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EFFECT OF MOISTURE CONTENT ON COLLAPSIBILITY RATE AT GAMBANG RESIDUAL SOIL

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AA06012

A thesis submitted in fulfillment of the
Requirements for the award of the degree of bachelor of civil engineering

Faculty of Civil Engineering & Earth Resources
University Malaysia Pahang

NOVEMBER, 2009

I declare that this thesis entitled **"EFFECT OF MOISTURE CONTENT ON COLLAPSIBILITY RATE AT GAMBANG RESIDUAL SOIL"** is the result of my own research except as cited in the references. The thesis has not been accepted for any degree is not concurrently submitted in candidature of any other degree.

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DEDICATION

MY BELOVED PARENTS

MOHD RAMDZAN BIN HARUN

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MY SIBLINGS

MOHD HAFFIZAN SAID

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MY LECTURER

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MY FRIENDS

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ABSTRACT

Residual soil is a material formed in situ by weathering of rock and remained at the place where it was formed. In Malaysia, residual soil covers more than 80% of the country land area. This type of soil has high possibility to collapse when raining or wetted. The objectives of this study are to determine the collapsibility rate of soil at Gambang and to determine the factors that cause collapsibility and the effect of wet soil on the collapsibility. Gambang has been choose as the case study because of the topography of the land is hilly and this place has a history of land slide, there is also a slop that is not covered by plan and it seems that the slope crack during the sunny day and if the rain comes, the soil will wetted and collapse. One-Dimensional consolidation test or oedometer test is carried out to test the soil sample. From the result obtained, the soil is found with collapse possibility because of the quantity of the void ratio is high and the soil has low shear strength. The soil collapsibility rate is found high after the test has been conducted.

ABSTRAK

Tanah baki adalah satu bahan dibentuk di suatu tempat oleh proses luluhawa batuan dan kekal pada tempat ia di bentuk. Di Malaysia, tanah baki meliputi lebih daripada 80% kawasan di negara ini. Jenis tanah ini mempunyai kemungkinan besar untuk roboh semasa hujan atau basah. Objektif-objektif bagi kajian ini adalah menentukan kadar tanah runtuh bagi tanah di Gambang, menentukan faktor yang menyebabkan tanah runtuh dan kesan kelembapan pada tanah runtuh. Gambang telah dipilih sebagai kes kejadian kerana topografi bagi tanah adalah berbukit dan tempat ini mempunyai sejarah berlakunya tanah runtuh, terdapat juga curam-curam yang tidak dilutupi tumbahan dan tanah merekah apabila cuaca panas, jika hujan turun pada keaadan tanah yang kering, kemungkinan tanah itu akan runtuh. Ujian pengukuhan 1 dimensi dijalankan untuk menguji sampel tanah. Daripada hasil kajian, didapati bahawa tanah di gambang akan runtuh, ini kerana kuantiti nisbah lowong adalah tinggi dan kekuatan ricih tanah adalah rendah. Kadar keruntuhan tanah adalah tinggi selepas kajian dijalankan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

i	-	Collapse potential
h_i	-	Initial height
h_0	-	Original height
h_f	-	Final height
δ_s	-	Collapsibility coefficient
Δe	-	Void ratio reduction during soil saturation
eL	-	Void ratio before saturation
i_c	-	Collapse potential
m	-	Natural moisture content
S_r	-	Soil saturation ratio
PL	-	Plastic limit
e_f	-	Final void ratio
G_s	-	Specific gravity
w	-	Moisture content
PI	-	Plasticity index
h_z, h_{zs}	-	Soil sample thickness
h_i	-	Initial soil sample thickness
γ_d	-	Dry unit weight
e_o	-	Original void ratio
e_i	-	Initial void ratio

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background of study

Collapsible soil is a phenomenon where the soil structures are unstable and thus collapse and residual soil is a type of soil that yields from the weathering process of rock. The collapsibility of residual soil can be found in every country in the world. The main problem of residual soil is that it always relate to the effect of high rain fall rate and the effect of water to the soil.

According to Kepli (1994), Taha, et al. (1997) and Khairul (2002), Malaysia Tropika Climate namely experience humid year round having average temperature between 22 °C till 32 °C and annual rainfall torrent between 1778 mm to 3659 mm. This state cause occurrence of very high weathering rate on granite rock. Hence, residual soil formed in granite rock surface part.

This factor has because many incidents happened particularly in Malaysia, whether it is a natural slope or man-made slope. Many landslides occurred on residual soil during heavy rain season. This incident could threaten human life and damage property. Although people know that it is dangerous to build something on the residual soil, but people still use is for development. This is because the addition of population and increase in standard of living and economic. Many construction work is carried out in residual soil area which found on highland area or hilly. Residential area, road, dam and recreation centre also involves at hilly area. Apart from that, because of residual soil is easy to get with lower cost, which is why residual soil is always selected as one of the building material.

Study of residual soil in Malaysia has long carried out. Among earlier researcher are Lee (1967), Chan & Chin (1972),Ting & Ooi (1976), Balasubramaniam, *et al.* (1985), Komoo (1985, 1989), Todo & Pauzi (1989), Tan & Ong (1993), Tan (1995), Taha, *et al.* (1997), Low, *et al.* (1997), Saravanan, *et al.* (1999), Ali (2000) dan Khairul (2002).

1.2 Problem statement

According to Brenner et al (1997) and Huat et al (2007), residual soil in Malaysia covering more then 80% of the country land area. The existence of this residual soil makes it difficult for engineer in Malaysia to choose the site that free from residual soil. Eventually site with residual soil is use for development.

Residual soils are defined as the product of insitu weathering of igneous, sedimentary and metamorphic rock (Blight, 1997). Ideally, there is no universally accepted definition of residual soils. Different researchers gave different definitions. For example, according to Fookes, (1990) residual soils are formed by the mechanical and chemical weathering of parent rocks at the present location. However, the common phenomenon in all such definitions is that the residual soil is a material formed in situ by weathering of rocks and remained at the place where it was formed.

Because of these factors, many incidents relate to the collapse of soil has occurred in Malaysia and has kill many people and damage properties. For example the Highland Towers apartment building which collapsed on Dec 11, 1993, killing 48 people and at Bukit Antarabangsa which collapsed on Dec 6, 2008 that involve more than 2000 resident in that area (The star team, 2008).

The thesis focused on the effect of moisture content on collapsibility rate at Gambang residual soil. Gambang situated at about 25.5km from Kuantan Pahang. Gambang also are no exempt experience landslide. This is because, several cases has occurred at this place for example slope near to the Kolej Komuniti Paya Besar (KKPB). Below is the picture of soil collapse near the KKPB.

Figure 1.1: The property damage because of the soil collapse

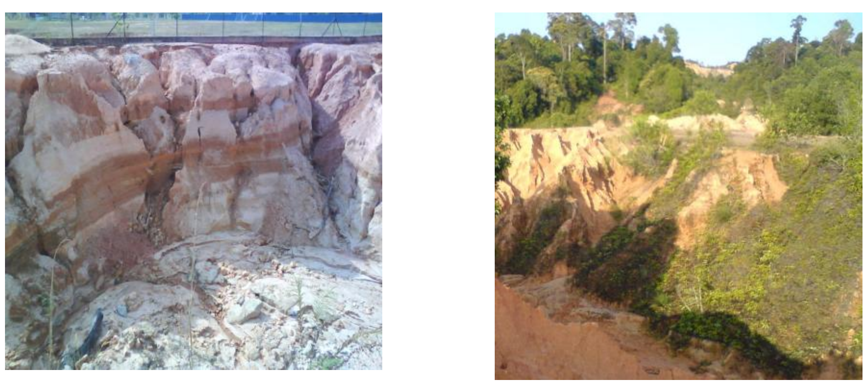


Figure 1.2: The effect of the soil collapse on the surrounding area

1.3 Objective

The main objective of this study is:

1. To determine the effect of moisture content on the residual soil
2. To determine the collapsibility rate of residual soil at Gambang.

1.4 Scope of study

The main purpose of this research is to determine the effect of moisture content on the residual soil and the collapsibility rate of residual soil at Gambang. Both objectives are determined via laboratory test. Two types of sample will be taken to succeed this objective. The first one is undisturbing sample and the second one is disturb sample.

Undisturbed sample will be used on single and double oedometer test. This test is carried out to determine the collapsibility rate of the soil sample from the calculation of this formula.

$$\text{Collapse Potential} = \frac{e_{\text{unsoked}} - e_{\text{soked}}}{1 - e_{\text{unsoked}}} \tag{1.1}$$

Where Δe represents the increase (for swelling condition) or decrease (for collapse condition) in void ratio (after 24 h) of the specimen on wetting under the desired pressure (20, 40, 80, 160, and 320 kPa) and unsoaked is the void ratio of the unsoaked specimen at that pressure. The term Δe assumes a positive sign when the sample swells and a negative sign when the sample collapses.

1.5 Expected result

From this research, the researchers expects that by adding more water to the residual soil the collapse potential will increase according to the amount of water is added. Researcher also expects that the value of collapse potential is more that 10%.

1.6 Thesis organization

This thesis composed of 5 chapters. Chapter 1 presents about general information regarding background of study, problem statement, objectives, scope of study and expected result. Chapter 2 provides the background of the study on different topics related to the research. This chapter contains the definition of the residual soil from the previous researchers, the more detail background of the study, material and method that can be used and a summary of the experiment that can be conduct in this study. Chapter 3 provides the method used in getting the result. This chapter also discusses the detail set up and procedures of using double oedometer test.

Chapter 4 present about the results obtained from the laboratory test and also calculation of collapse potential using theoretical formulae. The analysis of the result also will be doing in this chapter. Chapter 5 presents the summary and conclusions of major findings of this research and recommendation for future work on the topic related to the present study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In Malaysia, residual granite and sedimentary rock soils occur extensively, covering more than 80% of the country's land area. The ground water table is generally low causing the soils to be mostly unsaturated except immediately after rain. These soils generally belong to the residual soil category that may exhibit collapse settlement upon wetting (B.K. Huat et, al. 2008).

During rainfall, the water will penetrate to the soil and fill up the void in the soil. Soil with high void ratio and has low shear strength will slide especially soil at the hill side, when soil at hill or slop slide or fell, it called slope failure, slope failure is one of the nature disaster that can give a big impact to the development and safety in some places.

The thesis focused on the collapsibility rate of Gambang residual soil. Throughout this chapter, the relevant journals and articles of collapsibility of soil and residual soil was reviewed. To understand the soil behavior at Gambang, a soil sample is taken to be analyzed. This includes analyzing the shear strength of soil and void ratio of the soil.

Gambang situated at about 25.5Km from Kuantan Pahang with latitude 3.716667 longitudes 103.1 and temperature 28°C. Gambang has been chosen as a case study because of it topography is hilly and it also has a history on landslide.

The literature review was also undertaken to study the collapsibility rate using double oedometer test. With the available information, the theoretical, conceptual and methodological background of the entire research was established in the literature review.

Figure 2.1: Location of Gambang from Kuantan (Travelsjournals.net, 2009)

2.2 Definition

Ideally, there is no universally accepted definition of residual soils. Different researchers gave different definitions. Table 2.1 below shows that the definitions that has been made by the previous researchers.

Table 2.1: Some definition of residual soil

Author	Definition
Fauziah Ahmad et, al. (2006)	Residual soil is a material formed in situ by weathering of rock and remained at a place where it was formed.
Macari E.J. and Hoyos L. (1996)	Residual soil is product of the intensive in-situ weathering of igneous, sedimentary and metamorphic rocks, and they include the group of iron rich materials usually described as lateritious or lateritic soil that are very common in tropical regions.
The Public Works Institute of Malaysia	Residual soil is a soil which has been formed in situ by decomposition of parent material and which has not been transported any significant distance.
Huat B.K et, al. (2008)	Residual soils is a soil that formed by the mechanical and chemical weathering of parent rocks at the present location.
Mohd Ahmadullah Farooqi, 2006	The tropical residual soils are formed in tropical areas, physically defined as the zone contained between 20^0 N (Tropic of Cancer) and 20^0 S (Tropic of Capricorn) of the equator, which includes Malaysia
Faisal Hj. Ali, 2005	Residual soils are soil that has been developed by in situ weathering of parent rock. In the tropic, heavy rains and high tempreture has lead to intensive chemical weathering leading to formation of tropical soil of several tens meter deep.

Based on all the definitions of residual soil listed in Table 2.1, authors have made a generalization to the definition of residual soil as a soil that was formed due to the weathering process of underlying rock and resided at the present location.

For collapsible soil definition, it is defined as soil that is susceptible to a large and sudden reduction in volume upon wetting. Collapsible soil deposits share two main features, they are loose, cemented deposits, and they are naturally quite dry (Day, 2000). Collapsible soil can withstand a large applied vertical stress with small amount of compression, but then showed much larger settlement upon wetting, with no increase in vertical stress (Bujang B.K. Huat et. al., 2008).

2.3 Background of study

In 20's century, it seem that the increasing demand and requirement for space and clearing for purposes of development which covered city, satellite city and larger highway. Consequently those areas considered unsuitable to development have in explored. Slope which is common topography shape on earth do not miss in development activities. The fact is human had fully utilized natural resource by found up-to-date methods to adapt development to appearance diversity landform. (M. Daniel, 2006).

Slope term discussed in this study referring to any land mass which form horizon in land surface. Hills, mountains river bank is an example of natural slope, it is form from the movement of glassier, weathering, erosion, sedimentation and deposition. Example of man made slope is fill slope, like filling and earth dam. Example of cut slope is cutting on the hillside to build a highway, railway, build drain excavation for foundation. (M. Daniel, 2006).

According to Z. M. Mansor, Z. Chik and M.R. Taha (2005), soil prone to collapse when large and sudden reduction in volume upon wetting. In their natural, dry state most residual soils form good foundation ground, retaining vertical slopes and are quite capable of bearing soil pressures up to 400 kN/m^2. The main contributor to slope failure is the force of gravity. When the driving forces (shear stress) overcome the resisting forces or shear strength on the slope, gravity is able to displace and move the slope forming materials (T. Periasamy, K. Osman Salleh, 2008). The movement of slope material or regolith may take a few millimeters to a few meters.

However, on exposure to wetting, they undergo a sometimes catastrophic loss of strength, perhaps with an associated settlement of up to 20% of the soil volume (Jon L. Darwell and Bruce Denness, 1976). Beside of wetting that cause slope failure, there are other factors that cause slope failure like high void ratio, soil exhibit significant strength and low compressibility at their natural (D.Harmdee, H.Ochai and N.Yasufuku, 2004). Many authors have written on the causal factors of slope failures. The effect of collapsibility of soil results in lost of live, property, accommodation, and public amenities. Lot of land slide has occurred especially in Malaysia. At Dec 11, 1993 a tragedy at Highland Towers apartment building which collapsed has killed 48 people and now at 6 December 2008, a land slide has occurred at Bukit Antarabangsa. The incident make a lot of people lost their family members and properties. The occurrence of this entire land slide has open society's eyes of importance to understand landslide failure.

A study of slope failure has started in the early 19th century by a French engineer named Alexandre Collin he noted that the failure surfaces formed by landslides in clay along canal banks followed a curved form. In 1846 he published a memoir in which he proposed a statical method of analysis based on a curved surface and measured shear strength of the soils. Since that time various analyses have been proposed, resulting finally in the slip circle method developed by Swedish harbour engineers that forms the basis of techniques in current use.

General slope failure include falls, flow and slide. Most of the landslides occur are cause by a presence of water where rainfalls become a main factor (M. Daniel, 2005). The open structure that encourages strong root development also makes the soil susceptible to collapse upon the application of load and/or water. In Hong Kong for example, the study of movement of water in the soil because of a heave rain fall has been made to overcome the land slide from occur (J. J. Jiao and A. W. Malone, 2002).

Because of Malaysia experience a tropical climate and have a high rainfall distribution average, most of the collapsibility of residual soil is because of the reaction of water that is rain fall as a main factor other then erosion and weathering process.

Other then study the effect of water on the slope failure, the characteristic of the soil also taken to determine the condition of the soil using the appropriate test at the laboratory. Commonly residual soil is the most common soil that usually found in Malaysia and because of its certain characteristic that permeability and strength cause the influence of residual soil could not be dismissed.

2.4 Materials and Method

This section will discuss about the material and method that will be used in this study base on the literature review.

2.4.1 Material

From the entire journal that have collected and studied, material that had been used for the entire test that had been conducted by this people is soil that is undisturbed. For example in the journal entitle “Role of micro fabric in matrix suction of residual soils” written by Sudhakar M. Rao and K. Revanasiddappa. It stated at its method that the undisturbed sample was obtained from 2m deep test pits. Same with the other journal that I have collected for example journal written by Z. M. Mansor, Z and Chik, M.R. Taha, (2005). It stated that “the undisturbed soil specimen at natural moisture content loaded in the conventional oedometer” and journal written by Fauziah Ahmad, Ahmad Shukri Yahaya and Mohd Ahmadullah Farooqi, 2006. It stated in its journal that an undisturbed sample should be used to get more reliable result even though trimming of undisturbed samples is difficult because of gravel contents.

Undisturbed soil samples are those that are cut, removed, and packed with the least possible disturbance. They are samples in which the natural structures, void ratio, and moisture content are preserved as carefully as possible. Types of undisturbed samples are chunk samples, cut by hand with a shovel and knife, and cylinder samples, obtained by use of a cylindrical sampler or the CBR mold equipped with a sampling cutter. Expedient methods of obtaining cylinder samples are also used the method of sampling chosen depends upon the equipment available, the tests required, and the type of soil. All undisturbed samples must be handled with care.

Cohesionless soil samples must be kept in the container until ready for testing, and the container should be handled without jarring or vibration. Some soils are too hard or contain too many stones to permit sampling with the cylindrical samplers and can be sampled only by cutting out chunks by hand. Taking of undisturbed samples frequently requires a great deal of ingenuity in adapting the sampling devices to job conditions and in devising schemes for their use. Whatever method is used, the sample must be taken and packed in the container for shipment without allowing its structure to change. Protection against change in moisture content during sampling and shipment is also required.

2.4.2 Method

There are much different kind of test that has been conducted to test the collapsibility and residual soil that have been found after reviewing the journal. The test is conducted according to its purpose and objective. For example in journal entitle "Infiltration Characteristic of Granitic Residual Soil of Various Weathering Grade" (Faisal Hj Ali et al., 2005) it use field infiltration test (FIT). The purpose of this test is to determine the infiltration rate in residual soil. Other than that, Pressure Meter Test (PMT) and Cone Penetration Test (CPT) are used to give better information on the behavior of the residual soil. It stated that they can consider to be a preferred on strength characterization (Fauziah Ahmad et al., 2006). Apart from that, the in-situ load test is also been used to obtain stress-strain data comparable to that obtain in the laboratory (S. L. Houston et al., 2002). To determine the volume change of the unsaturated residual soils, the best test to determine this characteristic is using suction controlled isotropic compression test (Bujang B K Huat Faisal Hj. Ali and F. H. Choong, 2007). Other common test that usually been conducted to test the collapsibility and residual soil is Triaxial compression test, the purpose of this test is to determine the stiffness and compressibility of the soil. Oedometer test also can be used to determine this characteristic but it is not suitable for measuring compressibility of course grained soils (Fauziah Ahmad et al., 2006).

But, from the literature review that have been collected, I noticed that the most common test and test that usually been conducted to determine the collapsibility in the residual soil is Oedometer test or double Oedometer test. Almost all the journals that have been reviewed mention about this test. The quantification of volume change when soil undergoes collapse can be obtained from oedometer test – single and double oedometer test (Nor Azwati Azmi et al., 2008).

In a single oedometer test, undisturbed soil sample at natural moisture content is loaded in conventional odometer test to certain stress level and then in undated with distilled water to induce collapse. In the double oedometer test, two identical samples are placed in odometers; one tested at in-situ natural moisture content, and the other is wetted before the test begins, and then subjected to identical loading (Nor Azwati Azmi et al., 2008). The detail about the experiment of single and double oedometer test will be review in the section.

2.5 Experiment

This section will discuss about the experiment that can be done to achieve the objective of the study. In this part, the related experiment will be discuss and compare to choose the best experiment for this study

2.5.1 Oedeometer test

This is an example of oedometer test that I found in my journal collection. This method is very popular to determine the collapsibility of residual soil. To start this experiment first we must get the sample from the site.

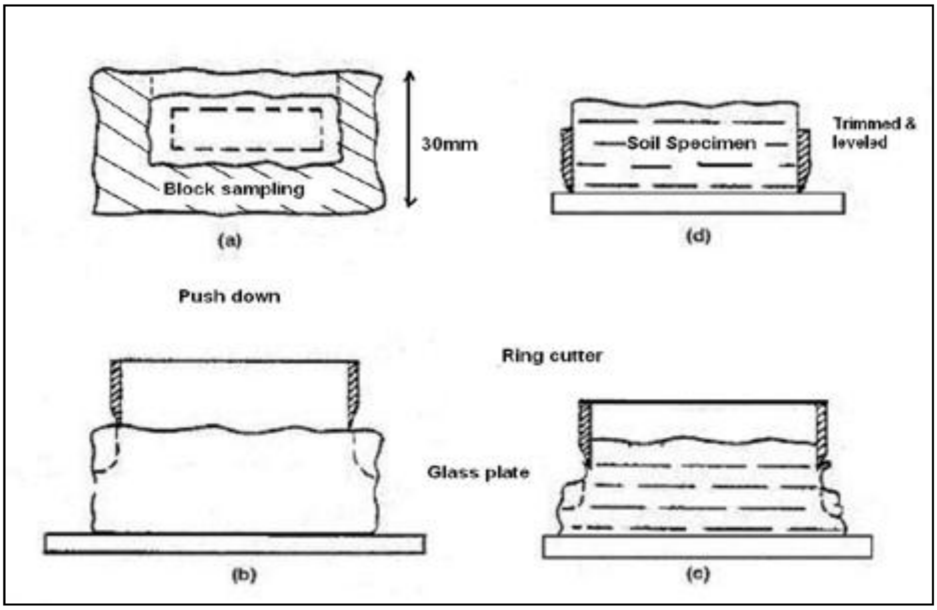


Figure 2.2: Undisturbed sample for oedometer test (Nor Azwati Azmi et al., 2008).

To get the undisturbed sample, first of all, remove the top soil for about 0.2m to 0.5m. Then use Thin-walled steel sampling tubes (152 mm diameter x 180 mm high) with sharpened ends to collect the soil samples. Get three sample of undisturbed sample from the site (Nor Azwati Azmi et al., 2008).

For the double shear box test, the undisturbed sample is prepared by pushing down the square cutting ring with the size of 60mm x 60mm into the sampling tube with the extruded portion sawn off using a wire saw (Nor Azwati Azmi et al., 2008).

For single oedometer test, the undisturbed soil sample is loaded up to a specific state of stress without wetting the specimen. On the attainment of equilibrium under the applied load, the soil sample is inundated with water. The test is then continued with the sample under wetted condition (Nor Azwati Azmi et al., 2008).

Further, for the double oedometer tested, two identical sample of the soil are test in conventional oedometer. One of the samples is stepwise load in the dry (natural moisture content) condition up to the desired pressure (650 kPa in this case) and the other sample was inundated. After the wetted soil collapse was completed, additional loads were applied to the soaked specimen.

To determine the effect of wetting on the residual soil shear strength, double shear box tests were carried out on identical soil samples inside the normal shear box assembly (soil sample size – 60cm x 60cm); one at in situ moisture content (dry condition), and the other at wetted condition, similar to the double oedometer mentioned. Below is the result of the oedometer test. The values of void ratios of the granitic and sedimentary residual soils are summarized in Table 2.2 (Nor Azwati Azmi et al., 2008).

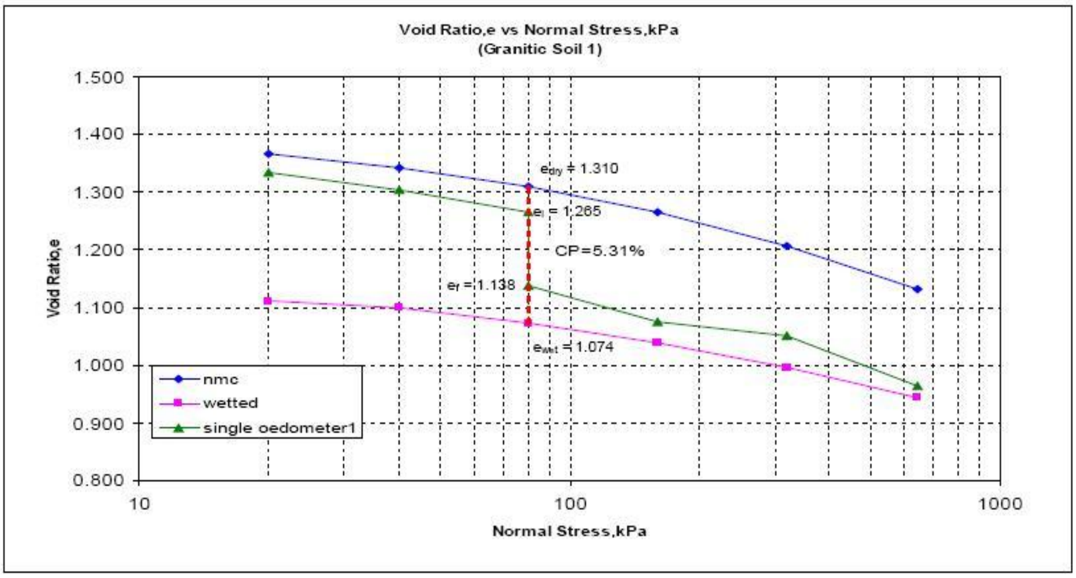
Table 2.2: Summary of void ratios of residual soils from single and double oedometer

(*a*) **Granitic residual soil**

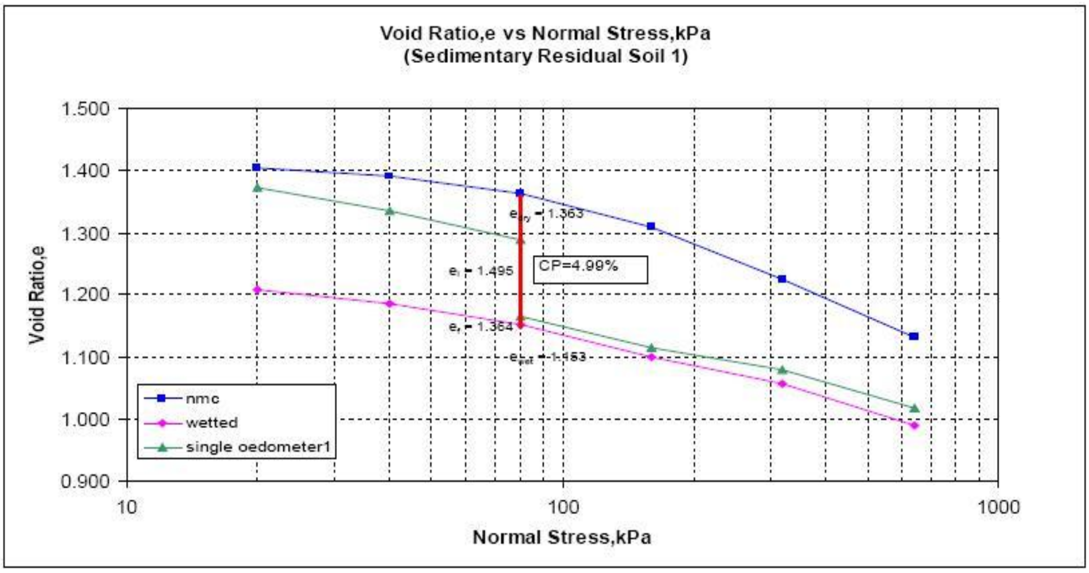
Sample No.	Single Oedometer: Initial void ratio, e_o	Void ratio (before wetted), e_i	Void ratio (after wetted), e_f	Δe	Double Oedometer: e_{dry}	e_{wet}	Δe
1	1.393	1.265	1.138	0.127	1.310	1.074	0.236
2	1.332	1.215	1.101	0.114	1.239	1.055	0.184
3	1.241	1.166	1.042	0.124	1.136	0.997	0.139

(*b*) **Sedimentary residual soil**

Sample No.	Single Oedometer: Initial void ratio, e_o	Void ratio (before wetted), e_i	Void ratio (after wetted), e_f	Δe	Double Oedometer: e_{dry}	e_{wet}	Δe
1	1.630	1.495	1.364	0.131	1.363	1.153	0.210
2	1.481	1.304	1.181	0.123	1.370	1.181	0.189
3	1.480	1.281	1.160	0.121	1.421	1.180	0.241



(a) Granitic residual soil - sample 1



(*b*) Sedimentary residual soil – sample 1

Figure 2.3: Graph for single and double oedometer test (Nor Azwati Azmi et al., 2008)

2.5.2 Plate load test

Other then oedometer test, there are other experiment that I think suitable to test the collapsible soil, the test is plate load test. Plate load test has been commonly used in the foundation highway design on collapsible by many investigators including Clevenger, Clemence and Finbarr, chen et al, Houstan et al, Yakov, Ferreiran, Rainobvich (H. A. Alawaji, 1998).

This is the example of plate load test, the characteristic of soil collapse is evaluating using plate load test. According to H. A. Alawaji (1998), one of the features of this testing program is the employment of small diameter plates which is identically to the plate diameter used in the in-situ collapse test developed recently by Houston. This test will determine the soaking period and loading/unloading experimentally. The water content will be measure at the end of each soak test to assess the extent of wetting front (H. A. Alawaji, 1998).

Table 2.3: The plate load test program (H. A. Alawaji, 1998).

Test type	P_0 (kPa)	D (mm)	Soil thickness (cm)
Double (Dry & Soaked)	5	70	15
~~	7	70	15
~~	9	70	15
Single (Soaked at 100 kPa)	7	50	5, 10, 15, 20
~~	7	70	5, 10, 15, 20

First of all prepare the sample by compact the sand bag at the bottom of the test container. A predetermine weight of sand needed to produce a dry density of 1.768g/cm³ was compacted in one 20cm tick layer. To assume uniform and continuous wetting during soaking the sand bed is consider highly permeable. It is also thin and dense to ensure it does not contribute to plate settlement and can be assumed a rigid layer during strain conclusion (H. A. Alawaji, 1998).

Table 2.4: Engineering properties of soil (H. A. Alawaji, 1998).

Table 1. Engineering properties of soils

Alluvial soil (HCS)	
Specific gravity	2.75-2.77
Liquid limit (%)	20-27
Plasticity index	1-6
Soil classification (USCS)	ML
Permeability coefficient	
At natural dry density and water content (cm/s)	1.31×10^{-4}
At 95% maximum dry density on dry side of compaction curve (cm/s)	1.83×10^{-6}
Sand bed	
% passing No. 4 US sieve	97.66
% passing No. 200 US sieve	0
Gravel (%) 2.34 D10 (mm)	0.33
Maximum dry density (gm/cm^3)	1.960
Minimum dry density (gm/cm^3)	1.627
Uniformity coefficient (Cu)	5.45
Curvature coefficient (Cc)	0.95
Dry density (gm/cm^3)	1.786
Permeability coefficient (cm/s)	9.5×10^{-2}

Take the soil from 1.7m depth and then used in its natural water content, and any lumped soil was broken into its original grain size such that the soil passes sieve no. 10 (2mm opening). Then compact the soil to 1.4 g/cm^3 dry density in layers of 50mm thickness. The container depth varies from one to four times the plate diameter, D. The depth variation was considered small enough to assume a finite soil medium for collapse strain calculation, and the final total depth was considered large enough relative to the plate diameter to assume a semi infinite soil medium (H. A. Alawaji, 1998).

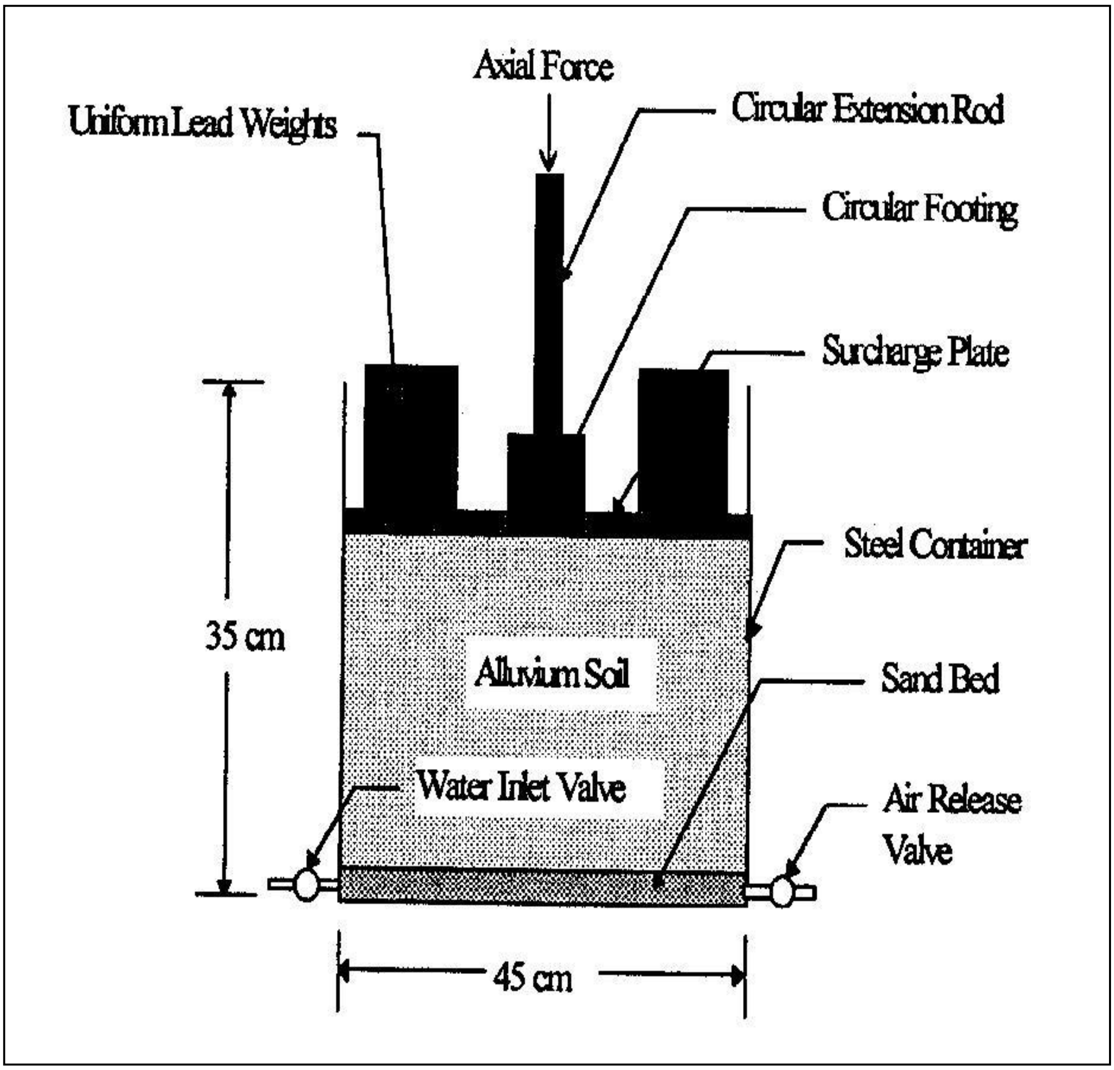


Figure 2.4: Schematic of plate load test (H. A. Alawaji, 1998).

Apply load in cumulative increments such that the net pressure follows, in general, the following path: 0.0, 13, 25, 50, 100, 50, 25, 50, 100, 200 and 300kPa etc. After the application of each load increment, the cumulative load was maintained until all settlements and collapse had ceased when the rate of deformation reaches less than or equal to 0.001mm/min. over the last 10 to 15 min. it was noticed that the equilibrium was reached after 15 min for the dry loading increments and after 2 hours for the wet loading increment. During soaking the pressure was kept constant for at least 12hours and until collapse settlement had ceased according to the above rate of deformation criteria. For soaked samples, water inlet was open and water allowed to flow into the sand layer at an initial pressure had of 15-30cm. the net pressure was maintained constant during each loading, unloading, and reloading steps, and displacement data were collected at approximately 50 to 60mm. Plate was unloaded, then test apparatus was disassembled at the completion of final unloading stage, and samples were obtain for moisture content determination (H. A. Alawaji, 1998).

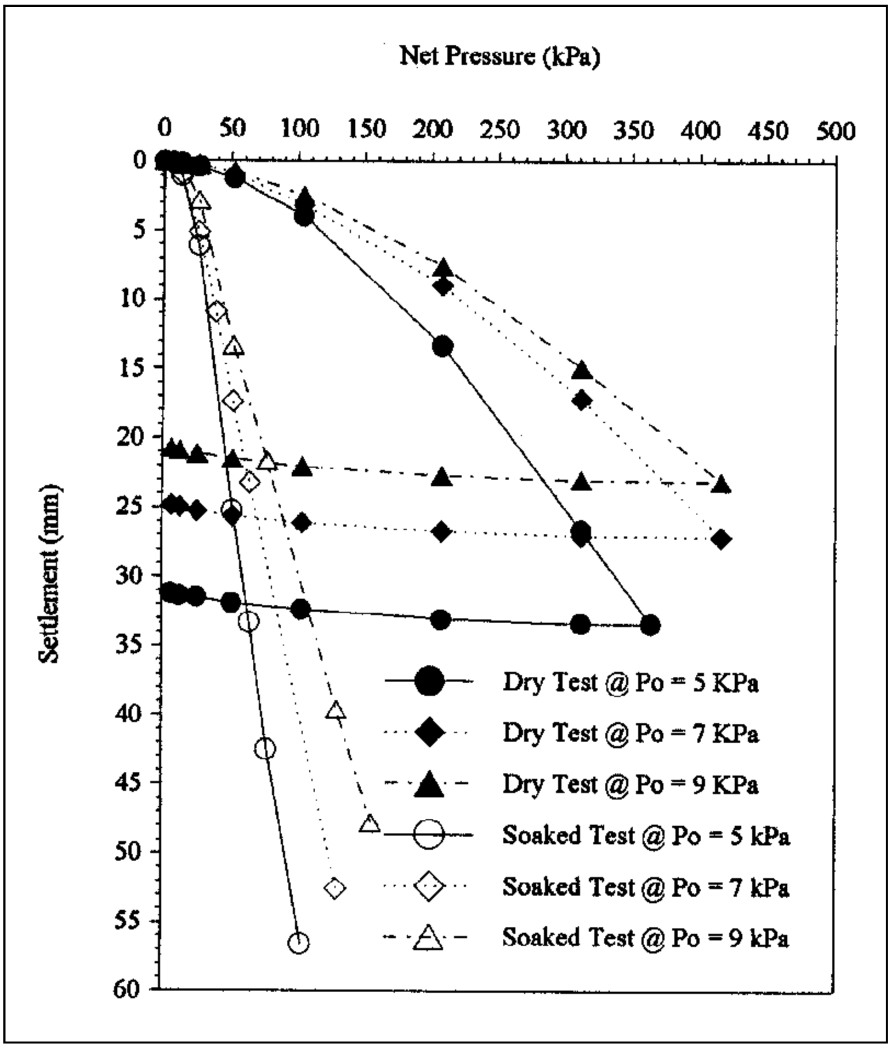


Figure 2.5: Pressure settlement of 7cm plate on A1 Helwah soil of 15 cm thickness compacted under natural condition under various over burden plate (H. A. Alawaji, 1998).

Figure 2.5 show the result of variation of net pressure settlement under 5, 7, 9 kPa over burden and figure 2.6 shows the result of variation of collapse settlement.

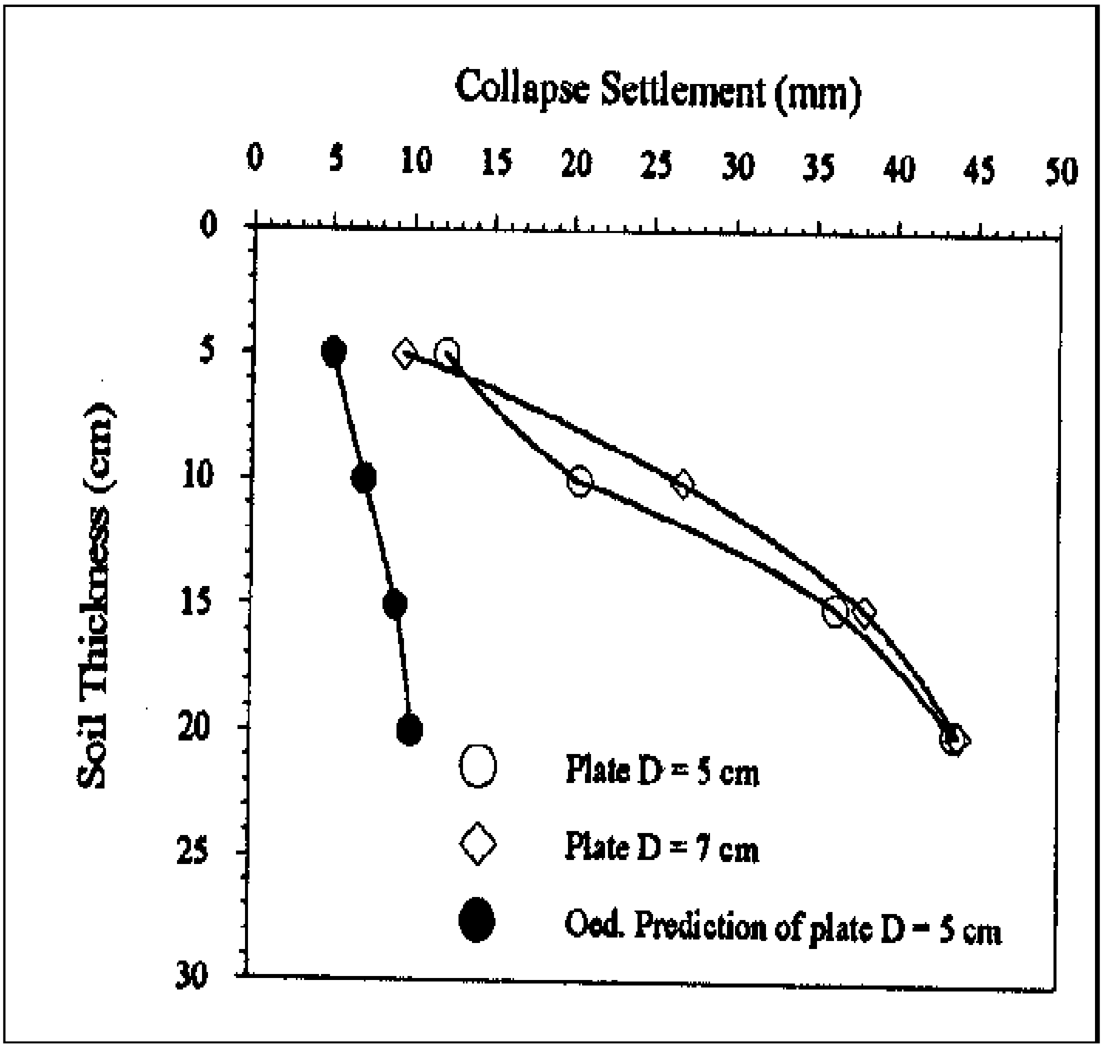


Figure 2.6: Variation of collapse settlement with soil thickness for various plates soaked under 100kPa (H. A. Alawaji, 1998).

2.6 Summary of literature review

Through this section, I will summarize the literature review that I have done in previous section. From what I have explained earlier at previous section, the objective of this study is to find the collapsibility rate of residual soil at Gambang Pahang. After I reviewed all the articles and journals that I have collected. I found that, there are a lot of definition that has been used regarding to collapsibility and residual soil. But actually the meaning and the objective is same. Collapsibility is a soil reduction upon wetting and residual soil is soil that is form by weathering of organic material.

From the literature review, there are a lot of test that can be conduct using residual soil according to its objective and purpose. Below are the types of test that I have found in my journal article. For example:

1. Field infiltration test (FIT) - to determine the infiltration rate in residual soil.
2. Pressure Meter Test (PMT) and Cone Penetration Test (CPT) are used - to give better information on the behavior of the residual soil.
3. in-situ load test - to obtain stress-strain data
4. suction controlled isotropic compression test - to determine the volume change of the unsaturated residual soils
5. Triaxial compression test - the purpose of this test is to determine the stiffness and compressibility of the soil
6. Oedometer test - to determine this characteristic but it is not suitable for measuring compressibility of course grained soils
7. Plate load test – to determine collapse of soil

Related to my topic, I think that oedometer is more suitable test to determine the collapsibility of residual soil. This is because in double oedometer test I can determine the collapsibility rate of residual soil and it can show the result of collapsible from the effect of wetting.

CHAPTER 3

METHODOLOGY

3.1 Overview of the study

In this chapter the procedures of experiment and sample preparation will be explain. To achieve the objective of study, two major laboratory experiments were carried out that is single oedometer test and double oedometer test. Other than that, experiment such as specific gravity, sieve analysis, Atterberg limit and moisture content will also carried out to get the soil properties.

3.2 Material of Sample

Before starting the study, the type of material of sample must be determine to ensure that this study is conduct according to the objective of this study.

3.3 Type of Soil Sample

There is two main type of residual soil that is Granatic residual soil and Sedimentary Residual Soil. The main different of this two type of soil is it origin. The type of sample used in this study is sedimentary residual soil.

Sedimentary residual soil is formed from sedimentary rocks. Sedimentary rocks often have distinctive layering or bedding. These rocks were composed of sediment and were formed from pre-existing rocks or pieces of once-living organisms.

3.4 Engineering properties and classification tests

Engineering properties and classification tests is a test to determine the specific value of engineering properties of the sample and to determine the type of sample by conducting a laboratory test. Further explanation will be discussed below.

3.4.1 Moisture content

Moisture content is an important parameter to determine the soil characteristics. The method used in this study is oven-drying method; this method is simple and easy to conduct.

First of all, take the weight of the container. Then, put the wet soil in the container and weighed the wet soil and the container. After that put the container with the wet soil in to the oven with temperature 105 ºC – 110 ºC as this is specified as the standard procedure and should be used as rule.

Leave the sample for 24 hours in the oven. After 24 hours, remove the container from the oven and cooled it. The dry soil with the container was then weighed. This procedure is repeated for at least 3 times to take the average moisture content. The moisture content of the soil can be calculated by the equation:

$$\text{Moisture content, w\%} = \left[\frac{\text{mass of soil} - \text{mass of dry soil}}{\text{mass of dry soil}}\right] \times 100\% \qquad (3.2)$$

3.4.2 Particle Size Distribution

The purpose of this test is to determine the particle size distribution of the coarse and fine aggregates. Other then to determine the particle size, it is also used to get the sample passing 2mm of sieve to do an Aterberg limit test and Specific gravity test.

Before start the test, a disturb sample has been taken about 2kg from the site. The sample is then dried by putting it in to the oven about 105 ºC – 110 ºC leave the sample for about 24 hours. After 24 hours, the oven dried sample is then is placed on top of the sieve using a set of sieves apparatus. The sieves set should be arrange according to sequence from the bigger size on the top to the smaller size at the bottom.

Sieve the sample for about 10minutes. After sieve the sample, take each of the sieve and weighed it according to it size. The bigger size of the sample will be retain on top of the sieve and sample that have size smaller then mesh opening will pass through the sieves.

The weight of sample retained on each sieve is then used to determine the particle size distribution as well as the mean diameter of the sample.

$$\%\,\text{retain} = \frac{W_{\text{sieve}}}{W_{\text{Total}}} \times 100\% \tag{3.2}$$

$$\%\text{ cumulative passing} = 100\% - \%\text{ cumulative retained} \tag{3.3}$$

The results of the sieve analysis are recorded graphically on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate.

3.4.3 Atterberg's limit

The objective of the Atterberg limits test is to measure the liquid and plastic limits for a soil sample or to obtain basic index information about the soil used to estimate strength and settlement characteristics.

Sample that have been sieved is use to determine the liquid and plastic limits, which are moisture contents that define boundaries between material consistency states. The liquid (LL) and plastic (PL) limits define the water content boundaries between non-plastic, plastic and viscous fluid states. The plasticity index (PI) defines the complete range of plastic state.

3.4.3.1 Liquid Limit

According to BS 1377:1990: part 2, clauses 4.3, 4.5, the liquid limit of a soil can be determined using the cone penetrometer or the Casagrande apparatus. In this test, cone penetrometer will be used to determine the liquid limit because it is essentially a static test which relies on the shear strength of the soil. The liquid limit determined at 20mm cone penetrometer.

Soil sample that passing 2mm of sieve is prepared to do this test. Place the sample in the mixing bowl and mix it with an increment of distilled or de-ionised water ad stir it using a spatula. Continue adding increments of water until the test portion becomes a thick homogeneous paste. Then the sample is placed in a 55mm diameter, 40 mm deep metal cup.

Fill the penetration container by placing a quantity of the cured test portion in the bottom of the container and exert adequate pressure on the spatula to displace the cured soil in an outward direction so as to remove air bubbles from the cured soil. Level the sample by removing the excess sample at the surface of the metal cup using blade.

Then, place the penetration container filled with the cured soil, approximately central under the point of the penetration cone. Lower the penetrometer head until the point of the cone just makes contact with the surface of the cured soil. Release the penetrometer shaft and allow the cone to penetrate the cured soil for a period of 5 seconds and then restrain the penetrometer shaft.

Release the penetrometer shaft 3 times at different places on the sample surface. Remove a test increment of approximately 10g, with a spatula, from near the area penetrated by the cone and determine the moisture content. Then repeat the test 3 times by adding more distilled water on the soil for each test.

To determine the liquid limit, plot the moisture contents against their corresponding penetration values on a linear graph with the percent moisture content on the horizontal axis and the penetration value on the vertical axis. The moisture content corresponding to the intersection of the line of best fit and the 20mm penetration ordinate is then determined. This moisture content is then Liquid Limit of the soil.

3.4.3.2 Plastic Limit

A 20g of soil paste is prepared and placed on the glass plate. The soil is then divided into two and shaped it into round shape. Then cut each ball into 4 parts and place each part in the same glass plate.

Take one of the parts and rolled it using fingers, the rate of rolling should be between 80 to 90 strokes per minute to form a 6mm diameter. If the diameter of the threads can be reduced to less than 3mm, without any cracks appearing, it means that the water content is more than its plastic limit. Knead the soil to reduce the water content and roll it into a thread again with a steady pressure.

Repeat the process of alternate rolling and kneading until the thread crumbles. Immediately place the sample into the container and weighed it. Put the sample in to the oven for 105 ºC – 110ºC. Take out and measure the sample after 24 hours to get the moisture content.

3.4.3.3 Plastic Index

Plastic index (PI) is the measure of the plasticity of the soil sample, PI is the difference between LL and PL. The plastic index is measure by using this formula;

$$PI = LL - PL \tag{3.4}$$

Where PI is the plastic index, LL is the liquid limit and PL is the plastic index.

3.4.4 Specific Gravity

To determine the specific gravity, the density bottle method has been used. This method is a most conventional method. In this test, distilled water has been used as a liquid in this experiment. If the soil contains salt, kerosene should be used as an alternative.

Before starting the experiment, clean the density bottle using distilled water after that dried the density bottle. Weighed the dried and empty density bottle with it stopper. Then, put about 10g of oven dried sample in to the density bottle.

Take the weigh of the density bottle, stopper and sample. After that, fill up the density bottle for about ¾ full. After the density bottle is filled up with distilled water, close the bottle with stopper and placed it in the vacuum desiccators for at least 1 hour.

After 1 hour, take out the density bottle from the vacuum desiccators. Measure the density bottle and it content against. Clean the bottle after weigh the density bottle and it content. The clean density bottle is then dried again.

The dried densities bottles are then are filling with distilled water and close it with stopper. The mass of bottle is measure. After take the mass, put the bottle inside the vacuum desiccators for at least 1 hour. After 1 hour, take the reading of the density bottle and it content. The test is carried out using 3 samples.

3.5 Major Experiment

There are two types of major experiment that were carried out for this study. The experiments are single and double oedometer test. Both test use undisturbed sample, the undisturbed sample is prepared at the site. The top soil is removed for about 0.2m to 0.5m with considering the factor of safety. Then sample ring (75mm diameter x 20mm high) with sharp end is push into the soil. Then dig the soil around the ring, cut the soil at bottom of the ring using blade. Then trimmed and leveled to the end face of the cutting ring by using sharp blade.

3.5.1 Single oedometer test

Weigh the undisturbed sample with the ring. The sample is then is place into the consolidation cell. The soil sample in the ring was place into the lower porous disc where it was located centrally on the base of the cell. After that, place the ring retainer and cell body fitted around the ring. Closed the specimen by putting the upper porous disc centrally on top of the specimen. After finish setting the consolidation cell, place the consolidation cell on the load frame where it was placed centrally on the cell platform.

Set the beam of the oedometer test to the vertical position. Then set the dial gauge so that it touches the screw spindle. The dial gauge is then check to make sure it is not to press the screw spindle, if these happen, the dial gauge cannot take the reading. Put a 1 kg of load and hold the beam with the screw jack. Add water to the specimen and start the test, leave the test for about 24 hours. After 24 hours end the test stage. Double the load and star the test. This procedure is repeated by doubling the load to 2kg, 4kg, 8kg and 16kg.

After completion of the experiment, remove the load from the load hanger and take out the consolidation cell. After that, carefully take the wetted sample and the ring out from the consolidation cell and weighed the sample. The sample is then takes and put it in to the oven dried to determine the moisture content. The result and characteristic of void ratio verses stress curved generated from this experiment discussed in detailed in chapter 4.

3.5.2 Double Oedometer test

For double oedometer test, the method is not much different from the single oedometer test. The different is it used two undisturbed sample and two set of oedometer apparatus. However, both samples were experimented at different condition. One of the samples is test at natural condition. For the other sample, it remained in the same condition until it reaches the loading at 80kPa. When it reach 80kPa, the sample is then wetted.

In this experiment, two void ratios against stress curve generated. One is generated from the sample at natural condition and the other one is at wetted condition.

CHAPTER 4

RESULT AND DISCUSSION

4.1 General

In this chapter the result of the experiment will be reviewed and discussed. The main experiment to determine the effect of wetting on collapsibility rate at gambang is Oedometer test (single and double oedometer test). The method to conduct this experiment is as explained in chapter 3. After the experiment has been done, the data are recorded and the results are presented in graphs and collapsibility index.

Beside that, the characterization of the residual soil also will be discussed in this chapter. The classification and engineering properties of the soil is determine by conducting a laboratory experiment that is moisture content, specific gravity, Atterberg limit test and particle size distribution (sieve analysis).

All the results related to the soil properties are presented in the form of table and graph. The calculation of all the experiments will be shown at the appendix section.

4.2 Soil Classification

In this study there are two types of laboratory testing that have been conducted to determine the soil classification. The testing is Atterberg limit test and particle size distribution (sieve analysis).

4.2.1 Particle Size Distribution (Sieve Analysis)

The purpose of this experiment is to classify the particle size of the soil sample. The result of the experiment is shown in table 4.1 below.

Table 4.1: Result of particle size distribution

Sample No.	Fine Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Classification
Sample 1	2.37	74.66	17.44	1.53	Silty Sand, SM
Sample 2	4.87	77.89	15.03	2.21	Silty Sand, SM
Sample 3	4.84	77.85	15.10	2.22	Silty Sand, SM

After the analysis has been done, the soil is classified as Silty Sand. This is because, from the result in the table above, it can be seen that the amount of sand and silt is much greater than the other type of soil.

Because of this sample is silty sand, it can be said that the soil has more void ratio. When the void ratio is high, the soil is more porous and it allows water to infiltrate easily. The silty sand in this result means that the amount of sand in the soil is higher than the amount of silt.

4.2.2 Atterberg Limit

The liquid limit, plastic limit and plastic index are determined by using the Casagrande's method called Atterberg Limit Test. These limits were created by Albert Atterberg, a Swedish chemist. They were later refined by Arthur Casagrande.

The data is collected and calculation of liquid limit, plastic limit and plastic index are shown in appendix C. The result of Atterberg limit test is shown in table 4.2.

Table 4.2: Liquid Limit, Plastic Limit and Plastic Index

Sample No	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)
1	43	27	16
2	45	22	23
3	49	26	23

The objective of this test is to obtain basic index information about the soil used to estimate strength and settlement characteristics. From the table 4.2, it can be seen that the range of liquid limit is at 43% to 49%, plastic limit is at range 22% to 27% and plastic index is at range 16 to 23%.

4.3 Engineering Properties of Soil

To determine the collapsibility rate of the residual soil, it is compulsory to determine the engineering properties of the residual soil. This is because the result of the test will be used to calculate the collapse potential of the soil. In this part, the result of natural moisture content and specific gravity will be viewed and discussed.

4.3.1 Moisture Content

Data collected and calculation of moisture content for the soil samples are shown in appendix A. The result are shown in table 4.3

Moisture content can be determined by using standard drying of soil at temperature 105°C to 110°C for 24 hours. Results of moisture content that is obtained from these 3 samples are 28.70%, 23.42%, and 26.32% where the different is not too large.

Table 4.3 Moisture Content

Sample No	Moisture Content (%)
1	28.70
2	23.42
3	26.32

To obtain the effective moisture content, the average moisture content is determined from each of the sample. Each sample has been replicated 3 times in order to obtain the average moisture content.

The moisture content will be used and inserted in the software to generate result and graph to determine the collapsibility rate of the soil at certain condition of moisture.

4.3.2 Specific Gravity

Data collected and the calculation of specific gravity of the samples are shown in appendix B. The results of Specific gravity are shown in table 4.4.

The specific gravity of this soil is determined using density bottle test. The average specific gravity for this soil is 2.327. The purpose of conducting this test is to find the initial void ratio e_0 by using this formula $\mathrm{e_o} = \mathrm{wG_s}$ where w is moisture content and G_s is specific gravity.

Table 4.4: Result of specific gravity

Sample No	Specific Gravity, Gs
1	1.98
2	2.54
3	2.46
Average	2.327

4.4 Oedometer test

The collapse potential of residual soil in this study is examined by using Oedometer test (single and double oedometer test). This method was introduced by previous researchers that are Jennings and Knight (1975). The sample is put in a different condition of moisture content. The data are analyzed by using semi log graph. The objective of this test is to obtain the amount of collapse potential of the soil sample. Discussion about the result will be shown in this section.

4.4.1Collapse Potential at Gambang

The collapse potential at Gambang is determined using double oedometer test. The test is done by putting the same amount of water to the sample that is at 180mL. After the entire three samples is tested and completed. The collapse potential of the entire three samples is calculated and the average of the collapse potential is taked as the value of collapse potential at Gambang. The result and analysis of the sample will be discussed below. Below are the results of the collapse potential at Gambang for sample 1 sample 2 and sample 3 at the same water content that is 180mL at pressure 80kPa.

Table 4.5: Double oedometer result

Samples	Void ratio	Normal Moisture content	Wetted 180mL	Wetted soil	Collapse potential %
Sample 1	Initial Void ratio	0.717	0.702	0.615	4.13
	Final void ratio	0.717	0.62	0.615	
Sample 2	Initial Void ratio	0.704	0.705	0.615	4.44
	Final void ratio	0.704	0.625	0.615	
Sample 3	Initial Void ratio	0.686	0.647	0.561	4.00
	Final void ratio	0.686	0.565	0.561	

From the table 4.5, there are three types of the condition of the soil that is the soil at normal moisture content, wetted at 180mL and wetted soil. The purpose of putting these samples at this condition is to see the different of the soil condition when it is wetted and before wetted. For sample 1, 2 and 3, we can seen that the void ratio of the soil that is wetted at 180mL at pressure 80kPa, the void ratio is slightly the same as the normal moisture content for initial void ratio and wetted soil for final void ratio.

From the observation, we can see that there is a drop of the amount of void ratio from initial to final void ratio when the soil is wetted at 180mL. The clear view of these changes can be observed at the graph below.

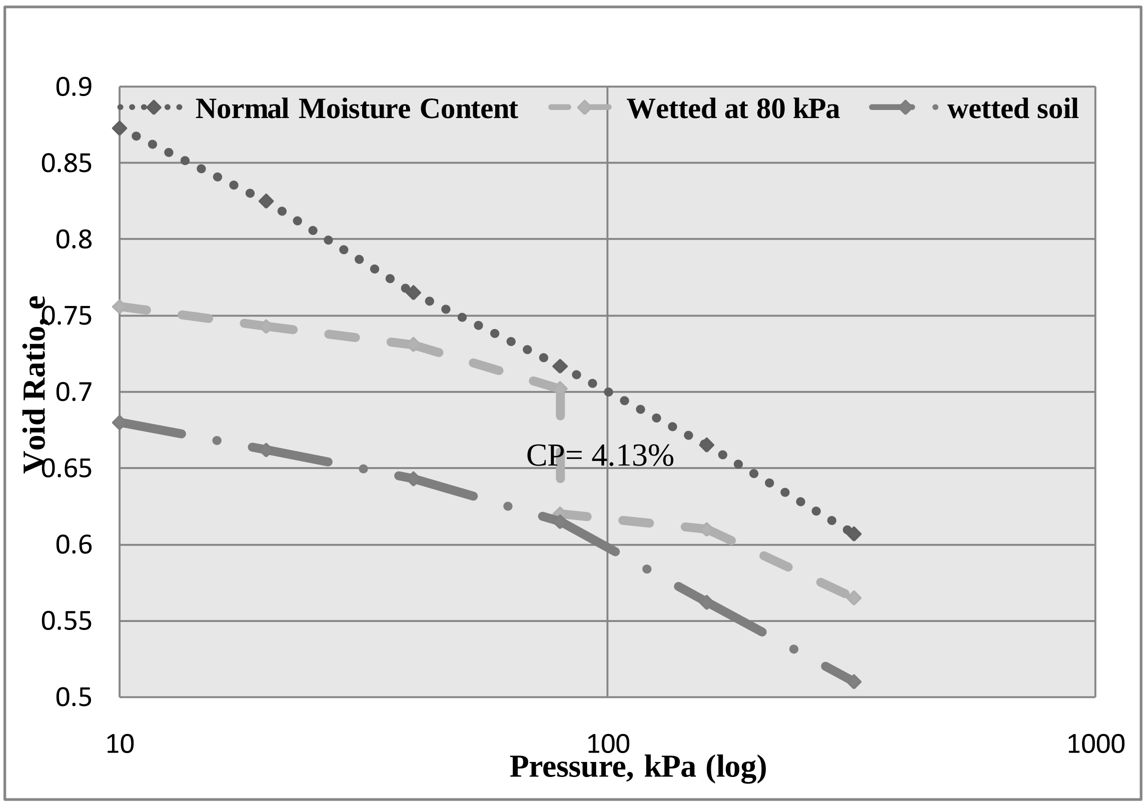


Figure 4.1: Graph of void ratio VS Pressure for sample 1 wetted 180mL

From the picture 4.1, we can see that there is a drop of void ratio value from initial to final void ratio and yield a collapse potential value. For this sample 1, the void ratio that is yield from this graph will be calculated and using formula that is proposed by Jennings and Knight (1975) the collapse potential of sample 1 is 4.13%. Same goes to sample 2 and sample 3, the graph of the collapse potential of these two samples are shown in figure 4.2 and figure 4.3.

Below are the graph of void ratio Vs pressure for sample 2 wetted at 180mL. From the result of the sample 2, the collapse potential yielded from this sample is 4.44%

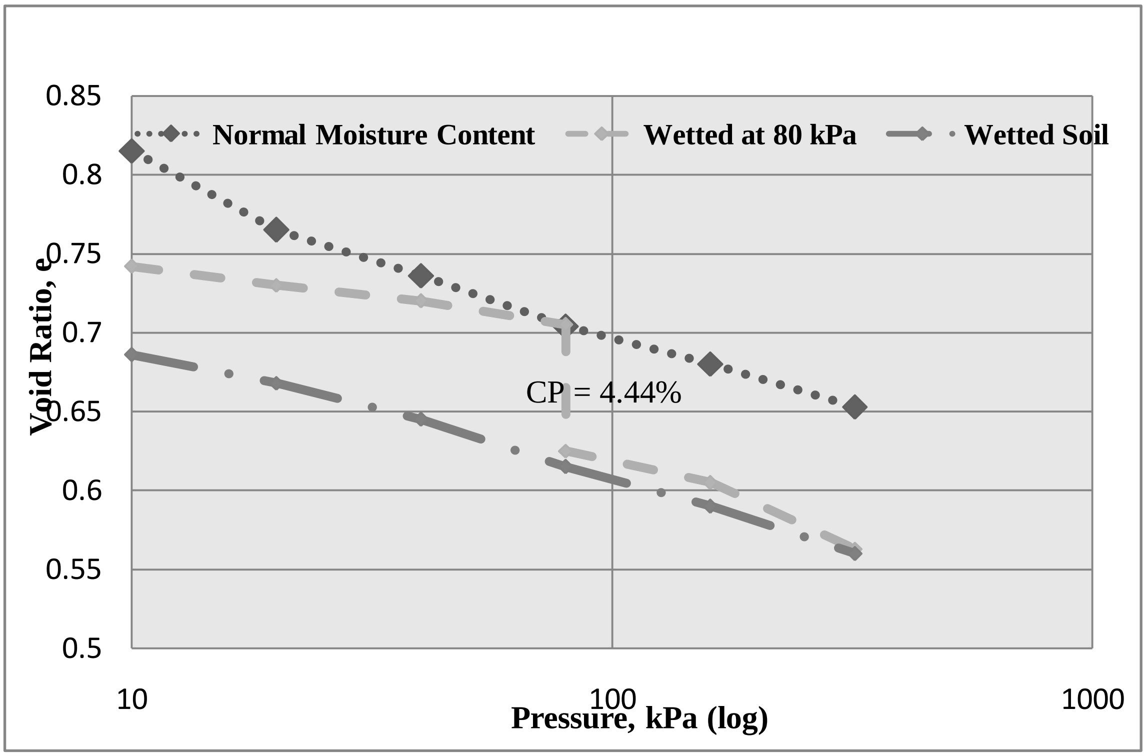


Figure 4.2: Graph of Void ratio VS Pressure for sample 2 wetted 180ml

From the graph we can see that the void ratio dropped and the initial void ratio is 0.705 and after the soil has been wetted at pressure 80kPa with the amount of water is 180mL, the value of final void ratio is 0.625.

Below shows the graph of void ratio Vs pressure for sample 3 wetted at 180ml. From the result of the sample 3, the collapse potential yielded from this sample is 4.00%.

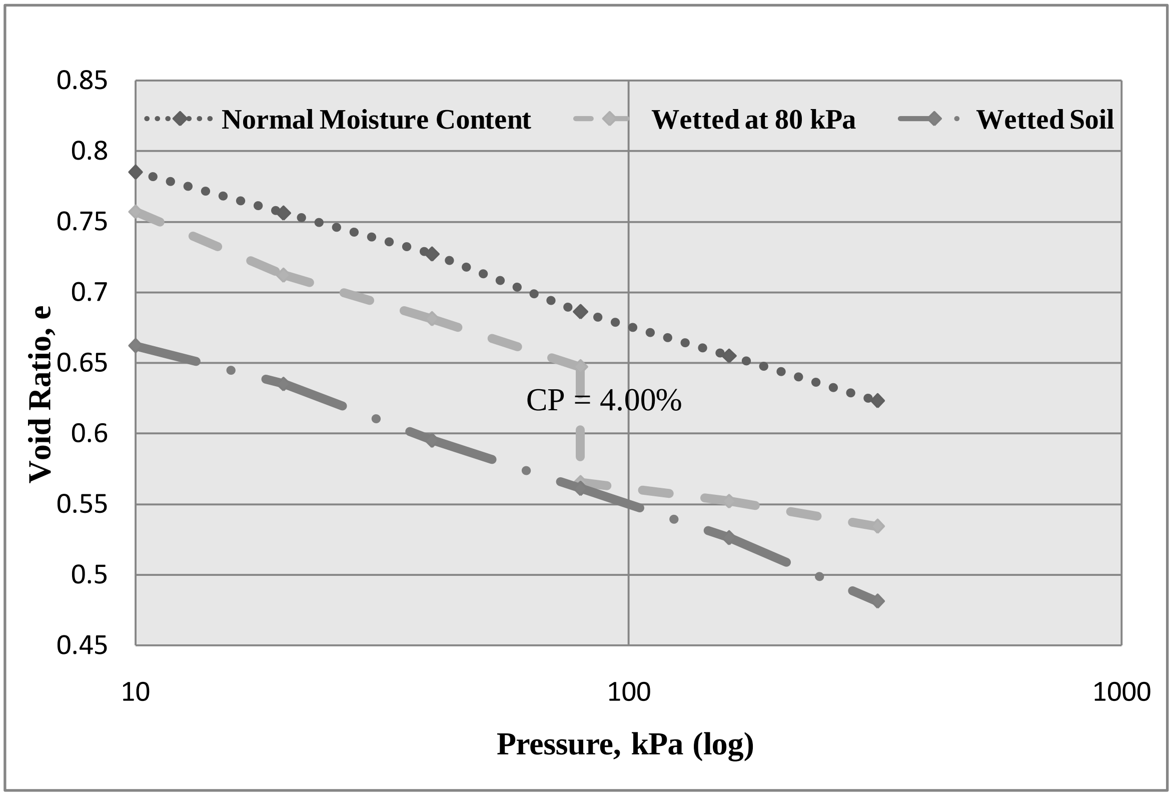


Figure 4.3: Graph of Void ratio VS Pressure for sample 3 wetted 180ml

From the graph we can see that the void ratio dropped and the initial void ratio is 0.647 and after the soil has been wetted at pressure 80kPa with the amount of water is 180ml, the value of final void ratio is 0.565.

The result of sample1, sample 2 and sample 3 recorded the collapse potential as 4.13%, 4.44% and 4.00% respectively. Therefore the collapse potential of Gambang is calculated by finding the average of the soil collapse potential that is gained from this test. The average collapse potential at Gambang is 4.19%.

Comparing the result of void ratio of Gambang and Bentong from the literature review shown in page 17. We can see that the void ratio at Gambang and Bentong is different where the void ratio at Bentong is higher than the void ratio at Gambang. At Bentong there is two types of soil that is obtained from Bentong. The type of soil is granitic residual soil and sedimentary residual soil compared to Gambang, the type of residual soil is silty sand. The type of soil in Gambang is silty sand because the percent of sand in this soil is greater than the percent of silt.

The void ratio at Bentong is greater than the void ratio at Gambang because the type of soil at Bentong is Sedimentary and Granitic. This type of soil has greater amount of poros compare to soil at Gambang. The collapse of the residual soil is depending on the porosity of the soil, the greater the poros the higher the collapse potential.

For the collapse potential, Bentong has the higher collapse potential compared to Gambang. From the result of Bentong shown in figure 2.3 page 18, it shows that for granitic residual soil, the collapse potential for this soil after wetted at pressure 80kPa the collapse potential is 5.31%. For the sedimentary residual soil at Bentong, the collapse potential obtained is 4.89%. Compared to Gambang, the collapse potential at Gambang is only 4.19%.

As mentioned earlier, the collapse potential of the soil is depend on the amount of void ratio or porosity of the soil. The porosity of the soil causes the water to penetrate easily and when the soil is saturated with the water. The water will coated the soil particle and make the friction between the soil particles loose.

When these occurred, the soil that is coated with water will tend to slide with each other and cause the soil to collapse.

4.4.2 Effect of Moisture Content on Gambang Residual Soil

For the effect of moisture content on Gambang residual soil, the test using double oedometer once again is used. To achieve this objective, for this time the amount of water added to the soil sample at pressure 80kPa is added in a different amount of water on a purpose at interval 80mL 130mL and 180mL to see the different of collapse potential that is yielded from this test. After the test has been completed the results are presented in table 4.6.

Table 4.6: Double oedometer result with different moisture content

Samples	Void ratio	Normal Moisture content	Wetted at 80kPa	Wetted soil	Collapse potential %
Sample 1 wetted at 180mL	Initial Void ratio	0.717	0.702	0.615	4.98
	Final void ratio	0.717	0.62	0.615	
Sample 2 wetted at 130mL	Initial Void ratio	0.704	0.667	0.615	2.98
	Final void ratio	0.704	0.621	0.615	
Sample 3 wetted at 80mL	Initial Void ratio	0.679	0.596	0.561	1.92
	Final void ratio	0.679	0.565	0.561	

The decrease of the void ratio from this table is shown clearly in the graph form that is shown in figure 4.4.

Below shows the graph of void ratio Vs pressure for sample 1 wetted at 180mL. From the result of the sample 1, the collapse potential yielded from this sample is 4.29%.

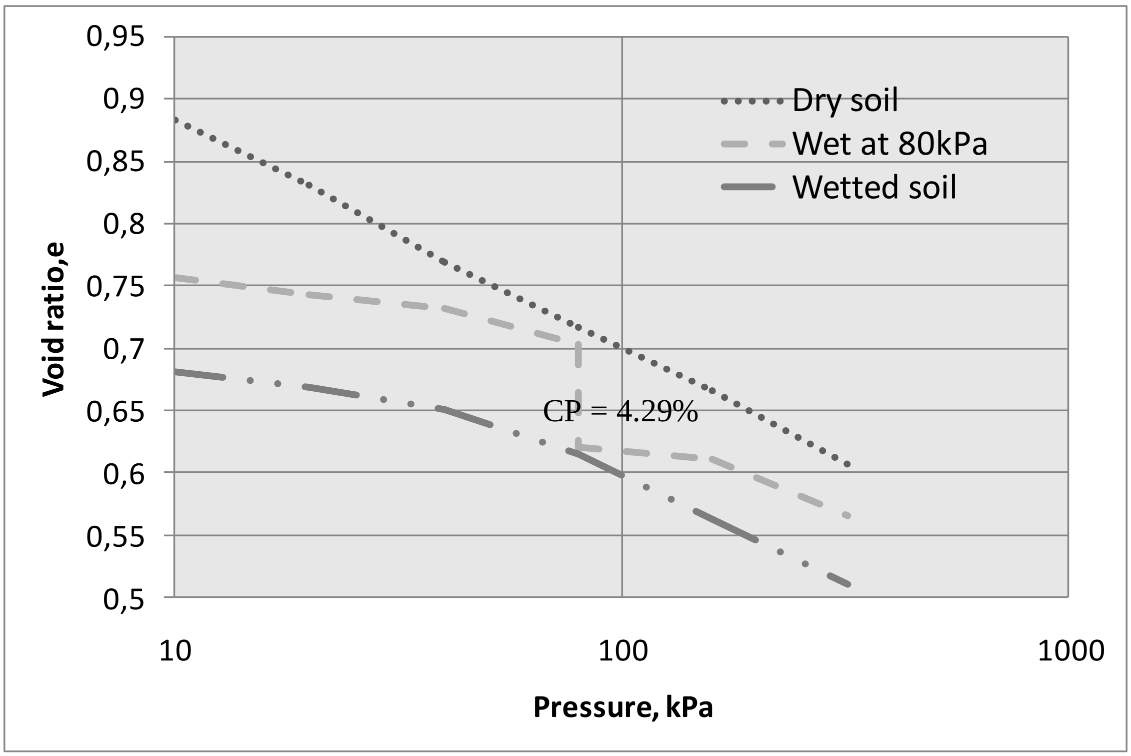


Figure 4.4: Graph of Void ratio VS Pressure for sample 1 wetted 180mL

From the graph above we can see that there is a drop of void ratio value from the initial to final void ratio and yielded a collapse potential. For sample 1, the void ratio that is yield from this graph was calculated and using formula that was proposed by Jennings and Knight (1975) thus the collapse potential of sample 1 is 4.29%.

Below shows the graph of void ratio Vs pressure for sample 2 wetted at 130mL. From the result of the sample 1, the collapse potential yielded from this sample is 2.98%.

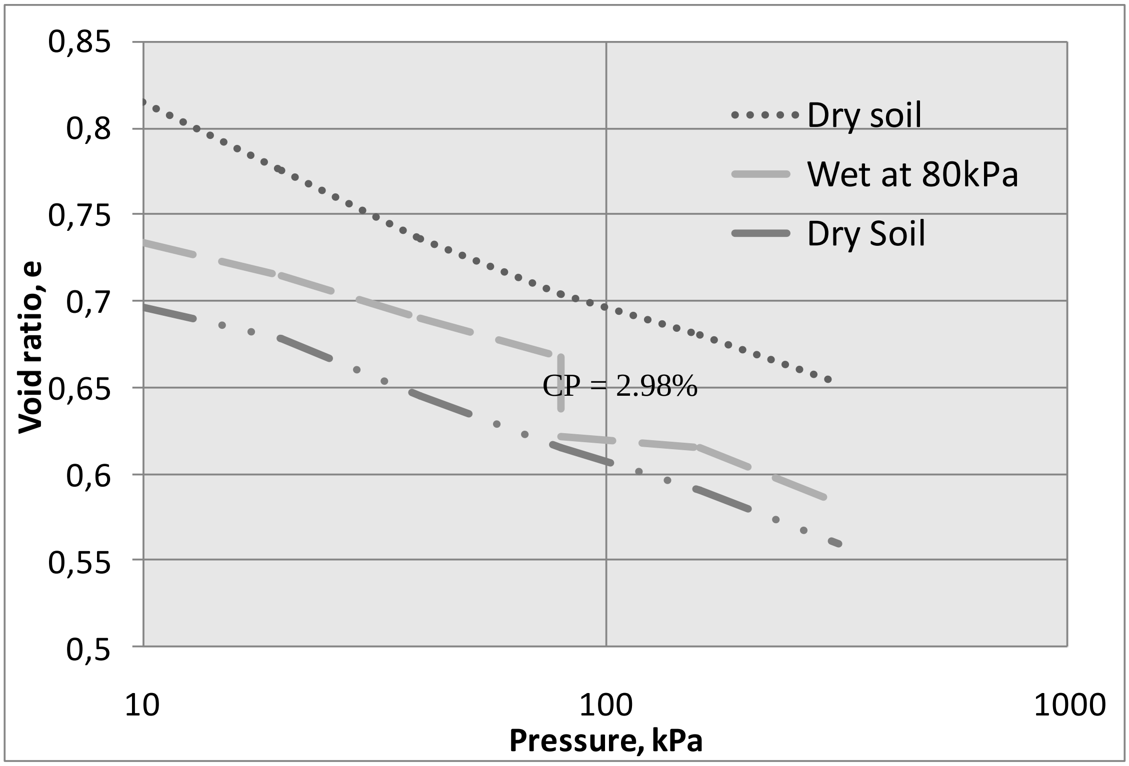


Figure 4.5: Graph of Void ratio VS Pressure for sample 2 wetted 130mL

Figure 4.5 shows the changes of void for sample 2. The water added at 80kPa for sample 2 was 130mL. From the graph, the changes of void ratio were from 0.667 to 0.621.

Below shows the graph of void ratio Vs pressure for sample 3 wetted at 80mL. From the result of the sample 1, the collapse potential yield from this sample is 1.92%.

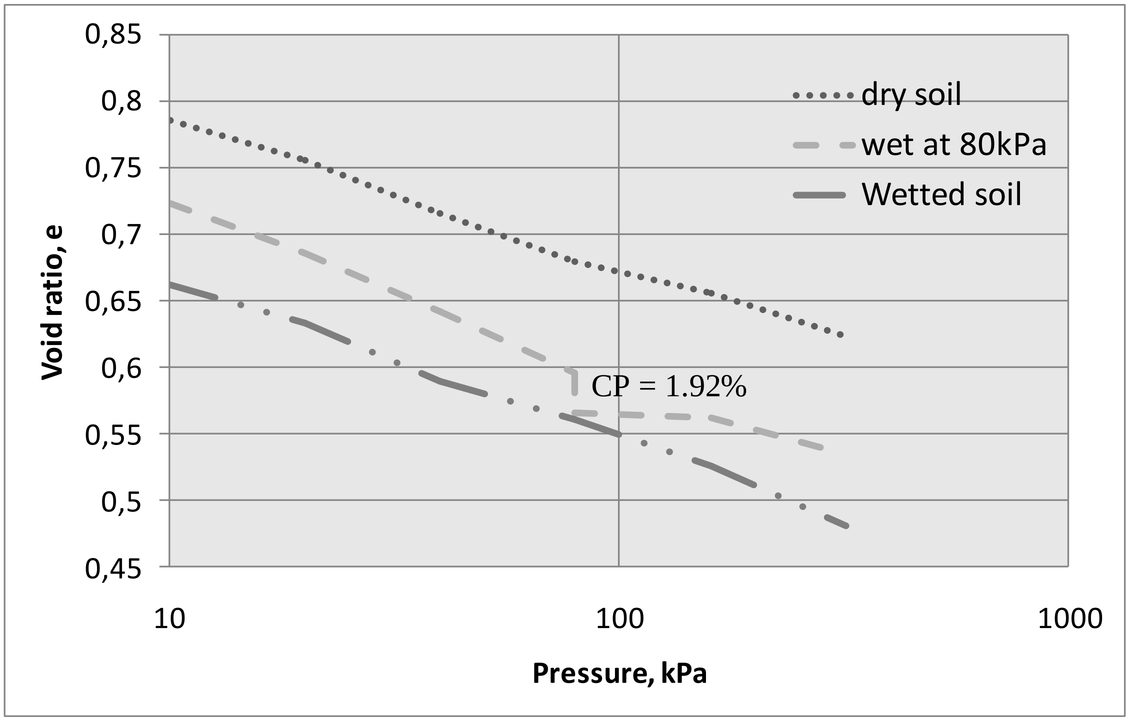


Figure 4.6: Graph of Void ratio VS Pressure for sample 3 wetted 80mL

Figure 4.6 shows the changes of void for sample 3. The water added at 80kPa for sample 3 was 80mL. From the graph, the changes of void ratio were from 0.596 to 0.565. The comparison of the collapse potential of these three samples is shown in figure 4.7.

Below shows the graph of void ratio Vs pressure for sample 1, 2 and 3 wetted at 80mL, 130mL and 180mL with different collapse potential.

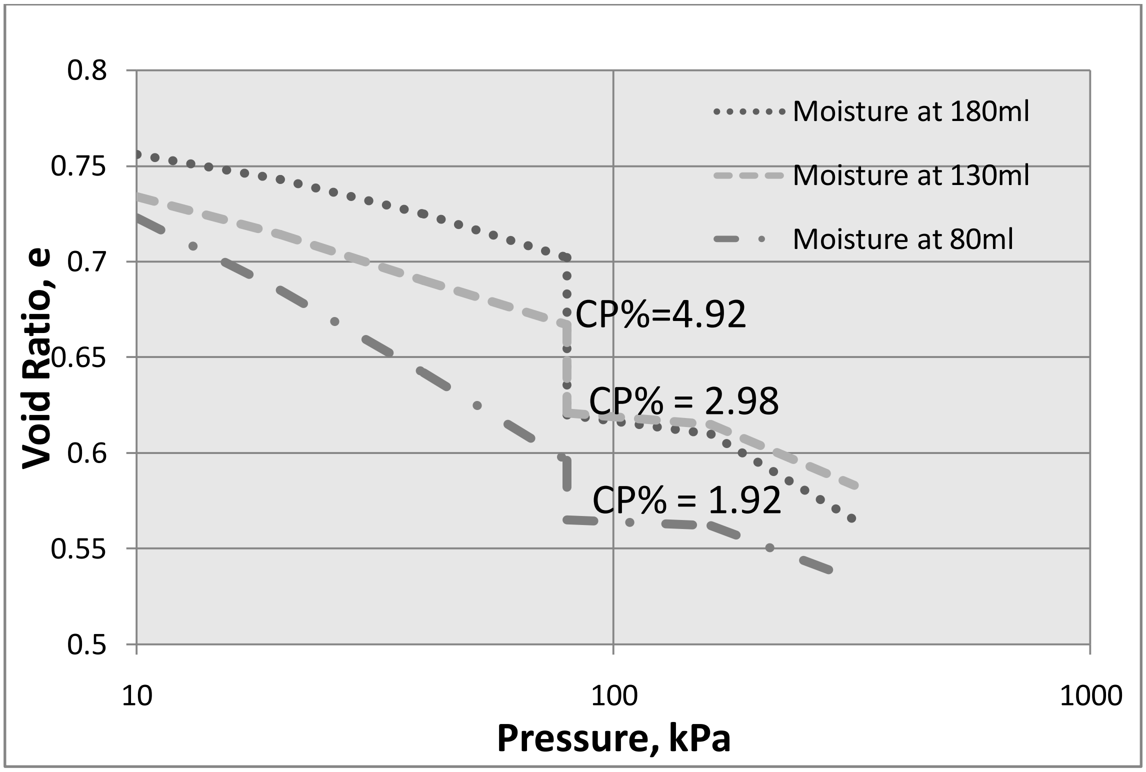


Figure 4.7: Graph of comparison of collapse potential in different moisture content

From the figure 4.7, the collapse potential of the 3 samples is at range 4.92 to 1.92. With referring to the table 4.7 and 4.8, it can be said that the soil is in the moderate trouble by referring to the percent of collapse and the soil is in the medium collapsibility if the collapse potential is referred to the collapsible intensity. The collapse potential classification is based on the table that the previous researchers have created that is Fookes (1990) and Rafie (2008).

Table 4.7: Severity of soil collapse

Percent Collapsibility (%)	Severity of problem
0 – 1	No problem
1 – 5	Moderate trouble
5 – 10	Trouble
10 - 20	Severe trouble
> 20	Very severe trouble

(Sources: Fookes, P. G. 1990)

Table 4.8: Intensity of soil collapsibility

Collapsibility index (%)	Collapse Intensity
0 – 1	No Collapsibility
1 – 5	Medium Collapsibility
5 – 10	High Collapsibility
10 - 20	Very high Collapsibility
> 20	Extremely Collapsible

(Sources: B.M.A Rafie et al, 2008).

From the result, we can see that when the soil is saturated at 180ml of water, the value of collapse potential is increased due to the lost of bonding between soil particles.

When the volume of water is increased, the soil particle that is coated with water also increased, due to this condition, the soil particle that is bonded to other soil particle will loose its bonding because the water added will increase the gap between particles. Since there is no friction occured between the soils particles, the probability of soil collapse also will increase.

Above statement is further strengthen by the other two test done. It seems that when the volume of water is decreased to 130ml and 80ml, the collapse potential also decreased. This is because, the soil particle that is coated with the water will loose its bond. According to Alonso and Gen (1994), collapse occurs as the soil particle bonds are no longer able to resist shear induced at contact forces once the suction is reduced.

When the amount of water is increased, the bonding between soil particles will be decreased. Based on the study of the effect of suction on soil void ratio conducted by Huat et al. (2005b, 2007) it stated that the suction of moisture to the soil provides additional rigidity to the soil structure. This additional rigidity however will be lost when the soil is saturated.

4.5) T-TEST

T-Test analysis is done on comparison between moisture content and collapsibility rate at gambang residual soil. For the null hypothesis, H_o there is no significant difference between collapsibility rate of Gambang and the amount of moisture content. Meanwhile, for the alternative hypothesis, H_A there is significant difference between collapsibility rate of Gambang and amount of moisture content.

The result of the T-Test is determined from the value that is generated from this test. If the value generate is greater than 0.05 the result is not significant and if the result shown is less then 0.05 the result is significant.

From the analysis of the effect of moisture content and collapsibility rate of Gambang residual soils shows that the T-Test calculated, 0.0059 is lower than the value from table which is 0.05. From the result of this test it can be conclude that the alternative hypothesis that is there is significant difference between collapsibility rate and amount of moisture content can be accepted. Due to this result, the analysis shows a significant result.

Table 4.9: T-Test result

Moisture content (ml)	Collapse potential %
80	1,92
130	2,98
180	4,92
T-Test Value = 0.00059 < 0.05	

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter represents the conclusion that has been made based on the previous chapter that is chapter 4. The recommendation will be given for future researches in extending the scope and the findings of this problem and also recommendations to prevent slope from failure.

5.2 Conclusion

From the observation of the tests and results that have been obtained it can be concluded that when the residual soil is wetted, the collapse potential value. The value will increase. The value of collapse potential is depends on the amount of water added in this study. The more water is added, the higher the collapse potential value will be.

This is because, when the moisture content is high, the bonding between the soil particles is weakened and the friction between the soil particles is lost. According to Huat et, al. (2008) wetting may dissolve or soften the bonds between soil particles.

Based on Huat statement (2007), it can be said that the amount of water that is added to the soil sample is directly proportional to the value of collapse potential. The results of collapse potential of this study also meet the criteria as stated by Huat, (2007).

From the result of this study, the value of collapse potential at Gambang is 4.19%. The value of the collapse potential does not reach the expected result from the early study that is more than 10%.

For the conclusion, it can be conclude that, this study has achieve its objective that is to determine the collapse potential of Gambang residual soil that is 4.19% and the collapse potential at Gambang can be classified as moderate trouble based on percent of collapsibility that is created by Fookes P. G (1990), and the soil is at medium collapse if the collapse potential is referred to intensity of soil collapsibility that is created by B.M.A Rafie et al, (2008).

For the effect of moisture content on Gambang residual soil, as mentioned earlier in this chapter, it can be conclude that when the amount of water increased, the value of collapse potential increased too. It can be proved by the result of the laboratory test that already been conducted, the value of collapse potential is increased from 1.92% to 4.92% by increasing water content that is 80mL, 130mL and 180mL.

5.3 Recommendations of the Study

For future study purpose, it is suggested that some changes listed below can be made for improvement and comparison of the research related to collapsibility rate of soil. Bellow are some factors that should be considered:

i. Choose other type of soil to determine the collapsibility rate for example clay to compare the collapsibility rate.

ii. When sampling, if want to take more than one sample, make sure the spacing between the sampling point is 1m to make sure the soil is not disturbed.

iii. Choose other type of testing to determine the collapsibility rate, to compare the result between both testing.

iv. Use the hydrometer test to compare the result of soil classification with particle size distribution.

5.4 Recommendations to prevent collapsibility of soil

As a student of civil engineer, I would like to apply my knowledge in this field by giving some recommendations on how to prevent the collapsibility of soil that is available near the Kolej Komunity Paya Besar. In my oppinion:

i. Build proper drainage at the slope. The purpose is for the water to flow down the slope and can prevent the slope from erosion.

ii. Vegetation. By planting trees at the slope area, the root can help to stabilize the slope. In addition it also helps to remove water through transpiration. The advantage is that this method is more economical than other methods.

iii. Reducing the slope angle. By reducing the slope angle for example the safe slope angle is 0^{o} - 25^{o}, it can reduces the collapsibility potential. This is because, the slope angle can prevent the soil or rock fall due to the gravitaional force.

iv. Build retaining wall. Retaining wall is a structure that holds back soil or rock from a building, structure or area. It also can prevent downslope movement or erosion and provide support for vertical or near-vertical grade changes.

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APPENDIX A

Moisture Content

<u>Moisture Content – Testing Sample 1</u>

1) Mass of container; Sample A = 52.26 g

   Sample B = 55.63 g

   Sample C = 53.43 g

2) Mass of container plus wet soil; Sample A = 62.34 g

   Sample B = 65.67 g

   Sample C = 63.44 g

3) Mass of container plus dry soil; Sample A = 60.06 g

   Sample B = 63.46 g

   Sample C = 61.21 g

$$W = \frac{m_2 - \ m_1}{m_2 - m_1} \times 100\%$$

m_1 = Mass of container (g)

m_2 = Mass of container and wet soil (g)

m_3 = Mass of container and dry soil (g)

Sample A = 29.23%

Sample B = 28.22%

Sample C = 28.66%

Average = 28.70%

Moisture Content – Testing Sample 2

1) Mass of container; Sample A = 21.48 g

   Sample B = 19.61 g

   Sample C = 21.04 g

2) Mass of container plus wet soil; Sample A = 50.16 g

   Sample B = 59.07 g

   Sample C = 65.13 g

3) Mass of container plus dry soil; Sample A = 44.60 g

   Sample B = 52.03 g

   Sample C = 56.45 g

$$W = \frac{m_2 - m_1}{m_2 - m_1} \times 100\%$$

m_1 = Mass of container (g)

m_2 = Mass of container and wet soil (g)

m_3 = Mass of container and dry soil (g)

Sample A = 24.05%

Sample B = 21.71%

Sample C = 24.51%

Average = 23.42%

Moisture Content – Testing Sample 3

1) Mass of container; Sample A = 19.04 g

   Sample B = 19.48 g

   Sample C = 18.52 g

2) Mass of container plus wet soil; Sample A = 34.86 g

   Sample B = 34.22 g

   Sample C = 33.78 g

3) Mass of container plus dry soil; Sample A = 31.50 g

   Sample B = 31.22 g

   Sample C = 30.59 g

$$W = \frac{m_2 - m_1}{m_2 - m_1} \times 100\%$$

m_1 = Mass of container (g)

m_2 = Mass of container and wet soil (g)

m_3 = Mass of container and dry soil (g)

Sample A = 26.97%

Sample B = 25.55%

Sample C = 26.43%

Average = 26.32%

APPENDIX B

Specific Gravity

Density Bottle Mehtod

Test number	1	2	3
Mass of bottle + bottle cap (W_1) (g)	23.07	22.86	21.31
Mass of bottle + bottle cap + dry soil (W_2) (g)	33.07	32.86	31.31
Mass of bottle + bottle cap + dry soil + water (W_3) (g)	81.30	81.15	79.51
Mass of bottle + bottle cap + water (W_4) (g)	75.48	75.09	73.57
Mass of dry soil (W_2 - W_1) (g)	10	10	10
($W_4 - W_1$) (g)	52.41	52.23	52.26
($W_3 - W_2$) (g)	47.36	48.29	48.20
($W_4 - W_1$) – (($W_3 - W_2$) (g)	5.05	3.94	4.06
Specific Gravity of soil, G_s $= \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$	1.98	2.538	2,463

G_s (Average) = 2.327

APPENDIX C

Atterberg Limit Test

Atterberg Limits – Cone Test

Location: Gambang	Sample type: -
Soil description: Residual soil	Date started: 01/March/2009

PLASTIC LIMIT

Test number	1	2	3
Container no.	A	B	C
Wet soil & container (g)	56.40	56.77	55.01
Dry soil & container (g)	55.61	55.92	54.30
Container (g)	53.43	53.47	52.24
Dry soil (g)	2.18	2.45	2.06
Moisture loss (g)	0.79	0.85	0.71
MOISTURE CONTENT	27%	22%	26%

LIQUID LIMIT

Test number	1		2		3	
Cone penetration (mm)	226	228	245	246	253	249
Average penetration (mm)	227		245.5		251	
Container no.	A		B		C	
Wet soil & container (g)	65.40		63.71		63.22	
Dry soil & container (g)	62.40		60.58		59.95	
Container (g)	55.44		53.63		53.20	
Dry soil (g)	6.96		6.95		6.75	
Moisture loss (g)	3.0		3.13		3.28	
MOISTURE CONTENT (%)	43%		45%		49%	

PLASTIC INDEX

PI = LL – PL

Sample 1 = 16%

Sample 2 = 23%

Sample 3 = 23%

APPENDIX D

Sieve Analysis

Particle Size Distribution

Mechanical Sieve Analysis Test Result

Sample No: 1	Date : 27/February/2009
Site : Gambang Area	Description : Residual Soil

Total mass of dry soil:

BS test sieve size	Mass of sieve	Mass retained	Total mass retained	Per cent retained	Per cent passing
	g	g	g	%	%
4.75 mm	511.33	523.19	11.86	2.37	97.63
2 mm	549.25	693.44	144.19	28.84	68.79
1.18 mm	427.97	542.64	114.67	22.95	45.84
600 µm	391.42	506.23	114.81	22.97	22.87
300 µm	432.66	502.91	70.25	14.05	8.82
212 µm	439.48	456.65	17.17	3.43	5.39
150 µm	429.03	439.82	10.79	2.16	3.23
63 µm	380.73	389.23	8.50	1.70	1.53
pan	289.80	297.46	7.66	1.53	0
TOTAL			499.99	100	

Sample No: 2	Date : 27/February/2009
Site : Gambang Area	Description : Residual Soil

Total mass of dry soil:

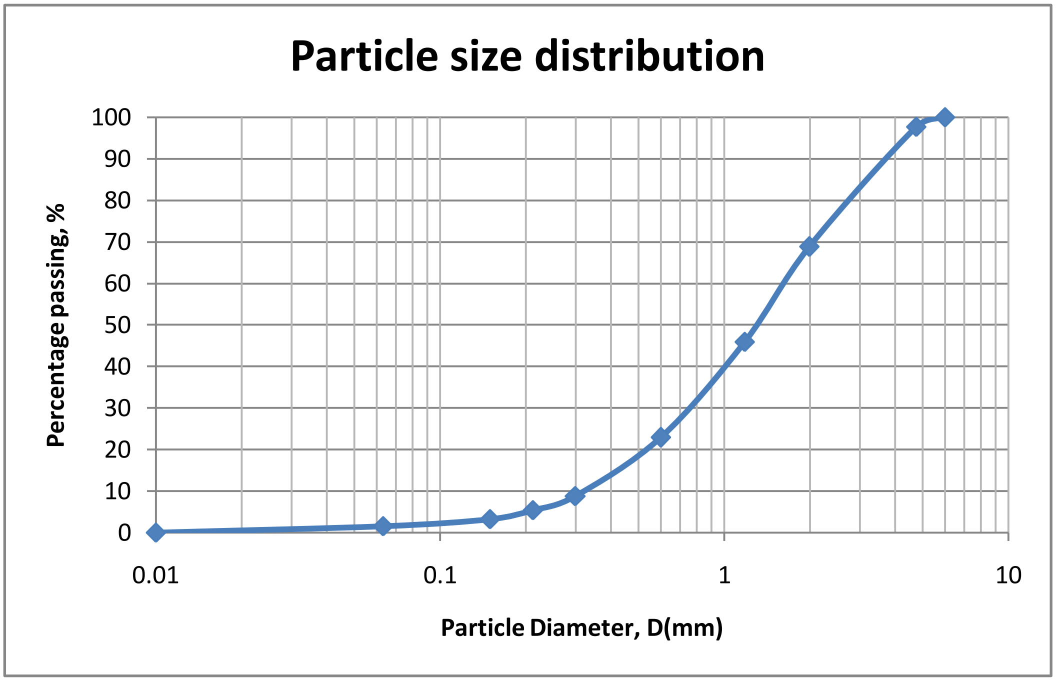
BS test sieve size	Mass of sieve	Mass retained	Total mass retained	Per cent retained	Per cent passing
	g	g	g	%	%
4.75 mm	511.45	535.81	24.36	4.87	95.13
2 mm	549.22	719.33	170.11	34.02	61.11
1.18 mm	432.42	551.56	119.14	23.83	37.28
600 µm	392.39	492.59	100.20	20.04	17.24
300 µm	429.58	486.91	57.33	11.47	5.77
212 µm	441.41	450.86	9.45	1.89	3.88
150 µm	433.10	441.47	8.37	1.67	2.21
63 µm	381.89	387.28	5.39	1.08	1.13
pan	290.10	295.75	5.65	1.13	0
TOTAL			500.00	100	

Sample No: 3	Date : 27/February/2009
Site : Gambang Area	Description : Residual Soil

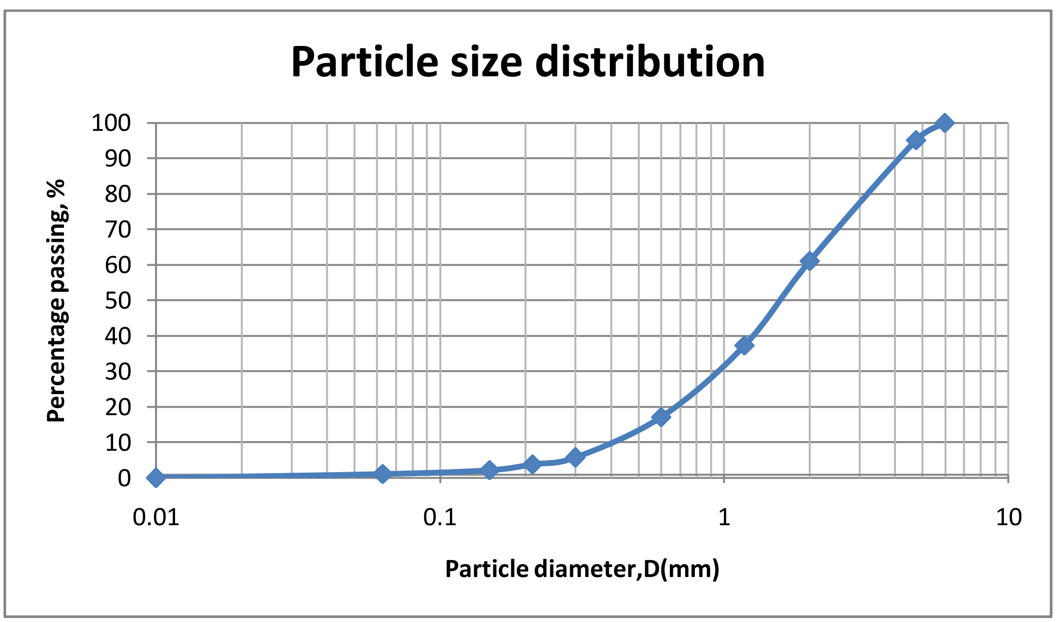
Total mass of dry soil:

BS test sieve size	Mass of sieve	Mass retained	Total mass retained	Per cent retained	Per cent passing
	g	g	g	%	%
4.75 mm	511.49	535.60	24.11	4.84	95.16
2 mm	550.55	720.91	170.36	34.21	60.95
1.18 mm	430.85	548.99	118.14	23.72	37.23
600 µm	393.84	493.04	99.20	19.92	17.31
300 µm	435.19	490.56	55.37	11.12	6.19
212 µm	440.20	451.53	11.33	2.28	3.91
150 µm	429.77	438.22	8.45	1.70	2.21
63 µm	380.97	387.28	6.31	1.27	0.94
pan	290.10	294.83	4.73	0.95	-0.01
TOTAL			498.00	100	

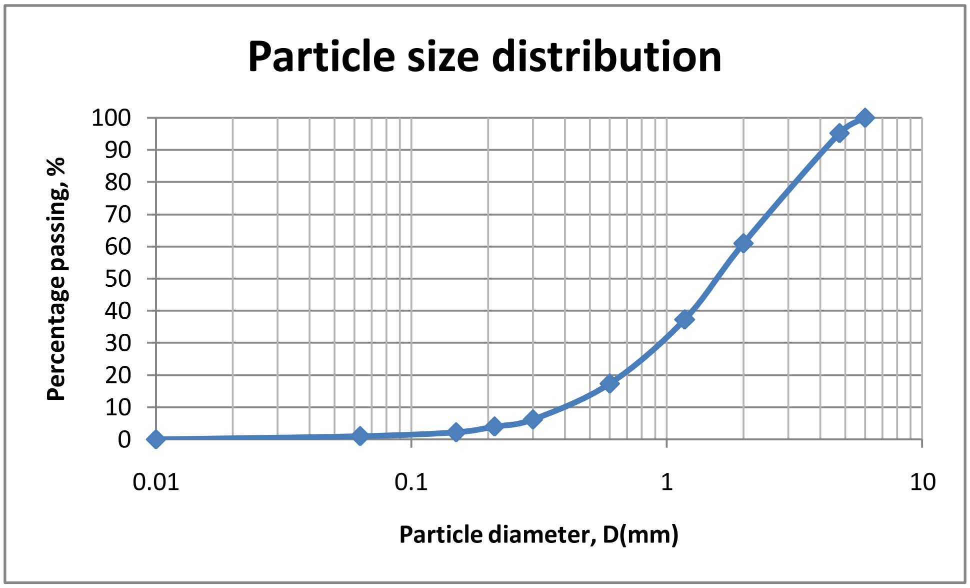
Graph of patricle size distribution for sample 1



Graph of patricle size distribution for sample 2



Graph of patricle size distribution for sample 3



APPENDIX D

Oedometer Test

<u>Oedometer Testing Sample 1</u>

At beginning of test:

Diameter of specimen, D = 75mm

Height of specimen, H = 20mm

Mass of specimen ring plus specimen = (a) Normal moisture content = 262.28 g

(b) Wetted = 276.10 g

(c) Single oedometer = 268.13 g

Mass of specimen ring = (a) Normal moisture content = 108.92 g

(b) Wetted = 109.03 g

(c) Single oedometer = 109.09 g

At end of test:

Mass of entire wet specimen = (a) Normal moisture content = 146.89 g

(b) Wetted = 168.83 g

(c) Single oedometer = 164.21 g

Mass of entire dry specimen = (a) Normal moisture content = 124.32 g

(b) Wetted = 133.37 g

(c) Single oedometer = 130.6

Oedometer Testing Sample 2

At beginning of test:

Diameter of specimen, D = 75mm

Height of specimen, H = 20mm

Mass of specimen ring plus specimen = (a) Normal moisture content

= 289.83 g

(b) Wetted = 277.55 g

(c) Single oedometer = 287.22 g

Mass of specimen ring = (a) Normal moisture content = 108.97 g

(b) Wetted = 117.18 g

(c) Single oedometer = 116.38 g

At end of test:

Mass of entire wet specimen = (a) Normal moisture content = 172.18 g

(b) Wetted = 161.67 g

(c) Single oedometer = 171.81 g

Mass of entire dry specimen = (a) Normal moisture content = 148.83 g

(b) Wetted = 127.61 g

(c) Single oedometer = 138.04 g

Oedometer Testing Sample 3

At beginning of test:

Diameter of specimen, D = 75mm

Height of specimen, H = 20mm

Mass of specimen ring plus specimen = (a) Normal moisture content = 287.08 g

(b) Wetted = 283.35 g

(c) Single oedometer = 287.68 g

Mass of specimen ring = (a) Normal moisture content = 116.26 g

(b) Wetted = 109.03 g

(c) Single oedometer = 109.09 g

At end of test:

Mass of entire wet specimen = (a) Normal moisture content = 160.24 g

(b) Wetted = 170.01 g

(c) Single oedometer = 155.72 g

Mass of entire dry specimen = (a) Normal moisture content = 147g

(b) Wetted = 135.41g

(c) Single oedometer = 138.5g