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# COMPARISON BETWEEN GAMBANG RESIDUAL SOIL AND BENTONG RESIDUAL SOIL IN TERMS OF COLLAPSIBILITY

**WARTINI BINTI WARNI**

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“I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Engineering (Civil)”.

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| Date | : | 16 November 2009 |

# COMPARISON BETWEEN GAMBANG RESIDUAL SOIL AND BENTONG RESIDUAL SOIL IN TERMS OF COLLAPSIBILITY

WARTINI BINTI WARNI

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 "*Comparison between Gambang residual soil and Bentong residual soil in terms of collapsibility*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

| | | |
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| Date | : | 16 November 2009 |

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# ABSTRACT

Residual soils are products of chemical weathering and thus their characteristics are dependent upon environmental factors of climate, parent material, topography and drainage, and age. Residual soils with extensive weathering of parent materials can yield collapsible soil deposits. Nowadays, most of tragedy that cause by collapsibility of residual soil occurs very extensively, for example the incident at Bukit Antarabangsa which occurred at the end of the year 2008. This tragedy happened because Malaysia is in the tropical climate area and its land is covered by more than 80 percent of residual granite and sedimentary rock soil. These types of soil have high possibility to collapse when wetted. The purpose of this study is to examine the collapsibility of Gambang residual soil in Pahang area, which is compared with Bentong residual soil in terms of collapsibility. The oedometer consolidation test is used to determine the consolidation parameters of soil. The testing give result both the residual soil in Gambang and Bentong have significant different on collapse potential. The influence of the particle size distribution, void ratio and density on the collapsibility of soil also has been compared. Determination of collapsibility of residual soil will be one of the best implementation and important in the future.

# ABSTRAK

Tanah baki merupakan hasil daripada tindakbalas cuaca dan ciri-cirinya adalah bergantung ke atas persekitaran disebabkan oleh factor iklim, batuan asal, bentuk muka bumi dan saliran serta usianya. Tanah baki yang terhasil apabila batuan asal dikenakan cuaca secara berluasa akan mengakibatkan timbunan tanah keladak. Pada masa kini, kebanyakan tragedi yang diakibatkan oleh keruntuhan pada tanah baki berlaku dengan meluasnya, sebagai contoh kejadian yang berlaku di Bukit Antarabangsa pada penghujung tahun 2008. Tragedi ini berlaku disebabkan Malaysia berada dalam kawasan iklim khatulistiwa dan tanahnya diselaputi dengan tanah jenis granit (batu besi) dan tanah keladak.Tanah jenis ini mempunyai kebolehan yang tinggi untuk runtuh apabila dibasahkan. Kajian ini adalah bertujuan untuk menyelidik keruntuhan tanah baki di Gambang yang terletak dalam kawasan Pahang, di mana ia akan dibandingkan dari aspek keruntuhan dengan tanah baki di Bentong. Odometer digunakan untuk menentukan parameter-parameter bagi kekukuhan sesuatu tanah. Hasil ujian terhadap keruntuhan tanah baki di Gambang menunjukkan terdapat perbezaan yang ketara dengan keruntahan tanah baki di Bentong. Pengaruh daripada pengagihan. saiz zarah-zarah tanah, liang tanah dah ketumpatan yang menyumbang kepada berlakunya keruntuhan juga turut di bandingkan. Mengenal pasti tentang keruntuhan tanah baki ini akan menjadi salah satu aplikasi yang begitu penting pada masa hadapan.

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## LIST OF ABBREVIATIONS & SYMBOLS

| | | |
|---|---|---|
| ASTM | - | American Standard Testing Machine |
| CP | - | Collapse Potential |
| w | - | Moisture content |
| BS | - | British Standard |
| LL | - | Liquid limit |
| PL | - | Plastic limit |
| PI | - | Plasticity Index |
| $G_S$ | - | Specific gravity |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Residual soils are products of chemical weathering and thus their characteristics are dependent upon environmental factors of climate, parent material, topography and drainage, and age. These conditions are optimized in the tropics where well-drained regions produce reddish lateritic soils rich in iron and aluminum sesquioxides and kaoliriitic clays.

The phenomenon of collapse received considerable attention of many researchers especially due to the residual soils. Criteria for determining susceptibility to collapse and experimental procedure to predict collapse were specifically dealt within several researchers.

Based on the history of landslides, most landslides occur after a heavy downpour. This tragedy happened because Malaysia is in the tropical climate area and its land is covered by more than 80 percent of residual granite and sedimentary rock soil. Malaysia being a tropical country, naturally receives heavy rainfall throughout the year. It is logic to say that collapsibility phenomenon in Malaysia has influenced by rainfall and the behavior of residual soil.

For that purpose, this study is required to examine the collapsibility of Gambang residual soil in Pahang area which has a high risk to collapse, which will be compared with Bentong residual soil in terms of collapsibility.

## 1.2 Problems Statements

In general, Malaysia is one of country that have humid tropical climate and more than 75% of its total area land is covered by residual soil which is widely distributed in Peninsular Malaysia. These types of soil have high possibility to collapse when wetted.

Nowadays, most of tragedy that cause by collapsibility of residual soil occurs very extensively, for example the Highland Tower collapsed on December 11, 1993, in Taman Hillview and followed the incident at Bukit Antarabangsa which occured at the end of the year 2008.

From all this influence, the author interested to investigate the area at Gambang which is also has a high possibility to collapse when raining season. Figure 1.1 shows the picture where the area of site investigation of this study. The situation can describe the problem that contributes to collapsibility of the soil as shown in Figure 1.2.

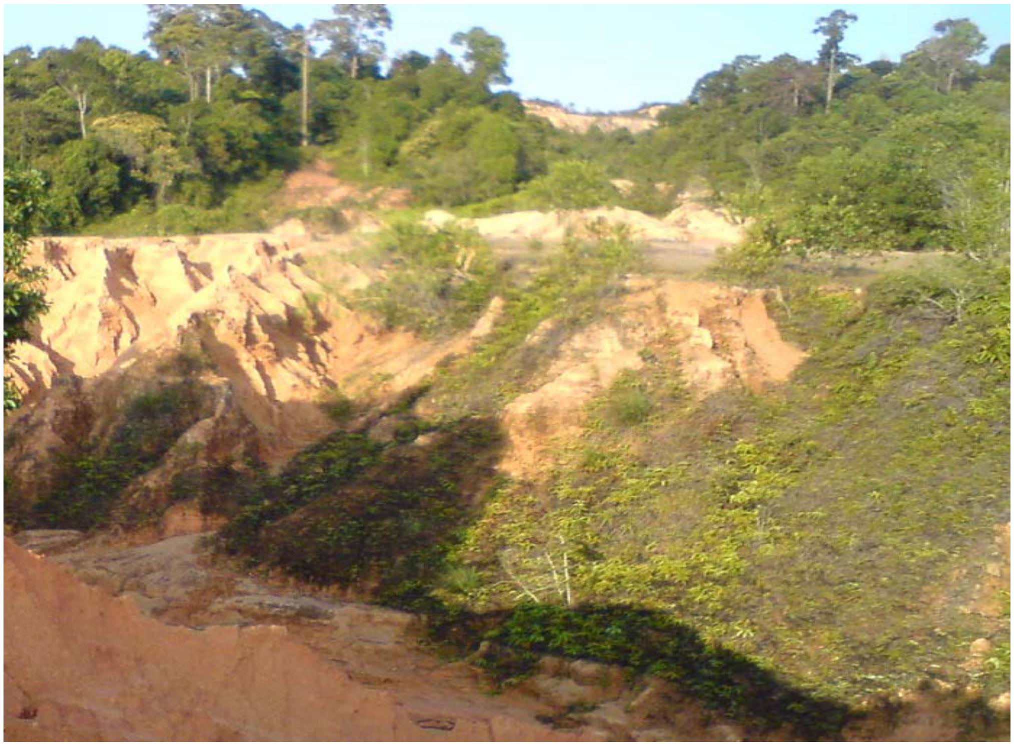

Figure 1.1: Investigation area of collapsibility soil at Gambang


Figure 1.2: The problem caused by collapse of soil at this area of study

## 1.3 Objectives

The objectives of this study are:

(1) To determine collapsibility rate of Gambang residual soil.

(2) To make comparison between Gambang residual soil and Bentong residual soil in terms of collapsibility.

## 1.4 Scope of Study

This study was focus on collapsibility of residual soil between two states in Pahang. Two sites were chosen and they are from two different area. The first one is in Bentong and the other is in Gambang. Bentong residual soil had been investigated by previous researcher. For this study, it is only required to investigate the residual soil at Gambang.

The practical technique of taking the sample and simple trimming method have been conducted. There are two types of sample which collected that is disturbed soil and undisturbed soil. The investigation also was carried out for engineering properties and collapsibility rate of Gambang residual soil.

The collapsibility of residual soil was examined using single oedometer test and double oedometer test, in order to measure the potential of collapse of this soil.

Meanwhile, all the data obtained from both tests are used to study the behavior of collapsibility and make the comparison between the Gambang residual soil and Bentong residual soil.

## 1.5 Thesis Organization

This thesis consists of five chapters. The descriptions of each chapter are described as follows. An introduction of the study is given in Chapter 1. Literature of study described in Chapter 2. In Chapter 3 author describe the methodology. The results and discussions presented in Chapter 4. Finally, in Chapter 5 some conclusions are extracted and include recommendations.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

The literature review will be focused on the explanation of residual soils, its formation process and characteristic of residual soil. This chapter also covered on the collapsibility of residual soil, and also includes several previous researchers' research about collapsibility of residual soil.

It will also focus on the determination of collapsibility rate at critical area with the methods that are used such as single and double oedometer test, also a series of suction controlled isotropic compression tests and any of the methods that are used in this project.

In world, residual soils cover more of land area and it will become collapsible soil upon wetting. The discussion is on the results from other researchers that show the characteristic of residual soil, their engineering properties, collapsibility rate of soil and the factor that contribute to soil collapse.

On the characterization of engineering properties of residual soils was concern on the natural moisture content, Atterberg limit, specific gravity and void ratio.

The results from other researcher are discussed for comparison in the analysis of results on chapter 4.

## 2.2 Residual Soils

Residual soils is a soil that formed by the mechanical and chemical weathering of parent rocks at the present location. There is no universally definition of term "residual soils" exists, soils that have weathered in situ are considered residual soil. Since mechanical weathering such as grinding and abrasion, is generally associated with transport agents, residual soil are considered to be products of chemical weathering.

The soil profiles of residual soil are developing from the factors of climate (temperature and rainfall), parent material, water movement (drainage and topography), age and vegetation. Normally, these factors occur in tropical regions where heavy rainfall and warm temperature are sufficient to existence of chemical weathering and deep residual soils develop.

### 2.2.1 Engineering Properties of Residual Soils

Table 2.1 shows the engineering properties of residual soil at Bentong District, Pahang, Malaysia (Huat B. B. K. et al., 2008) with the liquid limit, plasticity index, specific gravity, sand content, silt content, and clay content.

Table 2.1: Engineering properties of residual soils at Bentong District, Pahang, Malaysia

| Parameter | Value |
|---|---|
| Liquid limit | 74% |
| Plastic limit | 32% |
| Plasticity index | 42% |
| Specific gravity, $G_s$ | 2.63-2.65 |
| Sand content | 25% |
| Silt content | 42% |
| Clay content | 32% |

Residual soils at Bentong District, Pahang, Malaysia has liquid limit 74%, plastic limit 32% which is low with plasticity index of 42% and specific gravity is . The sand content of soil is 25%, silt content is 42% and clay content is 32%.

Table 2.2 shows the engineering properties of residual soil at KM 13 of the Kuala Lumpur-Karak Highway (Huat B. B. K. et al., 2005) with the liquid limit, plasticity index, specific gravity, sand content, silt content, and clay content.

Table 2.2: Engineering properties of residual soils at KM 13, Kuala Lumpur-Karak Highway

| Parameter | Value |
|---|---|
| Liquid limit | 98% |
| Plastic limit | 49% |
| Plasticity index | 49% |
| Specific gravity, $G_s$ | 2.7 |
| Sand content | 45% |
| Silt content | 15% |
| Clay content | 40% |

Residual soils at KM 13 Kuala Lumpur-Karak highway has liquid limit 98%, plastic limit 49% which is high with plasticity index of 49% and specific gravity is 2.7. The sand content of soil is 45%, silt content is 15% and clay content is 40%.

Table 2.3 shows the engineering properties of residual soil at Indian Institute of Science Campus, Banglore (Rao S. M. and Revanasiddappa K., 2006) with the liquid limit, plasticity index, specific gravity, sand content, silt content, and clay content.

Table 2.3: Engineering properties of red soils at Indian Institute of Science Campus, Bangalore

| Parameter | Value |
|---|---|
| Liquid limit | 37% |
| Plastic limit | 19% |
| Plasticity index | 18% |
| Specific gravity, $G_s$ | 2.71 |
| Sand content | 42% |
| Silt content | 26% |
| Clay content | 32% |

Residual soils at Bangalore has similar properties to KM 13, Kuala Lumpur-Karak Highway where studies of soil at Indian Institute Campus. The liquid limit is lower than Kuala Lumput-karak Highway which is 37% with lower plastic limit about 19%  and only 18%  for the plasticity index. The specific gravity of this soil is same with residual soil at Kuala Lumpur-Karak Highway which is about 2.7. The sand content of soil is 42%, silt content is 26% and clay content is 32%.

Table 2.4 shows the engineering properties of residual soil at Bukit Timah Granite of the Mandai area, central Singapore (Leong E. C. et al., 2006) with the liquid limit, plasticity index, specific gravity, sand content, silt content, and clay content.

Table 2.4: Engineering properties of red soils at Bukit Timah Granite, Singapore

| Parameter | Value |
|---|---|
| Liquid limit | 62% |
| Plastic limit | 29% |
| Plasticity index | 33% |
| Specific gravity, $G_s$ | 2.62 |
| Sand content | 70% |
| Silt&clay content | 30% |

Residual soils at Singapore have a 62% for liquid limit, 29% for plastic limit and 33% for plasticity index. The specific gravity at Singapore lowers than Lumpur-Karak Highway and Banglore which is 2.62. This soil also has high of sand content which is 70% and 30% for silt together with clay content.

### 2.2.2 Formation of Residual Soil

Figure 2.1 show the igneous activity leading to the formation of igneous rocks provides the beginning of the geologic cycle.

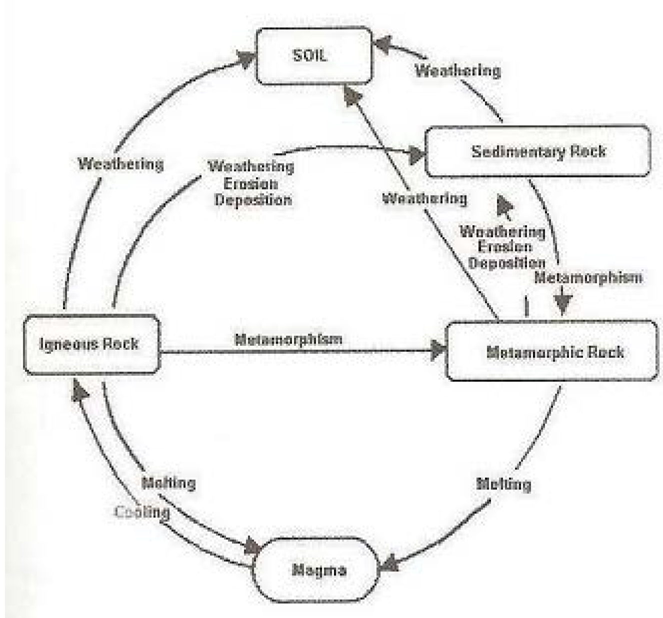


Figure 2.1: The geologic cycle (Singh & Huat, 2003)

The tropical residual soils are formed in tropical areas, physically defined as the zone contained between 20° N (Tropic of Cancer) and 20° S (Tropic of Capricon) of the equator, which includes Malaysia (Ahmad F. et al., 2006). The thickness of residual soil layer varies from place to place depending upon the factor responsible for weathering which show in Table 2.5.

Table 2.5: Weathering agencies and their description (Ahmad F. et al., 2006)

| Factors | Description |
|---|---|
| Climate | Refers to the effect on the surface by temperature and precipitation. |
| Geologic | Refers to the parent material (bedrock or loose rock fragment) that provide the bulk of most soils. |
| Geomorphic/Topographic | Refers to the configuration of the surface and is manifested primarily by aspects of slope and drainage. |
| Biotic | Consists of living plants and animals, as well as dead organic material incorporated into the soil. |
| Chronological | Refers to the length of time over which the other four factors interact in the formation of the particular soil. |

### 2.2.3 Product of Weathering

Bujang B.K. Huat et al. (2004) states that the products of weathering are important, as these constitute the residual soils. The weathering process can result in the following:

a) The complete loss of elements or compounds from rocks and minerals.

b) The addition of new elements or compounds to form new phases.
c) Only a mechanical breakdown of one mass intro two or more parts without any chemical change of minerals or rocks.

Huat B. B. K. et al. (2004) explain the characteristic of residual soil also depends on the parent rock it develops from. For examples, residual soil on weathered granite will initially be sandy, as sand-sized particles of quartz and partially weathered feldspar are released from the granite. The partially weathered feldspar grains will gradually over time further completely weather into fined-grained clay minerals. As the resistant quartz does not weather, the resulting soil will have both sand-sized quartz and clay. This will further change over time as this residual soil that develops from granite may become more clayey. The influence of the parent rock decreases over the passage of time. After a sufficient time period, the differences in the residual soils from different types of rocks example igneous, sedimentary and metamorphic may be obliterated. The present of coarse grains quartz in the parent rock becomes the only vestige that survives and has a long-term significance. The weathering products of some common rock types are listed in Table 2.6.

Table 2.6: Weathering products of some common rock types (Huat B. B. K. et al., 2004)

| Rock type | Product |
|---|---|
| Igneous<br>-Granite<br>-Basalt | <br>Quatrz sand and clay minerals.<br>Clay minerals. |
| Sedimentary<br>-Shale<br>-Sandstone<br>-Limestone | <br>Clay minerals.<br>Quartz sand.<br>Dissolved ions and residual clay sized particles. |
| Metamorphic<br>-Metasedments (schist/phyllite/amphibolites/slate)<br>-Gneiss, granulites and other quartz rich rocks | <br>Clay minerals (from biotite and muscovite), micaceous silt and clay size particles.<br>Quartz sand. |

### 2.2.4 Structure of Residual Soils

Residual soils, particularly in the tropics, have a vertical soil section, called the soil profile, which consists of a distinct layering termed the soil horizons formed more or less parallel to the ground surface. These genetically related horizons are a reflection of the weathering process. The soil profile also has a weathering aspect that gives rise to a vertical weathering profile that is critical aspect from the engineering perspective (Huat B. B. K. et al., 2004).

The entire weathering profile, generally, indicates a gradual change from fresh rock to a completely weathered soil as shown in Figures 2.2 and 2.3 for two rock types of in tropical terrain (Huat B. B. K. et al., 2004).

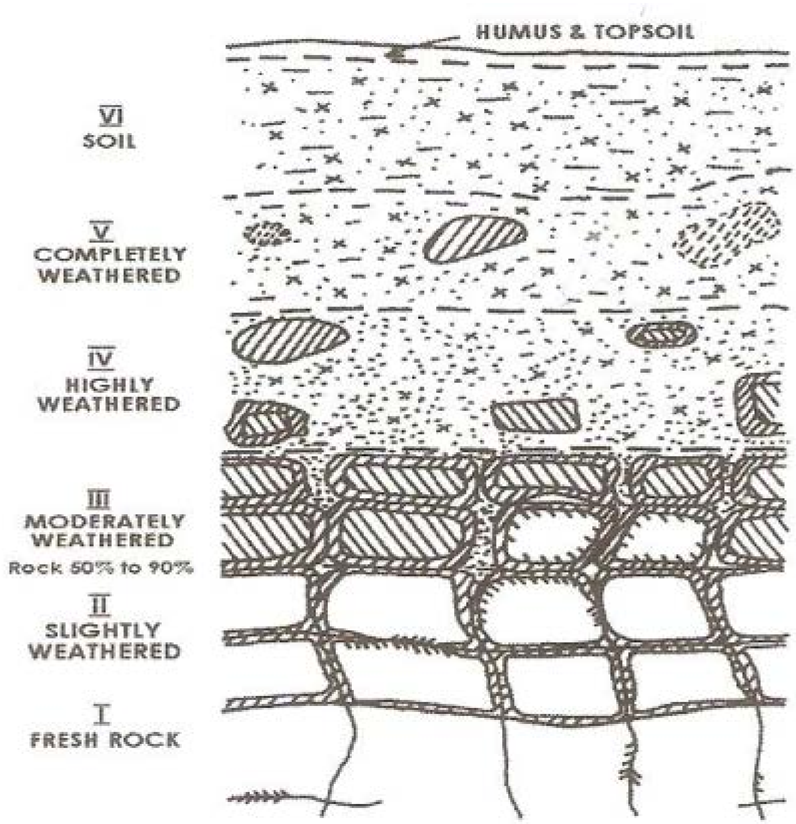


Figure 2.2: Typical weathering profile in granitic rock soil profile (Little, 1969)

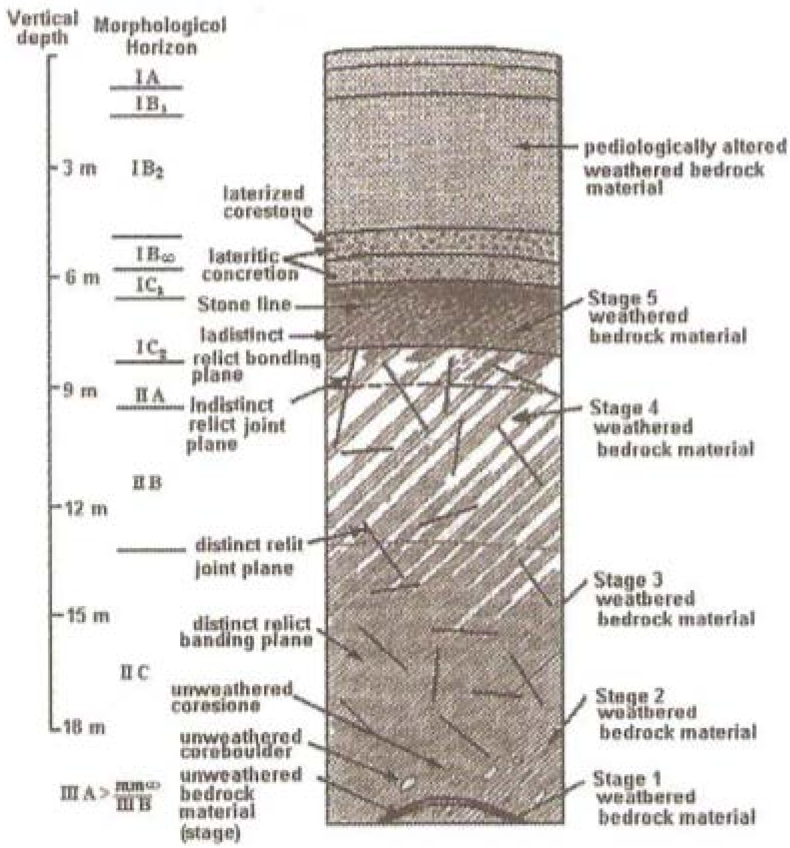


Figure 2.3: Weathering profile in a metamorphic rock* soil profile (Raj, 1994) (*amphibole schist).

Refers to Huat B. B. K. et al. (2004), the classifications for weathering profiles are generally suitable for most igneous rocks and some sedimentary and metamorphic rocks. An example of a classification is shown in Table 2.7. A proposed classification for weathering profiles over metamorphic rock is given in Table 2.8.

Table 2.7: Classification of the weathering profile (McLean & Gribble, 1979)

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

Table 2.8: Classification of weathering profile over metamorphic rock* in peninsular Malaysia (Komoo & Mogana 1988) (* Clastic Metasediment)

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

## 2.3 Collapsibility of Residual Soils

Based on Huat b. B. K. et al. (2008) collapsibility soil is defined as soil that is susceptible to a large and sudden reduction in volume upon wetting. Collapsible soil deposits share two main features:

1) They are loose, cemented deposits, and
2) They are naturally quite dry.

In 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 vertical stress (Huat B. B. K. et al., 2008).

From geotechnical and engineering geology point of view collapsible soils are classified as problematic soils (Rafie B. M. A. et al., 2008). They said the existence of collapsible soils has been reported in all of the world continents and found in different shapes such as swelling, high water absorption, quick, collapsible and loose soils.

The phenomenon of collapse settlement occurs on two types of residual soils (Rao S. M. and Revanasiddappa K., 2006). The first category of collapsing soils is believed to be transported soils that have undergone post-depositional pedogenesis. The second category is the highly weathered and leached residual soil.

According to Huat B. B. K. et al. (2008) collapse potential, CP is calculated using equation (1):

$$\mathrm{CP}(\%) = \left[\frac{(e_i - e_f)}{1 + e_o}\right] \times 100\% \ldots\ldots\ldots(1)$$

Where:

$\Delta e = e_i - e_f$ ; change of void ratio upon wetting

$e_o$ = Initial void ratio

Table 2.9 shows the classification the intensity of soil collapse of unsaturated soils based on their percent collapse value.

Table 2.9: Intensity of soil collapsibility (Rafie B. M. A. et al., 2008)

| Collapsibility | Index Collapse Intensity |
|---|---|
| 0 – 1 | No collapsibility |
| 1-5 | Medium collapsibility |
| 5- 10 | High collapsibility |
| 10 – 20 | Very high collapsibility |
| 20 | Extremely collapsible |

Regarding previously defined criteria for evaluation of soil collapsibility potential which includes the basic engineering judgments concerning soil collapsibility as shows in Table 2.10.

Table 2.10: The basic engineering judgment for jobsite soil collapsibility (Rafie B. M. A. et al., 2008)

| Proposed Criterion | Collapsibility Coefficient | Collapsibility Coefficient Range |
|---|---|---|
| Abelev (1948) | $\delta_s = \frac{0.54 - 0.45}{0.45 + 1} * 100 = 6.2\%$ | $6.2 > 2$ |
| Feda ( 1960) | $i_C = \left(\left(\frac{m}{S_r}\right) - PL\right)/PI = \left(\left(\frac{5}{0.23}\right) - 15\right)/17 = 0.396$ | $0.396 < 1$ |
| Denisov (1964) | $\frac{e}{e_{LL}} = \frac{0.54}{0.45} = 1.2$ | $1.2 > 1$ |
| Clevenger (1985) | $\gamma_d = 1.38\ g/cm^3$ | $1.28 < 1.38 < 1.44$ |
| Lin and Wang criteria (1988) | $i_{cz} = \frac{h_z - h_{zs}}{h_1} = \frac{1.8 - 1.66}{1.9} * 100 = 7.36\%$ | $5 < 7.36 < 10$ |

Based on the calculation results for soil collapsibility potential in Table 2.10, the collapse intensity evaluation in Table 2.9, could be conclude in following Table 2.11.

Table 2.11: Collapse intensity results regarding defined criteria (Rafie B. M. A. et al., 2008)

| Criterion | Abelev (1948) | Feda (1960) | Denisov (1964) | Clevenger (1985) | Lin and Wang (1988) |
|---|---|---|---|---|---|
| Collapse Intensity | High Collapsibility | No collapsibility | Medium Collapsibility | Medium Collapsibility | High Collapsiblity |

### 2.3.1 The Factors Contributes to Collapsibility

Aziz A. A. et al. (2006) stated the residual soils occur in most countries of the world but the greater areas and depths are normally found in tropical humid areas. In these places, the residual soil forming processes are still very active and the weathering development is much faster than the erosive factor.

Residual soils with extensive weathering of parent materials can yield collapsible soil deposits. In Malaysia, residual granite and sedimentary rock soils occur extensively, covering more than 80% of the country's land area. These types of soil have a high possibility to collapse when wetted. 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 (Huat B. B. K. et al., 2008).

Collapse behavior of soil can yield disastrous consequences for structures unwittingly built on such deposits. The process of their collapsing is often called hydro-consolidation, hydro-compression or hydro-collapse. The process of collapsibility, in almost all cases, is instantaneous or of short duration process (Huat B. K. K. et al., 2008).

Appreciable collapse is likely to be experienced by unsaturated soils when the following conditions are met (Huat B. K. K. et al., 2008):

- The soil has no open, potentially unstable, unsaturated structure (high void ratio, low dry density, high porosity).
- A high enough value of external stress is applied to develop a metastable condition.

- A high enough value of suction is available to stabilize inter-granular contacts and whose reduction on wetting leads to collapse of the soil.
- Low inter-particle bond strength.

In addition, to the possible collapse of tropical residual soil upon wetting, soil wetting due to rain may also bring about problem associated with slope instability (landslide). Wetting upon rain will cause a reduction in soil suction especially at shallow depths with a possibility of increase in pore water pressure to positive values, depending on the intensity and duration of rain, and soil permeability function among others. Loss of suction will also cause a significant reduction in soil shear parameters especially the soil apparent cohesion which has been found to be highly dependent on soil matric suction (Huat B. K. K. et al., 2008).

## 2.4 Testing Methodology/Procedures

All the tests done are focusing on determining the CP of residual soil

### 2.4.1 Oedometer Test (Double Oedometer Test)

From Schnaid F. et al. (2004), they includes the Jennings and Knight (1957) that proposed the first method to predict the collapse potential using results from the double oedometer test (Fernando Schnaid, 2004). The method consists of running two oedometer tests, one sample being at constant natural water content and another sample at soaked conditions. The collapse potential can be predicted by quantifying the volume decrease difference, at any given stress level, between the two compression curves. The collapse potential (CP) is then defined same as Equation (1). Jennings and Knight presented an alternative testing procedure to assess the collapse potential in the laboratory. An ordinary oedometer test at natural water content is conducted at any load level, and then, the sample is flooded with water, left for 24 h and the test is then carried on to its normal maximum loading limit. The collapse potential is still determined by Equation (1), but $\Delta e$ is conveniently replaced by $\Delta e_c$ that signifies the change in void ratio upon wetting. Fig. 2 shows an idealized view of this single oedometer collapse test.

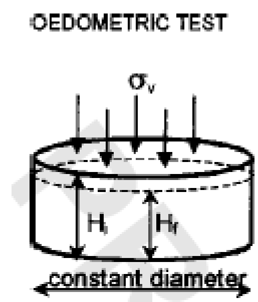


Figure 2.4: Oedometer test

### 2.4.2 Plate Load Test

As an alternative procedure, the collapse of soils can be evaluated from results of in situ plate loading tests (Schnaid F. et al., 2004). Schnaid F. et al. (2004) also includes by applying loading to a rigid circular plate at the base of a borehole; at a given stress level the water is introduced and the load displacement response of the soil is monitored

(Ferreira and Lacerda 1993; Houston et al. 1995; Mahmound et al. 1995). Interpretation would require assessment to the depth of influence of the stress field, the change in stresses due to wetting, and the depth of wetting throughout the test. Because evaluation of the stress field requires numerical analysis where coupling of flow and deformation takes place it is unlikely that accurate predictions of yielding stresses could be properly assessed. Figure 2.5 shows the plate load test.

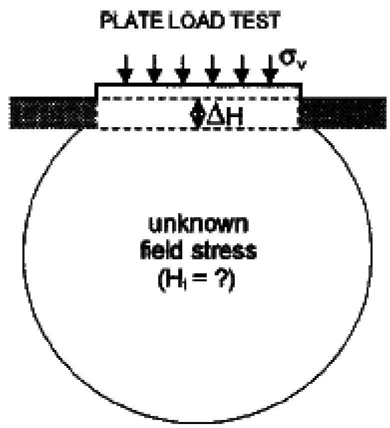


Figure 2.5: Plate load test

### 2.4.3 Pressuremeter Test

Pressuremeter is a more suitable technique to estimate the collapse potential of soils in situ (Schnaid F. et al., 2004). Schnaid F. et al. (2004) includes from Rollins et al. 1994; Smith et al. 1995; Smith and Rollins 1997 stated very few attempts have been reported on the use of pressuremeter tests to identify collapsible soils, however, in Schnaid F. et al. (2004) studies interpretations of experimental pressure-expansion curves were restricted to empirical observations. A suggestion is made that a better approach could make use of analytical solutions for the problem of the expansion of cylindrical cavity adopting different types of constitutive relationships from which it is possible to determine the value of the model parameters assumed in the analytical derivation. A methodology is proposed which consists of interpreting pressuremeter tests carried out on natural water content and soaked conditions with simultaneous measurements of in situ suction. The interpretation of the collapse phenomena is based on the concepts of cavity expansion theory extended to the framework of unsaturated soils by incorporating a Cam clay type model. Figure 2.6 shows the pressuremeter test.

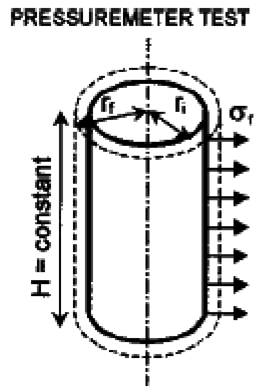


Figure 2.6: Pressuremeter test

### 2.4.4 Isotropic Compression Test

A series of suction controlled isotropic compression tests are performed to determine the collapsibility and volume change of the unsaturated residual soil (Aziz A. A. et al., 2006). Figure 2.7 shows a schematic diagram of the experimental set-up. The test panel consists of a double-walled cell, volume change indicators, diffused air volume indicators, pressure application system, pressure transducers and pressure gauges. The results of the test were monitored and recorded by a data logger connected to a personal computer. The suction was applied by means of axis-translation technique to avoid cavitations. In this technique, the air pressures (Pa) and back water pressure (Pw) were applied on the soil sample. The difference between the air pressure (Pa) and the back water pressure (Pw) applied on the sample is taken as the applied matric suction (Pa – Pw). In the study, the air pressure was applied to the top of the sample whereas the back water pressure was applied to bottom of the soil sample. The matric suction applied is not to exceed the air entry value of the high air entry ceramic disc at the pedestal of the cell. Net mean stress applied to the samples in the study is taken as P-Pa where P is the all round cell pressure applied to the soil sample and Pa is the air pressure applied to the top of the sample. The back water pressure was applied through an air/water bladder system and monitored by means of a pressure transducer. Another set of air/water bladder system with similar design is used for the application of cell pressure. The Wykeham Farrance constant pressure unit (motorized oil water system) is also used when the pressure applied exceeded 500 kPa. The structural (overall) volume change and water phase volume change are measured by means of automatic volume change indicators. The pressure and volume change measured by the pressure transducers and volume change indicators were recorded by means of a data logger, which can then be retrieved by a personal computer. In order to ensure that the triaxial cell does not experience significant volume change when the pressure is altered, a double-walled cell was specially designed and fabricated.

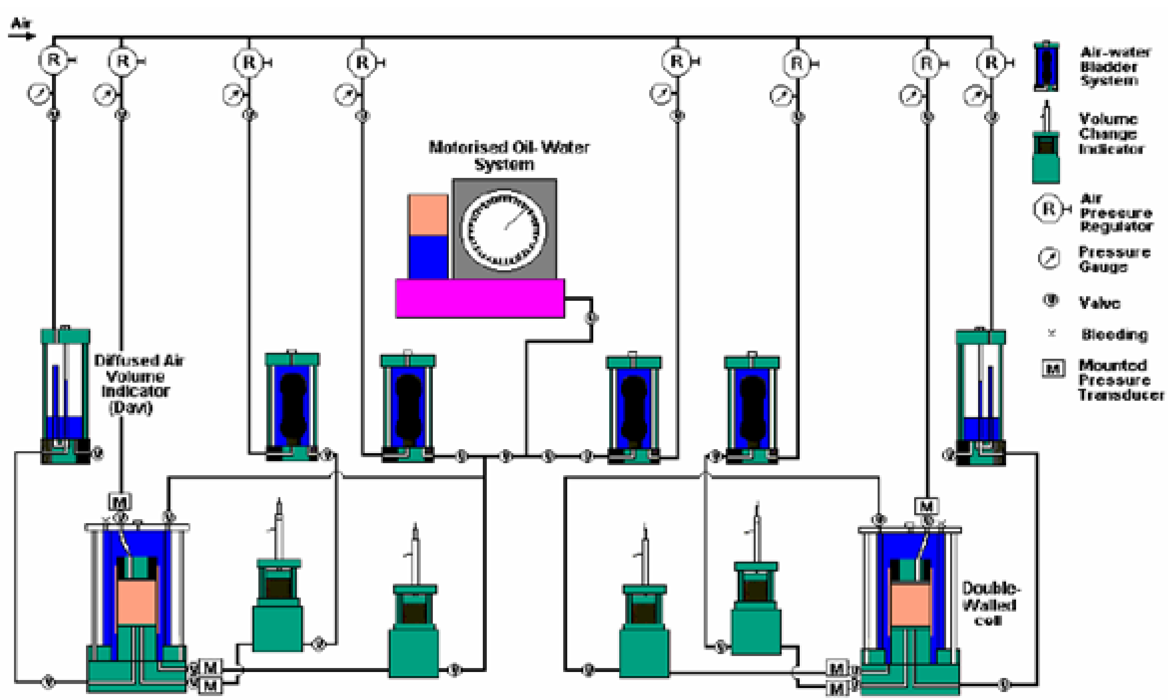


Figure 2.7: Schematic diagram of experimental set-up.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

An investigation to measure collapsibility rate of Gambang residual soil was planned and practiced to success the objective of study. The result obtained will be used to make a comparison between Gambang residual soil and Bentong residual soil in terms of collapsibility.

This practical strategy schedule must fit the suitable methods, starting from the sampling process to the final desired result. The methods related in obtaining the data must be arranged in series and practiced step by step. The target for this strategy was:

1. Produce the data for engineering properties and collapsibility rate of residual soil and also to classify the soil as a residual soil.
2. Produce the graph that shows the collapse potential of the residual soil.

The residual soil obtained in Gambang must fulfill two criteria: the engineering properties and its collapsibility rate in order to be compared with Bentong residual soil. Based on those criteria, a series of experimental works were carried out to study and examine the Gambang residual soil status.

Collapse tests were performed using the double oedometer method that was judged to be sufficiently accurate for evaluating wetting induced collapse that is the standard test for collapse test. The collapse potential purpose is to observe the residual soil's ability and the changes in void ratio. This test was incorperated with the various testing of the sample which is the particle size distribution, determination of moisture content, Atterberg limits, and determination of specific gravity. The summarization of work process is shown in Figure 3.1.

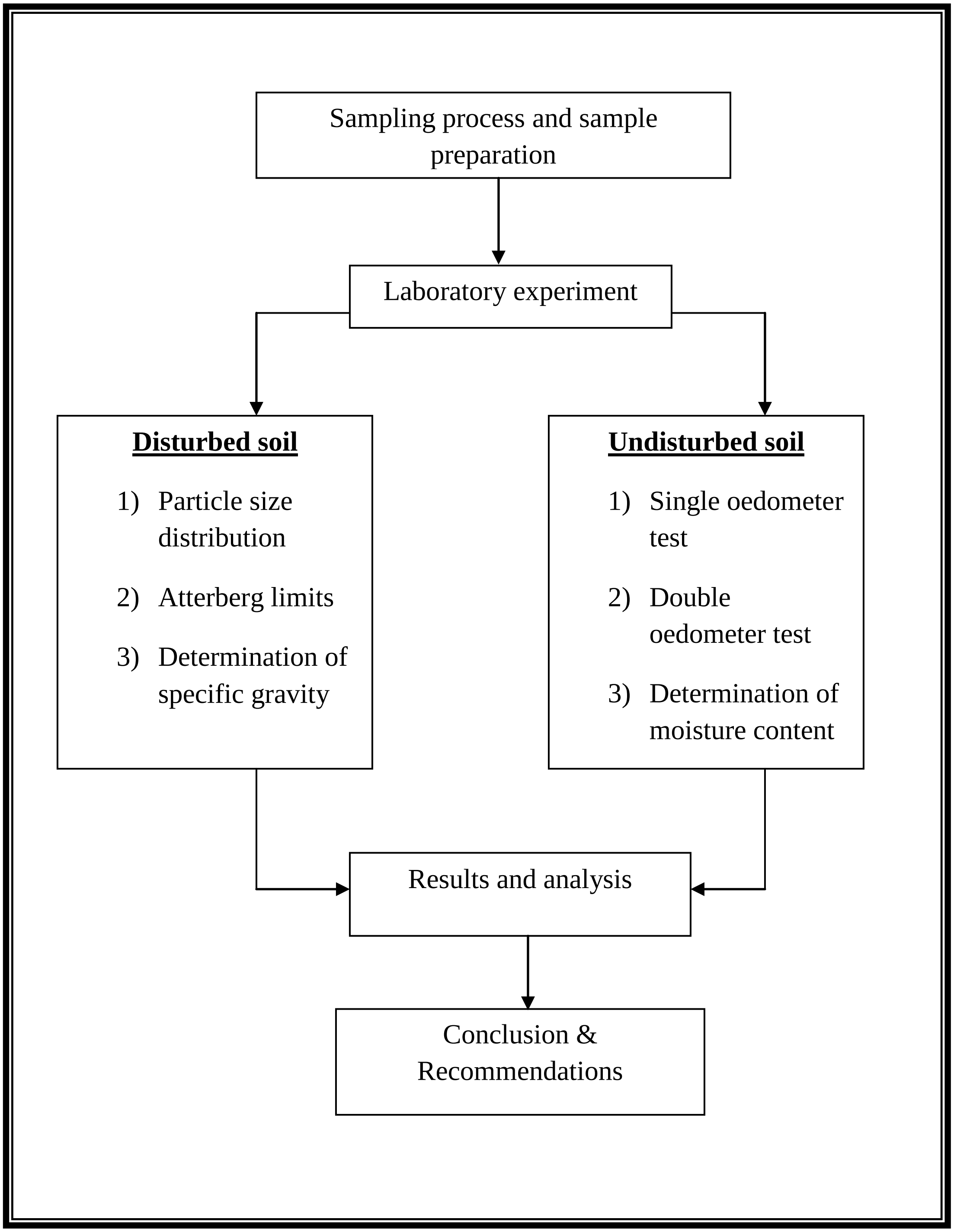


Figure 3.1: Flow chart of experimental work and data collection

## 3.2 Sampling Process

This study is required to do the sampling process for the specimens and then was tested in laboratory. Before go through at the site investigation, it is important to know better on the location of study. Besides, the preparing of suitable tools for sampling must be taken before going to the site investigation.

### 3.2.1 Location of Sampling

The soil sample for this study was collected from the residual soil area at Gambang, Pahang. Gambang is one of the towns in Pahang states of Peninsular Malaysia. It is located nearly to the Karak Highway which is about 25.5 km from Kuantan.

Undisturbed sample was taken from a depth of approximately 1m – 2m. It is required two types of soil which is disturbed soil and undisturbed soil. The Figure 3.2 below showed the Pahang map for location of soil investigation (Gambang) and the area that will be compared (Bentong).


Figure 3.2: Location of study area in Pahang states (source: www.etourz.com)

### 3.2.2 Sampling Tools

The tools that taken during the sampling process are as follow. Figure 3.3 shows the rubber mallet. Rubber mallet is used to push down the oedometer ring into the soil.

Figure 3.3: Rubber mallet

Hoe is used during taken the undisturbed sample as pictures in Figure 3.4. Besides, trowel in Figure 3.5 is used to level the soil specimen on the oedometer ring.

Figure 3.4: Hoe

Figure 3.5: Trowel

Finally, pail as in Figure 3.6 is used to carry the tools and put the disturbed and undisturbed soil.

Figure 3.6: Pail

## 3.3 Method and Material

Several test were used to collect data which are divided by two category disturbed and undisturbed sample. The disturbed samples are done by particle size distribution, Atterberg limit and determination of specific gravity. Whenever, the undisturbed samples are done by single oedometer test, double oedometer test and determination of moisture content.

### 3.3.1 Moisture Content (ASTM D 2216)

This test is performed to determine the water (moisture) content of soils. The water content is the ratio, expressed as a percentage, of the mass of “pore” or “free” water in a given mass of soil to the mass of the dry soil solids. This method is called the oven drying method. The moisture content of soil is expressed as a percentage of its dry mass.

Firstly, record the mass of an empty, clean, and dry container. Then, placed the moist soil in the container and weighed. After that, place the container (containing the moist soil) in the drying oven that is set at 105°C. Leave it in the oven overnight.

After 24 hours, remove the container from the oven and allow it to cool to room temperature. Determine and record the mass of the container and dry soil. The procedures are repeated for 3 samples. Figure 3.7 shows the soil sample for the moisture content test.

Figure 3.7: Sample for moisture content test

The moisture content of the soil, w, can be calculated from the Equation (2)

$$w = \frac{m_2 - m_3}{m_3 - m_1} \times 100\% \ldots \ldots \ldots \text{Equation (2)}$$

Where:

$m_1$ = Mass of container (g)

$m_2$ = The mass of container and wet soil (g)

$m_3$ = The mass of container and dry soil

### 3.3.2 Particle Size Distribution-BS 1377 (part 2, clauses 9.2, 9.3)

Soils consist of particles with various shapes and sizes. This test method is used to separate particles into size ranges and to determine quantitatively the mass of particles in each range. These data are combined to determine the particle-size distribution (gradation). This test method uses a square opening sieve criterion in determining the gradation of soil. Sieve analysis consists of shaking the soil sample through a set of sieves that have progressively smaller openings. Figure 3.8 shows the different size opening of sieve and Table 3.1 shows the standard sieve number and opening.

Figure 3.8: Test sieve

First the soil is oven dried and then all lumps are broken into small particle before they are passed through the sieves. About 500g of soil was weight depending on the soil that being used. Sieves are angled together with the largest aperture sieve at top and remaining pan under the smallest aperture sieve at the bottom. Weigh to 0.1 g each sieve which is to be used.

Then by using the mechanical shaker, the whole nest of sieve with receiving pan is placed in the shaker, and the dried soil is placed in the top sieve, which is then fitted with the lid. After the completion of the shaking period about 10 minutes, the mass of soil retained on each sieve is determined. The results of sieve analysis are generally expressed in terms of the percentage of the total weight of soil that passed through different sieves.

Table 3.1: Standard sieve number and opening

| Sieve Number | Opening (mm) |
|---|---|
| 4 | 4.750 |
| 6 | 3.350 |
| 8 | 2.360 |
| 10 | 2.000 |
| 16 | 1.180 |
| 20 | 0.850 |
| 30 | 0.600 |
| 40 | 0.425 |
| 50 | 0.300 |
| 60 | 0.250 |
| 80 | 0.180 |
| 100 | 0.150 |
| 140 | 0.106 |
| 170 | 0.088 |
| 200 | 0.075 |
| 270 | 0.063 |

(1) Percentage retained on any sieve calculate by using Equation (3):

$$= \frac{\text{Weight of soil retained}}{\text{Total soil weight}} \times 100\% \ldots\ldots\ldots \text{Equation (3)}$$

(2) Cumulative percentage retained on any sieve:

$$= \sum \text{Percentage retained}$$

(3) Percentage finer than an sieve size:

$$= 100\% - \sum \text{Pecentage retained}$$

### 3.3.3 Atterberg Limits (ASTM D 4318)

Atterberg limits are a basic measure of the nature of a fine-grained soil. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state the consistency and behavior of a soil is different and thus so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behavior. The Atterberg limits can be used to distinguish between silt and clay, and it can distinguish between different types of silts and clays.

The Atterberg define the boundaries of states in term of limits, such as:

(1) Liquid limit (LL) – change of consistency from plastic to liquid
(2) Plastic limit (PL) – change of consistency from brittle/crumbly to plastic
(3) Plasticity Index (PI) – The range of water content over which a soil has a plastic consistency

#### 3.3.3.1 Liquid Limit

In this experiment, Cone Penetrometer apparatus is used to determine the liquid limit. The test is based on the relationship between the moisture content at which clay soils pass from a plastic to a liquid state. The liquid limit determined at 20mm cone penetration.

About 200g to 250g of soil specimen, that passing 425μm sieve was prepared. The soil sample mixed with distilled water to prepared soil paste. Figure 3.9 shows the process on preparing the soil paste. Then, soil paste is pressed against the side of the cup, to avoid trapping air. More paste is pressed well into the bottom of the cup, without an air pocket. The soil paste in cup was leveled and placed properly so that the top of the cone shaft contacted with the soil paste surface. The value is recorded from the penetration capacity of the standard cone allowed to free fall into the sample for a period of 5 seconds. Figure 3.10 shows the penetrometer test. After each cone penetration reading, moisture content of sample was taken about 10g from the area penetration by cone. This all process must be repeated at least for four reading.

Figure 3.9: Preparing the soil paste

Figure 3.10: Penetrometer test

### 3.3.3.2 Plastic Limit

About 20g of the prepared soil paste was taken and spread it on the glass mixing plate. When the soil is plastic enough, shaped into ball and mould the ball between the fingers and rolled between the palm of the hands.

After slight cracks begin to appear on surface, the ball is divided into two portions about 10g. Then, divided each into four equal parts, but keeps each set of four parts together. One of the parts was kneaded by the fingers to equalize the distribution of moisture, and then form into a thread about 6mm diameter by using the first finger and thumb each hand.  Afterwards, the thread rolled using a steady pressure between the fingers and the surface of glass plate until the diameter of the thread reduced from 6mm to about 3mm diameter. This process must be repeated until the thread crumbled when it has been 3mm in diameter. As soon as the crumbling stage is reached, the thread placed into the container to determine the moisture content.

### 3.3.4 Specific gravity (ASTM D 854)

This test is done to determine the specific gravity of soil by density bottle method. Specific gravity is the ratio of the weight in air of a given volume of a material at a standard temperature to the weight in air of an equal volume of distilled water at the same stated temperature.

Before experiment was started, the density bottle along with the stopper, should be cleaned and dried at a temperature of 105 to 110$^{o}$C, cooled in the desiccators and weighed. Then, the 50g soil sample was prepared should if necessary be ground to pass through a 2mm BS Sieve. After that, about 50g to 10g of oven dried soil specimen were added into the density bottle.

The weight of density bottles and contents together with the stopper was measured. Afterward, added distilled water to fill the bottle to about ¾ full. Next, the bottle and the content were keeping into the vacuum desiccators for about 1 to 2 hours, until there is no further loss of air.

After an hour, the density bottle and it content was removed from vacuum desiccators, agiated and distilled water was filled completely. Again, the density bottle and it content was keep into the vacuum desiccators for about an hour or longer until no more air bubbles are observed in the soil-water mixture. Then, stopper was inserted in the density bottle, wiped and weighed.

The density bottle was cleaned and filled with distilled water, inserted the stopper and wipe dry from the outside. The mass of bottle, stopper and distilled water was measured. Take at least two such observations for the same soil.

### 3.3.5 Oedometer Test

To begin a particular test, the undisturbed sample was prepared by pushed down a 75mm diameter with 20mm thick cutting ring size onto the site investigation area. The top and bottom of the specimen was trimmed. To sampling process was carried out carefully to minimize any change in moisture content or disturbed. The soil with the ring was kept in airtight container.

#### 3.3.5.1 Single Oedometer Test

BS 1377: part 5:1990, clause 3 gives a standard procedure for the test. In this procedure the specimen is subjected to a series of pre-selected vertical stresses (e.g. 20, 40, 80, 160, 320 kPa) each of which is held constant while dial gauge measurements of vertical deformation of the top of the specimen are made, and until movements cease (normally 24 hours). The experiment started with weighed the soil specimen with the ring. The initial moisture content determined from trimming. The DS7 program is used by select oedometer for select machine. Next, the soil specimen was put into the consolidation cell and installs the vertical displacement transducer on top of the cell. The first loading started with initial weigh of 1kg on the lever. Afterward, the specimen was saturated by flooding. The specimen was placed under 20kPa for 24 hours. After 24 hours, resume the consolidation test by doubling the load to the desired pressure (40, 80, 160 and 320kPa). In this experiment, graph for void ratios against pressure generated. Figure 3.11 shows the oedometer machine for single oedometer and their components'.

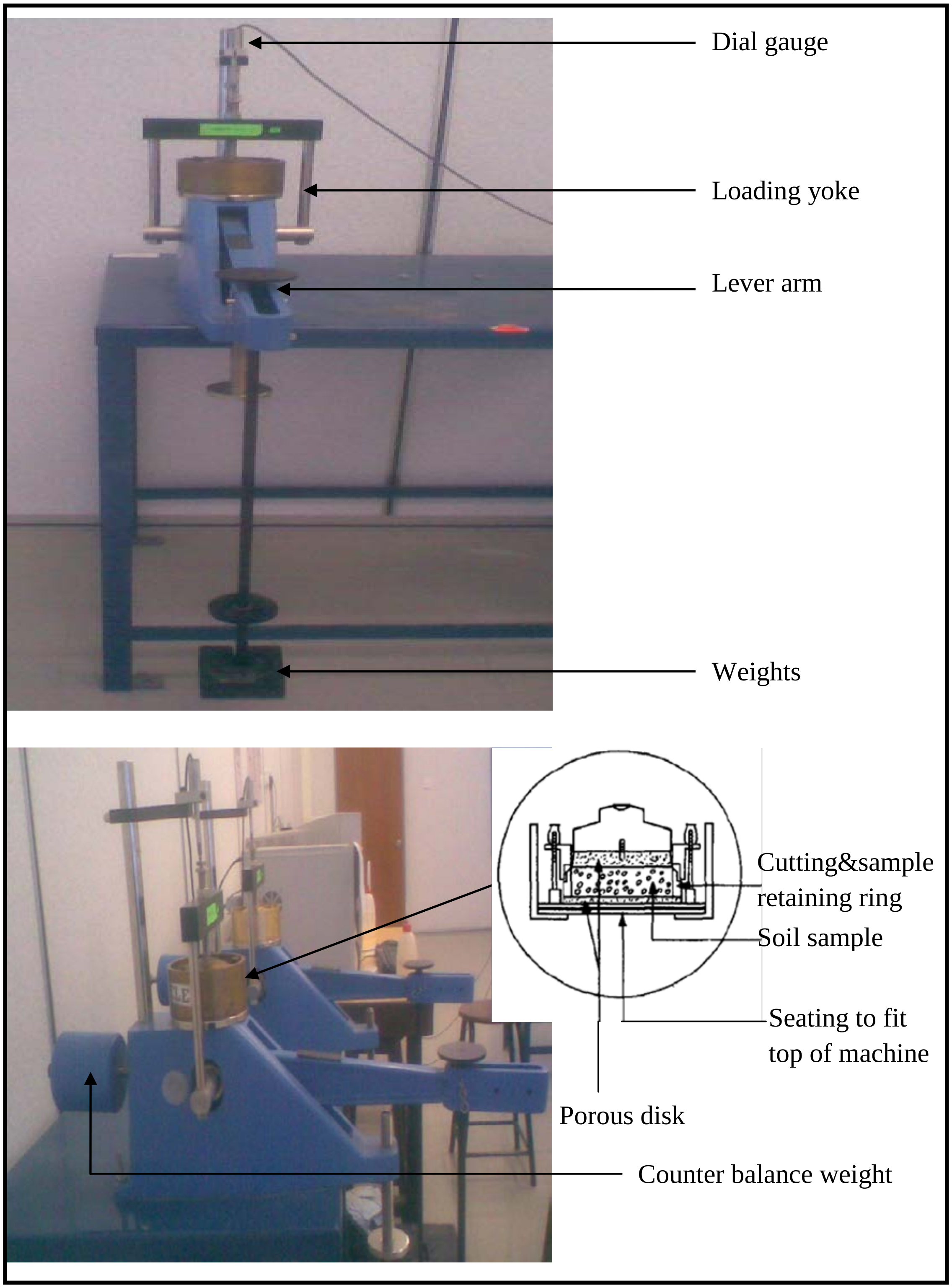


Figure 3.11: Oedometer test

### 3.3.5.2 Double Oedometer Test

In double oedometer experiment, there were two identical soil specimens placed in two oedometer. The preparation of soil specimen and procedures applied were similar to single oedometer experiment. Both of the soil specimens were experimented at different conditions. One of the soil specimens was stepwise loaded in the dry (natural moisture content) condition while the other soil specimen was inundated (wetting) during applied at vertical stress of 80kPa. BS 1377: part 5:1990, clause 3 gives a standard procedure for the test. In this procedure the specimen is subjected to a series of pre-selected vertical stresses (e.g. 20, 40, 80, 160, 320 kPa) each of which is held constant while dial gauge measurements of vertical deformation of the top of the specimen are made, and until movements cease (normally 24 hours) The experiment started with weighed the both of soil specimen with the ring. The initial moisture content determined from trimming. The DS7 program is used by select oedometer for select machine. Next, the soil specimen was put into the consolidation cell and installs the vertical displacement transducer on top of the cell. The first loading started with initial weigh of 1kg on the lever. The specimen was placed under 20kPa for 24 hours. After 24 hours, resume the consolidation test by doubling the load to the desired pressure (40, 80, 160 and 320kPa). In this experiment, graph for void ratios against stress generated. Figure 3.12 shows the oedometer machine for double oedometer test consist two of oedometer.

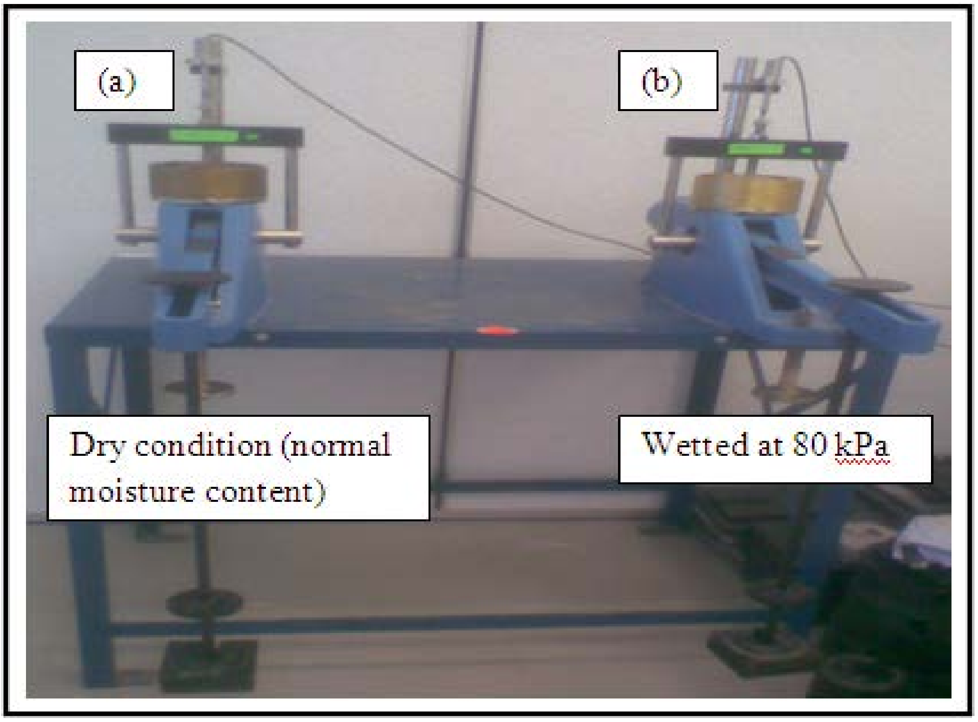


Figure 3.12: Double oedometer test

# CHAPTER 4

# RESULT AND ANALYSIS

## 4.1 Introduction

The results are recorded based on the determination of collapsibility rate of Gambang residual soil. After that, the collapsibility rate of Gambang residual soil is compared with Bentong residual soil in terms of collapsibility. These results are further discussed by cross referring them with the findings from other researchers.

On the characterization of engineering properties of residual soil, some of the testing has been conducted in the laboratory. The engineering properties of residual soil are focused on getting parameters like the natural moisture content, specific gravity, Atterberg's limit and particle size distribution.

Meanwhile, collapsibility rate of Gambang residual soil was obtained from single and double oedometer test as explained in Chapter 3.

## 4.2 Classification of Residual Soil

Classification of residual soil is done by result obtained from Atterberg limits test and sieve analysis test.

### 4.2.1 Atterberg's Limits

Table 4.1 shows the liquid limit, plastic limit and plasticity index result from the Atterberg's limits test for sample 1, sample 2 and sample 3.

Table 4.1: Atterberg's Limits test result

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

The liquid limit is in the range of 43 to 49%. Meanwhile, the plastic limit result was in the range of 22 to 27%. This residual soil at Gambang has lower plasticity index than Bentong which is in the range of 16 to 23%.

### 4.2.2 Sieve Analysis

Table 4.2 shows the particle size analysis result from sieve analysis test for sample 1, sample 2 and sample 3.

Table 4.2: Particle size distribution result from sieve analysis test

| 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 |

Based on the sieve analysis result, the soils contain high percentages of coarse grain content (sand and fine gravel), indicative of probably more open structure. In engineering term, the soil was classified as silty sand (SM) by according to USCS (Unified Soil Classification System).

The residual soil at Gambang contains high sand particles and it makes the soil more porous (high permeability) with tendency to infiltrate water easily. The effect of the quantity of sand and clay (S-C), on collapse potential, CP, was studied by Basma A. A and Tuncer R. E (1992) and suggested that higher the (S-C) is, lower the CP value at a particular applied wetting pressure, $p_w$. Higher the clay fraction is, higher the resistance is to densification and, consequently, higher the void ratio of soil would be. When the soil is allowed to free access of water, the clay bond is partially or fully broken, and the soil will collapse. Therefore, higher clay content in comparison to sand will results in higher collapse potential.

## 4.3 Engineering Properties of Residual Soil

To examine the collapsibility rate of Gambang residual soil, a comprehensive laboratory study was carried out to investigate the properties of residual soil for which the data will be used to determine the collapsibility rate. These engineering properties were focused on natural moisture content and specific gravity.

### 4.3.1 Natural Moisture Content

Table 4.3 shows the moisture content result from moisture content test for sample 1, sample 2 and sample 3.

Table 4.3: Moisture content result from moisture content test

| Sample No. | Moisture Content (%) |
|---|---|
| Sample 1 | 31.10 |
| Sample 2 | 28.41 |
| Sample 3 | 29.12 |

The moisture content for Gambang residual soil was in the range of 28 to 30%. When the moisture content is high, the bonding between the soil's particles is weakens 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.

### 4.3.2 Spesific Gravity

Table 4.4 shows the specific gravity from density bottle method test for sample 1, sample 2 and sample 3.

Table 4.4: Specific gravity of Gambang residual soil

| Sample No. | Specific Gravity |
|---|---|
| Sample 1 | 2.551 |
| Sample 2 | 2.700 |
| Sample 3 | 2.702 |

From Table 4.4, the Gambang residual soil has specific gravity value between 2.5 to 2.7.

## 4.4 Collapsibility Rate of Gambang Residual Soil

To examine the collapsibility rate of Gambang residual soil, a comprehensive laboratory test using single and double oedometer test was conducted.

### 4.4.1 Result for Single Oedometer Test

Table 4.5 shows the void ratio from single oedometer test for sample 1, sample 2 and sample 3.

Table 4.5: Single oedometer result

| Pressure (kPa) | Voids Ratio (e) | | |
|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 |
| 0 | 0.680 | 0.686 | 0.662 |
| 20 | 0.662 | 0.668 | 0.635 |
| 40 | 0.643 | 0.645 | 0.595 |
| 80 | 0.615 | 0.615 | 0.561 |
| 160 | 0.562 | 0.590 | 0.526 |
| 320 | 0.510 | 0.560 | 0.481 |

Table 4.5 shows the results of void ratio for single oedometer test for residual soil at Gambang. The result of oedometer test for sample 1, sample 2, and sample 3 is the lowest void ratio value range 0.5 to 0.7. The value void ratio for single oedometer test is plotted on Figure 4.1, Figure 4.2 and Figure 4.3. The single oedometer result shows the lowest void ratio because the pores between soils are filled by distilled water at beginning of the test. Generally, void ratio is one of the common characteristics of residual soil. The void ratio of residual soil is a function of the level reached in the weathering process, and directly dependent on the characteristics of its parent rock which induce influences on their deformation behavior.

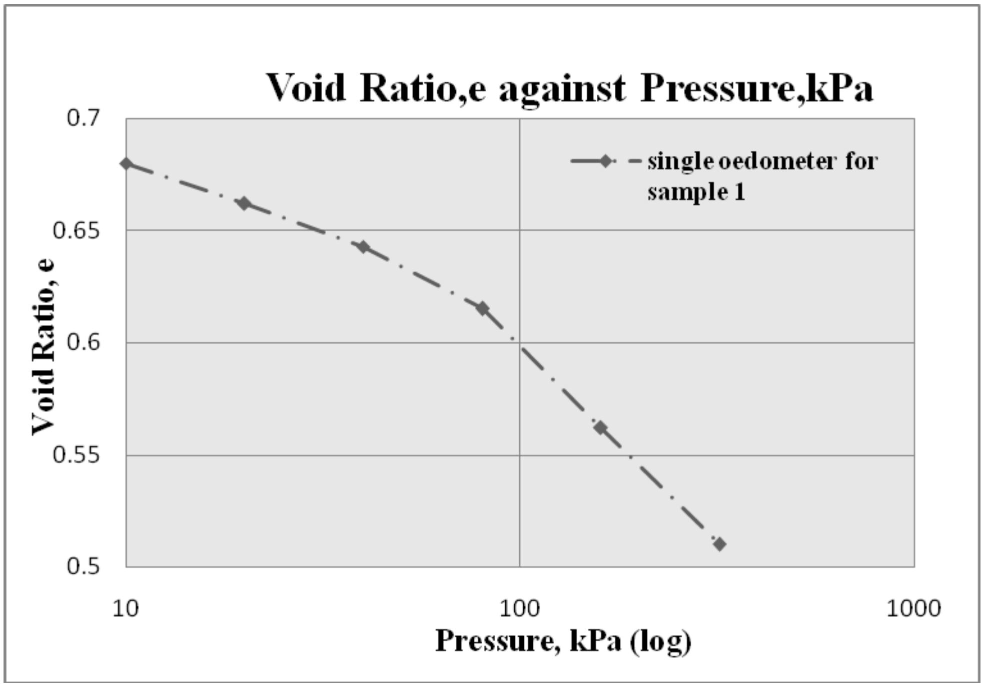


Figure 4.1 : Graph of single oedometer for sample 1

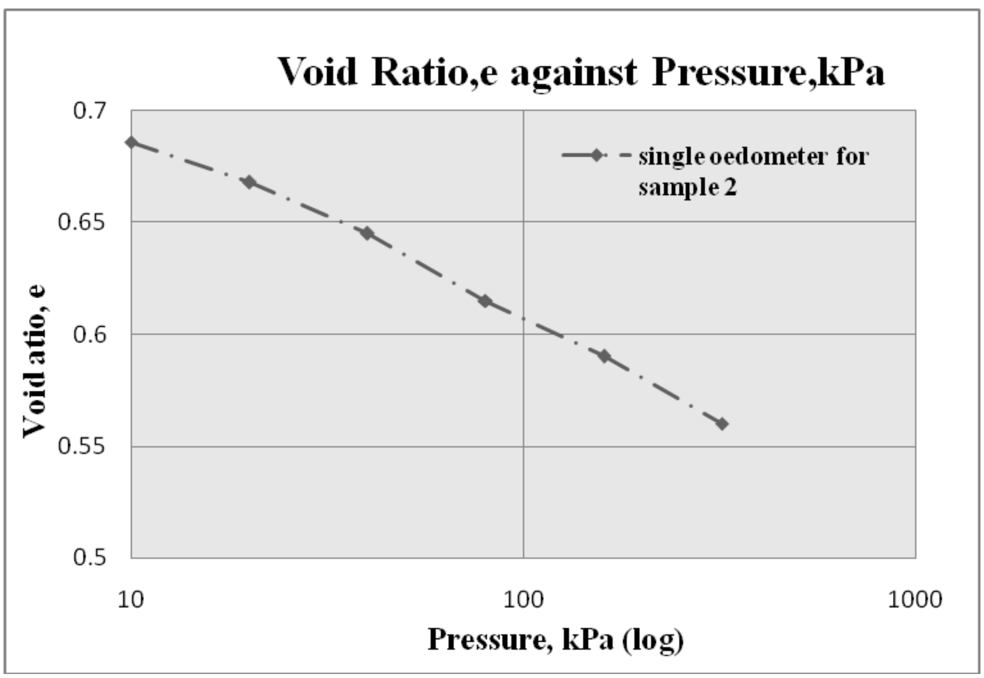


Figure 4.2 : Graph of single oedometer for sample 2

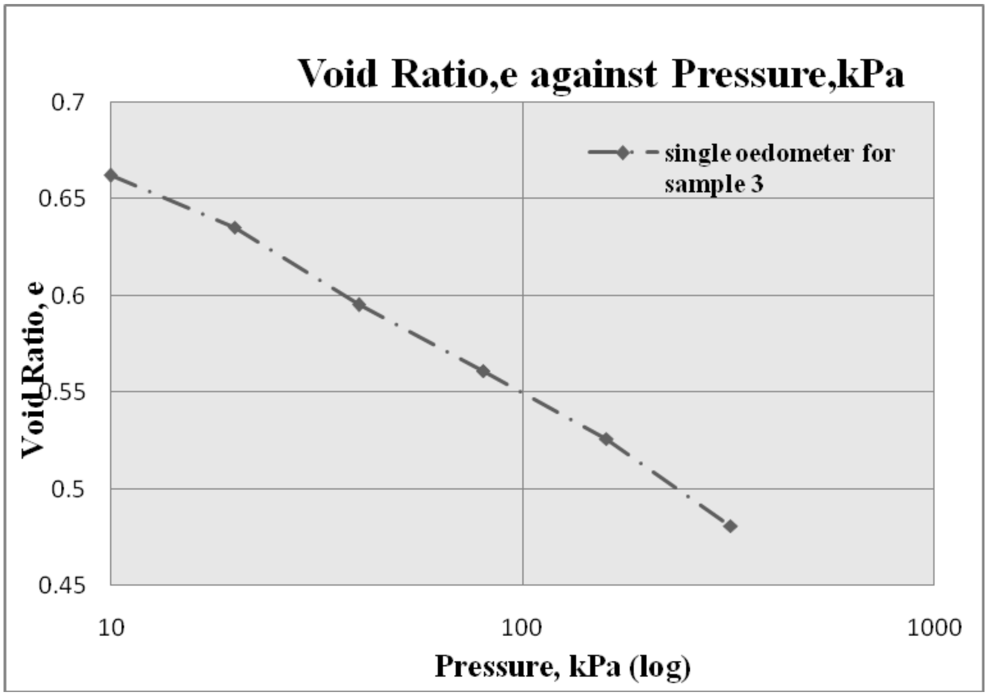


Figure 4.3 : Graph of single oedometer for sample 3

### 4.4.2 Result for Double Oedometer Test

Table 4.6 shows the void ratio from double oedometer test for sample 1, sample 2 and sample 3 for residual soil at Gambang. The result of double oedometer test consists of 2 categories which is double oedometer 1 and another 1 is double oedomter 2. The entire value void ratio for single oedometer test is plotted on Figure 4.4, Figure 4.5, Figure 4.6, Figure 4.7, Figure 4.8 and Figure 4.9.

Table 4.6: Double oedometer result

| Pressure (kPa) | Void Ratio (e) | | | | | |
|---|---|---|---|---|---|---|
| | Double oedometer 1 | | | Double oedometer 2 | | |
| | Sample 1 | Sample 2 | Sample 3 | Sample 1 | Sample 2 | Sample 3 |
| 0 | 0.873 | 0.815 | 0.785 | 0.756 | 0.742 | 0.757 |
| 20 | 0.825 | 0.765 | 0.756 | 0.743 | 0.730 | 0.712 |
| 40 | 0.765 | 0.736 | 0.727 | 0.731 | 0.720 | 0.681 |
| 80 | 0.717 | 0.704 | 0.686 | 0.702 | 0.705 | 0.647 |
| 80 | - | - | - | 0.620 | 0.625 | 0.565 |
| 160 | 0.665 | 0.680 | 0.655 | 0.610 | 0.605 | 0.552 |
| 320 | 0.607 | 0.653 | 0.623 | 0.565 | 0.563 | 0.534 |

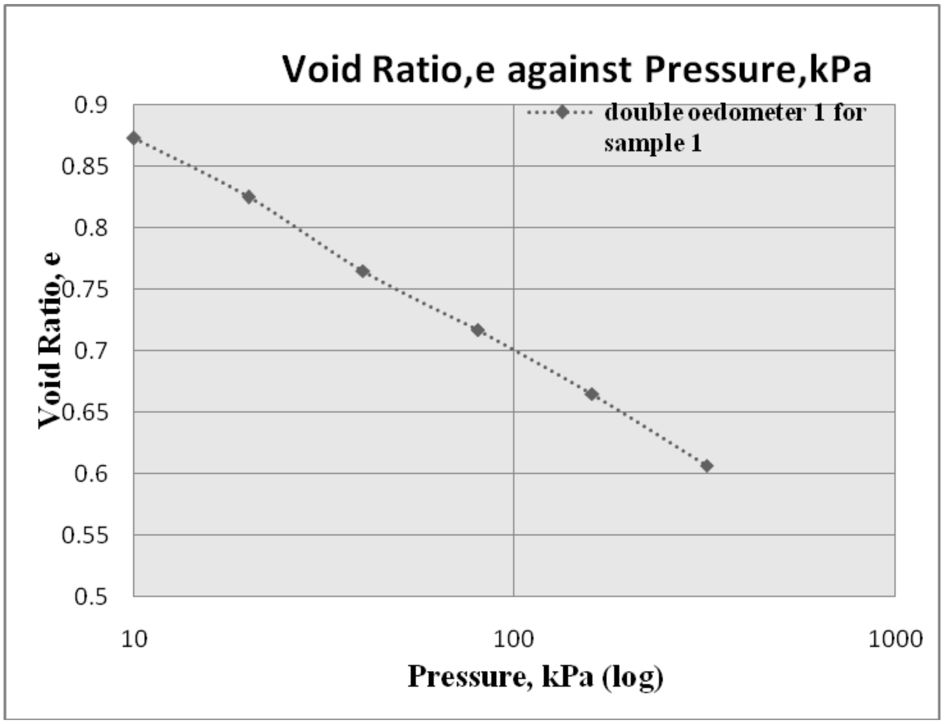


Figure 4.4: Graph of double oedometer 1 for sample 1

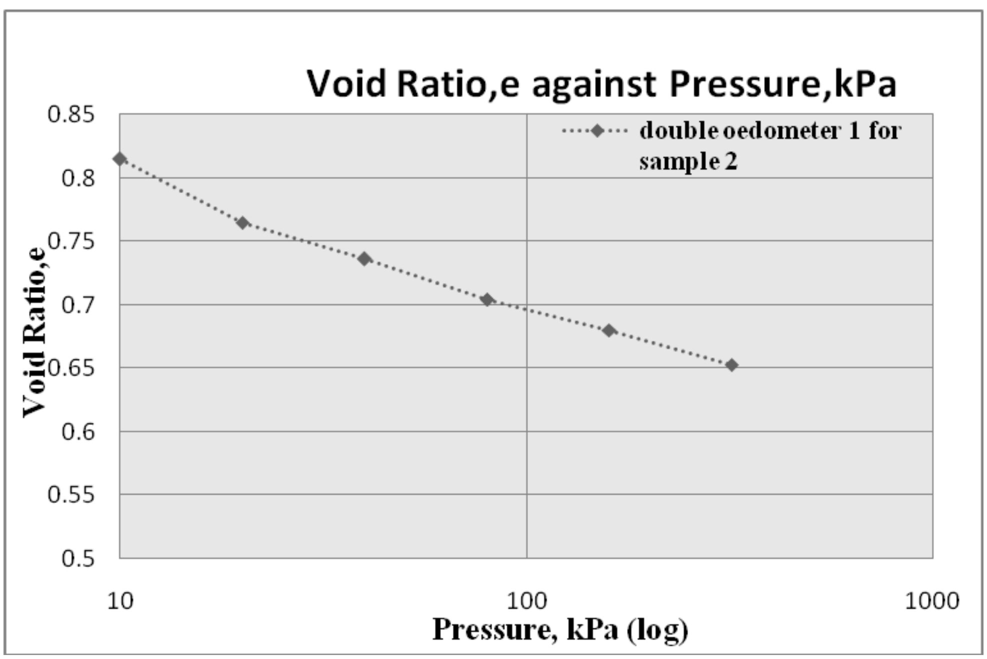


Figure 4.5: Graph of double oedometer 1 for sample 2

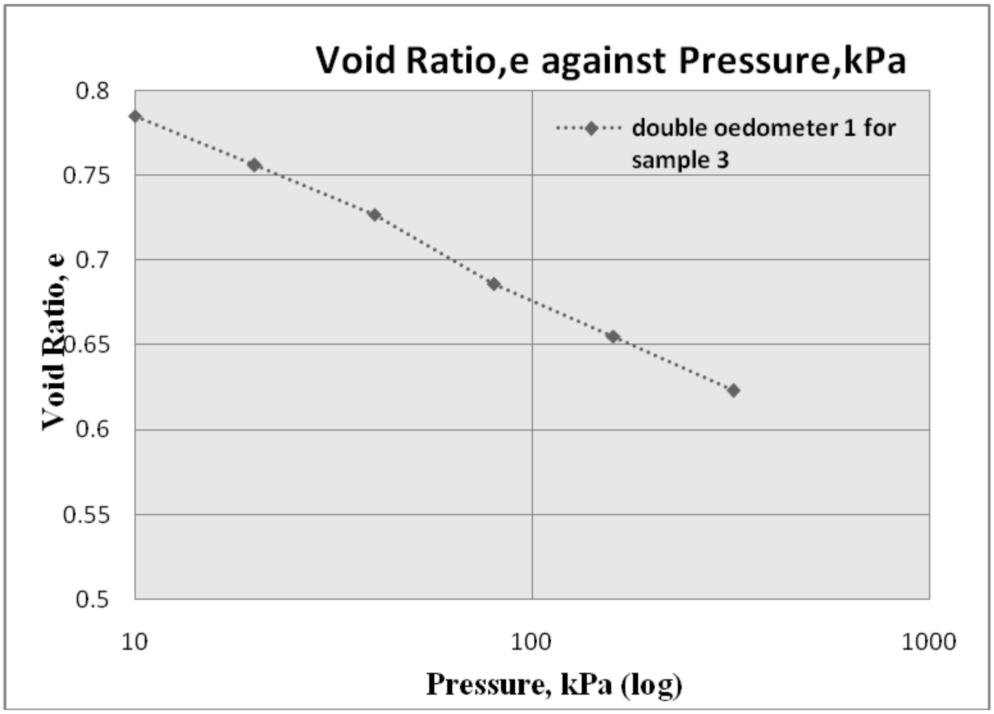


Figure 4.6: Graph of double oedometer 1 for sample 3

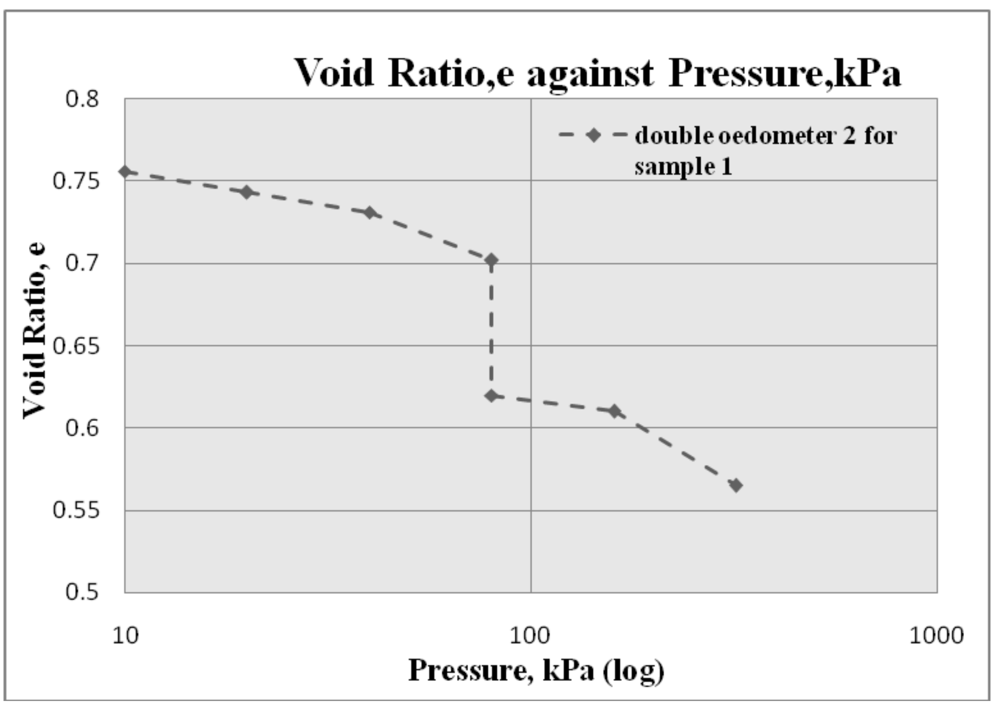


Figure 4.7: Graph of double oedometer 2 for sample 1

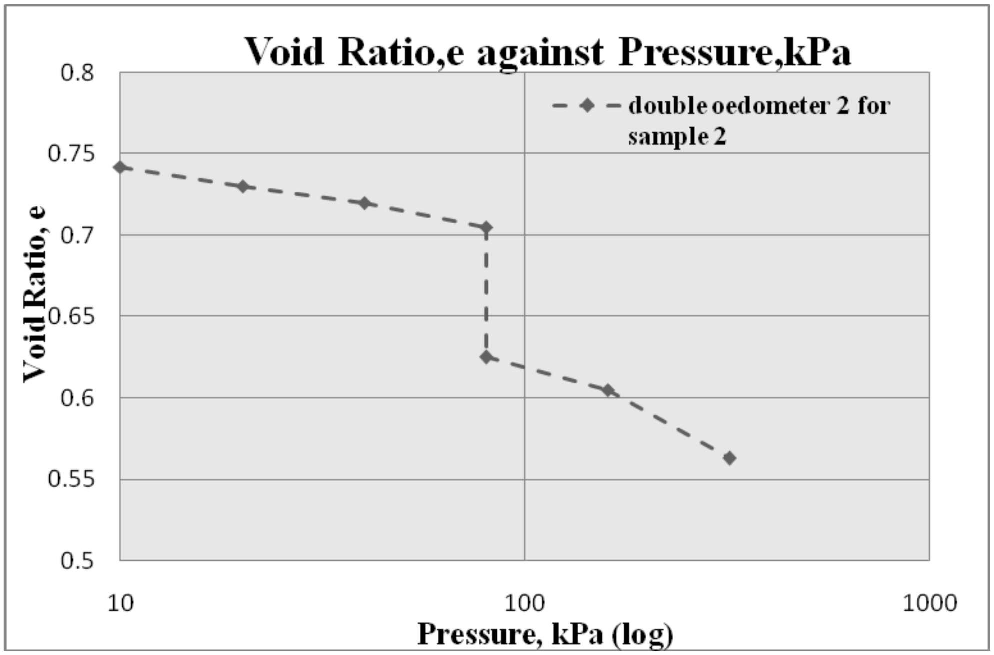


Figure 4.8: Graph of double oedometer 2 for sample 2

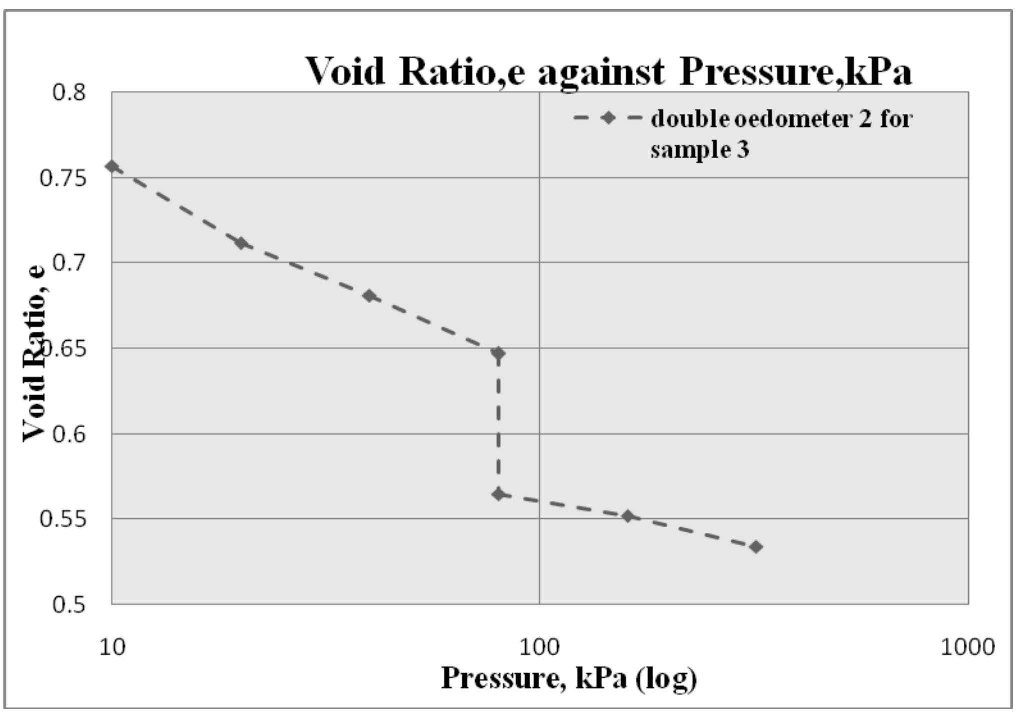


Figure 4.9: Graph of double oedometer 2 for sample 3

### 4.4.3 Collapsibility Rate

Table 4.7 shows the collapsibility rate from double oedometer 2 for sample 1, sample 2 and sample 3.

Table 4.7: Collapsibility rate at Gambang residual soil

| Sample No. | Initial void ratio, $e_o$ | Double oedometer 2 (wetted at 80kPa) | | | Collapse potential (%) |
|---|---|---|---|---|---|
| | | Void ratio (before wetting) $e_i$ | Void ratio (after wetting) $e_f$ | $\Delta e$ | |
| Sample 1 | 0.89 | 0.70 | 0.622 | 0.078 | 4.13 |
| Sample 2 | 0.73 | 0.61 | 0.533 | 0.077 | 4.44 |
| Sample 3 | 0.88 | 0.70 | 0.624 | 0..076 | 4.00 |

Based on Table 4.7, in terms of intensity of collapse potential, Gambang residual soil could be classified as moderate trouble with collapse potential, CP value between 4 to 5 percent. The CP value is influenced by the initial value and the changes of void ratio.

### 4.4.4 Combined Graph of Single Oedometer and Double Oedometer Result

Figure 4.10, Figure 4.11 and Figure 4.12 shows the combination graph of single and double oedometer result for every sample of testing.

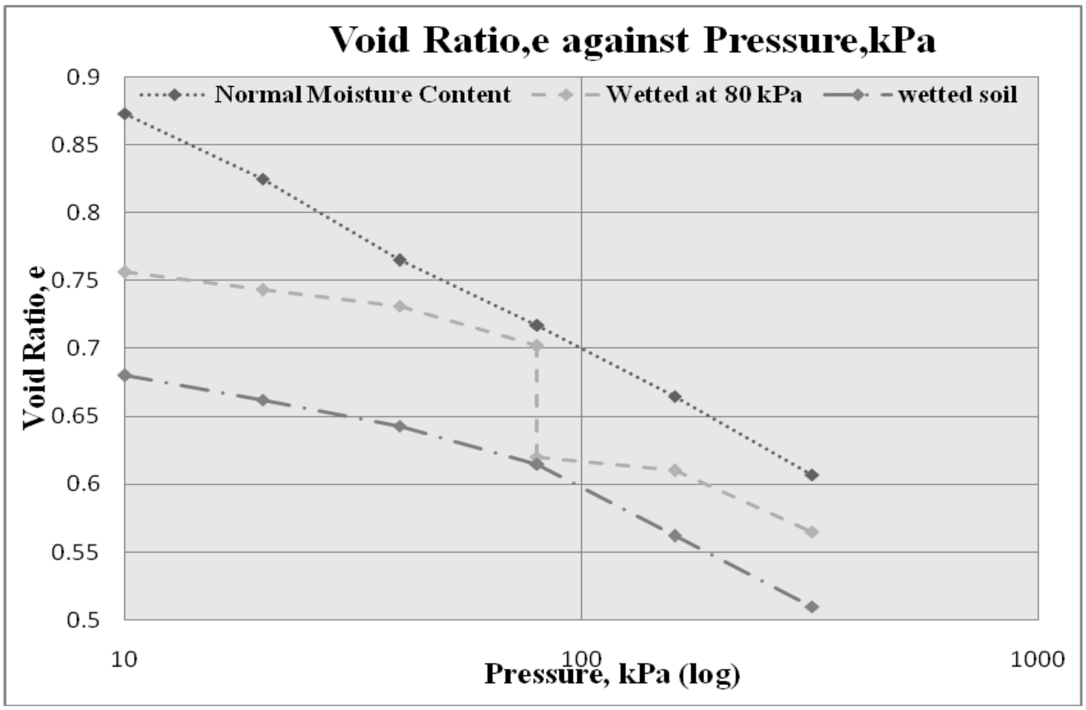


Figure 4.10: Sample 1

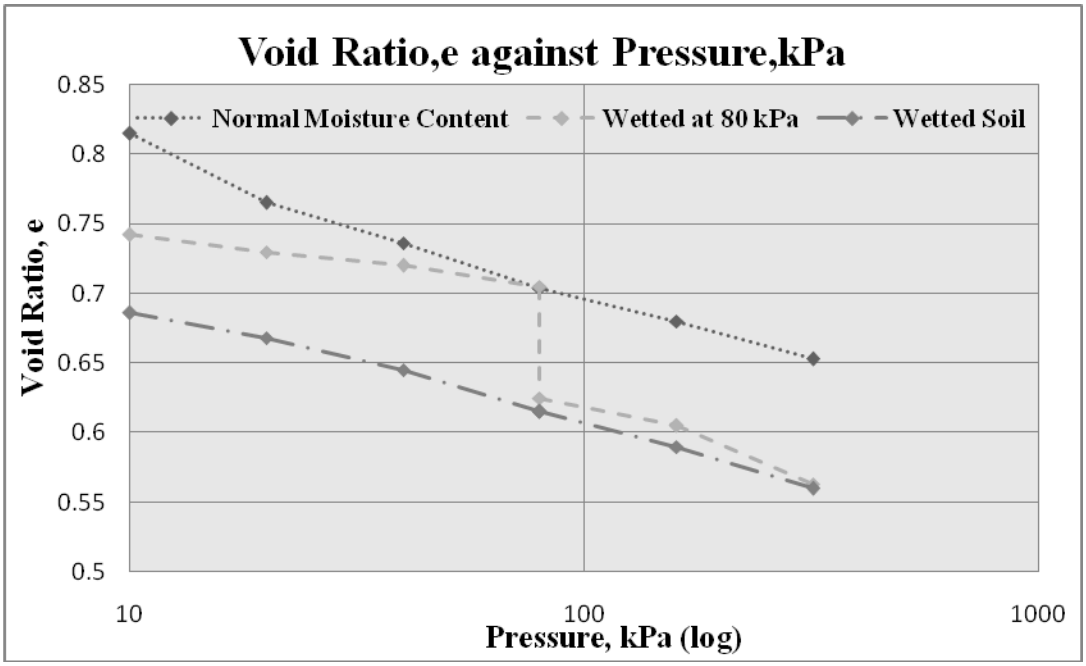


Figure 4.11: Sample 2

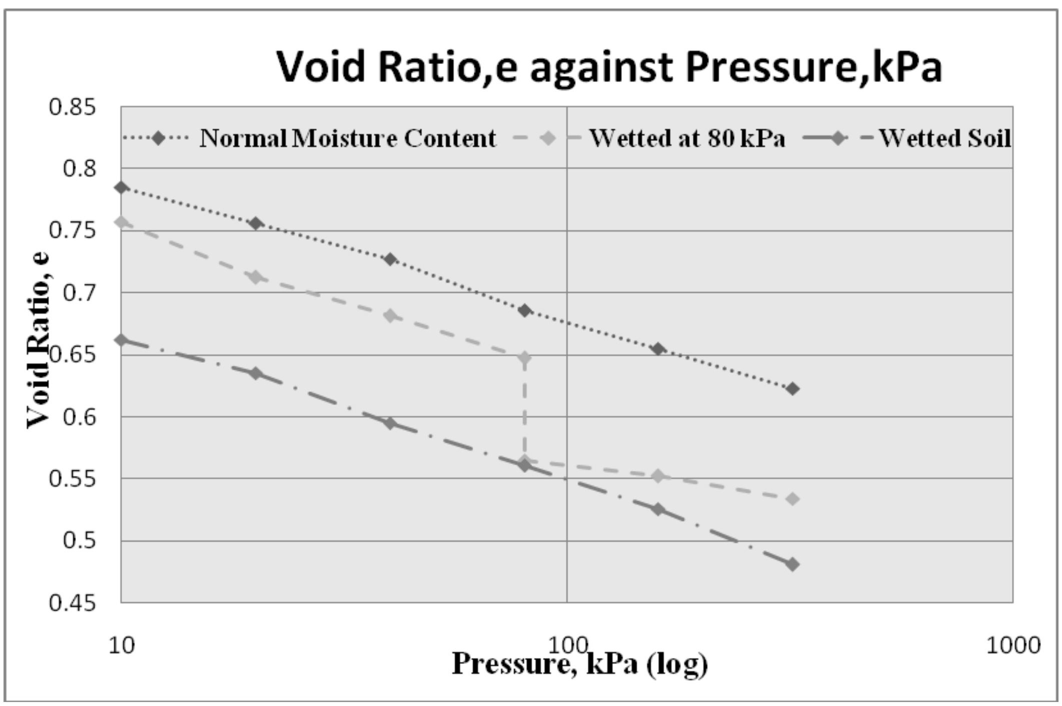


Figure 4.12: Sample 3

### 4.4.5 Influence to Collapse Soil

From the testing of consolidation test using double oedometer 2, the value of parameter that influenced to collapsibility was determined which is dry density and degree of saturation. Table 4.8 shows of these parameters.

Table 4.8: Result of parameter from double oedometer 2

| Sample No. | Dry Density, $\rho_d$ (Mg/m$^3$) | Degree of Saturation, $S_r$ (%) |
|---|---|---|
| Sample 1 | 1.51 | 88 |
| Sample 2 | 1.58 | 90 |
| Sample 3 | 1.49 | 87 |

Table 4.8 shows the Gambang residual soil has high initial dry densities and high degree of saturation which could influence the chance to have lower CP. Similar observation on CP increase with dry density decrease is reported by Day (2000). Collapsible soil as defined by Day (2000) is a 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. The Gambang residual soil has dry density values ranging between 1.5-1.6 (Mg/m$^3$). Huat B. K. K. et al. (2008) have similar result which is samples with higher initial dry densities and degree of saturation appeared to have lower collapse potential.

## 4.5 The t-test

T-test analysis is done on comparison between Gambang and Bentong residual soil. For the null hypothesis, $H_o$ there is no significant difference between collapsibility rate of Gambang and Bentong residual soil. Meanwhile, for the alternative hypothesis, $H_A$ there is significant difference between collapsibility rate of Gambang and Bentong residual soil. t-test result shows a significance result if the t-test that is calculated is lower than t-test that is obtained from standard table.

### 4.5.1 Comparison in Collapsibility Rate

Table 4.9 shows the t-test calculation on comparison of collapsibility rate between Gambang residual soil and Bentong residual soil.

Table 4.9: t-test calculation on comparison of collapsibility rate

| Sample No. | CP at Gambang (%) | CP at Bentong (%) | t-test Calculated | t-test Table |
|---|---|---|---|---|
| Sample 1 | 4.13 | 5.31 | 0.01304 | 0.05 |
| Sample 2 | 4.44 | 4.89 | | |
| Sample 3 | 4.00 | 5.53 | | |

Analysis of t-test for the comparison on collapsibility rate of Gambang and Bentong residual soils shows that the t-test calculated, 0.01304 is lower value than value from table which is 0.05. Null hypothesis, $H_o$ was rejected and accepts the alternative hypothesis, $H_A$. Due to this result, the analysis shows a significant result.

# CHAPTER 5

# CONCLUSIONS & RECOMMENDATIONS

## 5.1 Conclusions

The determination of collapsibility for Gambang residual soils was conducted by using single and double oedometer test. From the observation of the tests that have been conducted and the results obtained it shows that when the residual soil is wetted, it will collapse. This is because, when the moisture content is high, the bonding between the soil's particles is weakens 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. In terms of severity of collapse potential, Gambang residual soil is classified as moderate trouble with CP value between 4 to 5 percent. Collapsibility rate of Bentong is higher than Gambang with CP value between 5 to 6 percent. Therefore Bentong residual soil is termed as moderate trouble to trouble.

Table 5.1 shows a summary of data from the result testing. Besides, from the t-test analysis, there is significant difference between collapsibility rate of Gambang and Bentong residual soils. Therefore, collapsibility rate at Gambang residual soils is lower than Bentong residual soils.

Table 5.1: Summary of data

| | Huat B. K. K. et al. (2008) | Wartini (2009) |
|---|---|---|
| Location | Bentong | Gambang |
| Liquid limit (%) | 70-79 | 43-49 |
| Plastic limit (%) | 28-35 | 22-27 |
| Plasticity index (%) | 40-44 | 16-23 |
| Sand content (%) | 21-28 | 75-78 |
| Silt content (%) | 40-44 | 15-17 |
| Clay content (%) | 29-36 | 1.5-2.2 |
| Void ratio, $\Delta e$ | 0.114-0.127 | 0.076-0.078 |
| Natural moisture content (%) | 26-31 | 28-30 |
| Specific gravity | 2.63-2.65 | 2.5-2.7 |
| Dry Density, $\rho_d$ (Mg/m$^3$) | 1.10-1.17 | 1.49-1.58 |
| Degree of Saturation, $S_r$ (%) | 53-62 | 87-90 |
| Collapsibility rate (%) | 4.9-5.5 | 4.00-4.44 |

## 5.2 Recommendations

Most residual soil exhibit high suctions for most of the year. Ignorance or lack of understanding of the geotechnical behavior of soil in the partially or unsaturated state has caused a lot of damages to infrastructures, buildings and other structures. It is also observed that many shallow slope failures involve a slumping (collapse) type of failure. To avoid any tragedy will happen on the future after the incident at Bukit Antarabangsa, the authors suggest these kind of method testing must be conduct before begin any construction work on residual soil. This method is more effective to predict the collapsibility rate for the development area on residual soil. The recommended method is highly to use for foundation, roads and other structures. I hope, this research project will be expanding for the larger scope of work on soil condition. Besides, the collect of data must be doing in a correct way. Then, the result will be valid and acceptable.

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# APPENDIX A

## Overall Result of Preliminary Work

Table A1: Table of result from preliminary work

| No. | Test | Result of every Sample | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Liquid limit (%) | 43 | 45 | 49 |
| 2. | Plastic limit (%) | 27 | 22 | 26 |
| 3. | Sieve analysis | Silty Sand, SM | Silty Sand, SM | Silty Sand, SM |
| 4. | Moisture content (%) | 31.10 | 28.41 | 29.12 |
| 5. | Spesific gravity | 2.551 | 2.700 | 2.702 |
| 6. | Dry Density ($Mg/m^3$) | 1.51 | 1.58 | 1.49 |
| 7. | Degree of Saturation (%) | 88 | 90 | 87 |

# APPENDIX B

## Raw Data of Atterberg's Limit

Table B1: The raw data of plastic limit

| Sample no. | 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 |

Table B2: The raw data of liquid limit

| Sample no. | 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 | |

# APPENDIX C

## Raw Data of Sieve Analysis

Table C1: the raw data of sieve analysis for sample 1

| Sample No.: 1 | | | Date : 27/February/2009 | | |
|---|---|---|---|---|---|
| Site : Gambang Area | | | Description : Residual 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 | |

Table C2: The raw data of sieve analysis for sample 2

| Sample No.: 2 | | | Date : 6/March/2009 | | |
|---|---|---|---|---|---|
| Site : Gambang Area | | | Description : Residual 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 | |

Table C3: The raw data of sieve analysis for sample 3

| Sample No.: 3 | | | Date : 16/March/2009 | | |
|---|---|---|---|---|---|
| Site : Gambang Area | | | Description : Residual 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 | |

# APPENDIX D

## Raw Data of Moisture Content

Table D1: The raw data of moisture content for sample 1

| Test no. | 1 | 2 | 3 |
|---|---|---|---|
| Mass of container (g) | 52.26 | 55.63 | 53.43 |
| Mass of container + wet soil (g) | 62.34 | 65.67 | 65.07 |
| Mass of container + dry soil (g) | 60.06 | 63.46 | 61.21 |
| Moisture loss (g) | 2.28 | 2.21 | 3.86 |
| Moisture content (%) | 29.23 | 28.22 | 35.85 |
| Average (%) | 31.10 | | |

Table D2: The raw data of moisture content for sample 2

| Test no. | 1 | 2 | 3 |
|---|---|---|---|
| Mass of container (g) | 21.48 | 19.61 | 21.04 |
| Mass of container + wet soil (g) | 50.16 | 70.96 | 65.13 |
| Mass of container + dry soil (g) | 44.60 | 59.03 | 56.45 |
| Moisture loss (g) | 5.56 | 11.89 | 8.64 |
| Moisture content (%) | 24.05 | 36.67 | 24.51 |
| Average (%) | 28.41 | | |

Table D3: The raw data of moisture content for sample 3

| Test no. | 1 | 2 | 3 |
|---|---|---|---|
| Mass of container (g) | 19.04 | 19.48 | 18.52 |
| Mass of container + wet soil (g) | 34.86 | 37.20 | 33.78 |
| Mass of container + dry soil (g) | 31.50 | 33.22 | 30.90 |
| Moisture loss (g) | 3.36 | 3.98 | 2.88 |
| Moisture content (%) | 26.97 | 33.96 | 26.43 |
| Average (%) | 29.12 | | |

# APPENDIX E

## Raw Data of Specific Gravity

Table E1: The raw data of specific gravity

| Sample no. | 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, $G_s = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$ | 2.551 | 2.700 | 2.702 |

# APPENDIX F

## List of Material and Equipment

**Name** : Wartini Binti Warni

**ID No.** : AA06057

**Contact No.** : +013-2129434

**Supervisor** : Mr. Youventharan S/O Duraisamy

**Title** : Comparison Between Gambang Residual Soil and Bentong Residual Soil in Terms of Collapsibility

**Laboratory Used**

Soil and Geotechnical Lab

**List of Proposed Material and Equipment**

**List of Material**

| No | ITEM | QUANTITY |
|---|---|---|
| 1 | Distilled water | 2 bottle |

**List of Equipments**

| **No** | **ITEM** | **QUANTITY** |
|---|---|---|
| 1 | Rubber mallet | 2 |
| 2 | Hoe | 1 |
| 3 | Trowel | 2 |
| 4 | Garbage plastic bag | 1 packet |
| 5 | Pail | 1 |
| 6 | Small plastic | 1 packet |

List of Test Tools

| **No** | **ITEM** | **QUANTITY** |
|---|---|---|
| 1 | Sieve tools | 1 |
| 2 | Weighing | 2 |
| 3 | Humidity room | 1 |
| 4 | Oedometer tools | 3 |
| 5 | Dry oven | 1 |
| 6 | Density bottle | 3 |
| 7 | Container | 6 |
| 8 | Dessicator | 1 |

## APPENDIX G

### Letter for Using Geotechnical Laboratory

Encik Mohd Badwi Bin Yunus 20 Februari 2009

Ketua Makmal Kejuruteraan Tanah dan Geoteknik,

Universiti Malaysia Pahang

Lebuhraya Tun Razak,

26300 Kuantan,

**Pahang Darul Makmur**

Melalui dan salinan:

Encik Youventharan A/L Duraisamy

Pensyarah

Fakulti Kejuruteraan Awam dan Sumber Alam,

Universiti Malaysia Pahang

Lebuhraya Tun Razak,

26300 Kuantan,

**Pahang Darul Makmur**

Tuan,

**PERMOHONAN UNTUK MENGGUNAKAN MAKMAL DAN PERALATAN DI MAKMAL KEJURUTERAAN TANAH DAN GEOTEKNIK BAGI TUJUAN PROJEK SARJANA MUDA (PSM)**

Dengan segala hormatnya, merujuk kepada perkara di atas, saya Wartini Binti Warni (AA06057) wakil kepada senarai nama yang dilampirkan bersama surat ini merupakan pelajar tahun 4 Sarjana Muda Kejuruteraan Awam yang sedang menjalani kajian terhadap tanah baki di bawah penyeliaan pensyarah Encik Youventharan A/L Duraisamy. Di sini kami ingin memohon kebenaran daripada pihak tuan untuk menggunakan Makmak

Kejuruteraan Tanah dan Geoteknik .Kami mencadangkan untuk menggunakan pada hari dan masa berikut sepanjang semester ini;

Hari : Isnin, Selasa, Rabu, Khamis, Jumaat

Masa : 8.00 pagi – 5.30 petang

Tarikh : 23 Februari 2009 – 30 April 2009

2. Sehubungan dengan itu, kerjasama daripada pihak Tuan adalah dipohon untuk memberi kebenaran kepada kami menggunakan peralatan makmal dan makmal kejuruteraan tanah dan geoteknik ini.Bersama dengan surat ini saya lampirkan senarai nama pelajar dan senarai peralatan makmal yang diperlukan.

3. Sebarang masalah boleh merujuk terus kepada saya **Wartini Binti Warni**. Segala kerjasama daripada pihak Tuan adalah amat dihargai dan didahului dengan setinggi- tinggi ucapan terima kasih.

Yang Benar,

……………………………………………

(WARTINI BINTI WARNI)

AA06057

Disahkan oleh,

……………………………………………

(EN. YOUVENTHARAN A/L DURAISAMY)

Pensyarah

Fakulti Kejuruteraan Awam dan Sumber Alam,

Universiti Malaysia Pahang (UMP)

**LAMPIRAN 1**

**SENARAI NAMA PELAJAR**

| | |
|---|---|
| 1.MOHD HAFFIZUL SAID BIN MOHD RAMDZAN | AA06012 |
| 2. HASREN BINTI TONI | AA06103 |
| 3. WARTINI BINTI WARNI | AA06057 |

**LAMPIRAN 2**

**SENARAI PERALATAN MAKMAL**

1. Sieve tools
2. Weighing
3. Humidity room
4. Oedometer tools
5. Dry oven
6. Density bottle
7. Container
8. Dessicator