grain size. Rhyolite solidifies on the Earth surface which cause the cooling process much faster thus produce smaller grain that are not visible to naked eyes.

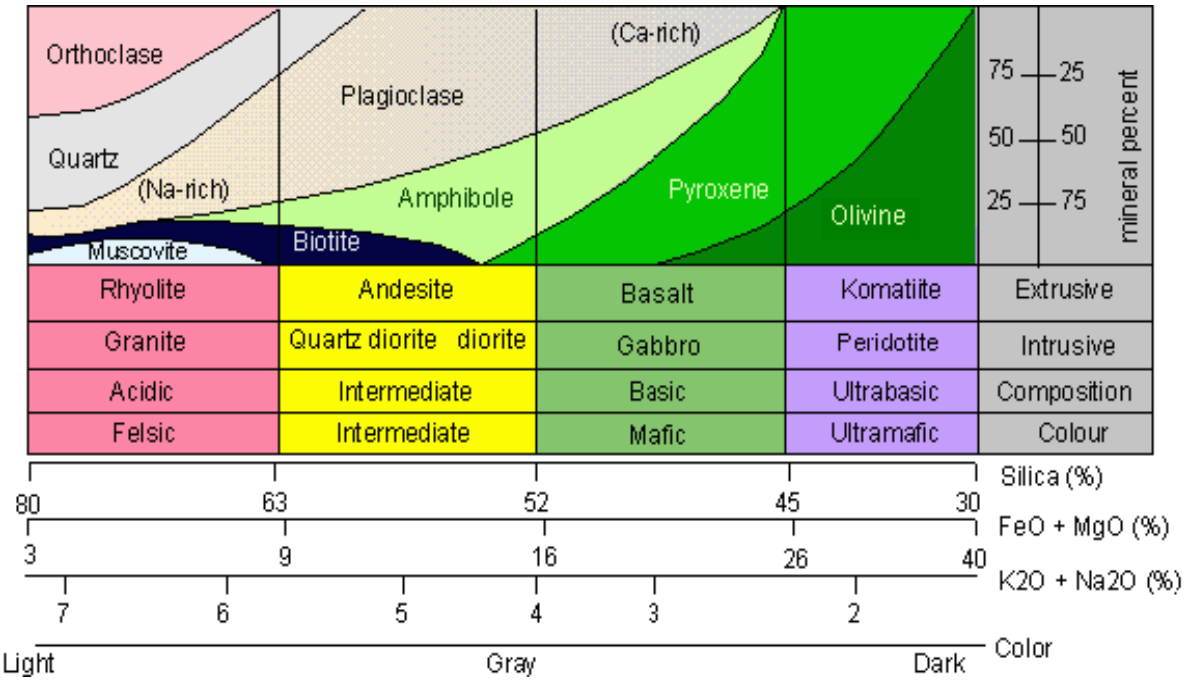

Figure 2.2 Mineral composition of igneous rocks

Based on figure 2.2, granite composed mainly of orthoclase, quartz, Na-plagioclase, muscovite, biotite and amphibole with highest amount of silica. Granite can be predominantly white, pink or gray in color. This depends on the degree on which basic rock mineralogy contaminated the granite magma(Keroher, 1966). The existence of Iron (II) Oxide and Magnesium Oxide in rocks contributes to the rock colors.

Average density of granite is in the range of 2.65-2.75 g/cm^3. It is always massive in size, hard and tough due to the existence of the silica minerals which having hardness of 7 based on Mohr hardness scale but the mechanical properties still depend on the weathering grade of the rock itself.

2.3.1 Mineralogy

Granite is an igneous rock with at least 20% quartz and up to 65% alkali feldspar by volume. Granite is a light-colored igneous rock with visible grains and formed from the slow crystallization of magma underneath Earth's surface. Granite composition is mainly quartz and feldspar with slight amounts of mica, amphiboles and other minerals. The presence of various mineral helps in determines the color of the rocks. Granite rock can exist in pink, gray, white with dark mineral grains visible on the surface of the rocks.

Granite is categorized according to the QAPF diagram for coarse grained igneous rocks as shown in Figure 2.3. It is named according to the percentage of quartz, alkali feldspar (orthoclase, sanidine, or microcline) and plagioclase feldspar on the half of the QAPF diagram, which is A-Q-P. True granite according to modern petrologic convention contain both plagioclase and alkali feldspars. When a granitoid is lack of plagioclase, the rock is referred to as alkali feldspar granite.

Figure 2.4 shows the photograph of granite that represent grade III of weathering taken from the site area. The grain size of the rock is medium to coarse grain and some of the individual crystals (phenocrysts) are larger than the groundmass and thus, called as porphyritic. Porphyritic surface exists when the rocks composed of minimum two minerals having clearly distinct in size. The rock in the photograph have been exposed to weathering, and caused the physical and mechanical features of the rock to differ.

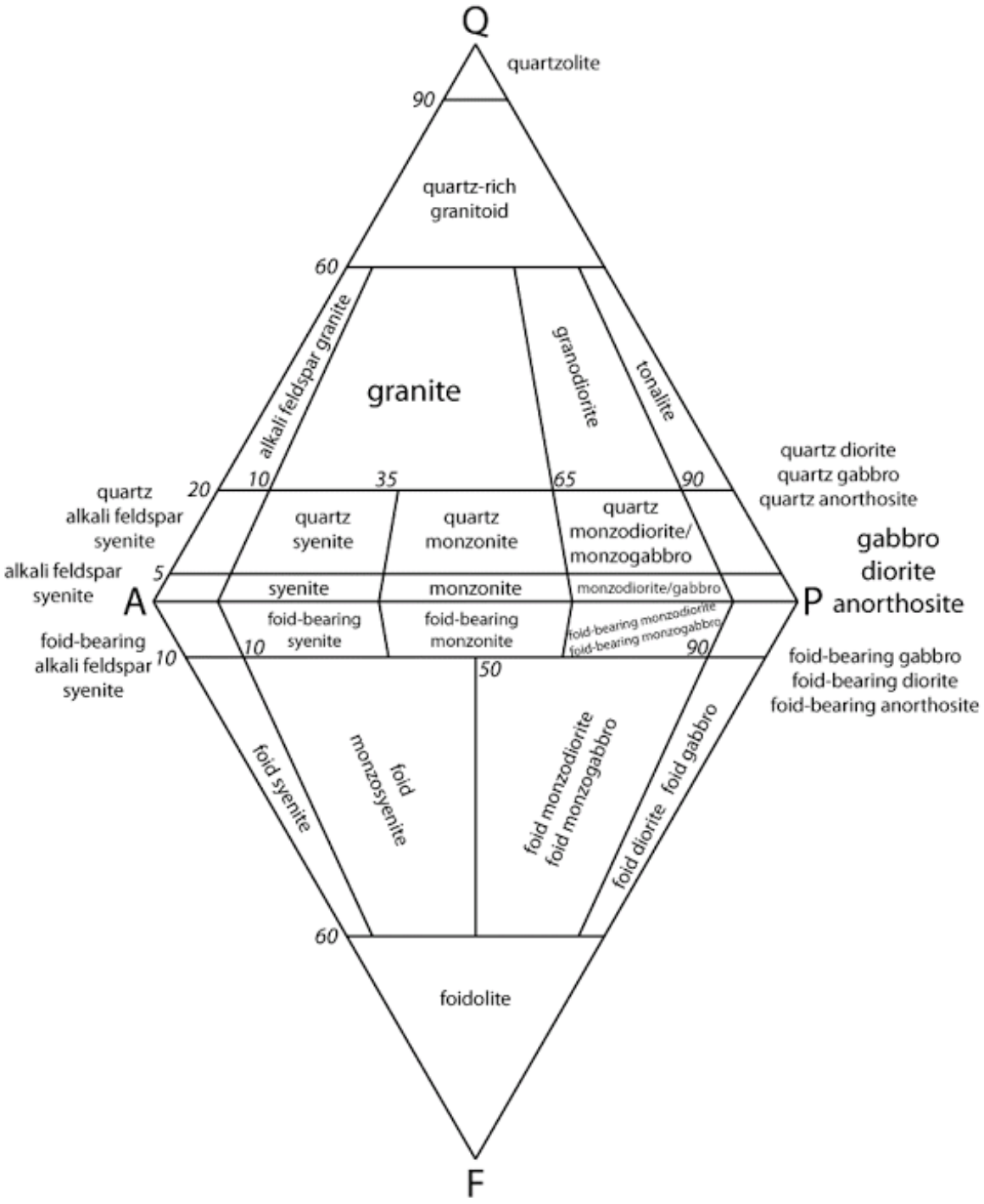

Figure 2.3 AQPF diagram for coarser grained plutonic rocks (Le Bas and Streckeisen, 1991)

Figure 2.4 Photograph of moderately weathered granite

All rocks are made up of minerals. Major mineral compositions of granite are quartz and feldspar with minor quantity of biotite and amphibole as accessory minerals. The type of mineral presence influences the color of the rock. If granite contain large amount of quartz and feldspar, the rock has high tendency to form pinkish to white in color.

2.3.2 Physical properties

The physical properties of the granitic rocks were determined by various methods such as by observing using naked eyes during field work and by laboratory tests. The common properties to be listed during observation are the color, size of the grain, the texture, minerals that can be seen clearly and the dip and strike of the sample location. All laboratory tests must follow accordingly to the procedure stated in ISRM (International Society for Rock Mechanics). Grain size for the decomposed granite soil can exist as

microcrystalline granite soil with some remaining bed rock that composed of mostly sandy soil and soil (Kwon, 2011)

For this study, physical properties of decomposed granite at weathering grade V behave like soil. So, properties of soil are determined by particle size distribution test, specific gravity and plastic and liquid limit and specific gravity. Test that have in common for rock and soil are the water content, X-ray fluorescence (XRF) and X-ray diffraction analysis to identify the composition exist in the sample. (Bhattarai, 2006)

2.3.3 Mechanical properties

Mechanical properties are very important parameters for geological engineering design and construction. These properties will determine the strength and toughness of the structure and how it is able to withstand huge force. However, it is important to determine the geometry and the mechanical properties of the rock mass of the fractures because it will relate to the mechanical weakness of the rock mass. The mechanical weakness gives significant impact on the deformability, strength and permeability that will lead to the failure of the engineering design.

The mechanical properties of the decomposed granitic rock were determined by laboratory tests according to the procedures in ISRM. For this study, the mechanical properties of the soil and rock are tested using different method of test. For soil, direct shear test is conducted to determine the shear strength of the soil whereas for rock, point load test. To conclude, drained simple shear test and drained ring shear test are to measure the strength characteristics. (Bhattarai, 2006)

Nevertheless, for soil and rock, they have one common in test that can be relatable to each other, which is crushing test. This entire test that will contribute in identifying the

strength of the rock mass will be really helpful in deciding the usefulness in certain application.

2.3.4 Correlation between rock properties to different weathering grade

The weathering grade has been related with the engineering properties and behaviors of rock. Chemical weathering caused the changes from hard minerals to softer as the rock structure loosens and thus affect the strength (Goel, 2015). Studies by (Santi, 2006) cited by (Goel, 2015) shows that different weathering grade has various properties of rock and thus affect the rock engineering application i.e. foundation, excavability, building material and slope stability. Properties that were affected by the weathering granite was point load index strength (MPa), moisture content, unconfined compressive strength (MPa),

2.4 Weathering

Weathering of rock is a natural phenomenon that will occur when rock is exposed to the Earth's surface. Rock will slowly break down under the influence of atmospheric and hydrospheric factors which act as weathering agent(Cabria, 2015). The agent can be wind, water, air, temperature and oxygen. Weathering that involved crystalline materials; normally result in the formation of voids, due to dissolution of certain mineral stages(Gupta, 1998a).

Generally, the process of weathering gives impact to the behavior of the rock. The rock is affected when the strength level drop and thus, becomes more plastic and permeable to weathering. Weathering of rock is affected by the weather changes, geographic environment, composition of source material, groundwater condition and

time span which weathering have been sparky(Ghiasi, 2009b). Not only that, the degree of weathering was influenced by the natures of bedrock, drain condition and the depth from the ground surface(Length, 2011). Climate, topography, joint spacing, orientation and behavior of parent rocks affect the speed of weathering progress (Rocchi, 2017)

Currently, the important challenges in the study of slope stability and excavation of rocks are to understand their weathering stages. Wrongly paired rock with their application will cause disruption and failure to the construction. Slope failures, landslides and soil erosion often affect areas that are exposed to weathering. This is because weathering activity affect the soil formation for provide and transport nutrient to plant for growth purpose. The growth plant helps to control the Earth's surface morphology for more stable environment (Arikan and Aydin, 2012). Weathering can be divided into two types; mechanical and chemical weathering. Every type of weathering is differentiated by the process and the reaction involved in the weathering process.

2.4.1 Mechanical weathering

Mechanical or physical weathering is a process for bed rock to be break down into smaller part due to climatic factors such as rainfall or winds. The disintegration process of rock is enhanced by exfoliation and slaking. Weathering process required physical forces to separate rocks apart without changing their composition. Mechanical weathering is the process that lead to the beginning of discontinuities by rock fractures or faults. Physical disintegration is frequently influenced by open fracture and nature of discontinuity (Baynes et al., 1978; Panthi, 2006; Hall et al., 2012) cited by (Firdaus, 2016)

The process of breaking the rock to a soil-like material required advanced stages of weathering (Arikan and Aydin, 2012) The discontinuity available in rock mass provides way for the water to infiltrate into the discontinuity, disintegration and decomposition of

the rock mass that convert into weathered rock (Twidale, 1982, 1986; Ehlmann et al., 2008; Velde and Meunier, 2008) cited by (Firdaus, 2016) Generally, factors that may contribute to the mechanical weathering are ice wedging or frost action, abrasion, exfoliation or unloading, thermal expansion and organic activity.

Smaller fragments of rock after being weathered will have the same properties as the parent rock. Based on readings, physical weathering is mostly because of the temperature and pressure changes. Ice wedging or frost action is the moment when the water starts to freeze in the cracks and pores of the crock. The ice will create expansion force that is strong enough to separate the rocks apart into small fragments(Kwon, 2011). Frost action activity has least potential to occur in Malaysia as Malaysia's climate is equatorial, hot, humid and rainy throughout the year without extreme cold temperature.

Abrasion is the easiest weathering activity as it is just involved rubbing of one object or surface against another such as the force of moving water. The water sources can be from rainfall, river and ocean waves. As the rainfall goes down the hill, the forces can help to wear away the particles of rocks thus, separate it into fragments. This cause the rock fragments to tumble downstream and hit each other. As they grind with each other, the tendency for the fragments to have angular shape is high.

Thermal expansion is activity that related to rapid cooling and heating of rocks. It is a break down process by expansion and contraction due to the changes in temperature. Rock will expand when exposed to high temperature and start to contract when the temperature drops. This continuous process of expansion and contraction will eventually weaken the rock and cause the rock to fracture.

2.4.2 Chemical weathering

Chemical weathering is one of the type of weathering that involve the alteration of mineral by either addition or removal of elements. It is totally different with mechanical weathering as it totally changed the composition and properties of the rock due to the action of the chemical agents. Chemical weathering is suitable and preferable in humid subtropical and tropical regions like Hong Kong, Malaysia and Brazil because the effect of weathering can be clearly seen to the rocks in these areas(Chiu, 2014).

Chemical weathering changed the properties of parent rock by produce new minerals. It involve decomposition of minerals through solution, hydration, carbonation and oxidation (Firdaus, 2016). The process happened when the rocks are exposed to the atmospheric conditions at or near the surface. The parent rocks react with the component in the air to form new minerals. The common atmospheric reactants are oxygen, carbon dioxide and water but during air pollution or when the Air Quality Index (AQI) are in extreme and hazardous level, sulphur dioxide and nitrogen oxide may involve.

When minerals in rocks are in contact with air and water, the minerals have high tendency to dissolve and react to form different minerals. Smaller particle sizes are more exposed to chemical weathering compare to large particle size due to the larger surface area. Chemical weathering is mostly influenced by the climate changes, living organism, time and mineral composition of rocks.

Hydrolysis is the reaction between acidic solutions and silicate minerals to form kaolinite. The Feldspar reacts with hydrogen ions to form products such as clay mineral. Silicate minerals that are unstable at the Earth’s surface will weathered to form minerals

that are more stable such as clay. Generally, feldspar weathered to produce clay minerals as in this equation:

$$2KAlSi_3O_8 + 3H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 4SiO_2 + 2K(OH)$$

Dissolution is the reaction where a mineral completely dissolves during weathering but still depends on the solubility of the rock minerals. For example, carbonate minerals are less soluble compare to evaporate minerals. Salt and gypsum which act as evaporate minerals tends to dissolve quickly in water. This activity is very common in limestone areas. Limestone can be dissolved when react with meteoritic water which contain dissolved carbon dioxide and lead to the formation of cavities.

Not only cavities, this activity will lead to larger scope of geologic hazards called sinkholes and karts. Underground cavities can also be formed in gypsum due to its large solubility(Brune, 1965). Dissolution equation where water, carbon dioxide and limestone will react and dissolve into calcium ion and bicarbonate ion:

$$H_2O + CO_2 + CaCO_3 \text{ --> } Ca^{+2} + 2HCO_3^-$$

Oxidation or rusting is the reaction that involved free oxygen with metallic elements. Generally, regular minerals contain iron and when the minerals react when dissolve in water with the presence of oxygen in the air, the iron will eventually form iron oxides or rust. It happened when the iron atoms contained in the minerals lose one or more electrons and precipitate as different minerals or amorphous substances. Equation of oxidation shows the reaction between ferrous iron and oxygen will form ferric iron oxide or hematite:

$$4Fe^{+2} + 3O_2 \text{ --> } 2Fe_2O_3$$

2.4.3 Classification of weathering

Weathering in general is the process which brings about several changes to the properties of rock due to the exposure to the physical and chemical environment. Weathering activity has been classified into six different grades depends on the rock strength, swelling potential, slaking index, compressibility, consolidation characteristics, etc. The six weathering grades are classified from grade I to VI which is I: fresh, II: slightly weathered, III: moderately weathered, IV: highly weathered, V: completely weathered, VI: residual soil.

Different weathered rocks are for different applications and usage. Classifying rock at site to their weathering grade are very challenging and tough task. This is because it is quite unpredictable and does not have any calculation method to refer (Patel, 2017) Researchers, engineering and geologist must put more attempt in classifying the weathered level and the effect on rock mass engineering properties. Based on the weathering grade, rock and soils are divided into fresh rock, slightly weathered, moderately weathered, highly weathered rock and residual soil.(Kwon, 2011).

On material scale, grade I to IV represent rock properties, whereas based on the soil mechanic principle, grade V and VI are classified as soil. In rock mass scale, grade I and II are rocks, grades III and IV are rock soil, and grades V and VI are soil. The chief engineering geological description in this dissimilarity was based on the visual identification of mineral alteration, rock and soil proportion, existence of original texture, joint staining, degree of discoloration, and a number of simple index tests proposed by ISRM cited by (Arikan and Aydin, 2012).

Table 2.1 summarizes the weathering classification system for granite and volcanic rock. The strength of the weathered rock varies widely and is unpredictable, especially