SHEAR STRENGTH STUDIES OF KUANTAN BAUXITE

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May Allah S.W.T the Almighty accept this humble contribution to knowledge, Amin.

ABSTRACT

Soil investigation is an important step in Civil Engineering, especially in construction of buildings. One of the soil investigations is determining the shear strength of the soil, where shear strength of soil is important in determining the condition of the soil. It is also important in determining the designing of the foundation structure for building. For this study, Unconsolidated Undrained (UU) Triaxial Test was conducted to measure the displacement and the strength of soil. This study also examines the suitability of the soil as foundation for development purposed. From the test, soil deviator stress, number of stress applied and soil type are considered. From the results obtained from testing that were carried out, parameter of the shear strength, cohesion ("c") and friction angle ("φ") can be determined from Mohr Circle. From the parameter obtained, the value of the bearing capacity can be calculated and used for foundation construction.

ABSTRAK

Penyiasatan tanah merupakan langkah penting dalam Kejuruteraan Awam, terutama dalam pembinaan bangunan. Salah satu penyiasatan tanah ialah menentukan kekuatan ricih tanah, di mana kekuatan ricih tanah adalah penting dalam menentukan keadaan tanah. Ia juga penting dalam menentukan reka bentuk struktur asas untuk bangunan. Untuk kajian ini, Ujian Tiga Paksi Tidak Terkonsolidasi Tidak Tersalir (UU) telah dijalankan untuk mengukur anjakan dan kekuatan tanah. Kajian ini juga mengkaji kesesuaian tanah sebagai asas untuk tujuan pembangunan. Dari ujian, tekanan penyimpangan tanah, bilangan tekanan yang dikenakan dan jenis tanah dipertimbangkan. Dari hasil yang diperoleh daripada ujian yang dijalankan, parameter kekuatan ricih, perpaduan ("c") dan sudut geseran ("φ") boleh ditentukan dari Bulatan Mohr. Daripada parameter yang diperolehi, nilai kapasiti galas dapat dikira dan digunakan untuk pembinaan asas.

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LIST OF SYMBOLS

M_S	Moisture Loss
M_{SL}	Mass of Wet Soil and Container
M_{DSL}	Mass of Dry Soil and Container
M_D	Mass of Dry Soil
M_{DL}	Mass of Container
w	Water/Moisture Content
ε	Strain
L_0	Original Specimen Length
ΔL	Deformation of Soil
A_0	Cross Sectional Area of Sample
d	Diameter of Sample
A'	Corrected Area
S_C	Specimen Stress
P	Load Applied
q_u	Ultimate Load
σ_3	Confining Stress
$(\sigma_1 - \sigma_3)$	Peak Different Stress
c	Cohesion
φ	Friction Angle

LIST OF EQUATIONS

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Bauxite is commonly used ore for the production of aluminium. It is a type of rock, usually red in colour, formed from reddish clay soil called laterite soil. Most of the bauxite can be found in tropic region in between 30 degree north and 30 degree south from equator (Gore, 2015). Bauxite is a primary source of aluminium, where 75% of the aluminium worldwide was extracted from bauxite ore. Bauxite comprising chiefly of hydrated aluminium oxides or gibbsite ($Al\ (OH)_3$), boehmite (γ-AlO (OH)) and diaspore (AlO (OH)), including some impurities in form of silica, clay, silt and iron oxides. Mineralogically, bauxite may be classified based on its predominant alumina minerals into 5 types such as pure gibbsitic bauxite, gibbsitic bauxite containing quartz, mixed gibbsitic-boehmite bauxite, boehmitic bauxite, and diasporic bauxite.

Most of the bauxite that used in world was exported from mineral-rich countries such as Australia, Brazil, China, and India. In 2015, world production of bauxite was higher than previous year where mine productions of 299 Mt total was reported from 30 countries. The leading producers of bauxite were, in decreasing order of tonnage mined, Australia, China, Brazil, Malaysia, India, Guinea, and Jamaica. These countries accounted for 91% of total world production; Australia and China together accounted for 49% of the world's production. In 2014, Malaysia accounted for only 1% of total world production of bauxite, but it increased production in 2015 by more than 850% (31.3 Mt) and was the fourth leading producer (12%) (United States Geological Survey, 2016). Table 1.1 shows the world production of bauxite by country with its value for year 2015.

Table 1.1 World productions of bauxite by country and its value for year 2015.

BAUXITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2011	2012	2013	2014	2015
Australia	69,976	76,282	81,109	78,633	80,910
Bosnia and Herzegovina	686 [r]	800	657 [r]	605 [r]	787
Brazil	33,625	34,988 [r]	33,896 [r]	36,308 [r]	37,057
China[e]	45,000	47,000	50,400 [r]	59,200 [r]	65,000
Dominican Republic	--	11	770	1,446 [r]	1,724
Fiji	50	300	460	376	250 [e]
Ghana	236 [r]	710 [r]	817 [r]	906 [r]	1,026
Greece	2,324	1,816	1,844 [r]	1,873 [r]	1,832
Guinea[4]	15,696	16,041	16,887 [r]	17,258 [r]	16,303
Guyana[4]	1,818	2,210	1,649	1,602	1,500 [e]
Hungary	155 [r]	144 [r]	94 [r]	14 [r]	8
India	13,000 [r]	15,300 [r]	20,420 [r]	22,580 [r]	27,064
Indonesia	40,644	31,443	57,024 [r]	2,555	202
Iran	847 [r]	892 [r]	789 [r]	931 [r]	900 [e]
Jamaica[4, 5]	10,189	9,339	9,435	9,677	9,629
Kazakhstan	5,495	5,170	5,192	4,516 [r]	4,683
Malaysia	183 [r]	122	209	3,665 [r]	35,000 [e]
Mexico[6]	14	96	--	--	-- [e]
Montenegro	159 [r]	--	61 [r]	155 [r]	50
Mozambique	10	8	7 [r]	3 [r]	5 [e]
Pakistan[e]	9 [r]	30 [3]	27 [r, 3]	30	31
Russia	5,943	5,700 [r]	6,028 [r]	6,293 [r]	5,900
Saudi Arabia[6]	206 [r]	760 [r]	1,044 [r]	1,965 [r]	2,397
Sierra Leone	1,300	776	616	1,161	1,334
Solomon Islands	--	--	--	--	270
Suriname	3,236	2,873 [r]	2,706 [r]	2,708 [r]	1,600
Tanzania	38	59 [r]	33 [r]	26 [r]	26 [e]
Turkey	1,025	1,521 [r]	796 [r]	1,091 [r]	1,100 [e]
United States	W	W	W	W	W
Venezuela	2,455	2,286	2,341 [r]	2,346 [r]	992
Vietnam[e]	100	100	482 [3]	1,090 [3]	1,150
Total	254,000	257,000 [r]	296,000 [r]	259,000 [r]	299,000 [e]

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes data available through May 12, 2017.

[3]Reported figure.

[4]Dry bauxite equivalent of crude ore.

[5]Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.

[6]Includes low-grade bauxite consumed for nonmetallurgical uses.

In Malaysia, the exploitation of bauxite mining starts to rise after government of Indonesia has ban the exportation of bauxite and other unprocessed mineral ores in 2014 . The export ban was part of the 2009 Mining Law and was intended by government of Indonesia to increase the economic development in the country through investment in mineral processing facilities. Several foreign companies have invested in alumina refineries in Indonesia (Yee, 2014). The export ban causing sudden increase demand of mineral resources by manufactures country, especially from China. To fill the demand, Malaysia has increase the production of bauxite ore in 2014 by approximately 3,445 thousand metric tons and reach highest peak in 2015 by approximately 35,000 thousand metric tons.

The sudden outburst of mining gives negative impact on surrounding environment around the mining site. There are much pollution caused by bauxite industries such as air pollution, water pollution and sound pollution. The processing of bauxite caused red dust to cover all the nearby roads, vehicles, and may cause hazard to resident and other living organism that stays nearby the plant. The river nearby the mining site becomes full of red mud, causing the river become cloudy and totally useless for cleaning purposes. These problems caused Malaysia government to declare a temporary ban on mining aluminium at the end of 2015.

1.2 Problem Statement

As Kuantan is a city of state of Pahang, it experiences rapid development, causing many engineering structures need to be built. Engineering structures such as manufacturing factories need to be built to increase the manufacturing activities, causing increasing of demands for residential area for workers which lead to insufficient land to be used for development.

To overcome the problem, new land area must be proposed to fulfil the needs. Unusable land such as abandoned mining site around Kuantan can be one of proposed land that can be used for development.

Before the construction begins, the soil must be verified its integrity as foundation for the structure. In order to verify the integrity of the soil, a series of test must be performed to ensure whether the bauxite-rich site is suitable for engineering application or not especially shear strength of the soil. Figure 1.1 shows the simple diagram which the soil is failed in shear strength.

Therefore, due to the stated above problem, this study is carried out to investigate the engineering properties especially the shear strength of the soil that originated from bauxite deposit in Kuantan area.

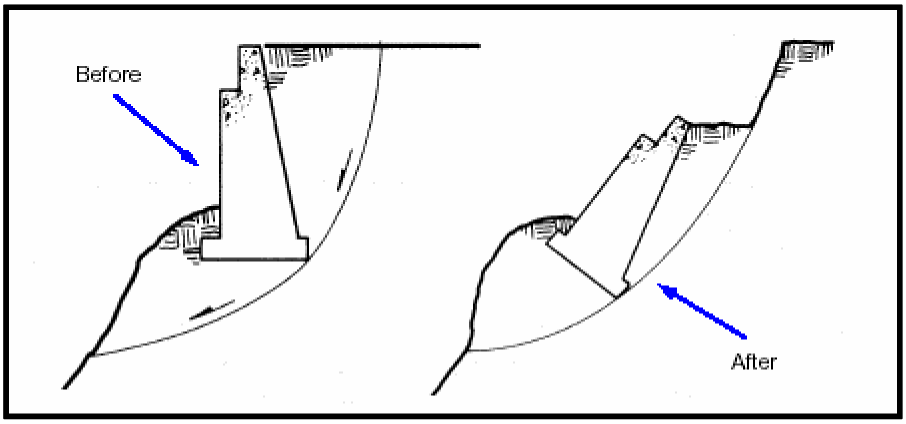

Figure 1.1 Failure of soil due to lack of shear strength

1.3 Objective of Study

The objective of this study is to investigate the shear strength of the bauxite deposit with their value by determine the undrained shear strength of Kuantan bauxite. Another objective is to determine the suitability of the soil as foundation for development purposed.

1.4 Scope of Study

In order to conduct this study, soil samples from three sites will be collected from Bukit Goh, Indera Mahkota and Semambu (Figure 1.2). The samples will be collected by simply dig the soil around the site and will be bought back to laboratory.

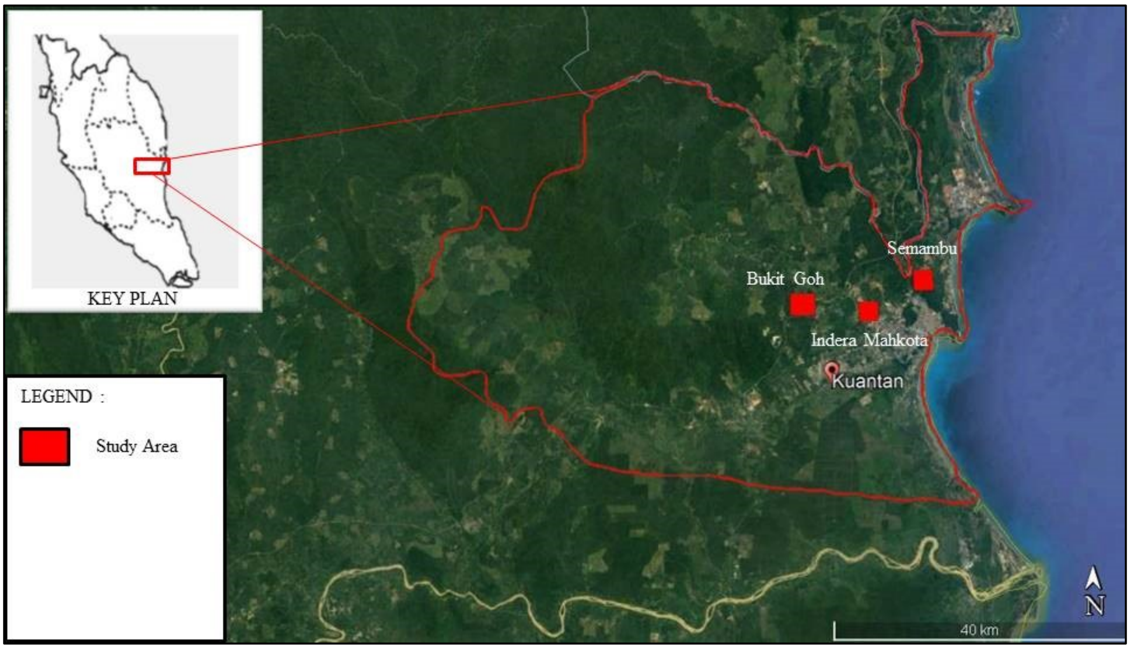

Figure 1.2 Location of study area

For lab test, various tests will be conducted to determine the shear strength of soil. Test such as Undrained Unconsolidated Test (Triaxial test) will be conducted in order to determine the shear strength of soil.

The result of the test will determine whether the shear strength of soil is suitable for development proposed or not and the mode of failure for the soil.

1.5 Significant of Study

The importance of this study is to determine the suitability of the soil whether the soil of Kuantan bauxite is suitable as the foundation of engineering structures or not. The study also significant in order to predict how the soil failing.

Undrained Compression Test (UU Test) is used to determine the shear strength of cohesive soil, where it can predict the mode of failure of the soil especially on a slope area where the shear strength plays major role.

1.6 Layout of Thesis

From Chapter 1, the topic will discuss about the background of study, problem statement, objectives of study, scope of study, and the significant of study that will be conducted. From the chapter, can know about what will be studied by student.

In chapter 2, the topic will touch on the history of bauxite and its general characteristics. The topic also discuss on the shear strength of the bauxite.

For chapter 3, the topic will focussed on the method that will be used to conduct the test and their procedure by detail.

In chapter 4, the topic will discuss on the result obtained from the tests conducted for this study. The topic also discuss on the parameter that can be obtained from the result.

In chapter 5, the topic will be the conclusion of the study and the recommendation that can be used for further study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses about shear strength of bauxite soil deposit and its component from the previous studies and from the conceptual knowledge.

Before conducting the study, various past journals from other researchers were reviewed in order to grasp brief idea and methods on how to conduct the study and what will be gained from the study.

2.2 Bauxite

Bauxite is a type of rock that primarily mined in global to get aluminium. Named after a village of Les Baux-de-Provence in southern France, it was firstly discovered in 1821 by French geologist, Pierre Berthier at the village of Les Baux (Authier-Martin et al. 2001). The name of “Bauxite” was used after a French chemist, Henri Rouvére name the rock in 1861.

2.2.1 Definition

Bauxite is an amorphous, clayey rock containing aluminium hydroxide which is the principle ore of aluminium. The amorphous rock of bauxite consists of largely hydrated alumina with variable proportions of iron oxides. Generally, bauxite does not have specific composition. It is mainly the combination of hydrous aluminium oxides, aluminium hydroxides, clay minerals and insoluble materials namely quartz, hematite, magnetite, siderite and goethite. The aluminium minerals in bauxites includes gibbsite Al(OH)3, boehmite γ-AlO(OH) and diaspora α-AlO(OH).(Akademi Sains Malaysia, 2017). Bauxite can be categorized in 2 different types, which are lateritic bauxite and karst bauxite.

Lateritic bauxites, or more popularly known as silicate bauxites, occur predominantly above carbonate rocks namely limestone and dolomite. Lateritic bauxite is formed by lateritic weathering and residual accumulation of intercalated clay layers. Lateritic bauxites are found mainly in tropical countries. The lateritic bauxites are formed through lateritization of various silicate rocks namely granite, gneiss, basalt, syenite and shale. The formation of bauxites depends mainly on the intensity of weathering conditions in location which have good drainage. Good drainage and high intensity of weathering conditions enable the dissolution of kaolinite and the precipitation of gibbsite. High aluminium content can be located below a ferruginous surface layer. The aluminium hydroxide in lateritic bauxite deposits is mainly gibbsite (Akademi Sains Malaysia, 2017).

Karst bauxite is a type of bauxite that occurs in paleokarst depressions as accumulation of clayey material within carbonate sequences. Karst bauxite tends to have dark colour ranging from black to grey in colour, admixed with organic matters and chemically reduced minerals such as pyrite (Pajović, 2009).

Most of the bauxite can be found in tropic region, which is between 30 degree north and 30 degree south from equator. Figure 2.1 shows the distribution of bauxite deposit around the world and what type of bauxite formed at the location.

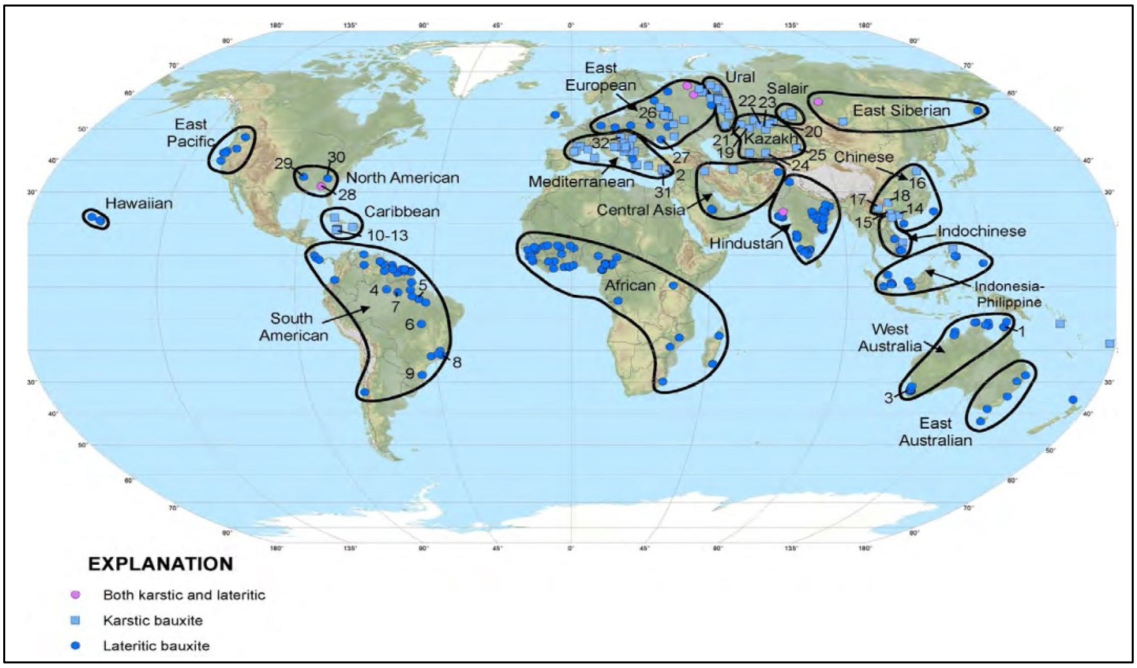

Figure 2.1: Distribution of bauxite deposits around the world (Schulte & Foley, 2014).

2.2.2 Physical Properties of Bauxite

Bauxite is typically soft with the Mohs Hardness of Bauxite ranging from 1-4. The colour of bauxite is white, grey, sometimes stained yellow, orange, red, pink, or brown, which is varies according to its mineral content. Bauxite is also opaque, earthly luster and has relatively low specific gravity that ranging from 2-5(International Aluminium Institute, 2014). The physical properties of bauxite can be referred in Table 2.1.

Table 2.1: The physical properties of bauxite. (International Aluminium Institute, 2014)

Properties	Description
Colour	White, grey, sometimes stained yellow, orange, red, pink, or brown
Streak	Usually white, but iron stain can be discolour
Luster	Dull, earthy
Diaphaneity	Opaque
Cleavage	None
Mohs Hardness	1 – 4
Specific Gravity	2 – 5
Diagnostic	Often exhibit pisolitic structure; colour

Properties	
Chemical Composition	Variable but always rich in aluminium oxides and aluminium hydroxides
Crystal System	n/a
Uses	Primary ore of aluminium, also used as an abrasive

2.3 Shear Strength

Shear strength of soil is the internal resistance per unit area that the soil mass can offer to resist failure and sliding along any plane inside it. The shearing resistance is important in order to analyse soil stability problems such as bearing capacity, slope stability, and lateral pressure on earth retaining structures. The parameter of the shear strength, cohesion ("c") and friction angle ("φ") are crucial properties in designing an engineering structure (Hajdarwish et. al., 2013).

In 1990, Mohr presented a theory for rupture in materials that contended that a material fails because of a critical combination of normal stress and shearing stress, and not from either maximum normal or shear stress alone. Thus, the relationship between normal stress and shear stress on a failure plane is expressed into equation below.

$$\tau_f = f(\sigma) \qquad 2.1$$

The equation then revised as it is sufficient to approximate the shear stress on the failure plane as linear function of the normal stress, thus precede equation 2.2 that called as Mohr-Coulomb failure criterion. Figure 2.2 shows the Mohr – Coulomb failure criterion graphically.

$$\tau_f = c + \sigma \tan \varphi \qquad 2.2$$

Where c = cohesion

φ = angle of internal friction

σ = normal stress on the failure plane

τ = shear strength

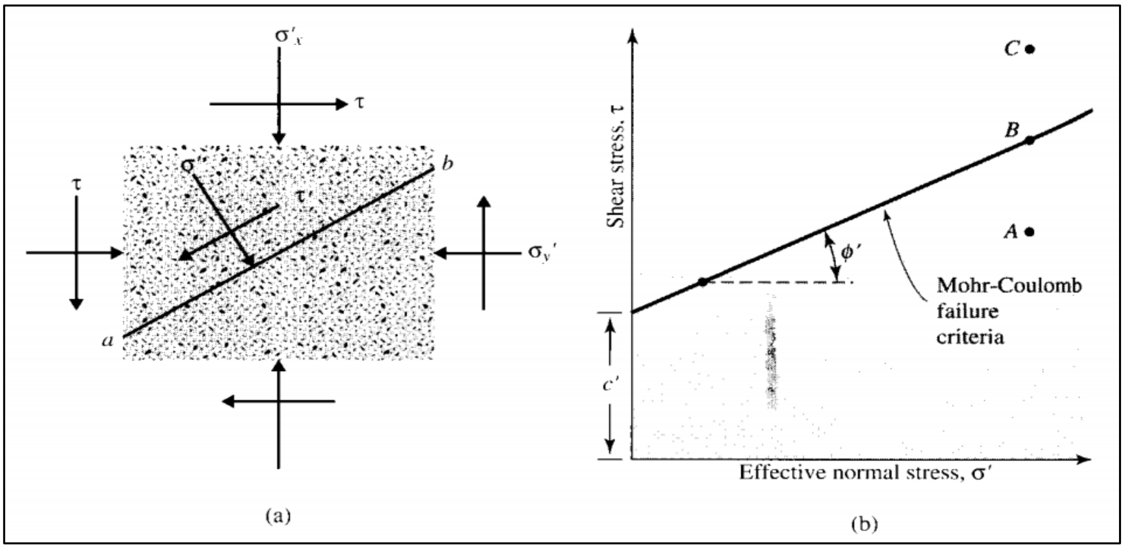

Figure 2.2: Mohr-Coulomb failure criterion

2.3.1 Failure of the Shear strength

The failure of shear strength in soil can influences the soil to undergo liquefaction. According to Hasan et al. (2018) stated that liquefaction occurs when the shear strength of the soil decrease and become to zero. Liquefaction, which usually occurred in ground due to increase in pore water pressure in the sandy soils and the loose saturated layers at the time of seismic movement which happens because of the tendency of the soil to lose volume, leads to decrease of the comprehensive tension of the soil.

According to Janulikova (2015), the high deformation on the material means that the material is more pliant and a small shear resistance arises in the sliding joint, which then the smaller deformation occurs means the shear resistance of the material is high.

Yoshida et al. (1991) reported that both angle of friction and cohesion tend to decrease with increasing degree of saturation, which is can lead to landslides. Figure 2.3 and 2.4 shows the consequences when the shear strength of the soil is fail.

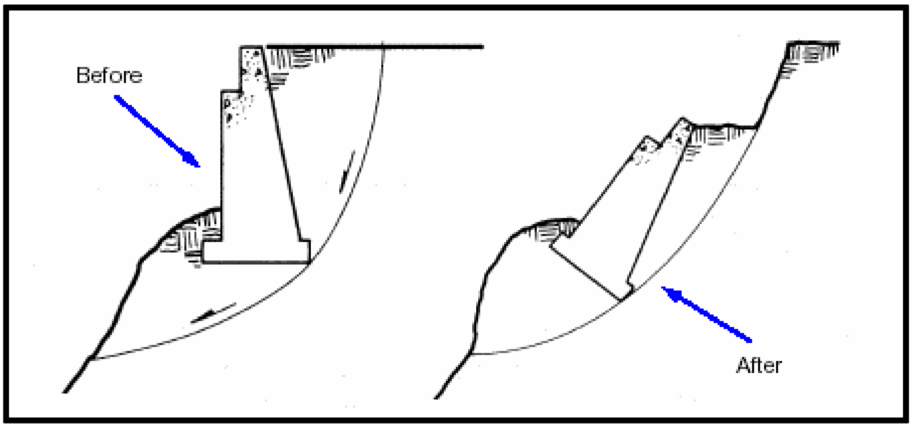

Figure 2.3 Fail of shear resistance at slope

Figure 2.4: The erosion caused by shear strength fail.

According to Terzaghi (2007) and Vesic (2003), the mode of failure of the soil under shallow foundation can be categorised into general shear failure, local shear failure and punching shear failure. Figure 2.5 shows the failure mechanism for the soil under shallow foundation.

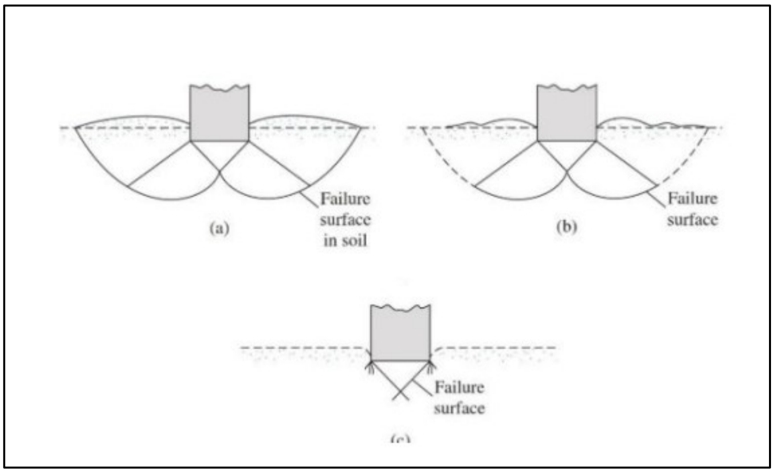

Figure 2.5: The failure mechanism of soil under shallow foundation; (a) general shear failure, (b) local shear failure, (c) punching shear failure

2.3.2 Shear Strength of Bauxite Soil Deposit

Many researchers have conducted studies related to the shear strength of bauxite. Among them are researching on the shear strength differences between bauxite and other soil samples. Also, there are some of the researchers focussing on the shear strength of bauxite residue.

Newson et al. (2006) have studied on the effect of structure on the geotechnical properties of bauxite residue. They suggested that the undrained shear strengths of the residue are lower than the clays with similar plasticity and moisture content.

Based on previous study, the average friction angle ("φ") of the bauxite is ranged between 27 – 46 (Newson et al., 2006; Nikraz et. al., 2007). Apparent cohesion ("c") for the bauxite is ranged between 1.6 lb/in^2 to 4.2 lb/in^2 (Deelwal et. al., 2014; Kola and Kumardas, 2013; Shahin et. al., 2011). From previous study by Bumij (2015), the apparent cohesion for the soil is 27.95 kPa with friction angle ("φ") of 33.2°. Based on studies by Nikraz et al. (2007), the effect of the carbonite treatment at one Alcoa plant in Australia had the strength properties of as its pertained to drying stacking, and further explained of reported friction angles and stated that the friction range ("φ") of 37° - 46° recorded on the untreated bauxite residue.

P. Wang and D. Liu (2012) have studied about bauxite residue and concluded the sintering bauxite residue has higher shear strength than Bayer bauxite residue although the particle of Bayer residue is finer and more disperse. This is due to Bayer bauxite residue has higher value of water content while Sintering bauxite residue has higher hydraulic conductivity.

From his studies, M. Gore (2015) reported that the bauxite has proper strength to resist liquefaction under normal stress up to 50 lb/in^2 when in compacted state. He also concluded that the past slide incident caused by liquefaction of bauxite due to its relatively high void ratio.

2.3.3 Gap of Studies

From the literature review, it can be seen that most of the researchers only studies on the properties and the strength of the bauxite residue, means there are lack of information regarding the properties and the strength of the bauxite deposits. Table 2.2 shows the summary of the previous study, the differences between this study and the previous studies are highlighted.

From the Table 2.2, the gap of study between the previous researches and this research is that the previous study focussed on the shear strength of the residual bauxite while this study emphasise on the shear strength of bauxite deposit. The previous researches mostly correlated with the environmental problems. Different with the current study that investigate the bauxite deposit use for engineering purposes such as a foundation soil therefore this study on shear strength is important to be conducted.

Table 2.2: The gap of studies by previous researchers

Author	Year	Title	Remarks/Finding
Newson, Tim; Dyer, Tom; Adam, Chris; Sharp, Sandra	2006	Effect of Structure on the Geotechnical Properties of Bauxite Residue	Comparison of the undrained shear strengths of the red mud with clays of similar plasticity and moisture content suggest that the shear strength should be much lower.
Gore, M. S.	2015	Geotechnical Characterization of Bauxite Residue (Red Mud)	In term of shear strength, bauxite residue has higher strength parameter (effective friction angle in near mid-30° range).
Hassan, M; Faez, A. A; Mosqud, M. A; Tam, W. L; Phang, B. Y.	2018	Geotechnical Properties of Raw and Processed Bauxite from Bukit Goh, Kuantan, Pahang	Bauxite samples collected from Bukit Goh mine are distributed sample; hence the tendency for this sample to liquefy is higher than undisturbed soil because of the shear force of anti-liquefaction of undisturbed soil is 1.5 to 2 times greater than disturbed soil.
Ping, W; Dong-Yan, L.	2012	Physical and Chemical Properties of Sintering Red Mud and Bayer Red Mud and the Implications for Beneficial Utilization	Shear strength of two kinds of red mud was tested on a DigiShear™ (Trautwein, CA, USA) multi-functional direct shear testing system.
Current Studies (Syahmi Syafiq)	**2018**	**Shear Strength Studies of Kuantan Bauxite**	**The study will focus and compare the shear strength of bauxite soil deposit between 3 location in Kuantan**

CHAPTER 3

RESEARCH AND METHODOLOGY

3.1 Introduction

This section of research report is about the process and methods to determine the shear strength of the bauxite. The objectives of this research can be achieved by conducting several tests in field and laboratory. The area of study for this research is located at 3 different locations in Pahang.

Before conducting the test, planning of the research is carried out in order to investigate the shear strength of the bauxite. The content in this chapter will discuss in detail about the planning of the research and the test that will be carried out in order to inspect the shear strength of the bauxite.

3.2 Methodology

Before proceeds the study, the planning sessions was conducted in order to ensure the progress is going smoothly. In the planning session, the location of the sample is chosen. Besides, the sessions also used to discuss the flow of the work from start until end of report and the suitable method to test the sample. The summary of the plan can be represented by Figure 3.1.

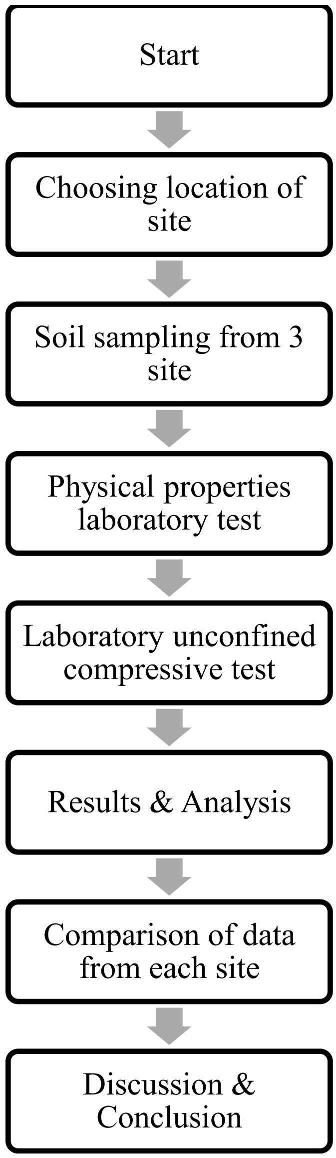

Figure 3.1: The research methodology flow chart

3.3 Soil Sampling

The soil samples were collected at 3 different locations in Pahang that contains bauxite deposits. There are two types of samples that will be collected to be tested which are disturbed samples and undisturbed samples. The disturbed soil samples are used for the basic soil properties laboratory experiment while for the undisturbed soil sample, it is used for laboratory unconfined compression test. For each site, 5 points with distance of 25m from each other was determined to collect soil sample. Table 3.1, 3.2 and 3.3 shows the coordinate of the points selected for site at Bukit Goh, Indera Mahkota, and Semambu respectively.

Table 3.1: Coordinate of Points for Bukit Goh Site

Distance (m)	Easting	Northing	Elevation (m)	Remarks
0.0	103°15.116'	03°55.281'	42	UD1 & D1
25.0	103°15.122'	03°55.269'	45	UD2 & D2
50.0	103°15.123'	03°55.256'	46	UD3 & D3
75.0	103°15.124'	03°55.243'	50	UD4 & D4
100.0	103°15.125'	03°55.230'	50	UD5 & D5

Table 3.2: Coordinate of Points for Indera Mahkota Site

Distance (m)	Easting	Northing	Elevation (m)	Remarks
0.0	103°15.914'	03°50.502'	28	UD1 & D1
25.0	103°15.927'	03°50.503'	30	UD2 & D2
50.0	103°15.942'	03°50.501'	29	UD3 & D3
75.0	103°15.955'	03°50.502'	31	UD4 & D4
100.0	103°15.967'	03°50.500'	32	UD5 & D5

Table 3.3: Coordinate of Points for Semambu Site

Distance (m)	Easting	Northing	Elevation (m)	Remarks
0.0	103°19.833'	03°52.806'	79	UD1 & D1
25.0	103°19.834'	03°52.820'	82	UD2 &D2
50.0	103°19.835'	03°52.833'	84	UD3 & D3
75.0	103°19.836'	03°52.847'	87	UD4 & D4
100.0	103°19.838'	03°52.860'	87	UD5 & D5

3.3.1 Disturbed Soil Samples

Disturbed soil sample is the type of sample that does not retain the in-situ properties of soil during the collection process. Disturbed soil samples are generally used for soil identification, classification and quality test. The collecting of disturbed soil sample does not required precision as the samples does not representing the soil structures.

For this research, disturbed soil sample was obtained by digging the soil at a point, in certain depth where it is possible to preserve the in- situ moisture content of the soil. In general, disturbed soil sample are mainly required for soil identification, classification and quality test. The soil sample is dug by using hand shovel and were placed into plastic bag and sealed.

As required to BS 5930: 1999 which is Code of Practice for Site Investigations, a minimum of five kilograms of soil sample are needed for test but extra amount of the sample were taken from site. Figure 3.2 show process of acquiring the disturbed soil sample.

Figure 3.2: Soil digging process

3.3.2 Undisturbed Soil Sample

Undisturbed soil sample is the type of soil sample that retains its structural integrity. The collection of undisturbed soil samples is important in order to determine the geotechnical properties of soil such as the strength, permeability, compressibility, and fracture patterns of the soil.

For this research, hand auger is used to acquire undisturbed soil sample. Then, the soil sample will be sealed in order to maintain its moisture content. Undisturbed soil sample will be used for laboratory tests that need to use undisturbed soil samples such as moisture content and triaxial test.

Figure 3.3: Undisturbed soil sample

3.4 Experimental Works

In this methodology process, the series of laboratory tests were carried out in order to determine the physical properties and the shear strength of the soil. The tests that will be conducted such as moisture content, particle size distribution test, and triaxial test are explained and shown. The entire laboratory tests were conducted according British Standard Methods of Test for Soils for Civil Engineering Purposes – Part 2: Classification Tests (BS 1377-2: 1990).

3.4.1 Moisture Content

Moisture content determination test was used for most field and laboratory test. The purpose of this test is to determine the moisture content contained in soil sample. This test was conducted refer to ASTM D 2216– Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixture.

Firstly, the container was cleaned to remove unnecessary dirt or dust such as excess soil from previous usage. It needs to be done in order to prevent any error on result. Next, the container was weighed on electronic balance and recorded its mass before proceeds to place the soil samples in the container. About 20 grams of soil samples were divided and placed loosely into the container by using a scoop. The soil was ensured to free from any unnecessary impurities such as dry leaves, broken branches and waste materials.

Next, the containers with the soil contained in it were weighed before placed into drying oven with temperature set at 105° to 110°. The samples were left overnight. Next day, the samples were taken out from the drying oven and left on table to allow it cool down to room temperature. After the sample cool down, the samples were weighed using electronic balance and the mass were recorded as shown in Figure 3.4.

Figure 3.4: The container contained with dry soil was weighed

To determine the mass of moisture soil, M_S, equation 3.1 below was used in order to determine it.

$$M_S = M_{SL} - M_{DL} \quad 3.1$$

Where M_S = Moisture Loss (g)

M_{SL} = Wet Soil and Container (g)

M_{DSL} = Dry Soil and Container (g)

To determine the mass of dry soil, M_D, the equation 3.2 is shown below:

$$M_D = M_{DSL} - M_{DL} \quad 3.2$$

Where M_D = Dry Soil (g)

M_{DSL} = Dry Soil and Container (g)

M_{DL} = Container (g)

To determine the water/moisture content of the soil sample, w, the equation 3.3 below was used:

$$w = \frac{M_D}{M_S} * 100 \qquad 3.3$$

Where w = Water/Moisture Content (%)

M_D = Dry Soil (g)

M_S = Moisture Loss (g)

Finally, the average moisture content was calculated and recorded.

3.4.2 Particle Size Analysis (Sieve Analysis)

Particle size analysis was conducted in order to get the percentage of different grain sizes that contained within the soil. There are 2 type of particle size analysis, which is sieve analysis that performed to determine the distribution of the coarser, larger-sized particles and the hydrometer method that was used in order to determine the distribution of the finer particles. The reference that was used to conduct this test was ASTM D 422 – Standard Test Method for Particle-Size Analysis of Soils.

This test must be performed first as this test can classify the soil whether it is clay, silt, sandy, or coarse type of soil. This test also can determine the fineness of the soil which is important to determine the suitable test that can be conducted as the distribution of different grain sizes can affects the engineering properties of soil.

Firstly, disturbed soil samples were placed into a tray and weighed for approximately 500 grams and recorded. Next, there are different types of sieve that was used to conduct the test, which are start from #4 sieve at the top until #200 sieve which placed at bottom. The pan was placed below #200 sieve. This set of sieve was cleaned before weighed and recorded. Figure 3.5 below shows the stack of sieve used.

Figure 3.5: The stack of sieve used

Then, the soil samples that have been weighed were poured into the top sieve and the cap was placed. The sieve stack then placed onto the mechanical shaker as shown in Figure 3.6 and shacked for 10 minutes. After 10 minutes, the stack was removed from the shaker and each of the sieves and the bottom pan were weighed with its retained soil as shown in Figure 3.7. The mass obtained were recorded.

Figure 3.6: The stack of sieve placed onto mechanical shaker

Figure 3.7: The sieve with its retained soil was weighed

To get the mass of the retained soil, the weight of sieve with retained soil need to subtract with the weight of empty sieve. The total mass of retained soil must be approximately equal to initial mass of soil sample used. It will become unsatisfactory if there is loss of more than 2% from total initial mass.

Next, the percent retained on each sieve was calculated by dividing the weight retained on each sieve with the original sample mass before calculating the percent passing. The percent passing was calculated by starting with 100% and subtract the percent retained on each sieve as a cumulative procedure.

After all of the calculation, a semi logarithmic plot of grain size against percent finer created before C_C and C_U for the soil computed.

3.4.3 Unconfined Unconsolidated Test (Triaxial Test)

This test purpose is to determine the unconfined compressive strength of the soil, which then will be used in order to calculate the unconsolidated undrained shear strength of the soil under unconfined condition. Undrained shear strength (S_U) is necessary to determine the bearing capacity of the foundation, dams, etc.

According to ASTM standard, the unconfined compressive strength (q_U) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test.

The reference of the test is based on ASTM D 2850 – Standard Test Method for Unconsolidated- Unconfined Triaxial Compression Test on Cohesive Soil.

Firstly, the soil sample was extruded from Shelby tube sampler. The Shelby tube sampler and soil sample extruder are shown as in Figure 3.8 and Figure 3.9 respectively. Then, the soil sample was cut in the ratio (L/d) of approximately between 2 and 2.5, where the L and d are the length and diameter of soil specimen respectively.

Next, the exact diameter of the top and bottom of sample was measured at 3 location 120° apart, and the average measurement was recorded. The exact length of the sample also measured at 3 location of 120° apart. Then, the average length was recorded. Then, the sample was weighed and recorded.

Figure 3.8: Shelby tube sampler used in the study

Figure 3.9: Soil extruder used to extrude soil sample

After that, the deformation, ΔL corresponding to 15% strain (ε) was calculated by using equation 3.4 below.

$$Strain, \varepsilon = \frac{\Delta L}{L_0} \qquad 3.4$$

Where L_0 = Original specimen length

Then, the sample was carefully placed in the compression device and centred on the bottom plate. The device was adjusted to make sure the upper plate just makes contact with the sample before the load and deformation dials were set to zero. The Unconfined Unconsolidated device can be shown in Figure 3.10 and the testing of soil sample for Undrained Unconsolidated triaxial test shown in Figure 3.11.

Figure 3.10: Unconfined Unconsolidated devices

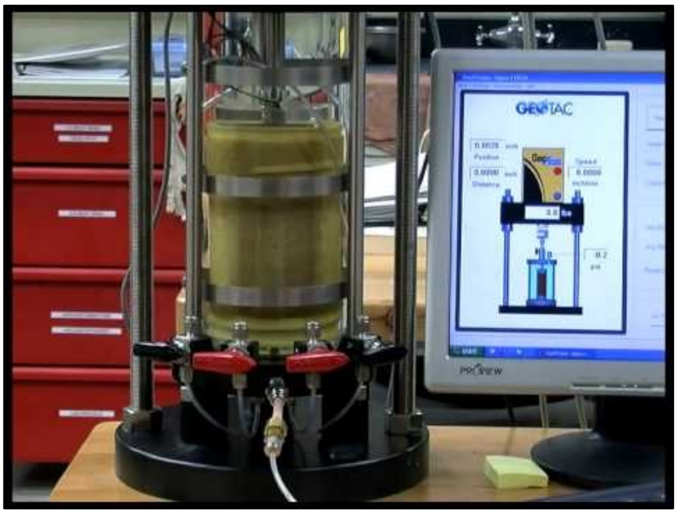

Figure 3.11: Testing the Soil Sample for UU test

After adjustment, the load was applied, where the device produces an axial strain at a rate of 0.5% to 2.0% per minute, while the load and deformation dial readings were recorded at every 20 to 50 division on deformation the dial. The load was applied until:

a) The load (load dial) decreases on the sample significantly
b) The load holds constant for at least four deformation dial readings,
c) The deformation is significantly past the 15% strain that was determined earlier.

After the load stopped, the sample failure sketch was drawn. Finally, the sample was removed from the compression device and another sample was used to determine the water content by conducting water content determination test.

After test was conducted, the results were analysed first in order to determine the undrained shear strength of the soil. Firstly, the dial reading was converted to the appropriate load and length units, and the values are inserted into data sheet in the deformation and total load columns. Next, the sample cross-sectional area was computed using the equation 3.5 below.

$$A_0 = \frac{\pi}{4} \times d^2 \qquad 3.5$$

Next, the strain was computed using equation 3.6.

$$\varepsilon = \frac{L}{L_0} \qquad 3.6$$

The corrected area was computed after that using equation 3.7.

$$A' = \frac{A_0}{1 - e} \qquad 3.7$$

Then, the specimen stress by equation 3.8 was computed using value of A'.

$$S_C = \frac{P}{A'} \qquad 3.8$$

After those values were calculated, the water content of the soil was computed. Then, the stress versus strain graph was plotted. The q_u was shown as peak stress of the test. The strain is plotted on the abscissa.

Finally, the Mohr's circle was drawn by using q_u gained and the undrained shear stress were shown using equation 3.9 below.

$$S_u = c = \frac{q_u}{2} \qquad 3.9$$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Moisture Content

By conducting the moisture content test, the results are tabulated in Appendix A. From the results obtained, the average moisture content was calculated in percentage for each site. Based on the average, the graph of average moisture content was plotted as shown in Figure 4.1. From the graph, moisture content for Semambu has the highest percent, with the value of 33.27% than Bukit Goh and Indera Mahkota, which has value of 21.47% and13.07% respectively.

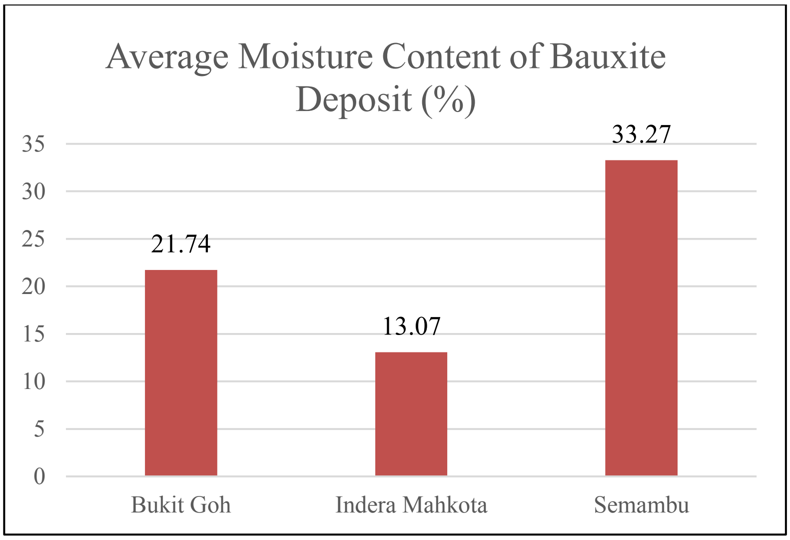

Figure 4.1: Average Moisture Content of Bauxite Deposit for Each Site

4.2 Sieve Analysis

The results for sieve analysis of soil sample are tabulated in Appendix B. From the results obtained through the test, the bauxite soil can be determined as clayey sand, where the samples have coarser fraction passing through No. 4 sieve (4.75 mm). Based on the results, particle size distribution curve were plotted for each site as shown in Figure 4.2 for Bukit Goh, Figure 4.3 for Indera Mahkota, and Figure 4.4 for Semambu.

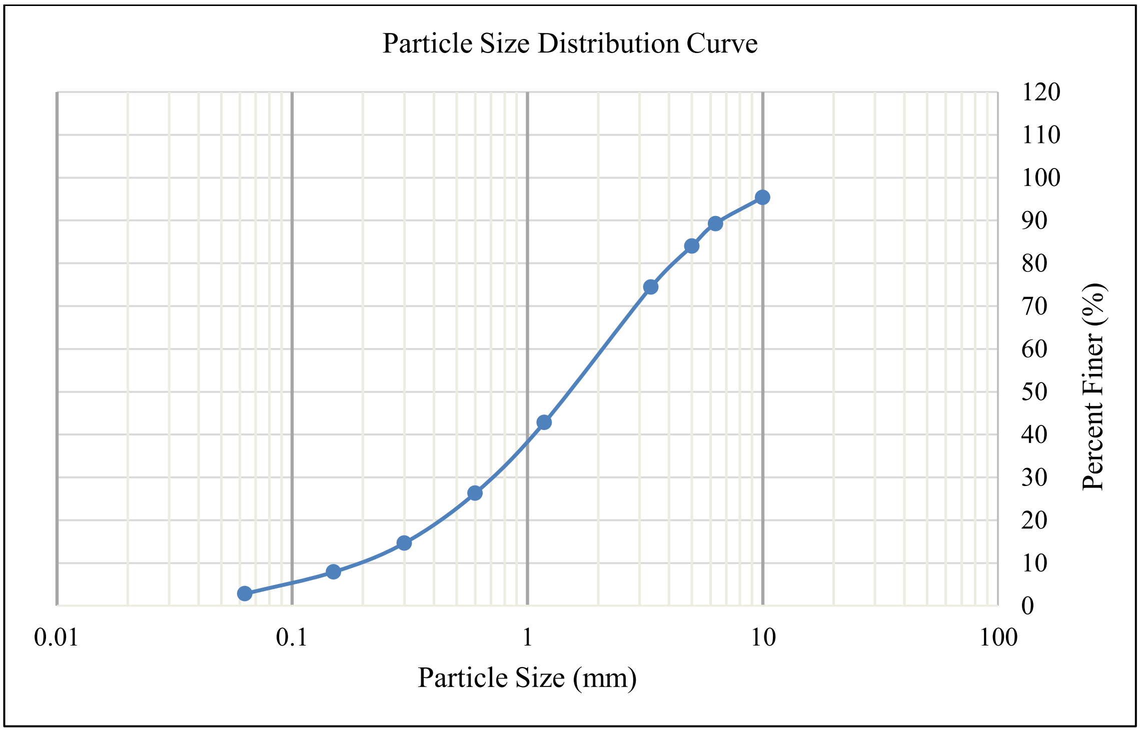

Figure 4.2: Particle Size Distribution for Bukit Goh

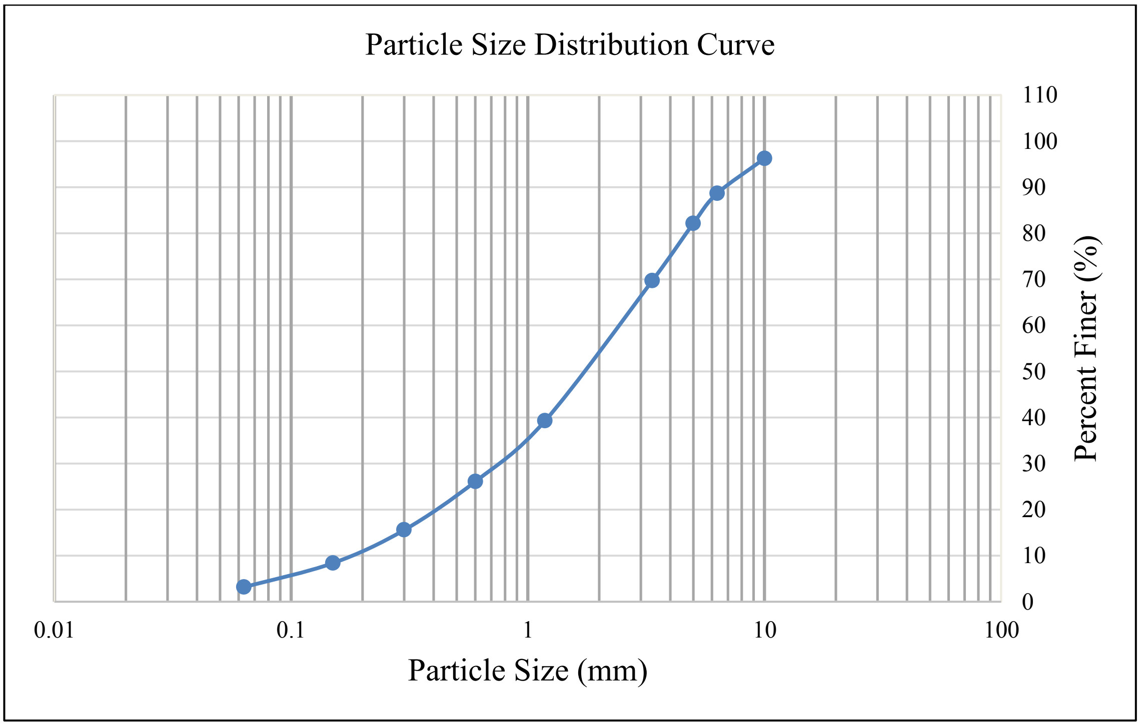

Figure 4.3: Particle Size Distribution for Indera Mahkota

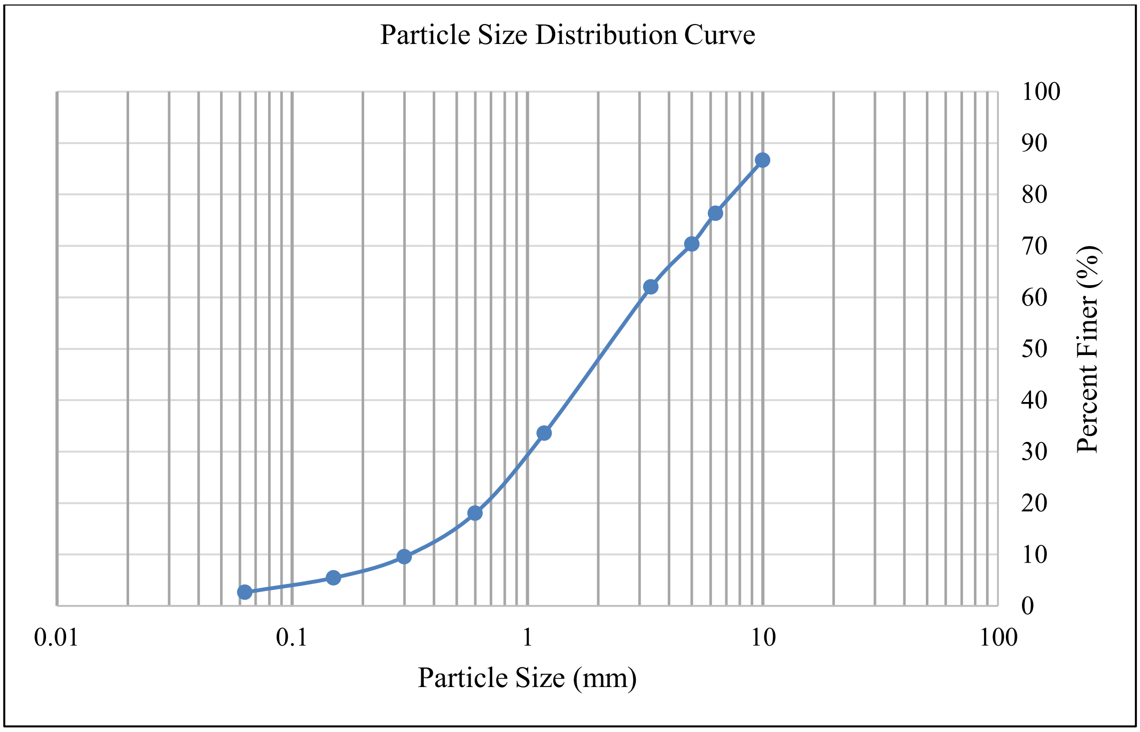

Figure 4.4: Particle Size Distribution for Semambu

4.3 Shear Strength Analysis

For the triaxial test, the value of confining stress, (σ_3) is determined by increase its value until the soil is fail. From the test conducted, the value of peak different stress, ($\sigma_1 - \sigma_3$) is obtained and analysed to draw Mohr's circle. The value of confining stress, (σ_3) and peak different stress, ($\sigma_1 - \sigma_3$) can be referred in Appendix C.

From the results obtained, Mohr Circle can be drawn to get the value of cohesion ("c") and the friction angle ("φ"), which shown in Figure 4.5 – 4.9 for each point in Bukit Goh, Figure 4.11 – 4.15 for 5 point in Indera Mahkota, and Figure 4.17 and Figure 4.18 for 2 point in Semambu.

Bukit Goh:

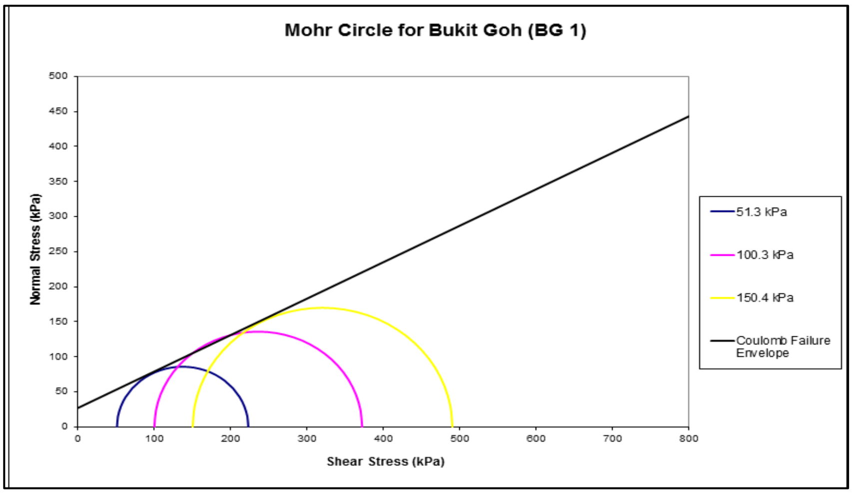

Figure 4.5: Mohr Circle for Point BG 1

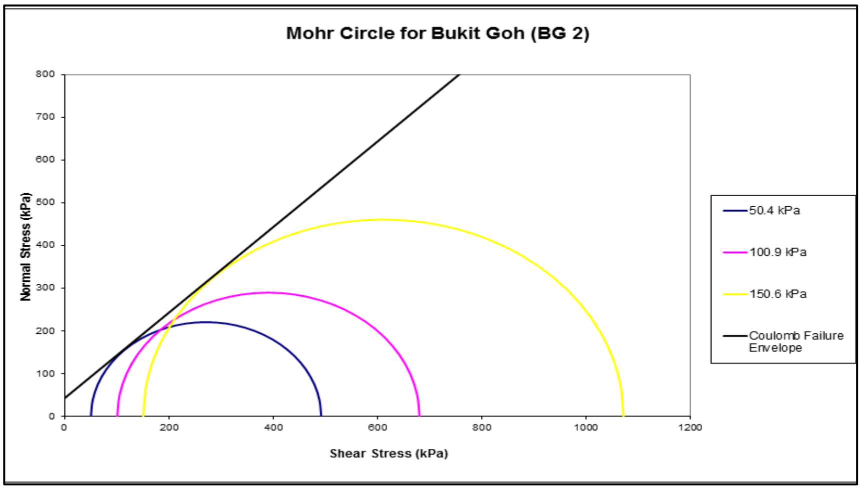

Figure 4.6: Mohr Circle for Point BG 2

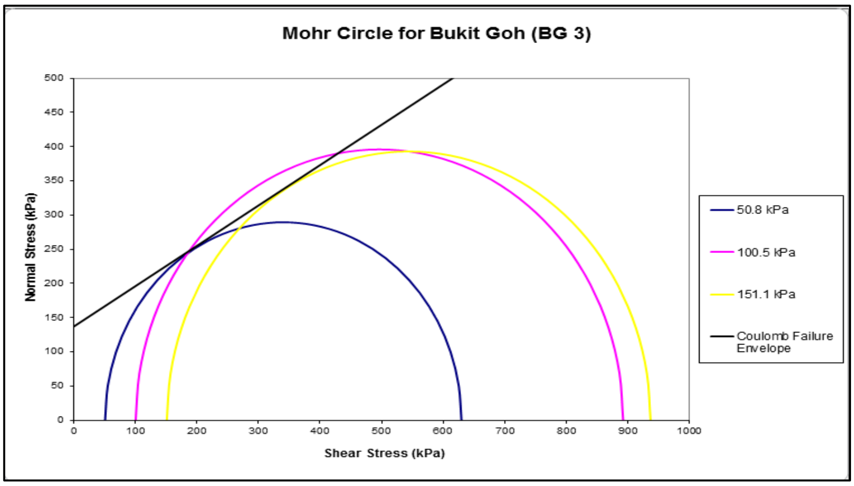

Figure 4.7: Mohr Circle for Point BG 3

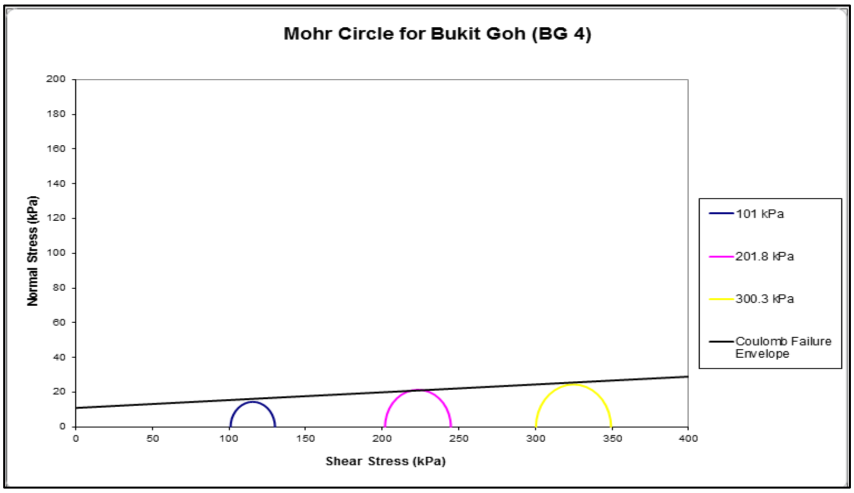

Figure 4.8: Mohr Circle for Point BG 4

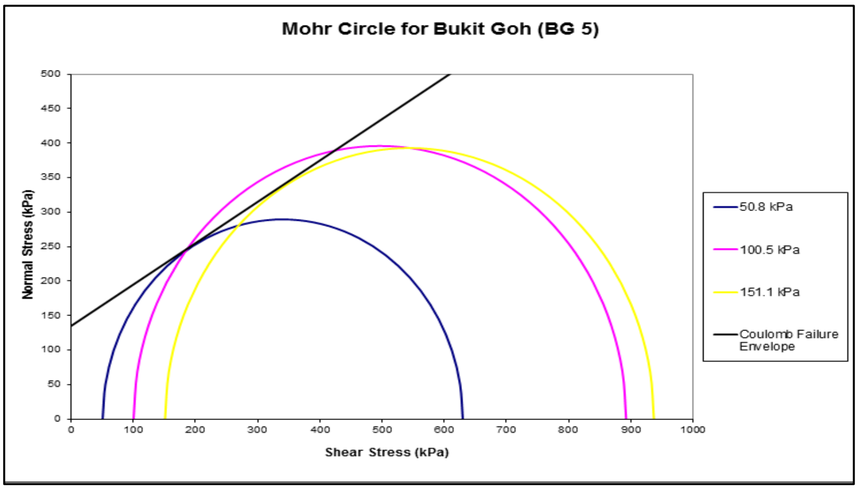

Figure 4.9: Mohr Circle for Point BG 5

From the Mohr circle for the Bukit Goh site, the value of the cohesion ("c") and friction angle ("φ") can be summarized by Table 4.1 and Figure 4.10.

Table 4.1: Value of Cohesion ("c") and Friction Angle ("φ") Obtained for Bukit Goh Site

Point	Shear Strength	
	Cohesion, c	**Internal Friction Angle, φ**
BG 1	27	27.47
BG 2	43	45
BG 3	137	30.54
BG 4	11	2.58
BG 5	135	30.96

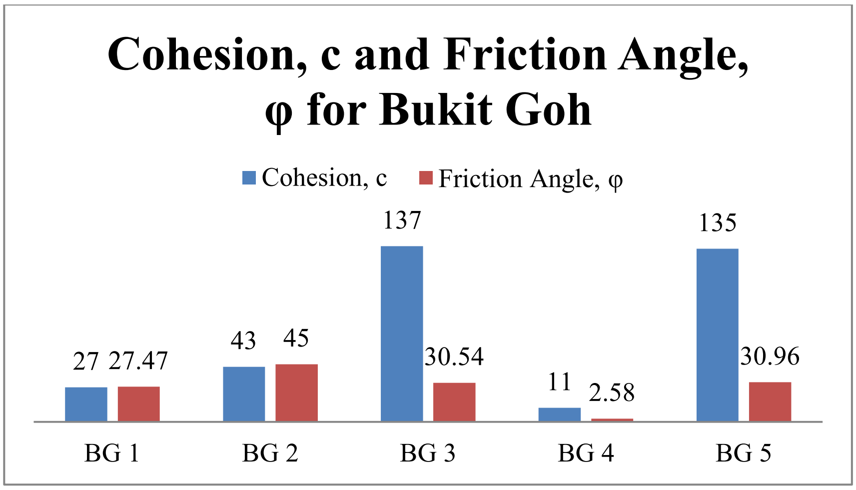

Figure 4.10: Comparison of Shear Strength parameter for Bukit Goh

Indera Mahkota:

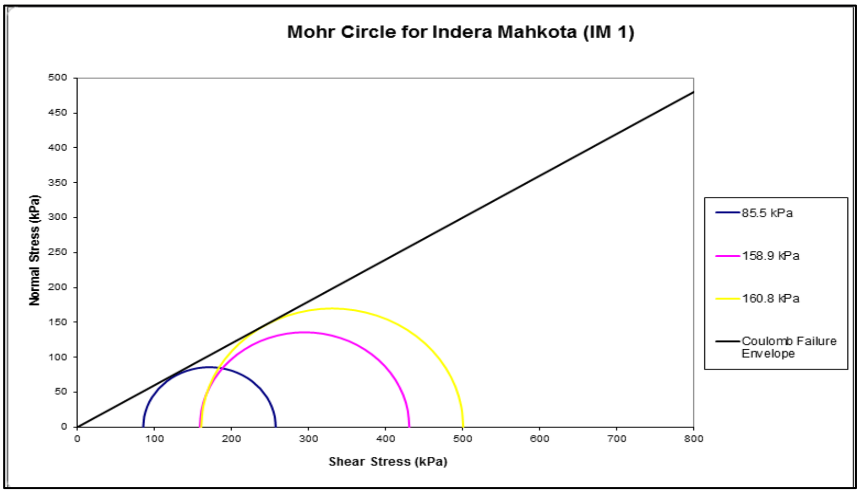

Figure 4.11: Mohr Circle for Point IM 1

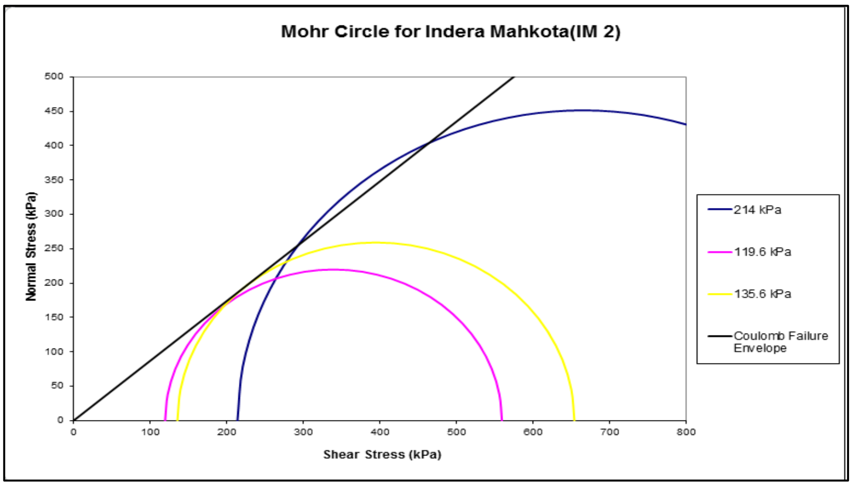

Figure 4.12: Mohr Circle for Point IM 2

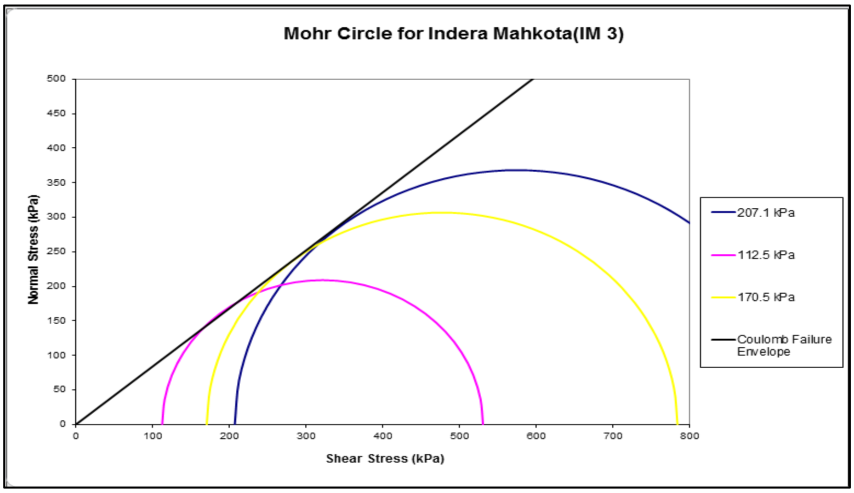

Figure 4.13: Mohr Circle for Point IM 3

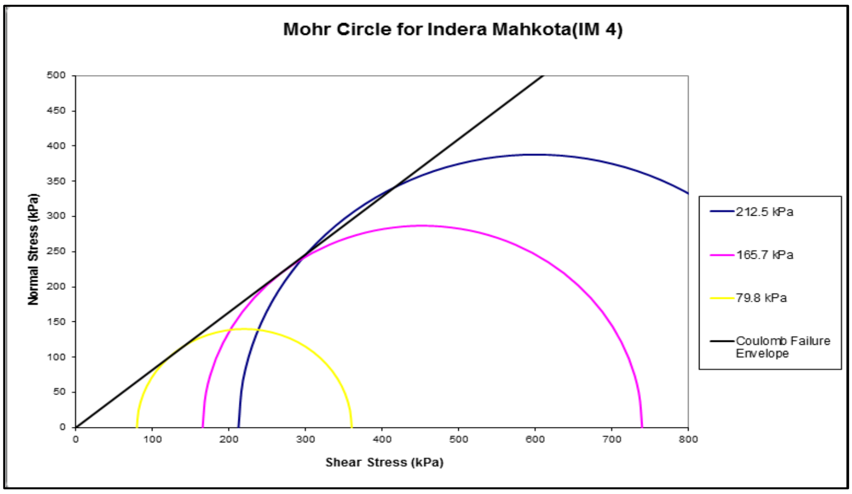

Figure 4.14: Mohr Circle for Point IM 4

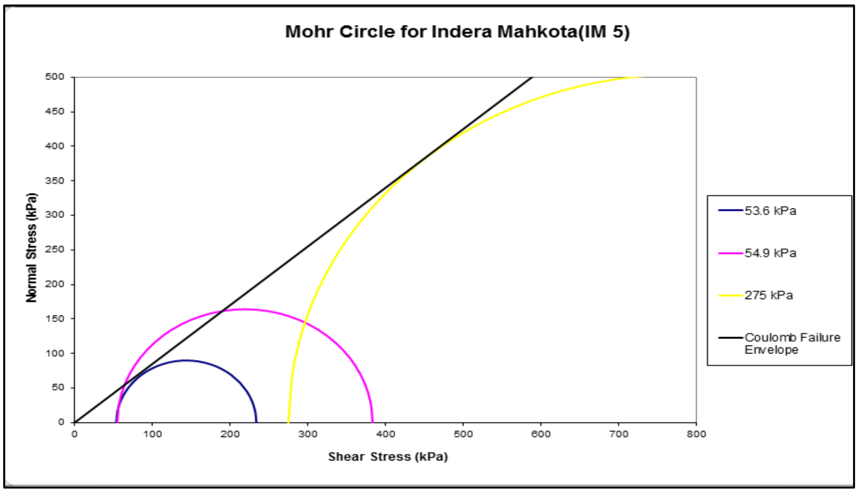

Figure 4.15: Mohr Circle for Point IM 5

From the Mohr circle for the Indera Mahkota site, the value of the cohesion ("c") and friction angle ("φ") can be summarized by Table 4.2 and Figure 4.16.

Table 4.2: Value of Cohesion ("c") and Friction Angle ("φ") Obtained for Indera Mahkota Site

Point	Shear Strength	
	Cohesion, c	Internal Friction Angle, Ø
IM 1	0	30.96
IM 2	0	41.02
IM 3	0	40.03
IM 4	0	39.35
IM 5	0	40.36

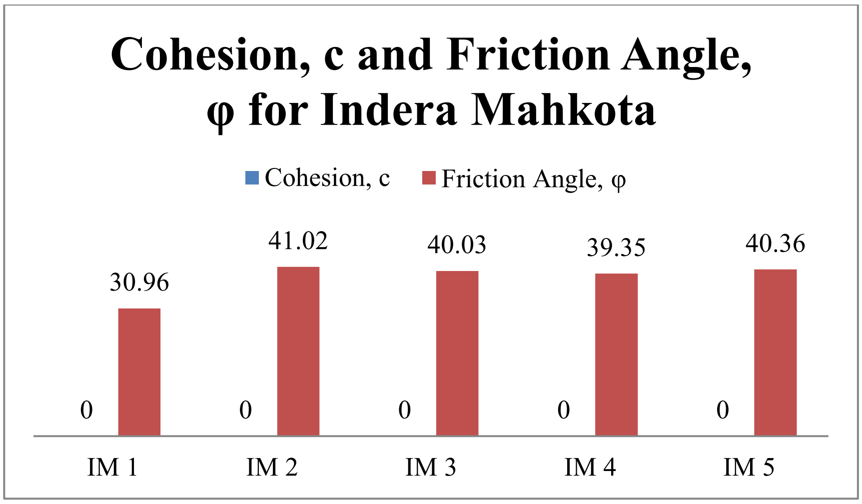

Figure 4.16: Comparison of Shear Strength Parameter for Indera Mahkota

SEMAMBU:

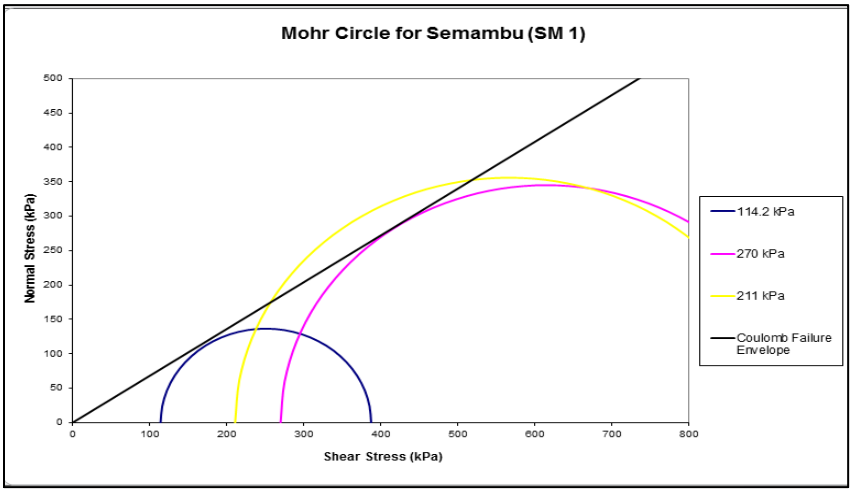

Figure 4.17: Mohr Circle for Point SM 1

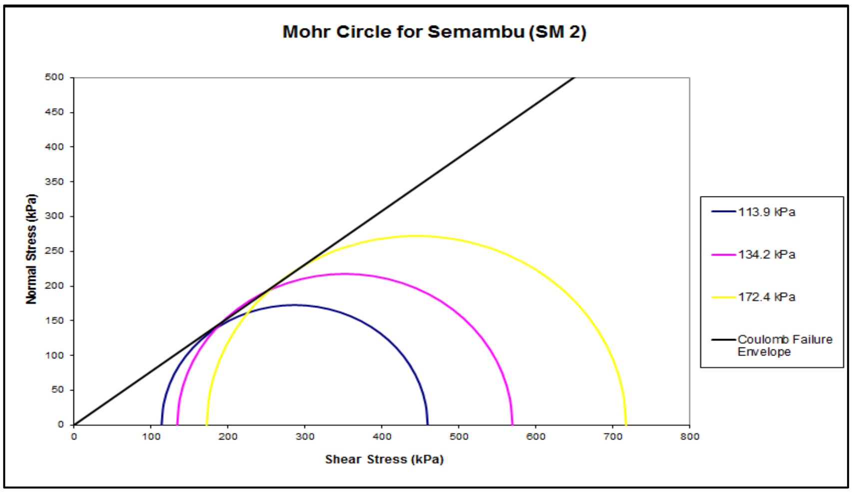

Figure 4.18: Mohr Circle for Point SM 2

From the Mohr circle for the Semambu site, the value of the cohesion ("c") and friction angle ("φ") can be summarized by Table 4.3 and Figure 4.19.

Table 4.3: Value of Cohesion ("c") and Friction Angle ("φ") Obtained for Semambu Site

Point	Shear Strength	
	Cohesion, c	**Internal Friction Angle, φ**
SM 1	0	34.23
SM 2	0	37.6

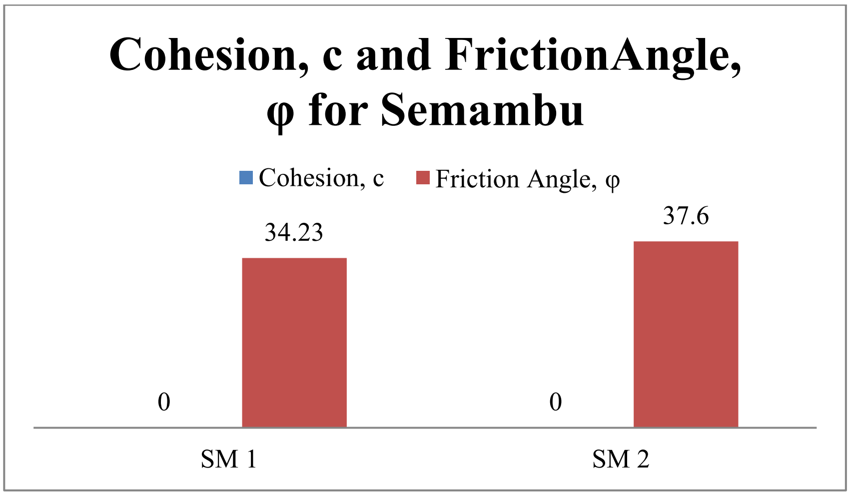

Figure 4.19: Comparison of Shear Strength Parameter for Semambu

4.4 Discussion

Based on the particle size distribution curve, the bauxite soil sample for three sites is classified as clayey sand, where most of the soil passes through sieve No. 4 (4.75 mm).

From the results obtained from the test, the value of cohesion for Bukit Goh is average from 27 to 32, which is in range according to previous study (Bumij, 2015; Deelwal, 2014; Kola & Kumardas, 2013; Shahin et al., 2011). The friction angle for the soil is ranged from 27° to 45°, which is inside the range reported in previous study (Newson et al., 2006; Nikraz et al., 2007). The cohesion of the soil for point 4 in Bukit Goh was different drastically due to crack occurs at the soil sample. The average cohesion, c for the sample is 70.6, with average friction angle, φ of 27.31°.

For the sample from Indera Mahkota, the cohesion for the soil is uncalculated due to shear pressure line set at negative value during the test. To determine the shear strength of the soil, the value of friction angle were used. The value of the friction angle for the soil ranged from 30 to 41, with average friction angle, φ of 38.34°.

The value of cohesion for Semambu also uncalculated due to shear pressure set to negative during the test. The friction angle for the soil is ranged from 34 to 37, with average friction angle, φ of 35.92°.

The higher value of cohesion value depends on intermolecular space between particles, surface area to volume ratio and moisture content of the soil. The angle of friction value determines the intermolecular interaction between soil, where it depends on the arrangement of particles and interlocking capability of constituent particles of soil.

From the Mohr circle, it clearly shown that there a several circle is not meeting or crossing the tangent line. This is because the increment of deviator stress is not constant and the error when the soil sample is remoulded. The variation of the results of the triaxial test also can be caused by mistake when handling triaxial apparatus. The apparatus is computerized system, where there are many setting need to be done before the machine can be run. Here, small mistake will contribute to the value of the readings.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Based on the discussion, the value of the cohesion and friction angle can be determined by using Mohr circle, which later can be used to calculate the bearing capacity, which is important especially for the foundation construction. From the results for 3 sites, there is slightly difference on the value of cohesion (“c”) and friction angle (“φ”), where soil sample from Indera Mahkota has the highest strength in term of friction angle, which followed by Semambu and Bukit Goh respectively. For the suitability as the foundation, high shear strength means high shear resistance, where the soil has high resistance against deformation, which is good for foundation. High shear resistance also means the soil can bear higher load before failing.

5.2 Recommendation

Along on my work progress, I experienced that there are some essential things that should be consider and corrected. Some recommendation that I would like to evoke are the way how to conduct the triaxial test especially on the preparing the soil samples to be testing. Even the result that I obtained is acceptable, it is shown a clearly some errors on the Mohr circle, where the tangent line does not fully intercept with the circle. I recommend that on the preparing samples especially when doing compaction should be done in proper manner and full attention. Moreover, the way to handling the triaxial cell also should be done carefully to avoid leakage on the specimen.

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APPENDIX A

MOISTURE CONTENTS

A.1 Raw data of moisture content at each site

1) Moisture content at Bukit Goh :

TEST NUMBER	Unit	BG1	BG2	BG3	BG4	BG5
Container weight	Gm	30.49	23.54	22.69	23.94	23.64
Wet soil + container	Gm	86.04	81.46	74.92	83.22	79.18
Wet soil, W_w	Gm	55.55	57.92	52.23	59.28	55.54
Dry soil + container	Gm	75.02	72.81	63.18	72.79	71.50
Dry soil, W_d	Gm	44.53	49.27	40.49	48.85	47.86
Moisture loss, (W_w-W_d)	Gm	11.02	8.65	11.74	10.43	7.68
Moisture content, $(W_w-W_d) / W_d$	%	24.75	17.56	29.00	21.35	16.05
Range of moisture content	%	16.05 – 29.00				
AVERAGE MOISTURE CONTENT	%	21.74				

2) Moisture content at Indera Mahkota :

TEST NUMBER	Unit	IM1	IM2	IM3	IM4	IM5
Container weight	Gm	23.50	23.11	24.15	25.53	31.94
Wet soil + container	Gm	85.88	64.81	65.28	77.63	76.99
Wet soil, W_w	Gm	62.38	41.70	41.13	52.1	45.05
Dry soil + container	Gm	78.69	59.91	60.55	71.61	71.83
Dry soil, W_d	Gm	55.19	36.80	36.40	46.08	39.89
Moisture loss, (W_w-W_d)	Gm	7.19	4.9	4.73	6.02	5.16
Moisture content, (W_w-W_d) / W_d	%	13.03	13.32	12.99	13.06	12.94
Range of moisture comtent	%	12.94 – 13.32				
AVERAGE MOISTURE CONTENT	%	13.07				

3) Moisture content at Semambu :

TEST NUMBER	Unit	SM1	SM2	SM3	SM4	SM5
Container weight	Gm	13.84	23.18	24.59	22.97	24.06
Wet soil + container	Gm	48.65	72.58	76.38	75.83	78.59
Wet soil, W_w	Gm	34.81	49.40	51.79	52.86	54.53
Dry soil + container	Gm	39.65	60.89	64.07	62.25	64.53
Dry soil, W_d	Gm	25.81	37.71	39.48	39.28	40.47
Moisture loss, (W_w-W_d)	Gm	9.00	11.69	12.31	13.58	14.06
Moisture content, (W_w-W_d) / W_d	%	34.87	31.00	31.18	34.57	34.74
Range of moisture content	%	31.00 – 34.87				
AVERAGE MOISTURE CONTENT	%	33.27				

APPENDIX B

PARTICLE SIZE DISTRIBUTION

A.2 Raw data of particle size distribution at each site

1) Particle size distribution at Bukit Goh:

Sieve size (mm)	**Weight of sieve and retained (g)**	**Weight of sieve (g)**	**Weight retained (g)**	**Percentage Cumulative Passing (%)**	**Perfect Finer (%)**
10.000	616.67	592.12	24.55	4.61	95.39
6.300	548.00	515.37	32.63	10.73	89.27
5.000	536.53	508.49	28.04	15.99	84.01
3.350	591.05	540.06	50.99	25.56	74.44
1.180	683.14	514.48	168.66	57.21	42.79
0.600	478.92	391.16	87.76	73.68	26.32
0.300	510.53	448.35	62.18	85.35	14.65
0.150	462.21	426.18	36.03	92.11	7.89
0.063	326.31	299.30	27.01	97.18	2.82
Pan	258.39	243.28	15.11	100	0
Total			532.96		

2) Particle size distribution at Indera Mahkota :

Sieve size (mm)	**Weight of sieve and retained (g)**	**Weight of sieve (g)**	**Weight retained (g)**	**Percentage Cumulative Passing (%)**	**Perfect Finer (%)**
10.000	611.89	592.09	19.80	3.78	96.22
6.300	449.81	409.87	39.94	11.4	88.6
5.000	542.45	508.46	33.99	17.88	82.12
3.350	605.37	540.01	65.36	30.35	69.65
1.180	673.71	514.26	159.45	60.76	39.24
0.600	459.78	390.92	68.86	73.89	26.11
0.300	503.49	448.21	55.28	84.43	15.57
0.150	463.77	426.14	37.63	91.61	8.39
0.063	326.45	298.97	27.48	96.85	3.15
Pan	259.80	243.30	16.50	100	0
Total			524.29		

3) Particle size distribution at Semambu :

Sieve size (mm)	Weight of sieve and retained (g)	Weight of sieve (g)	Weight retained (g)	Percentage Cumulative Passing (%)	Perfect Finer (%)
10.000	659.74	592.14	67.60	13.37	86.63
6.300	567.59	515.48	52.11	23.68	76.32
5.000	444.30	414.18	30.12	29.63	70.37
3.350	585.34	542.98	42.36	38.01	61.99
1.180	629.29	485.54	143.75	66.45	33.55
0.600	562.35	483.83	78.52	81.98	18.02
0.300	473.96	431.18	42.78	90.44	9.56
0.150	442.52	421.76	20.76	94.54	5.46
0.063	314.56	300.36	14.20	97.35	2.65
Pan	256.64	243.25	13.39	100	0
Total			505.59		

APPENDIX C
MOHR CIRCLE

A.3 Raw data of for Mohr circle at each site:

1) Confining stress, (σ_3) and peak different stress, ($\sigma_1 - \sigma_3$) for Bukit Goh Site

Location	Point	Moisture Content (%)	Confining stress, σ_3 (kPa)	Peak Different Stress, ($\sigma_1 - \sigma_3$) (kPa)
Bukit Goh	1	24.75	51.3	172
			100.3	272
			150.4	340
	2	17.56	50.4	442
			100.9	580
			150.6	922
	3	29	50.8	579
			100.5	792
			151.1	786
	4	21.35	101	29
			201.8	43
			300.3	49
	5	16.05	50.8	579
			100.5	792
			151.1	786

2) Confining stress, (σ_3) and peak different stress, ($\sigma_1 - \sigma_3$) for Indera Mahkota Site

Location	Point	Moisture Content (%)	Confining stress, σ_3 (kPa)	Peak Different Stress, ($\sigma_1 - \sigma_3$) (kPa)
Indera Mahkota	1	13.03	85.5	321.5
			158.9	588.4
			160.8	588.6
	2	13.32	214	902.6
			119.6	439.7
			135.6	518.3
	3	12.99	207.1	736.4
			112.5	418.1
			170.5	613.6
	4	13.06	212.5	775.9
			165.7	573.8
			79.8	280.5
	5	12.94	53.6	180.2
			54.9	328.5
			275	1007.7

3) Confining stress, (σ_3) and peak different stress, ($\sigma_1 - \sigma_3$) for Semambu Site

Location	Point	Moisture Content (%)	Confining stress, σ_3 (kPa)	Peak Different Stress, ($\sigma_1 - \sigma_3$) (kPa)
Semambu	1	24.75	114.2	273.4
			270	690.2
			211	711.8
	2	17.56	113.9	345.6
			134.2	435.4
			172.4	544.8