# THE CHARACTERISTICS OF TAPAH KAOLIN SOIL

By

HAYATI SYAHEELA BINTI RAZALI

FINAL PROJECT REPORT

Submitted to the Civil Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Civil Engineering)

Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

# CERTIFICATION OF APPROVAL

## THE CHARACTERISTICS OF TAPAH KAOLIN SOIL

by

Hayati Syaheela Binti Razali

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
Bachelor of Engineering (Hons)
(Civil Engineering)

Approved:

____________________________

Miss Niraku Rosmawati Ahmad
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2007

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Hayati Syaheela Binti Razali

# ABSTRACT

Tapah kaolin is widely used in ceramics industry and as construction materials. Kaolin commonly known as one type of clay because of the *kaolinite* mineral in it. Different type of clay has different behavior depend on its index and engineering properties. The properties of soil are depending on the type of formation and the geological area. The objectives of this report are to determine the index and engineering properties of Tapah kaolin and determine the soil distribution of kaolin in Tapah. Four soil samples are taken from Associated Kaolin Industries Sdn. Bhd in Tapah, Perak. Laboratory experiments, which are sieve analysis, hydrometer analysis, particle density and vane shear test, were carried out on four soil samples taken from the study area. The results indicated that the soil in the studied area is predominantly sand. The samples are classified as silty sand and sandy clay. As for the engineering properties, the soil is low in undrained shear strength between 12.5 to 25 kpa. The condition of soil is soft due to low cohesiveness of soil since the soil contains more sand. The formation is resulted from the hydrothermal alteration of the metasediments and granite because the samples collected are located in granitoids area.

# ACKNOWLEDGEMENTS

First of all, the author is grateful to Allah S.W.T for the completion of this Final Year Project. Deepest gratitude goes to project supervisor, Miss Niraku Rosmawati Ahmad for her guidance and patience in ensuring that the author accomplished the project objectives, also for her supports and commitments. Special thanks to FYP technician, Mr. Zaini for his assistance in helping the author completed the tasks related.

The author also would like to express a thousand appreciations to other Civil Engineering lecturers and colleagues who have involved directly or indirectly with this project for all the help and guidance throughout the year.

The gratitude extended to author's family who has given undivided support to the author throughout the completion of the project. The author will always be grateful for their sacrifices and sincerity.

Finally, million thanks to all parties who had also contributed directly or indirectly towards the success of this project.

Thank you.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF NOTATIONS

| | |
|---|---|
| **AASHTO** | American Association of State Highway and Transportation Officials Classification System |
| **BSCS** | British Standard Classification System |
| **CE** | Clay of extremely high plasticity |
| **I** | Intermediate plasticity |
| **M** | Silt (restricted plastic range) |
| **MH** | Silt of high plasticity |
| **SEM** | Scanning electron microscopy |
| **SM** | Silty sand |
| **SW** | Well graded sand |
| **SC** | Clayey sand |
| **SP-SC** | Poorly graded sand with clay (or silty clay) |
| **SW-SC** | Well graded sand with clay (or silty clay) |
| **USCS** | Unified Soil Classification System |
| **S1** | Soil sample at area 1 |
| **S2** | Soil sample at area 2 |
| **S3** | Soil sample at area 3 |
| **S4** | Soil sample at area 4 |

# CHAPTER 1
# INTRODUCTION

## 1.1 Background of Study

Clay minerals are an important group of minerals because they are among the most common products of chemical weathering, and thus are the main constituents of the fine-grained sedimentary rocks called mud rocks (including mudstones, claystones, and shale's). Clay minerals make up about 40% of the minerals in sedimentary rocks. Clay might consist one of the three important clay minerals which are *Kaolinite, Illite* and *Montmorillonite*. Clay minerals are used extensively in the ceramics industry and are thus important economic minerals. Tapah Kaolin soil which is used in this study contain *kaolinite* mineral that have been extensively used in making ceramics, mosaic tiles, sanitarywares, fillers for the paper, paint and fertilizer industries. The studies cover the Tapah area only due to numerous number of Kaolin industries there.

## 1.2 Problem Statement

Different type of clay has different behavior depend on its index and engineering properties. Strength, stiffness, flow and particle distribution may give impact to the construction and structure performance. Among the three clay minerals, Kaolinite has greater shear strength as compared to the other minerals. However the formation of clay is different in every region. This may results in different of soil properties. Moreover, lack of kaolin data is provided for Tapah area and hence difficult for other (e.g. engineers, developers) to know the properties of the soil. This study is essential to know the behavior and properties of Kaolin soil which can be used in the solution of geotechnical and geoenvironmental problems.

## 1.3 Objective and Scope of Study

### *1.3.1 Objectives*

- To investigate the index properties of Tapah Kaolin soil.
- To determine the shear strength of soil.
- To determine the particle size distribution of Kaolin soil in Tapah.

### *1.3.2 Scope of Study*

This study focuses on determination of the kaolin soil characteristic. The soil used is kaolin soil which was taken from Associated Kaolin Industries Sdn Bhd. mines in Tapah, Perak (refer to Appendix A). Tapah is choose as the investigated area due to numerous numbers of kaolin mines and to compare the data obtain with other researcher. All the testing for this study is conducted in laboratory by using British Standard (BS) as a reference.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Introduction

Kaolin also known as china clay is a mixture of different minerals. The main component of kaolin clay is kaolinite. The name "kaolin" is derived from the word Kau-Ling, or high ridge, the name given to a hill near Jau-chau Fu, China, where kaolin was first mined (Sepulveda et al., 1983). Kaolin, commonly referred to as china clay, is clay that contains 10–95% of the mineral kaolinite and usually consists mainly of kaolinite (85–95%). In addition to kaolinite, kaolin usually contains quartz and mica, feldspar, illite, montmorillonite, ilmenite, anastase, haematite, bauxite, zircon, rutile, kyanite, silliminate, graphite, attapulgite, and halloysite. Some clay used for purposes similar to those for which kaolin is used may contain substantial amounts of quartz: "kaolin-like" clays used in South African pottery contained 23–58% quartz and, as the other major constituent, 20–36% kaolinite (Rees et al., 1992).

## 2.2 Minerals

### *2.2.1 Mineral Composition in Kaolin*

Kaolinite is made up of tiny sheets of triclinic crystals with pseudohexagonal morphology. The structure of kaolinite is a tetrahedral silica sheet alternating with an octahedral alumina sheet. These sheets are arranged so that the tips of the silica tetrahedrons and the adjacent layers of the octahedral sheet form a common layer (Grim, 1968). In the layer common to the octahedral and tetrahedral groups, two-thirds of the oxygen atoms are shared by the silicon and aluminium, and then they become $O^-$ instead of $OH^+$. The charges within the structural unit are balanced. Analyses of many samples of kaolinite minerals have shown that there is very little substitution in the lattice (Grim, 1968). The molecular formula that is common for the kaolinite group (kaolinite, nacrite, dickite) is $Al_2Si_2O_5(OH)_4$ (Grim, 1968). Kaolinite, the main constituent of kaolin, is formed by rock weathering. It is white, greyish-white, or slightly coloured. It is made up of tiny, thin, pseudohexagonal, flexible sheets of triclinic crystal with a diameter of 0.2–12 μm. It has a density of 2.1–2.6 g/cm$^3$. The cation exchange capacity of kaolinite is considerably less than that of montmorillonite, in the order of 2–10 meq/100 g, depending on the particle size, but the rate of the exchange reaction is rapid, almost instantaneous (Grim, 1968).

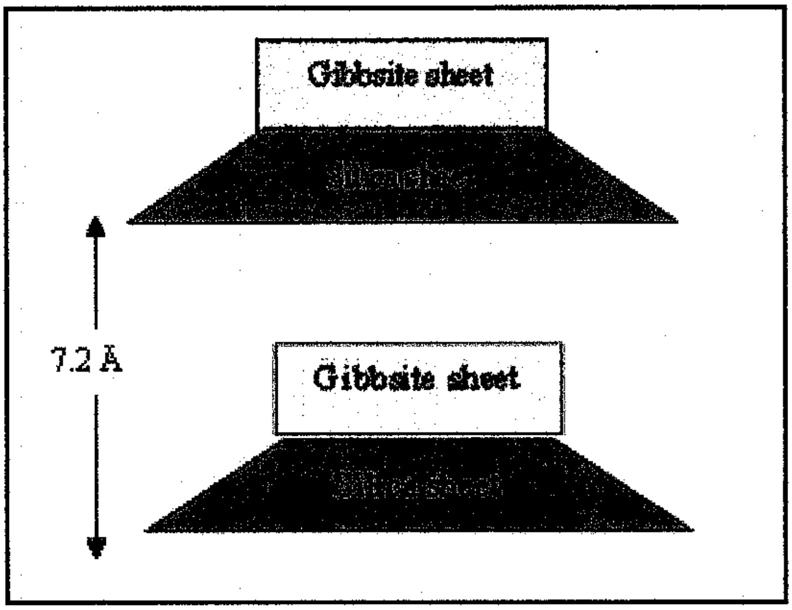


Figure 2.1 : Diagram structures of kaolinite

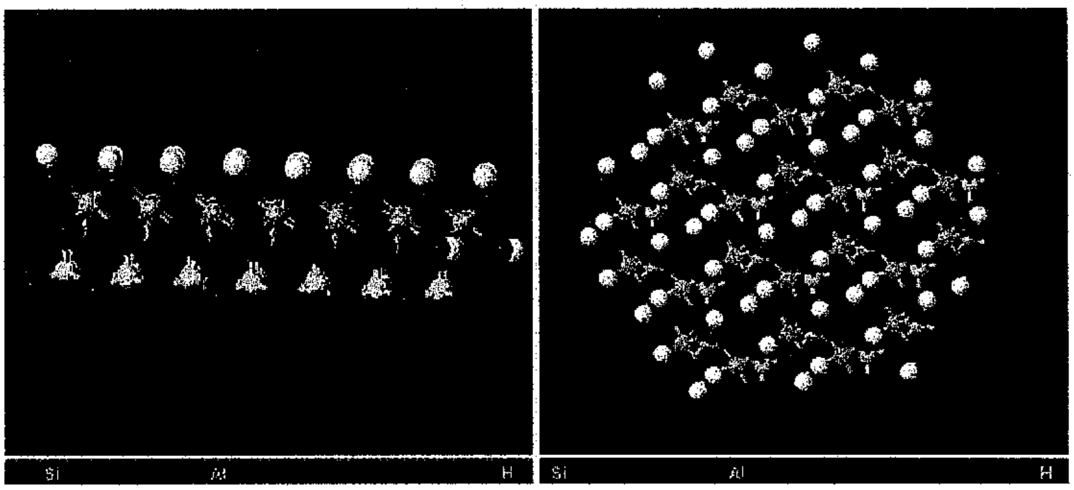


Figure 2.2 : Crystal structure of kaolin (SMI Analytical Laboratory service)

Figure 2.2 shows a model of a Kaolin Crystal viewed from different angles, showing its structure. Kaolin minerals form plate like structures which are visible by Electron Microscopy.

## 2.3 Index Properties of Kaolin Soil

The index properties of kaolin cover the Atterberg limit (plastic and liquid limit of soil), particle size and specific gravity.

### *2.3.1 Atterberg Limits*

Atterberg limit provide an indirect measure of the relationship between composition and properties of fine grained soil. Atterberg limits have an extensive use in geotechnical engineering for identification, description and classification of soils as a basis for preliminary assessment of their mechanical properties. This was indicated by Terzaghi (1925) when he noted, "the results of simplified soil tests (Atterberg limits) depend precisely on the same physical factors which determine the resistance and the permeability of soils (shape of particles, effective size, uniformity) only in a far more complex manner." Casagrande developed a standard device for determination of the liquid limit and noted that the nonclay minerals quartz and feldspar did not develop plastic mixtures with water, even when ground to sizes less than 2μm further studies led to the formation of a soil classification system based on the Atterberg limits for identification of cohesive soils (Casagrande, 1948). This system was adopted, with minor modification, as a part of the Unified Classification System. Although both the liquid and plastic limits are easily determined quantities and their qualitative correlations with soil composition and physical properties have been quite well established, fundamental interpretations of the limits and quantitative relationships between their values and compositional factors are more complex.

#### *2.3.1.1 Liquid limit*

Liquid limit test is analogous to a dynamic shear test. Casagrande (1932) realize that the liquid limit corresponds approximately to a water content at which a soil has shear strength of about 2.5 kPa. Later studies have indicated that the liquid limit for all fine-grained soil corresponds to shearing resistance of about 1.7-2.0 kPa and a pore water suction of about 6 kPa (Whyte, 1982).The approximately equal strengths, pore water suctions and hydraulic conductivities for all clays at the liquid limit can be explained by the concepts that:

i. The aggregates are the basic units that interact to develop the strength;i.e., the aggregates act somewhat like single particles
ii. The average adsorbed water layer thickness about the same for all particle surfaces
iii. The average size of intercluster pores is the same for all clays

Concept (ii) provides the key to why the different clays have different values of liquid limit. All clays have essentially the same surface structures; i.e., a layer of oxygen coordinated octahedrally with aluminium or magnesium. The forces of interaction between these surfaces and absorbed water should be the same for the different clay minerals. Thus the amount of water absorbed per unit area of surfaces that corresponds to a pore water suction of 6 kPa should be about the same. This means the greater the specific surface, the greater the total amount of water required to satisfy the conditions at the liquid limit. As for kaolin soil the typical liquid limit range or moisture content is between 35 to 100% (Grim, 1982).

### *2.3.1.2 Plastic limit*

The plastic limit has been interpreted as the water content below which the physical properties of the water no longer correspond to those of free water (Terzaghi, 1925) and as the lowest water content at which the cohesion between particles or groups of particles is sufficiently low to allow movement, but sufficiently high to allow particles to maintain the moulded positions (Yong and Warkentin, 1966). Whatever the structural status of the water and the nature of the interparticle forces, the plastic limit is the lower boundary range of water contents within which the soils exhibits plastic behavior; that is above the plastic limit of soil can be deformed without volume change or cracking and will retain its deformed shape. As for kaolin the typical plastic limit range is between 20 to 40% (Grim, 1982).

### *2.3.2 Particle Size and Shape*

Clayey soils contain a considerably amount of finely dispersed clayey particles less than 0.002mm in size (Das, 2002). These particles impart a number of specific properties to clayey soils, of which cohesiveness is the most important. Table 2.1 shows that, most countries included Malaysia had particle sizes less than 2μm. Particles of kaolinite are relatively large, thick and stiff. Figure 2.3 shows the thickness and shape of Tapah kaolin observe from scanning electron microscopy (SEM).

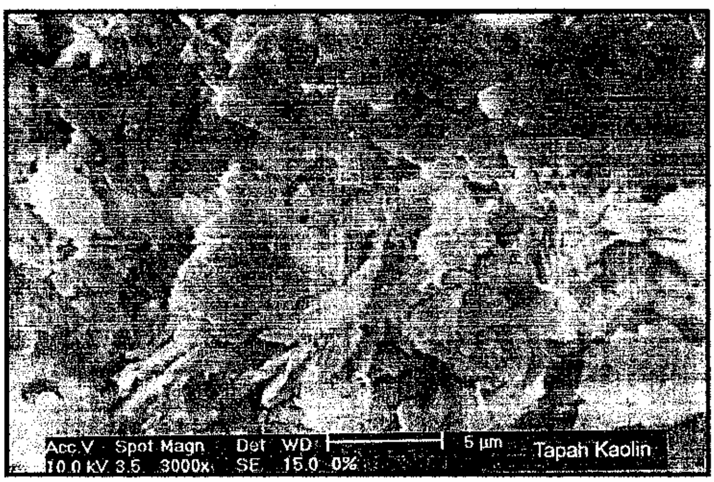


Figure 2.3 : SEM of Tapah kaolin (5μm)

### *2.3.3 Specific Gravity*

Specific gravity is defined as the ratio of the unit weight of a given material to the unit weight of water. It can be determined accurately in the laboratory. Most of the common minerals specific gravity falls within a range of 2.6 to 2.9, where the specific gravity for kaolinite is 2.6 (Das, 2002). The specific gravity of solids of light colored sand, which is mostly made of quartz, may be estimated to be about 2.65; for clayey and silty soils, it may vary from 2.6 to 2.9 (Grim, 1982).

## 2.4 Shear Strength of Soil

The shear strength of a soil mass is the internal resistance per unit area that the soil mass can offer to resist failure and sliding along any plane inside it. The soil with the higher percentage of iilite or kaolinite clay has greater shear strength than a soil with a significant amount of montmorillonite clay (Das, 2002). It needs to be well recognized that the presence of clay minerals in a soil aggregate has a great influence on the engineering properties of the soil as whole. When moisture is present, the engineering behavior of soil will change greatly as the percentage of clay mineral content increase. For all practical purposes, when the clay content is about 50% or more, the sand and silt particles float in a clay matrix and the clay mineral primarily dictate the engineering properties of soil (Grim, 1982).

## 2.5 Classification of Soil

Soil can be classified as either granular or cohesive. The classification systems take into account such factors as particle sizes, grain-size distribution, and the effect of moisture on the soil. Because of the wide variations among soils that might be encountered on a specific job site, soil testing is wise and usually mandated. There are three (3) standards usually used to classified soils which are BSCS, AASHTO and USCS that have different criteria to classified soil. However these three standards will lead to the same result.

### *2.5.1 The British Soil Classification System for Engineering Purposes (BSCS)*

Any soil can be placed in one of a number of soil groups on the basis of the grading of the constituent particles, and the plasticity of that fraction of the material passing a 425μm BS sieve. This may be done on the basis of estimation (field) or from laboratory test. For more detailed classification, the groups may be divided into sub-groups on the basis of laboratory test. The classification is carried out on material nominally finer than 60 mm, coarser material consisting of boulders (60 mm to 200 mm) and cobbles (over 200 mm).

### *2.5.2 AASHTO Classification System*

i. Grain size
   - *Gravel*: fraction passing the 75 mm (3-in.) sieve and retained on the No. 10 (2 mm) U.S sieve
   - *Sand*: fraction passing the No. 10 (2mm) U.S sieve and retained on the No. 200 (0.075 mm) U.S sieve
   - *Silt and clay*: fraction passing the No. 200 U.S sieve

ii. Plasticity

iii. If cobbles and boulders (size larger than 75mm) are encountered, they are excluded from the portion of the soil sample from which classification is made. However, the percentage of such material is recorded.

### *2.5.3 Unified Soil Classification System (USCS)*

The soils are divided into two categories:

i. *Coarse-grained soils* that are gravelly and sandy in nature with less than 50% passing through the No. 200 sieve (that is, $F_{200}<50$). The group symbols start with prefixes of either G or S. G stands for gravel or gravelly soil, and S for sand and sandy soil.

ii. *Fine-grained soils* with 50% or more passing through the No. 200 sieve (that is, $F_{200}>50$). The group symbols start with prefixes of M, which stands for inorganic silt, C for inorganic clay and O for organic clays. The symbol Pt is used for peat, muck and other highly organic soils.

## 2.6 Formation of Kaolin Soil

Kaolin formed in three ways which are; transformation of rocks due to climatic factors, transformation of rock due to hydrothermal effects and formation due to both effect. The type of clay mineral formed during the decay of rocks containing aluminium silicates is influenced by the climate, the aluminium/silicon ratio, and pH. Conditions conducive for kaolinite formation are strong dissolution of $Ca^{2+}$, $Mg^{2+}$, and $K^+$ ions and the presence of $H^+$ ions (pH 4–5) (Parker, 1988).

Kaolin and the clay mineral kaolinite are natural components of the soil and occur widely in ambient air as floating dust. Kaolinite is formed mainly by decomposition of feldspars (potassium feldspars), granite, and aluminium silicates. It is also not uncommon to find kaolin deposited together with other minerals (illite, bentonite). The process of kaolin formation is called kaolinization (Grim, 1968). Due to weathering process, clay is the residue of granite after it is weathered to sandy soils.

Hence it gives greater shear strength to the soil and support steeper cut faces because of the cohesive nature of the clay. As dry clay absorbs water, its shear strength decreases because water films separate the clay particles and reduce its cohesive strength. However kaolinite provides stability to the soil even saturated. Because of the chemical weathering resistance and non-swelling nature they are the clay of choice in ceramics and porcelain products.

### *2.6.1 Formation of Tapah Kaolin*

The kaolin found in Tapah-Bidor is probably derived from hydrothermal alteration of the metasediments and granite due to the intrusion of a granitic stock near tapah, see appendix A(Zainol Abidin, 1991).

Figure 2.4 show the investigated area in Tapah-Bidor map and Figure 2.5 is the enlargement of the kaolin mines.

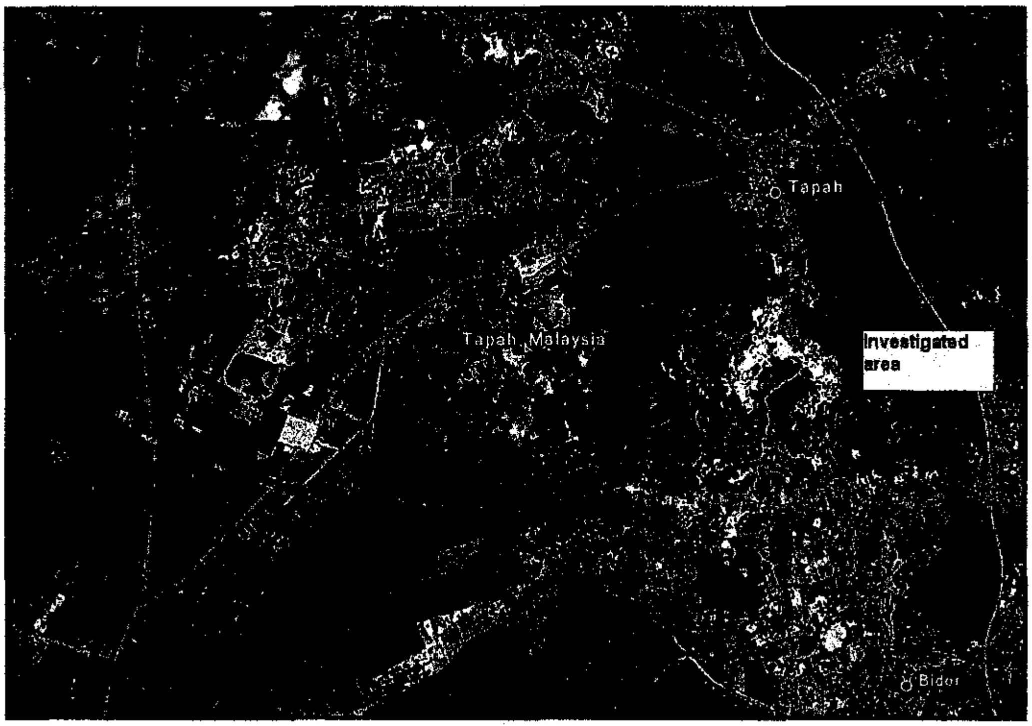


Figure 2.4 : Tapah-Bidor map (Google earth 2007)

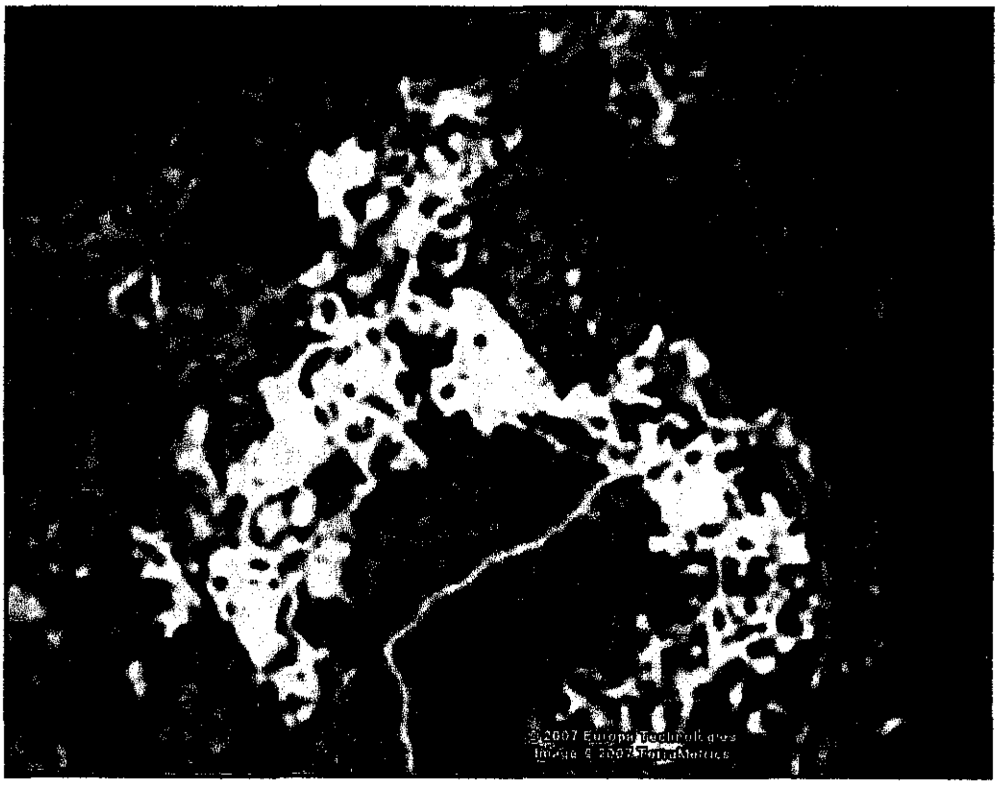

Figure 2.5 : Enlargement of Investigated area (Google Earth 2007)

Table 2.1 : Index properties of kaolin from different country of the world

| Author | Emhammed A. Basha, Roslan hashim, Aguss. Muntohar | Wiriyakitnateekul Wanpen, Hart Robert, Gilkes Robert | | Tsolis-katagas P., Papoulis D. | | G. Vlahos, C.M. Martin, M. J. cassidy | James K. Mitchell | Dan taka, Yacov Berry |
|---|---|---|---|---|---|---|---|---|
| Year | | | | | | | Cornell University (1951), Samuels (1950), Lambe and Martin (1955), warkentin (1961), Grim (1962) | |
| Reference | Effect of the cement-Rice husk Ash on the Plasticity and Compaction of soil | Properties of soil Kaolins from Thailand | Chapter 6:Geotechnical and mineralogical characterization (white spess china clay) | Physical and Chemical properties of Some Greek kaolins of Differerent environment of Origins | | Experimental Investigation of a Model Jack Up Unit in Clay | Fundamentals of soil Behavior | Measurement of Soil stiffness Using Bender Element Test in Triaxial Apparatus |
| Country | Malaysia | Thailand | United Kingdom | Greece | | Western Australia | Unknown location | Israel |
| | | | | Leucogia | Kos | | | |
| Particle size | < 2µm 26-35%<br><10µm 85-98% | 0.02-0.75µm | | <2µm 21% | < 2µm 25% | 0.06-0.12µm | < 2µm | |
| Liquid limit | 36.77% | 50% | 50% | 28.70 | 35.22 | 61% | 30 -110% | 43% |
| Plastic limit | 22.95% | 28.81% | 27% | 11.51 | 19.09 | 27% | 25 – 40% | 22% |
| Shrinkage limit | 6.71% | 25.44% | | | | | 25 – 29% | |
| Plasticity index | 13.82% | 20.94% | 23% | 17.19 | 15.08 | 34% | 37.5% | 21% |
| Moisture content | 26% | | | | | | | |
| Size distribution | Sand 46%<br>Silt 44%<br>Clay 10% | Silt and organic | Clay 78%<br>Silt 22% | | | | Clay 10%<br>Sand 90%<br>Silt | Sand 1.6%<br>Silt 33%<br>Clay 65.4% |

# CHAPTER 3
# METHODOLOGY

## 3.1 Project identification

In this project, the methodologies are as below:

**Selection of project topic**

**Preliminary research work**

Literature review

**Field work**

Determine site location

Sampling

**Laboratory work**

Sieve analysis

Hydrometer analysis

Plastic limit

Liquid limit

Particle density

Vane shear test

**Result and calculation analysis**

**Final report draft**

**Oral presentation**

**Submission of final report**

## 3.2 Collecting Samples

Soil samples were collected randomly in four different areas at Associated kaolin Industries mines, refer to Appendix A. Four samples of disturbed and undisturbed kaolin soil were collected at 3m depth by using hand auger and with the help of backhoe.

Figure 3.1 : Collecting undisturbed samples by using hand auger

## 3.3 Laboratory Tests

The properties determined were particle size distribution, Atterberg Limits (Plastic and liquid limit), particle density and shear strength of soil.

### *3.3.1 Determination of Particle Size Distribution*

#### *3.3.1.1 Dry sieving method (sieve analysis)*

After air drying, the kaolinite sample is weighted first. Since the sample is fine grained soil, sieves sizes 2mm, 1.18 mm, 600 μm, 425 μm, 300 μm, 212 μm, 150 μm, 63 μm, lid and receiver was used. The sample was placed on the top sieve and the mechanical sieve will shake it for 5 minutes. The amount retained on each sieves then is weighted.

#### *3.3.1.2 Wet sieving method (hydrometer analysis)*

The silt/clay fraction is determined through the use of a hydrometer, while classes of sand are separated with sieves. The hydrometer method is a type of mechanical analysis that is based on the specific gravity of a sediment/fluid mixture.

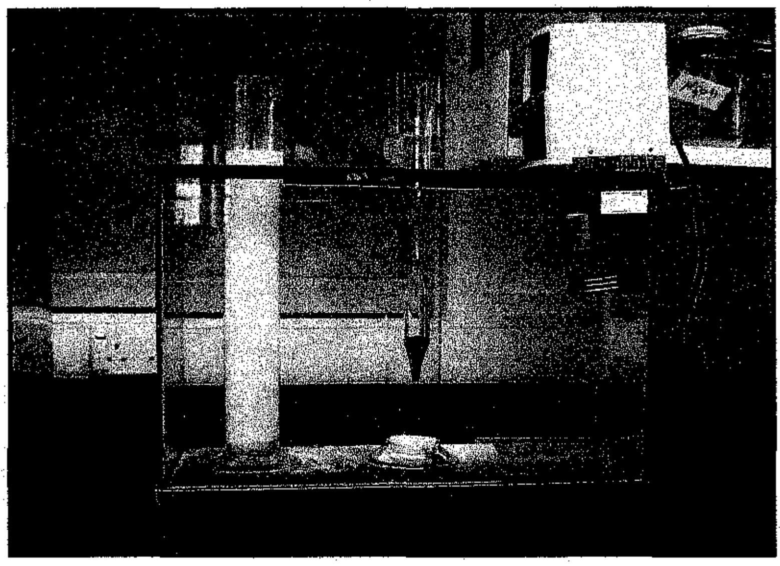

Figure 3.2 : Hydrometer analysis

### *3.3.2 Determination of the Liquid Limit*

#### *3.3.2.1 Cone Penetrometer method*

This method covers the determination of the liquid limit of a sample soil in its natural state or of a sample from which material retained on a 425 μm test sieve has been removed. 300 g of soil sample which passes the 425 μm test sieve is placed on the glass plate. Water is added and mixed for 10 minutes. A portion of the paste is placed in the brass cup and the tip of the cone is lowered to touches the surface of the soil. The release button is pressed for 5 s and the controller will locked the cone shaft after 5 s. The stem of the dial gauge is lowered to get contact with the cone shaft and the reading of the dial gauge is recorded.

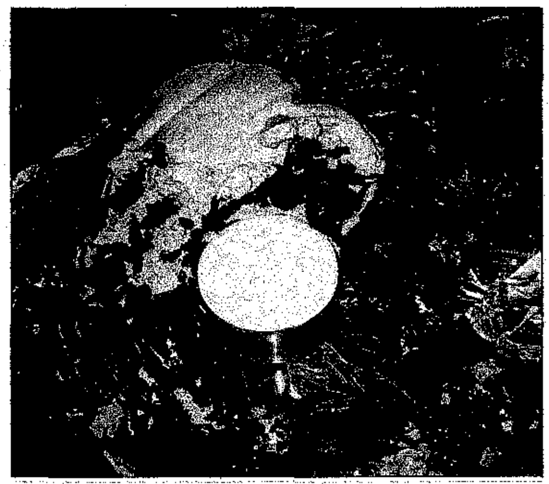

Figure 3.3 : Kaolin sample in brass cup

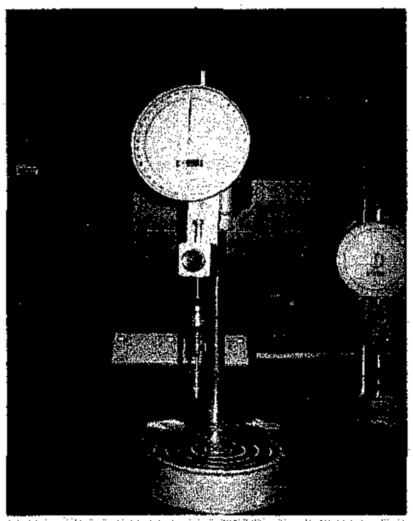

Figure 3.4 : Cone Penetrometer

### *3.3.3 Determination of the Plastic Limit*

20 g of soil sample which passes the 425 μm test sieve is placed on the glass plate. Water is added and mixed thoroughly. The moist soil is mould into the ball with fingers to equalize the distribution of moisture content. Half of the ball is then rolled on a ground glass plate into ellipsoidal shaped and rolled until it breaks into several small pieces. The samples then is put into the container and placed in the oven for 24 hours.

### *3.3.4 Determination of Particle Density*

The value of particle density of soil is determined by using pyknometer method. Small pyknometer method is used for soils consisting of clay silts and sand sized particles.

### *3.3.5 Determination of Vane Shear Test*

This test is used to measure the shear strength of a sample of soft to cohesive soils is useful for soils of low shear strength for which triaxial or unconfined tests cannot be performed.

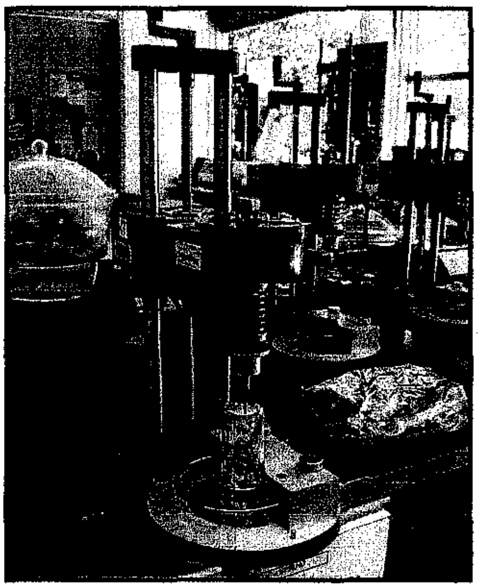

Figure 3.5 : Vane shear test

# CHAPTER 4
# RESULTS AND DISCUSSIONS

## 4.1 Results

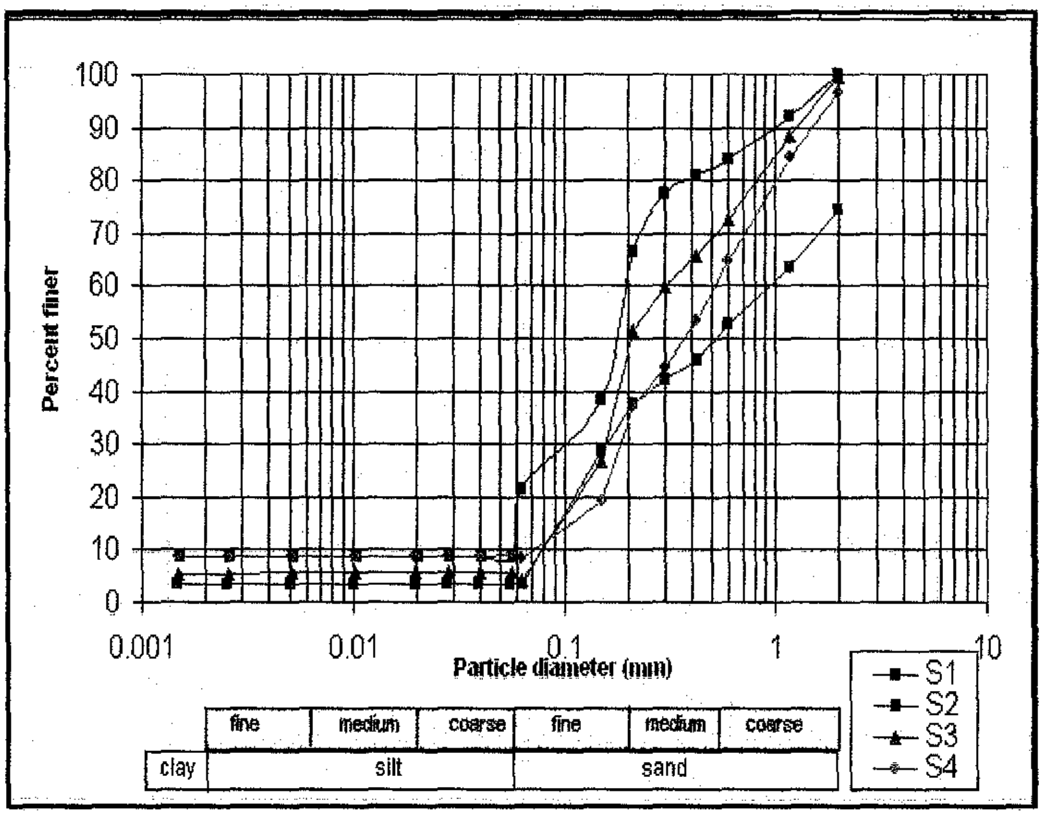


Figure 4.1 : Particle size distribution curve

Figure 4.1 shows particle size distribution of S1, S2, S3 and S4 from sieve analysis and hydrometer analysis. For calculation refer to Appendix B. For sieve analysis the particle size distribution is between 2mm to 0.063mm while hydrometer analysis gives readings from 0.063mm to 0.001mm.

Table 4.1 : Particle size distribution of S1, S2, S3 and S4

| **Size(mm)** | **Type** | **Percent finer (%)** | | | |
|---|---|---|---|---|---|
| | | **S1** | **S2** | **S3** | **S4** |
| 2.000 | Sand | 85.60 | 71.41 | 93.93 | 87.88 |
| 0.060 | Silt | 5.80 | 0.06 | 0.10 | 0.19 |
| 0.002 | Clay | 8.60 | 3.39 | 5.43 | 8.65 |

The particle size distribution curve in Figure 4.1 illustrates combination of sieve analysis and hydrometer analysis. The entire samples approximately show the same results where less than 35% of the soil is finer than 0.06mm. S1 sample demonstrate that about 86% of the soil contains sand and only 8.6% of it contains clay. S2 sample shows that 70% of the soil contains sand and the remaining of it is silt and clay. The percentage finer of S2 sample is not totally 100% because 26% of the soil not passing 2mm due to the soil contains clay that absorb water and cause the particles to bond with each other and form large diameter of soil. Whereas S3 and S4 gives about the same results where samples predominantly contains more sand than clay. The presence of silt and clay is too low in this area. About 5% to 9% of the soil sample contains kaolinite minerals.

Table 4.2 : Test data for Liquid limit, Plastic limit and Plasticity index

| | **S1** | **S2** | **S3** | **S4** |
|---|---|---|---|---|
| **Liquid limit** | 32.20 | 38.00 | 36.50 | 38.00 |
| **Plastic limit** | 26.87 | 27.81 | 28.02 | 29.15 |
| **Plasticity index** | 5.33 | 10.19 | 8.48 | 8.85 |

Table 4.2 shows the results of liquid limit and plastic limit test. For the calculation and graph refer to Appendix B. The liquid limit is empirically established moisture content at which a soil passes from the liquid state to the plastic state. It provides a means of classifying a soil, especially when the plastic limit is known. Three or four

test at varying moisture contents of soil is conducted and a graph off the moisture content corresponding to a cone penetration of 20mm is plot. From the linear graph (Refer to Appendix B), when the penetration is 20 mm, 32% to 38% is the moisture content for all four soils.

The plastic limit is the empirically established moisture content at which a soil becomes too dry to be plastic. It is used together with the liquid limit to determine the plasticity index which when plotted against the liquid limit on the plasticity chart provides a means of classifying cohesive soils. Four tests were conducted on four different soils and the average value for the plastic limit is between 26% to 29%. These values are in the range of typical plastic limit for kaolinite which is 20 to 40%.

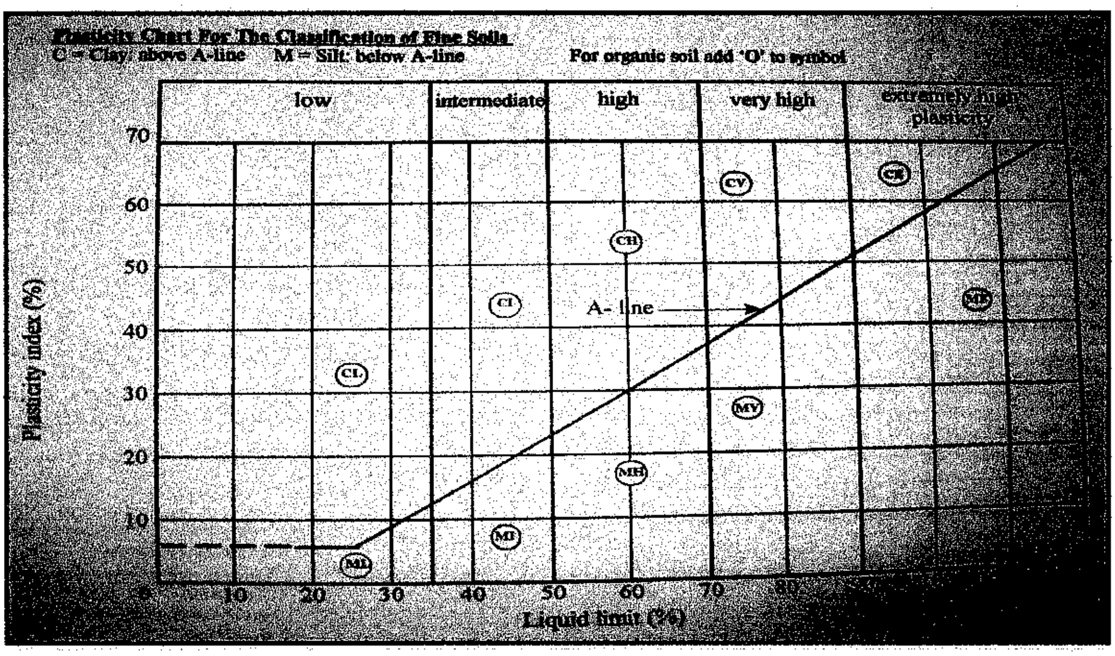


Figure 4.2 : Plasticity chart

Figure 4.2 show the plasticity chart for the classification of fine soils and the finer part of coarse soils. It is used to determine the plasticity of silt and clay. The results obtained from plastic limit test and liquid limit test are then used to get the plasticity index. From the plasticity chart, it is found that all four samples lay in the range of intermediate in plasticity and below A-line which is MI.

Table 4.3 : Result from Particle Density test

| | S1 | S2 | S3 | S4 |
|---|---|---|---|---|
| **Particle density, $Mg/m^3$** | 2.63 | 2.60 | 2.63 | 2.60 |

Table 4.3 show the result obtained from particle density experiment of the four samples. Refer to Appendix B for the calculation. The specific gravity or particle density of the soil particles should lie within the range of 2.65 to 2.85. From table 4.3, the value obtain from experiment is between 2.60 to 2.63, nearer to the typical kaolinite range which is 2.6.

Table 4.4 : Result of Vane shear test

| | S1 | S2 | S3 | S4 |
|---|---|---|---|---|
| **Vane shear strength, kpa** | 19.35 | 14.70 | 15.62 | 13.98 |
| **Mosture content (%)** | 32.30 | 39.90 | 38.40 | 38.90 |

Table 4.4 shows the result from laboratory vane shear test. From the calculation obtained, the vane shear strength of Tapah kaolin is between 13.98 kpa to 19.35 kpa (Refer to Appendix B). The values fall in the range where the undrained shear strength is between 12.5 to 25 kpa. Since this soil is soft it can easily moulded with fingers and indented considerably with thumb. The moisture content is high and approximately nearer to the liquid limit of the soil.

Table 4.5 : Comparison Properties of Tapah Kaolin

| **Data Source** | K.A. Kassim, R. Hamir, K.C. Kok | Geological Survey of Malaysia Zainol Abidin bin Sulaiman | | | | Results from the experiments | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Area** | | 6501 | 6502 | 6503 | 6504 | S1 | S2 | S3 | S4 |
| **Soil** | Tapah kaolin | | | | | | | | |
| **1.Physical properties** | | | | | | | | | |
| Particle density | 2.64 | | | | | 2.63 | 2.60 | 2.63 | 2.60 |
| Liquid limit (%) | 93 | | | | | 32.0 | 38.5 | 37.0 | 38.0 |
| Plastic limit (%) | 43 | | | | | 26.9 | 27.8 | 28.0 | 29.0 |
| Plasticity index (%) | 50 | | | | | 5.0 | 10.7 | 9.0 | 9.0 |
| **2.Particle size distribution** | | | | | | | | | |
| Sand | 6.0 | | | | | 85.6 | 70.41 | 93.93 | 87.88 |
| Silt | 57.6 | | | | | 5.8 | 0.06 | 0.1 | 0.19 |
| Clay | 36.4 | 25.9 | 5 | 6.7 | - | 8.6 | 3.390 | 5.43 | 8.65 |
| Clay Activity | 1.37 | | | | | 0.58 | 3.24 | 1.66 | 1.04 |
| **3.Soil classification** | | | | | | | | | |
| BSCS | CE | Sandy clay | | | | SM | SW | SC | SC |
| USCS | MH | | | | | SM | SW | SP-SC | SW-SC |
| AASHTO | A-7-5 | | | | | A-2-4 | A-2-6 | A-2-4 | A-2-4 |

## 4.2 Discussions

The three different standards in Table 4.5 (BSCS, USCS, AASHTO), classified that S1 area is silty sand, S2 is well graded sand with few existence of clay in it whereas S3 and S4 are poorly and well graded sand with clay. Throughout the results obtained from four different samples, the types of soil in this area are prone to form sand rather than clay. This is due to hydrothermal alteration of the metasediments and granite because the samples collected located in granitoids area, refer to Appendix A. As from physical observation in this area, the soil is white or greyish white because the presence of quartz mineral in soil.

From the comparison made between all the properties obtained through experiments and other data sources of Tapah kaolin it is found that soil in Tapah area consist of sandy clay (intermediate plasticity). Only certain location (unknown location investigated by K. A. Kassim) contains clay of extremely high plasticity. The Tapah kaolin soil is predominantly sand and only a few are found to be silt and clay. The data obtained from this study can be used to support data at area 6504 since the area covered by the previous researchers is too large and they only investigated the small parts of this zone (Refer to Appendix A). As for area 6504, no grain size analysis was conducted by the researcher on kaolin potential due to very high sand content.

Climate does really affect the particle size distribution of a horizon. Heat, rain, wind and sunshine and other environmental forces breakdown the parent material, affect the rate of soil forming processes and resulting soil properties. In addition the area studied is in granitoids area cause the granite to residue to kaolin after it is weather to sandy soils. The project already show that the climate and geology of Malaysia form kaolin soil which is predominantly sand nevertheless with some existence of kaolinite minerals in it. Table 2.1 shows that Kaolin in certain area like Britain and Israel has kaoline which is prone to clay as compared to other area.

# CHAPTER 5
# CONCLUSIONS

## 5.1 Conclusions

As conclusions, the results of the study show that all four samples of Tapah kaolin soil contain about 90% of sand and the remaining are silt and clay. As the author classified the soil by using three different standards, it can be classified that S1 area is silty sand, S2 is well graded sand with few existence of clay in it whereas S3 and S4 are poorly and well graded sand with clay. Types of soil in this mine are prone to form sand rather than clay. This is due to hydrothermal alteration of the metasediments and granite because the samples collected located in granitoids area refer to Appendix A. As from physical observation in this area, the soil is white or greyish white because the presence of quartz mineral in soil. The four samples of kaolin soil are low in shear strength where the undrained shear strength is between 12.5 to 25 kpa. This is due to the low cohesiveness of soil since the soil contains more sand.

# CHAPTER 6
# RECOMMENDATIONS

## 6.1 Recommendations

Based on the intensive study being taken by the author, it is found that the kaolin properties in the studied area gives different fact about kaolin soil as compared to the properties of kaolin from other country. There are a few areas that need further investigation by other parties which study can give better results and some modification to the soil. The author cannot perform better results or data since lack of samples due to time constraint and difficult to get the samples. In the future, more samples from different distinguished and wide coverage area should be used to give complete data for this study. Undisturbed samples should be collected in variety of depth, for instance 1.5m, 3m, 4.5 m and etcetera. More tests should be carried out to determine the exact properties of the soil by performing Permeability test, Hydraulic conductivity, Oedometer test or chemical test to check the mineral of the kaolin soil.

# REFERENCES


AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (1977). Geometric design for resurfacing, restoration and rehabilitation of highway and streets. AASHTO Washington D.C., U.S.A.

BASSAM, Z.M , Dead Sea Water As A Soil Improvement Agent, Mu'tah University, Jordan.

BRITISH STANDARD INSTITUTION, 1990, Methods of test for soils for civil engineering purposes, BS 1377 – 1990: Part 2, and 4.

BRITISH STANDARD INSTITUTION, 1981, Code of practice for Site investigations, BS 5930.

DAS, BRAJA M., " Principles of Geotechnical Engineering", Fifth Edition Brook/Cole, 2002, p 311-358.

EMHAMMED, A.B, ROSLAN, H. AND AGUS, S.M. Effect of the Cement-Rice Husk Ash on the Plasticity and Compaction Soil.University of Malaya, Kuala Lumpur and Yogyakarta, Indonesia.

H.M. ABUEL-NAGA AND D.T. BERGADO (2005), Thermal Conductivity Fabric Anisotropy Of Saturated Clays.

K.A. KASSIM, R. HAMIR AND K.C. KOK (2005), Modification And Stabilization Of Malaysian Cohesive Soils With Lime.

LIU, JACK B. EVETT, "Soil Properties: Testing, Measurement and Evaluation", 5th ed.

MUHAMMAD SOFIAN, A. 2006, Determination of Optimum Concentration of Lime Slurry for Soil Stabilization, Master Thesis, Universiti Teknologi Malaysia.

S.R. MESCHYAN, "Experimental Rheology of Clayey soil".

TAN, C.C. 2005. Application of Soil Nailing as Protection and Reinforcement for Slope Stabilization. Degree Thesis, Universiti Teknologi Malaysia.

Z. ABIDIN, 1991, Investigation Into The Kaolin Occurences of Tapah-Bidor Area, Perak, Report No 6, Geological Survey of Malaysia.

# APPENDICES

**APPENDIX A: LOCATION MAP & PICTURES**

**APPENDIX B: DATA & CALCULATION**

# APPENDIX A

# LOCATION MAP & PICTURES

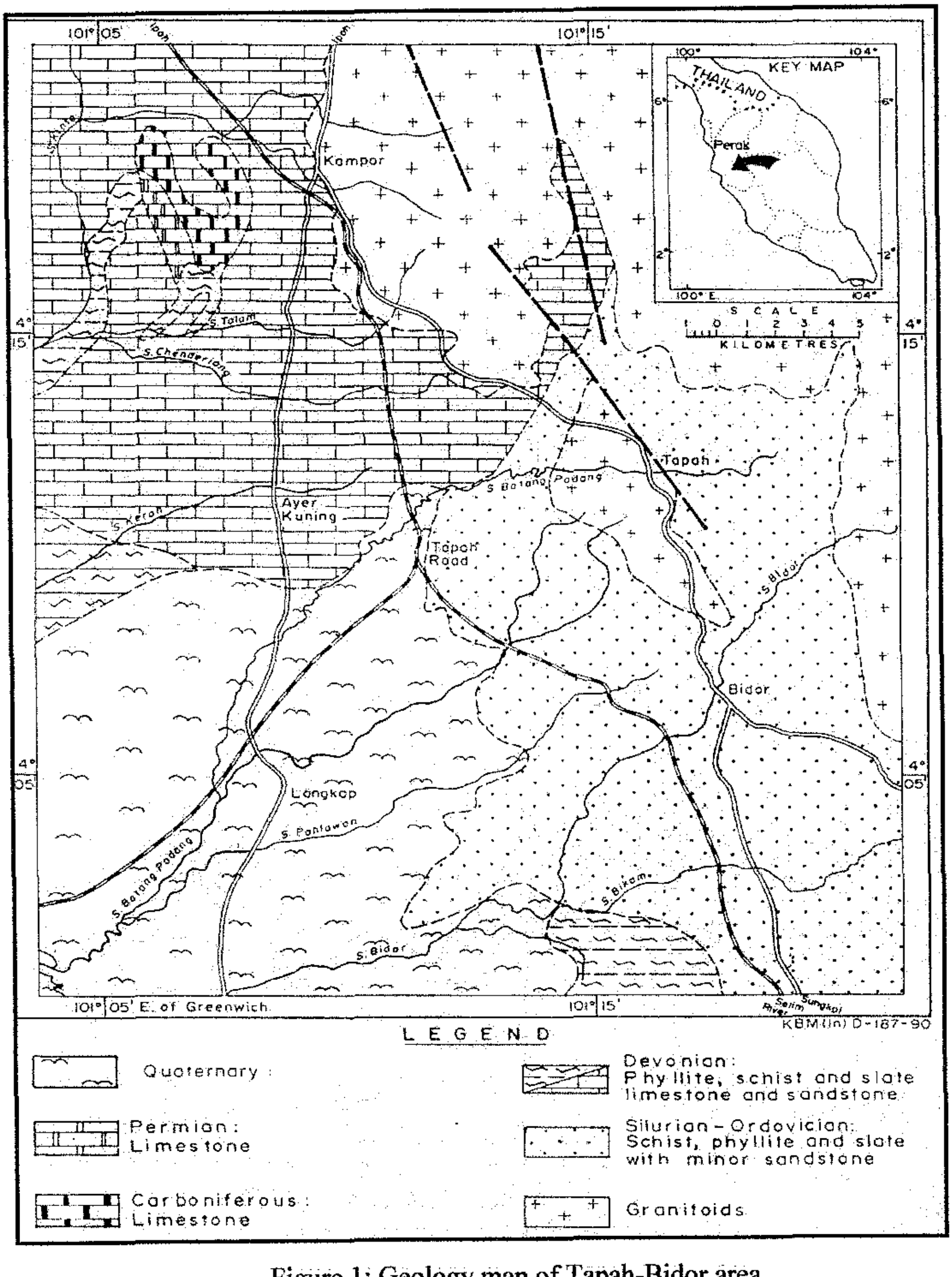


Figure 1: Geology map of Tapah-Bidor area

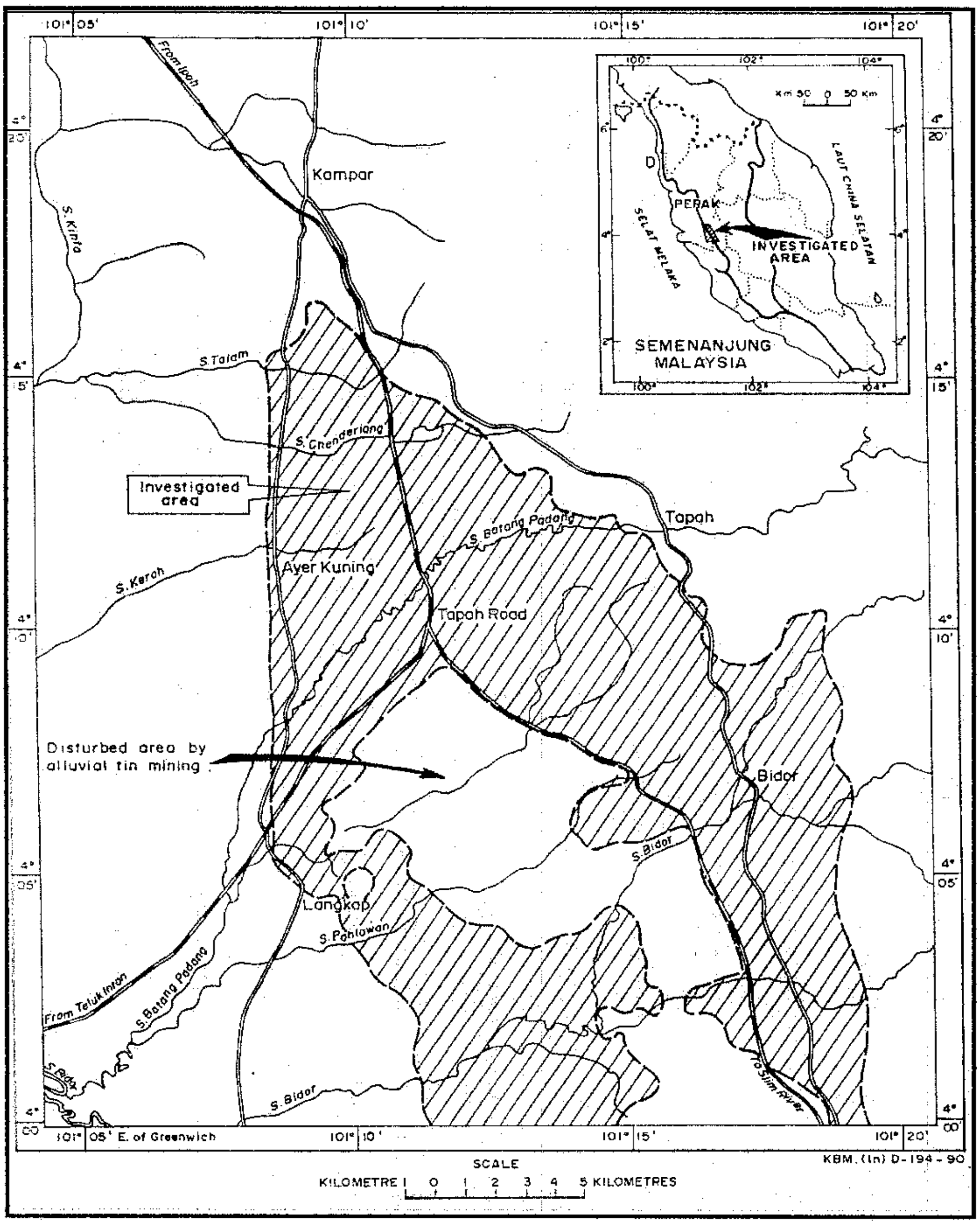


Figure 2: Area investigated for kaolin by Geological Survey of Malaysia

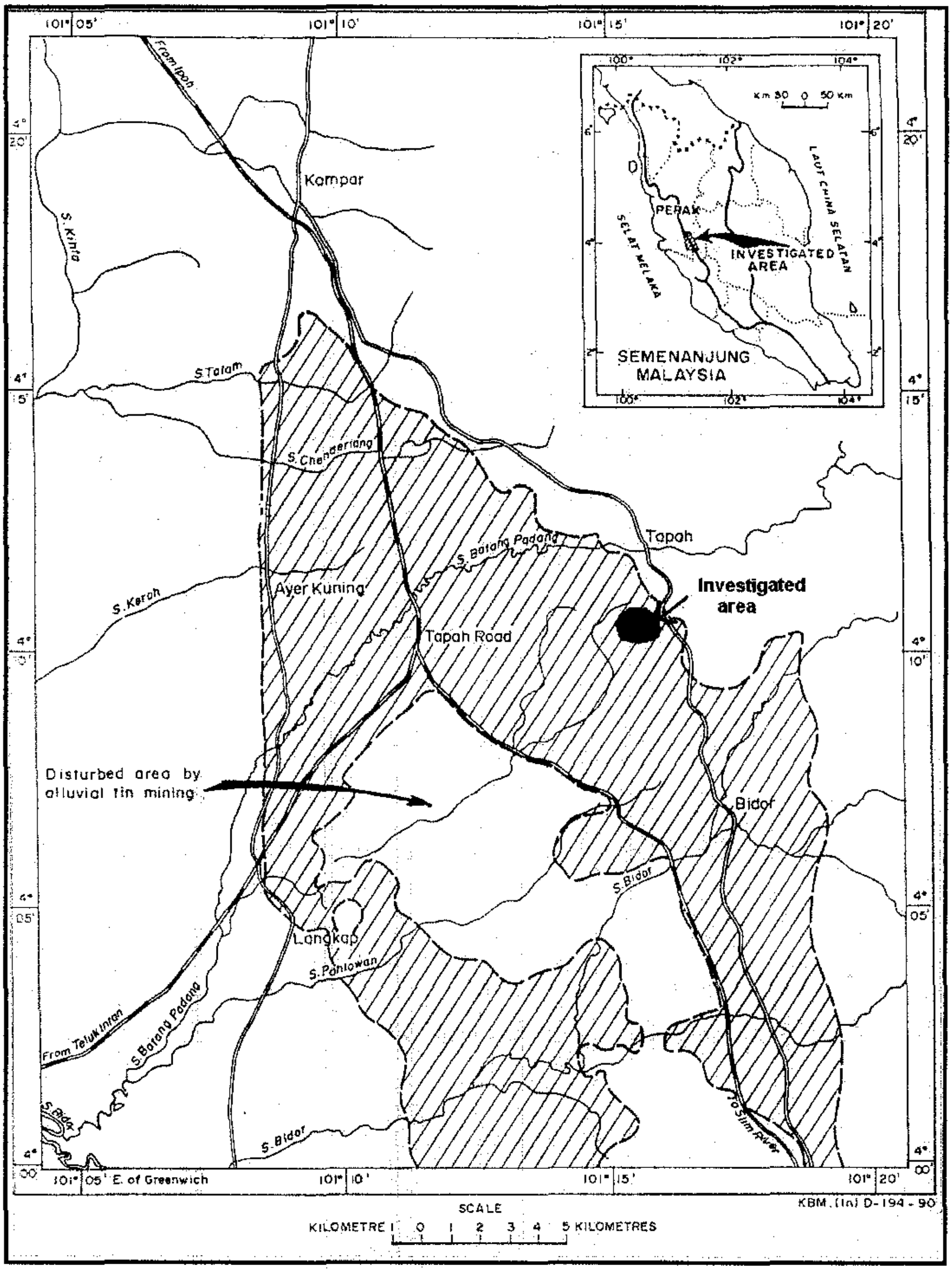


Figure 3: Area investigated by the author

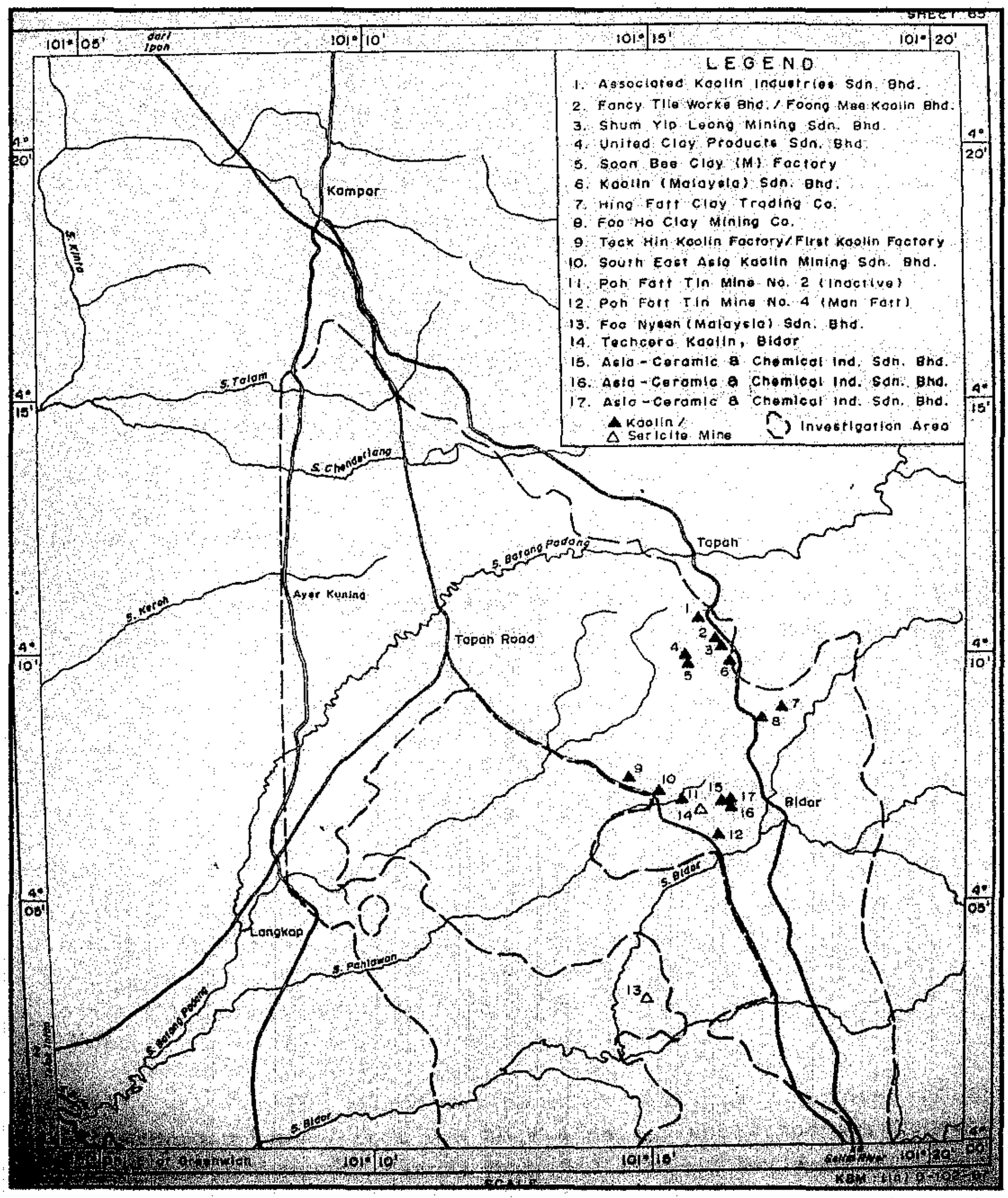


Figure 4: Location of kaolin mines in Tapah-Bidor, Peral (Geological survey of Malaysia)

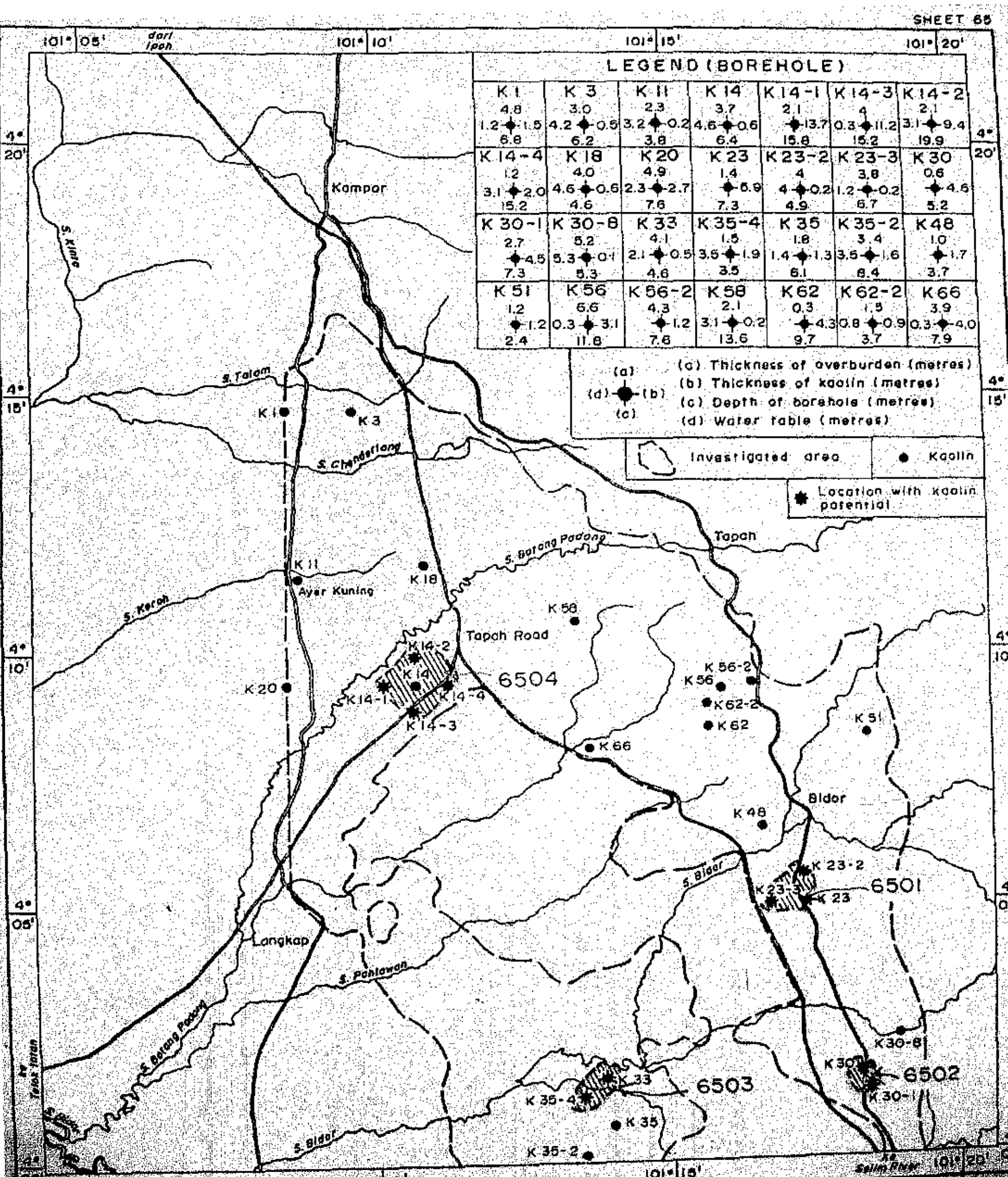


Figure 5: Kaolin occurrences in Tapah-Bidor, Perak (as investigated by Zainal Abidin Sulaiman, 1991)

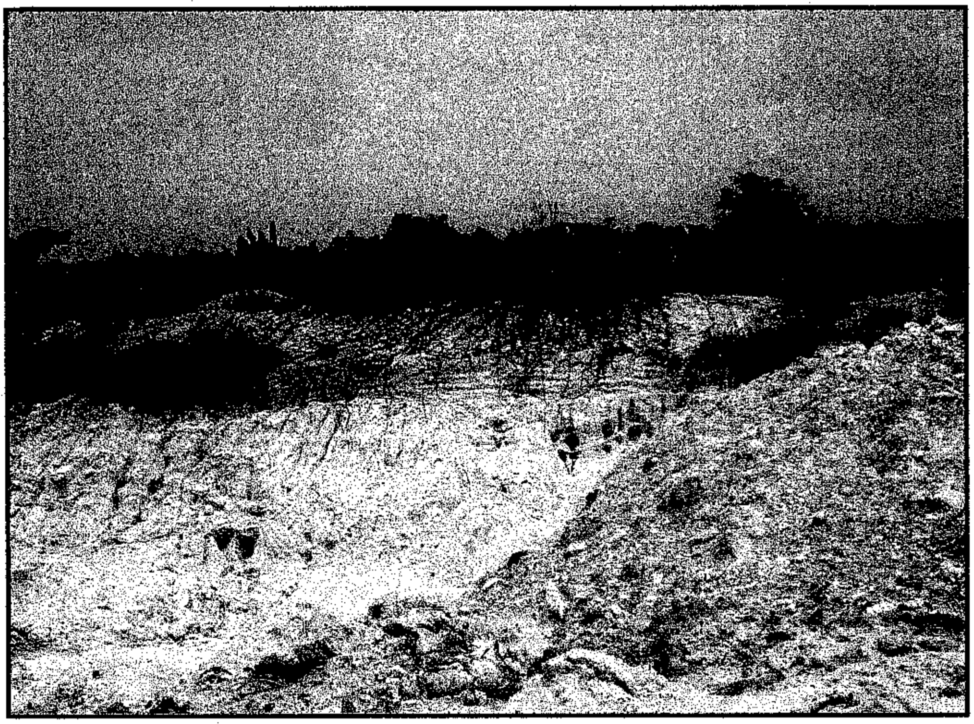

Figure 6: Area of S3

Figure 7: Area of S4

# APPENDIX B

# DATA AND CALCULATION

**Result of Sieve Analysis:**

Table 1:Particle Size distribution of S1

| Opening (mm) | Mass retained (g) | Cumulation mass retained (g) | Percent finer |
|---|---|---|---|
| 2 | 0 | 0 | 100 |
| 1.18 | 96.11 | 96.11 | 92.08 |
| 0.6 | 101 | 197.11 | 83.76 |
| 0.425 | 36.17 | 233.28 | 80.78 |
| 0.3 | 42.25 | 275.53 | 77.3 |
| 0.212 | 132.09 | 407.62 | 66.41 |
| 0.15 | 339.79 | 747.41 | 38.42 |
| 0.063 | 206.14 | 953.55 | 21.43 |
| 0 | 260.1 | 1213.65 | 0 |

Table 2:Particle size distribution of S2

| Opening (mm) | Mass retained (g) | Cumulation mass retained (g) | Percent finer |
|---|---|---|---|
| 2 | 206.22 | 206.22 | 74.41 |
| 1.18 | 87.74 | 293.96 | 63.52 |
| 0.6 | 87.23 | 381.19 | 52.70 |
| 0.425 | 55.03 | 436.22 | 45.87 |
| 0.3 | 31.72 | 467.94 | 41.94 |
| 0.212 | 33.62 | 501.56 | 37.76 |
| 0.15 | 74.03 | 575.59 | 28.58 |
| 0.063 | 202.26 | 777.85 | 3.48 |
| 0 | 28.05 | 805.9 | 0.00 |

Table 3: Particle size distribution of S3

| Opening (mm) | Mass retained (g) | Cumulation mass retained (g) | Percent finer |
|---|---|---|---|
| 2 | 5.46 | 5.46 | 99.46 |
| 1.18 | 110.9 | 116.36 | 88.49 |
| 0.6 | 160.65 | 277.01 | 72.60 |
| 0.425 | 70.24 | 347.25 | 65.65 |
| 0.3 | 60.8 | 408.05 | 59.63 |
| 0.212 | 80.51 | 488.56 | 51.67 |
| 0.15 | 250.86 | 739.42 | 26.85 |
| 0.063 | 230.91 | 970.33 | 4.01 |
| 0 | 40.56 | 1010.89 | 0.00 |

Table 4: Particle size distribution of S4

| Opening (mm) | Mass retained (g) | Cumulation mass retained (g) | Percent finer |
|---|---|---|---|
| 2 | 23.85 | 23.85 | 96.72 |
| 1.18 | 90.25 | 114.1 | 84.30 |
| 0.6 | 143.65 | 257.75 | 64.53 |
| 0.425 | 81.01 | 338.76 | 53.38 |
| 0.3 | 65.8 | 404.56 | 44.33 |
| 0.212 | 50.8 | 455.36 | 37.34 |
| 0.15 | 130.7 | 586.06 | 19.35 |
| 0.063 | 80.2 | 666.26 | 8.31 |
| 0 | 60.41 | 726.67 | 0.00 |

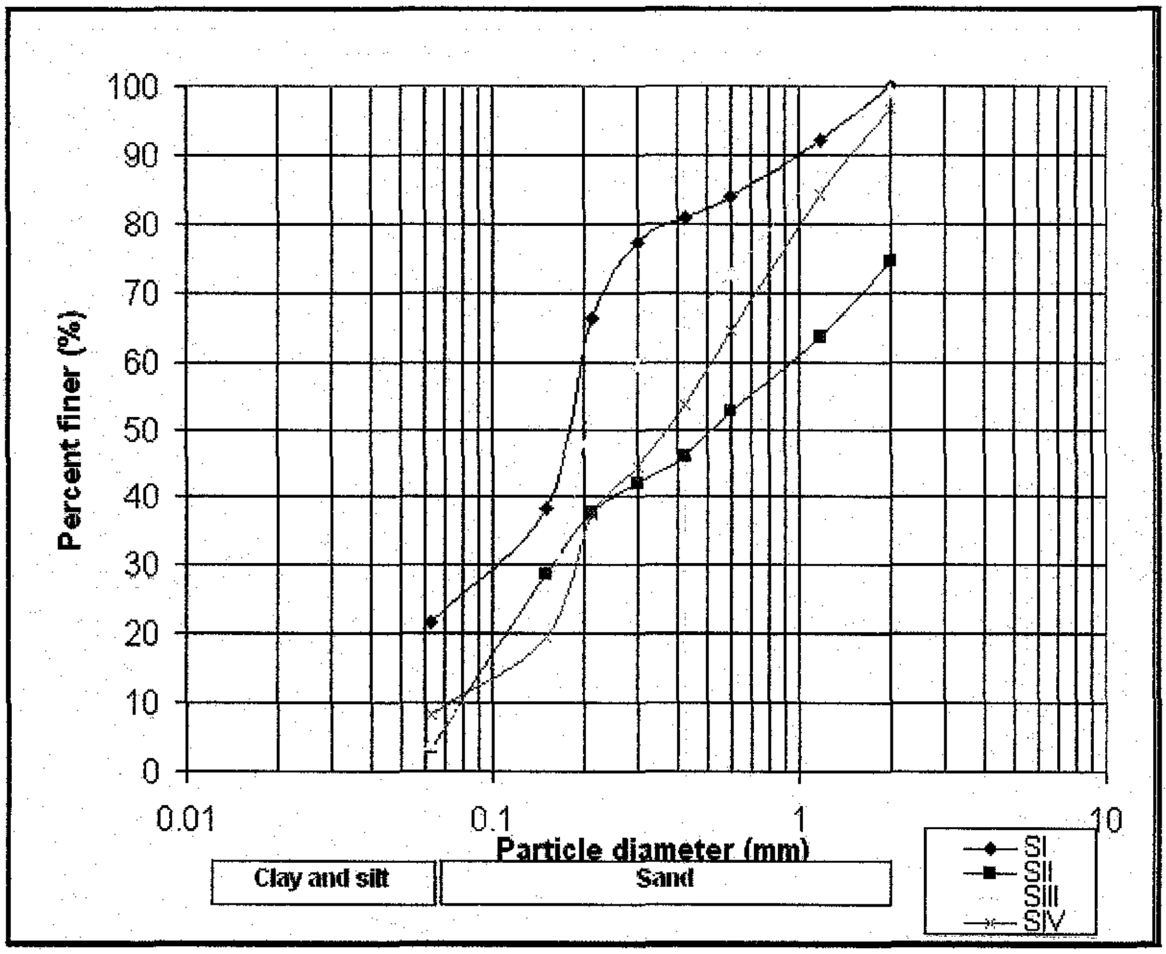


Figure 1: Particle size distribution of S, S2, S3 and S4.

**Results of Hydrometer Analysis:**

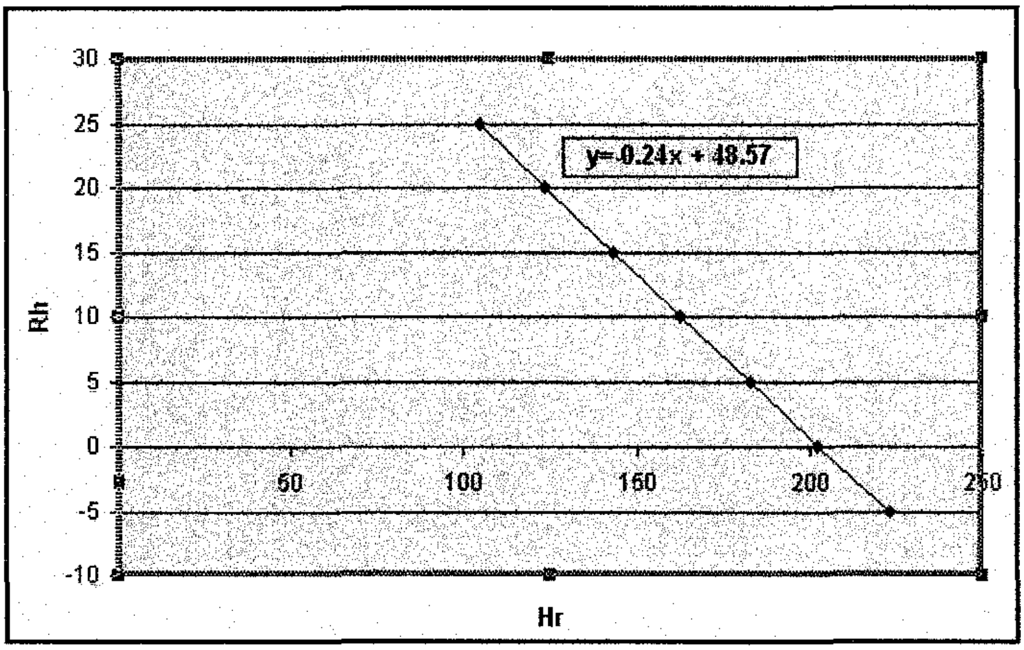


Figure 2: Hr Vs Rh for S1 and S2

Table 5: Test data for S1

| time(min) | Rh' | Rh=Rh+Cm | Hr | D(mm) | Rd | k% |
|---|---|---|---|---|---|---|
| 0.5 | 1.031 | 1.0315 | 198.08 | 0.081392 | 1.0285 | 8.8182 |
| 1 | 1.029 | 1.0295 | 198.09 | 0.057554 | 1.0265 | 8.8010 |
| 2 | 1.0275 | 1.028 | 198.09 | 0.040698 | 1.0250 | 8.7881 |
| 4 | 1.025 | 1.0255 | 198.10 | 0.028778 | 1.0225 | 8.7667 |
| 8 | 1.022 | 1.0225 | 198.12 | 0.020350 | 1.0195 | 8.7410 |
| 30 | 1.018 | 1.0185 | 198.13 | 0.010509 | 1.0155 | 8.7067 |
| 120 | 1.0137 | 1.0142 | 198.15 | 0.005255 | 1.0112 | 8.6698 |
| 480 | 1.0092 | 1.0097 | 198.17 | 0.002628 | 1.0067 | 8.6312 |
| 1440 | 1.005 | 1.0055 | 198.19 | 0.001517 | 1.0025 | 8.5952 |

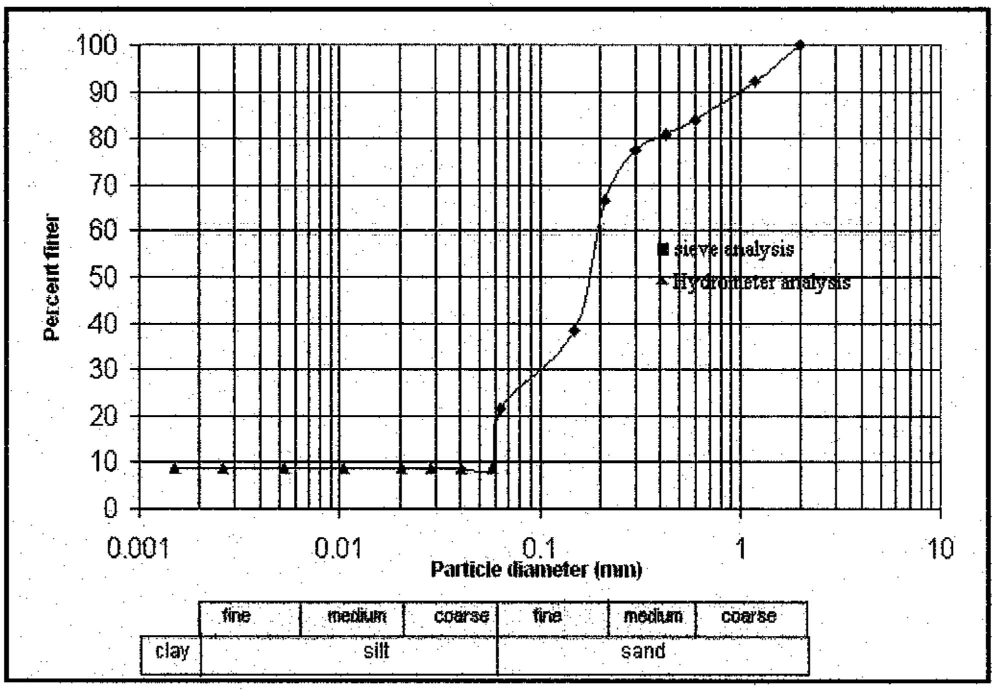


Figure 3: Particle size distribution curve-sieve and hydrometer analysis of S1

| **Size (mm)** | **% finer** | |
|---|---|---|
| 2.000 | 100 | 85.6% of sand |
| 0.060 | 14.4 | 5.8% of silt |
| 0.002 | 8.6 | 8.6% of clay |
| - | | |

Table 6: Test data for S2

| time(min) | Rh' | Rh=Rh+Cm | Hr | D(mm) | Rd | k% |
|---|---|---|---|---|---|---|
| 0.5 | 1.009 | 1.0095 | 198.17 | 0.078158 | 1.011500 | 3.400109 |
| 1 | 1.009 | 1.0095 | 198.17 | 0.055266 | 1.011500 | 3.400109 |
| 2 | 1.009 | 1.0095 | 198.17 | 0.039079 | 1.011500 | 3.400109 |
| 4 | 1.0085 | 1.009 | 198.17 | 0.027633 | 1.011000 | 3.398428 |
| 8 | 1.008 | 1.0085 | 198.17 | 0.019540 | 1.010500 | 3.396747 |
| 30 | 1.007 | 1.0075 | 198.18 | 0.010090 | 1.009500 | 3.393386 |
| 120 | 1.006 | 1.0065 | 198.18 | 0.005045 | 1.008500 | 3.390024 |
| 480 | 1.005 | 1.0055 | 198.19 | 0.002523 | 1.007500 | 3.386663 |
| 1440 | 1.0025 | 1.003 | 198.20 | 0.001456 | 1.005000 | 3.378259 |

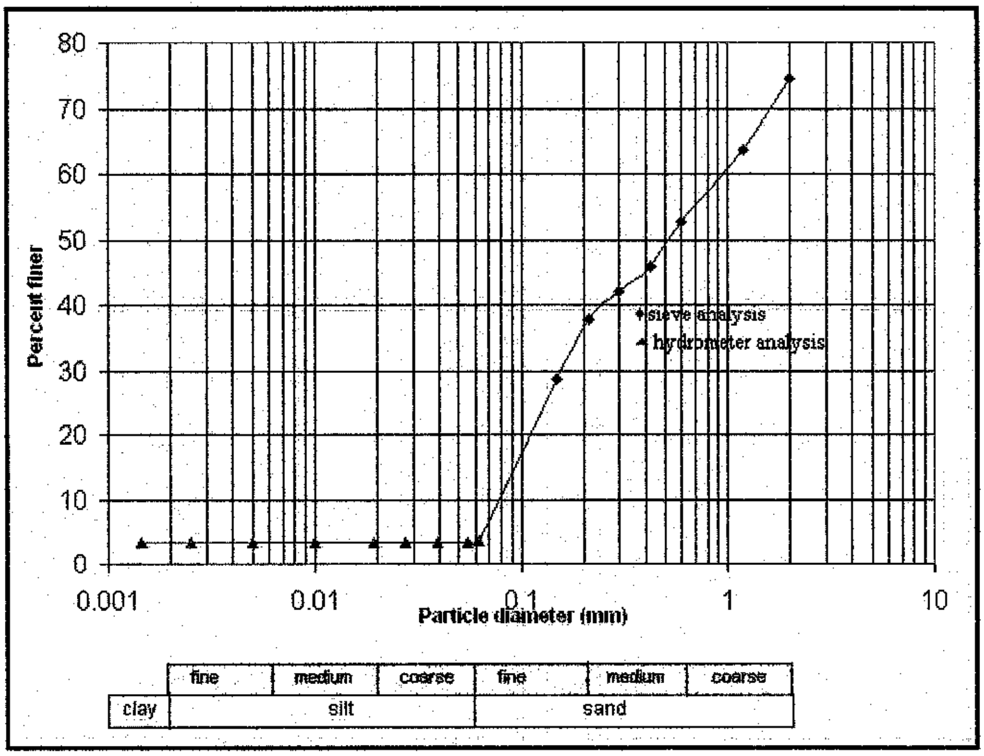


Figure 4: Particle size distribution curve-sieve and hydrometer analysis of S2

| Size (mm) | % finer | |
|---|---|---|
| 2.000 | 74.41 | 70.41% of sand |
| 0.060 | 3.45 | 0.06% of silt |
| 0.002 | 3.39 | 3.39% of clay |
| - | | |

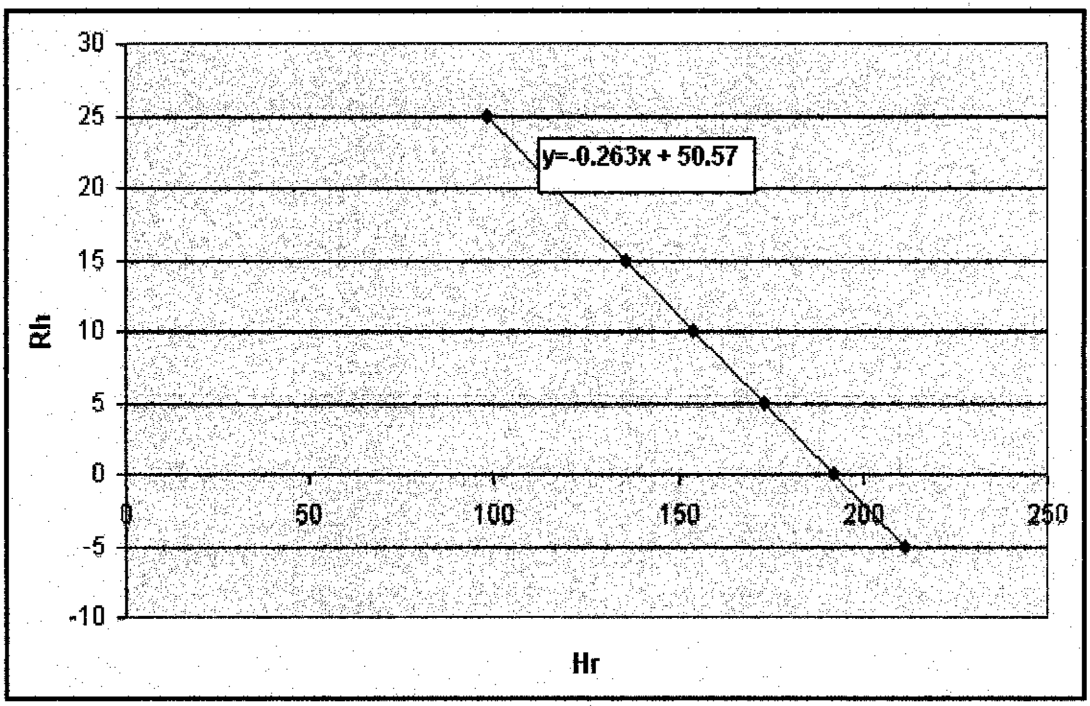


Figure 5: Hr Vs Rh for S3 and S4

Table 7: Test data for S3

| time(min) | Rh' | Rh=Rh+Cm | Hr | D(mm) | Rd | k% |
|---|---|---|---|---|---|---|
| 0.5 | 1.03 | 1.0305 | 188.36 | 0.079371 | 1.032500 | 5.55 |
| 1 | 1.028 | 1.0285 | 188.37 | 0.056125 | 1.030500 | 5.54 |
| 2 | 1.0275 | 1.028 | 188.37 | 0.039687 | 1.030000 | 5.54 |
| 4 | 1.026 | 1.0265 | 188.38 | 0.028063 | 1.028500 | 5.53 |
| 8 | 1.022 | 1.0225 | 188.39 | 0.019844 | 1.024500 | 5.51 |
| 30 | 1.016 | 1.0165 | 188.42 | 0.010248 | 1.018500 | 5.48 |
| 120 | 1.014 | 1.0145 | 188.42 | 0.005124 | 1.016500 | 5.47 |
| 480 | 1.009 | 1.0095 | 188.44 | 0.002562 | 1.011500 | 5.44 |
| 1440 | 1.006 | 1.0065 | 188.46 | 0.001479 | 1.008500 | 5.42 |

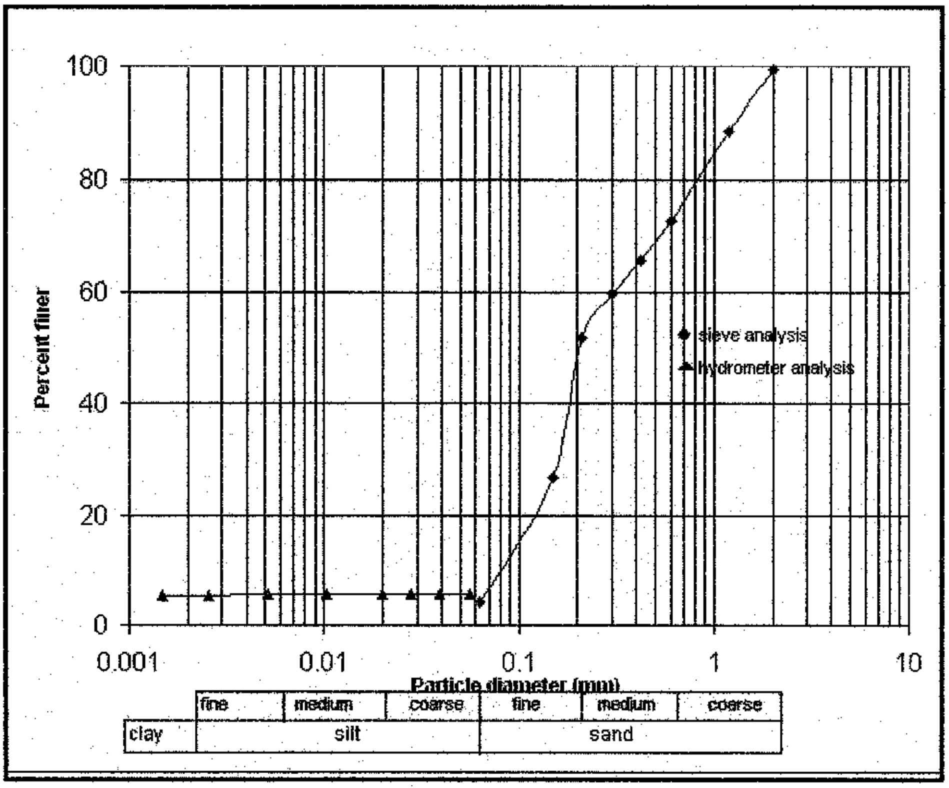


Figure 6: Particle size distribution curve-sieve and hydrometer analysis of S3

| **Size (mm)** | **% finer** | |
|---|---|---|
| 2.000 | 99.46 | 93.93% of sand |
| 0.060 | 5.53 | 0.1% of silt |
| 0.002 | 5.43 | 5.43% of clay |

Table 9: Test data for S4

| **time(min)** | **Rh'** | **Rh=Rh+Cm** | **Hr** | **D(mm)** | **Rd** | **k%** |
|---|---|---|---|---|---|---|
| 0.5 | 1.03 | 1.0305 | 188.36 | 0.079371 | 1.032500 | 8.85 |
| 1 | 1.029 | 1.0295 | 188.37 | 0.056124 | 1.031500 | 8.84 |
| 2 | 1.0275 | 1.028 | 188.37 | 0.039687 | 1.030000 | 8.83 |
| 4 | 1.026 | 1.0265 | 188.38 | 0.028063 | 1.028500 | 8.82 |
| 8 | 1.02 | 1.0205 | 188.40 | 0.019845 | 1.022500 | 8.77 |
| 30 | 1.015 | 1.0155 | 188.42 | 0.010248 | 1.017500 | 8.72 |
| 120 | 1.01 | 1.0105 | 188.44 | 0.005124 | 1.012500 | 8.68 |
| 480 | 1.007 | 1.0075 | 188.45 | 0.002562 | 1.009500 | 8.66 |
| 1440 | 1.005 | 1.0055 | 188.46 | 0.001479 | 1.007500 | 8.64 |

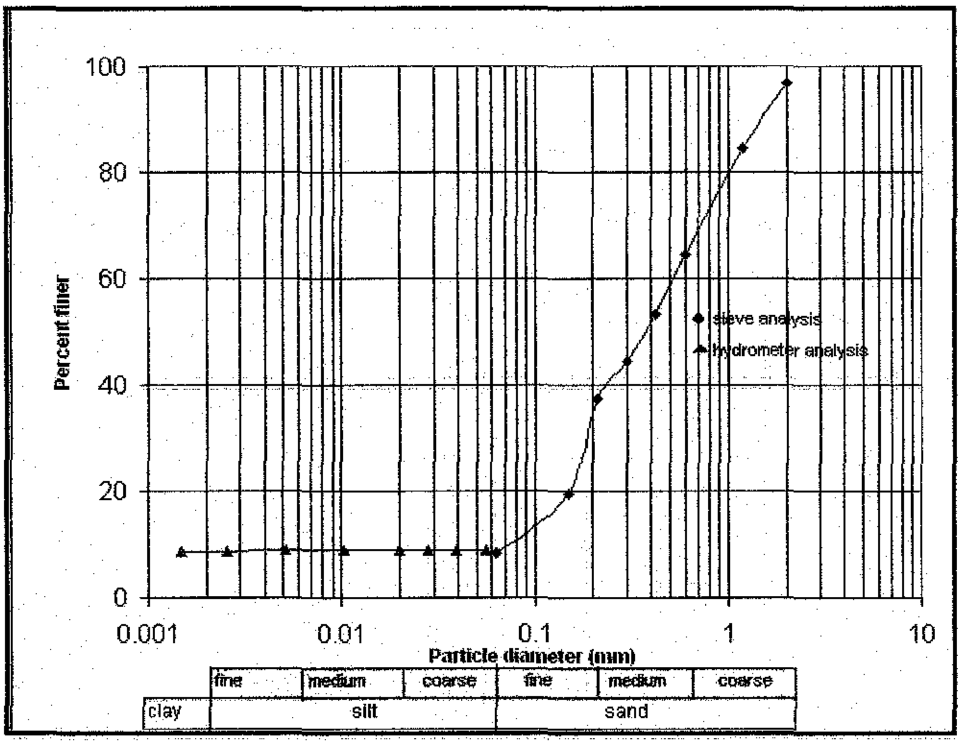


Figure 7: Particle size distribution curve-sieve and hydrometer analysis of S4

| Size (mm) | % finer | |
|---|---|---|
| 2.000 | 96.72 | 87.88% of sand |
| 0.060 | 8.84 | 0.19% of silt |
| 0.002 | 8.65 | 8.65% of clay |

**Result of Liquid & Plastic Limit:**

Table 10: Liquid limit of S1

| Liquid limit Test No | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Average penetration (mm) | 17.65 | 19.2 | 24.5 | 26.8 |
| mass of wet soil +container, $w_2$ (g) | 40.1 | 42.2 | 48.5 | 50.47 |
| mass of dry soil +container, $w_3$ (g) | 37.66 | 39.7 | 45.88 | 47.5 |
| mass of container, $w_1$ (g) | 29.9 | 31.9 | 38.05 | 39.1 |
| mass of moisture (g) | 10.2 | 10.3 | 10.45 | 11.37 |
| mass of dry soil (g) | 7.76 | 7.8 | 7.83 | 8.4 |
| Moisture content (%) | 31.44 | 32.05 | 33.46 | 35.36 |

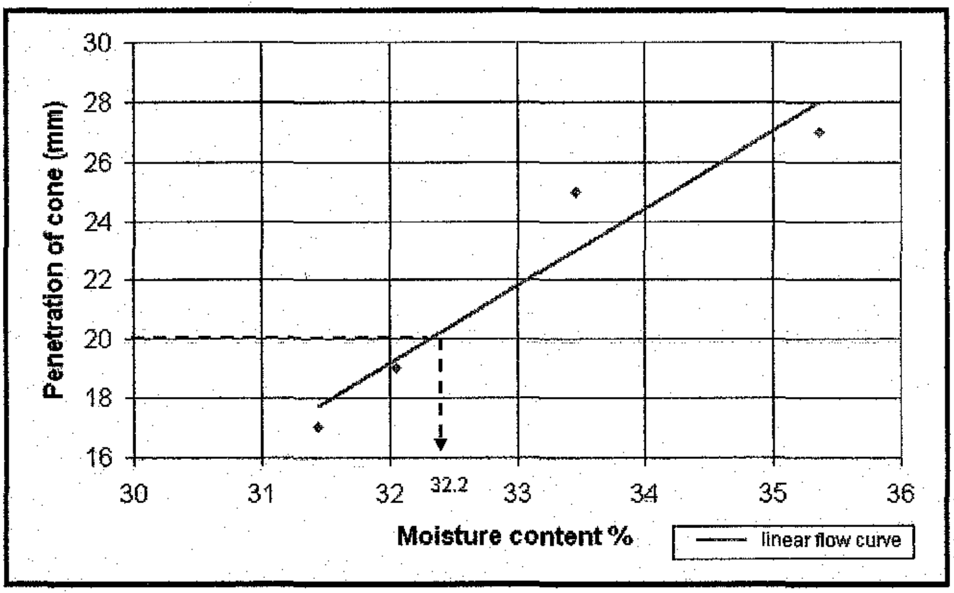


Figure 8: Liquid limit Of S1

Table 11: Plastic limit of S1

| Plastic limit Test No | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|
| mass of wet soil +container, $w_2$ (g) | 36.45 | 42.71 | 36.74 | 34.69 | 37.65 |
| mass of dry soil +container, $w_3$ (g) | 35.00 | 41.66 | 35.17 | 33.54 | 36.34 |
| mass of container, $w_1$ (g) | 29.43 | 37.80 | 29.65 | 29.08 | 31.49 |
| mass of moisture (g) | 7.02 | 4.91 | 7.09 | 5.61 | 6.16 |
| mass of dry soil (g) | 5.57 | 3.86 | 5.52 | 4.46 | 4.85 |
| moisture content (%) | 26.03 | 27.20 | 28.44 | 25.78 | **26.87** |

$PI = LL - PL = 32.2 - 26.87 = 5.33$

Table 12: Liquid limit of S2

| Liquid limit Test No | 1 | 2 | 3 |
|---|---|---|---|
| Average penetration (mm) | 19.5 | 21 | 28.8 |
| mass of wet soil +container, $w_2$ (g) | 36.4 | 28.1 | 26.4 |
| mass of dry soil +container, $w_3$ (g) | 34.4 | 26.0 | 24.0 |
| mass of container, $w_1$ (g) | 29.2 | 20.7 | 19.6 |
| mass of moisture (g) | 2.0 | 2.1 | 2.4 |
| mass of dry soil (g) | 5.2 | 5.3 | 4.4 |
| Moisture content (%) | 38.46 | 39.62 | 54.55 |

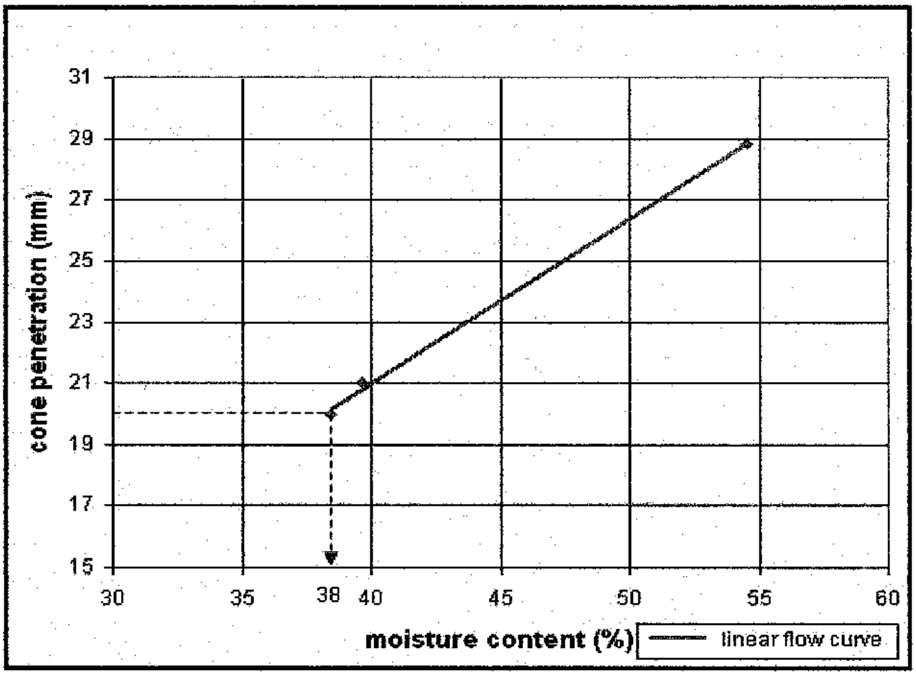


Figure 9: Liquid limit of S2

Table 13: Plastic limit of S2

| Plastic limit Test No | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|
| mass of wet soil +container, $w_2$ (g) | 38.0 | 36.6 | 37.0 | 37.0 | 37.2 |
| mass of dry soil +container, $w_3$ (g) | 36.2 | 35.1 | 35.4 | 35.2 | 35.5 |
| mass of container, $w_1$ (g) | 29.1 | 29.6 | 29.6 | 29.4 | 29.4 |
| mass of moisture (g) | 1.8 | 1.5 | 1.6 | 1.8 | 1.7 |
| mass of dry soil (g) | 7.1 | 5.5 | 5.8 | 5.8 | 6.1 |
| moisture content (%) | 25.35 | 27.27 | 27.59 | 31.03 | **27.81** |

$PI = LL - PL = 38 - 27.81 = 10.19$

Table 14: Liquid limit of S3

| Liquid limit Test No | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Average penetration (mm) | 16.5 | 22.2 | 24.4 | 28.1 |
| mass of wet soil +container, $w_2$ (g) | 41.3 | 43.6 | 45.3 | 48.7 |
| mass of dry soil +container, $w_3$ (g) | 38.3 | 40.4 | 43.3 | 45.8 |
| mass of container, $w_1$ (g) | 29.9 | 31.9 | 38.05 | 39.1 |
| mass of moisture (g) | 11.4 | 11.7 | 7.25 | 9.6 |
| mass of dry soil (g) | 8.4 | 8.5 | 5.25 | 6.7 |
| Moisture content (%) | 35.71 | 37.65 | 38.10 | 43.28 |

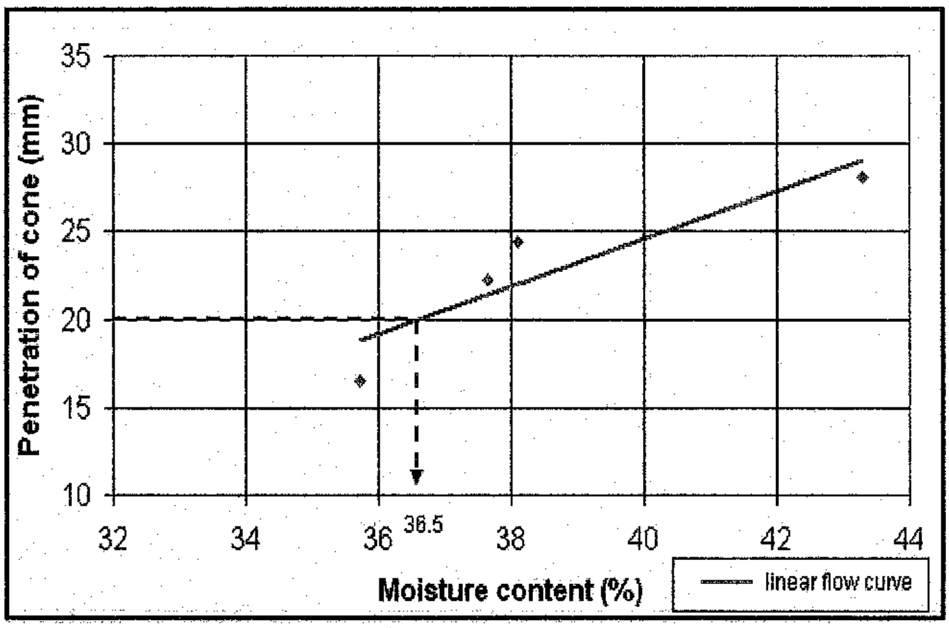


Figure 10: Liquid limit of S3

Table 15: Plastic limit of S3

| Plastic limit Test No | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|
| mass of wet soil +container, $w_2$ (g) | 34.4 | 40.3 | 37.74 | 35.7 | 37.04 |
| mass of dry soil +container, $w_3$ (g) | 33 | 39.7 | 36.2 | 34.7 | 35.90 |
| mass of container, $w_1$ (g) | 29.43 | 37.8 | 29.65 | 29.08 | 31.49 |
| mass of moisture (g) | 4.97 | 2.5 | 8.09 | 6.62 | 5.55 |
| mass of dry soil (g) | 3.57 | 1.9 | 6.55 | 5.62 | 4.41 |
| moisture content (%) | 39.22 | 31.58 | 23.51 | 17.79 | 28.02 |

$PI = LL - PL = 43.28 - 28.02 = 15.26$

Table 16: Liquid limit of S4

| Liquid limit Test No | 1 | 2 | 3 |
|---|---|---|---|
| Average penetration (mm) | 18.5 | 23.2 | 25.4 |
| mass of wet soil +container, $w_2$ (g) | 35.5 | 29.7 | 27.4 |
| mass of dry soil +container, $w_3$ (g) | 33.8 | 27.2 | 25.2 |
| mass of container, $w_1$ (g) | 29.3 | 20.7 | 19.6 |
| mass of moisture (g) | 6.2 | 9 | 7.8 |
| mass of dry soil (g) | 4.5 | 6.5 | 5.6 |
| Moisture content (%) | 37.78 | 38.46 | 39.29 |

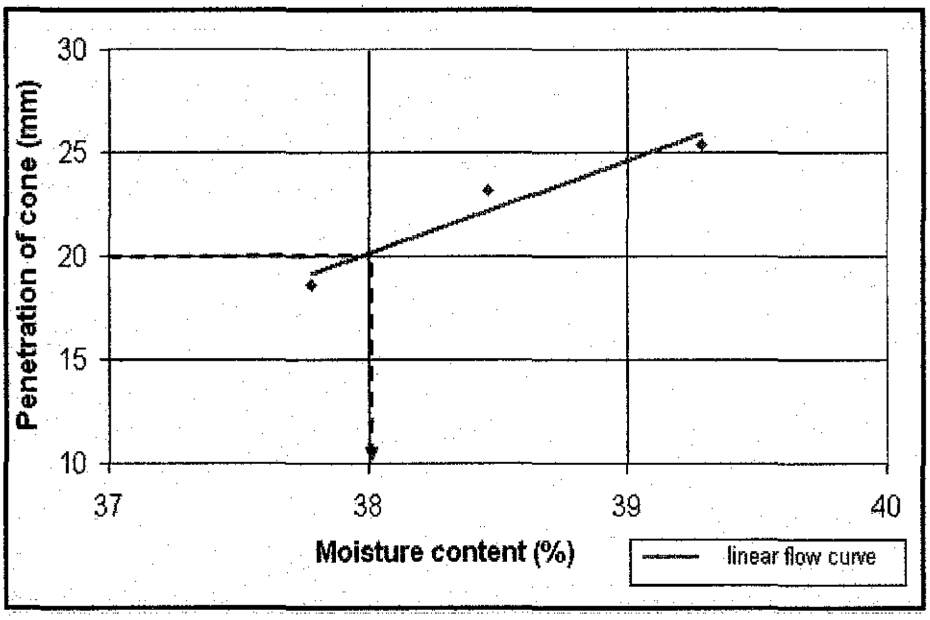


Figure 11: Liquid limit of S4

Table 17: Plastic limit of S4

| Plastic limit Test No | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|
| mass of wet soil +container, $w_2$ (g) | 34.6 | 36.4 | 37.5 | 38 | 36.63 |
| mass of dry soil +container, $w_3$ (g) | 33.2 | 34.6 | 35.4 | 37.2 | 35.10 |
| mass of container, $w_1$ (g) | 29.1 | 29.6 | 29.6 | 29.4 | 29.43 |
| mass of moisture (g) | 5.5 | 6.8 | 7.9 | 8.6 | 7.20 |
| mass of dry soil (g) | 4.1 | 5 | 5.8 | 7.8 | 5.68 |
| moisture content (%) | 34.15 | 36.00 | 36.21 | 10.26 | 29.15 |

$PI = LL - PL = 39.29 - 29.15 = 10.14$

**Result of Particle density:**

| | | S1 | S2 | S3 | S4 |
|---|---|---|---|---|---|
| Mass of jar + gas jar + plate + soil + water ($m_3$) | g | 1686.20 | 1720.2 | 1571 | 1610.4 |
| Mass of jar + gas jar + plate + soil ($m_2$) | g | 738.00 | 750.3 | 695.2 | 706.4 |
| Mass of jar + gas jar + plate + water ($m_4$) | g | 1560.50 | 1587.7 | 1471.7 | 1504.8 |
| Mass of jar + gas jar + plate ($m_1$) | g | 535.00 | 535 | 535 | 535 |
| Mass of soil ($m_2$-$m_1$) | g | 203.00 | 215.30 | 160.20 | 171.40 |
| Mass of water in full jar ($m_4$-$m_1$) | g | 1025.50 | 1052.70 | 936.70 | 969.80 |
| Mass of water used ($m_3$-$m_2$) | g | 948.20 | 969.90 | 875.80 | 904.00 |
| Volume of soil particles ($m_4$-$m_1$) - ($m_3$-$m_2$) | ML | 77.30 | 82.80 | 60.90 | 65.80 |
| Particle density $p_s = (m_2-m_1)/(m_4-m_1)-(m_3-m_1)$ | $Mg/m^3$ | 2.63 | 2.60 | 2.63 | 2.60 |

Table 18: Comparison Properties of Tapah Kaolin

| **Data Source** | K.A. Kassim, R. Hamir, K.C. Kok | Geological Survey of Malaysia | | | | Zainol abidin bin Sulaiman | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Area** | | 6501 | 6502 | 6503 | 6504 | S1 | S2 | S3 | S4 |
| **Soil** | | | | Tapah kaolin | | | | | |
| **1.Physical properrties** | | | | | | | | | |
| Particle density | 2.64 | | | | | 2.63 | 2.63 | 2.63 | 2.63 |
| Liquid limit (%) | 93 | | | | | 32.0 | 38.5 | 37.0 | 38.0 |
| Plastic limit (%) | 43 | | | | | 26.9 | 27.8 | 28.0 | 29.0 |
| Plasticity index (%) | 50 | | | | | 5.0 | 10.7 | 9.0 | 9.0 |
| **2.Particle size distribution** | | | | | | | | | |
| Sand | 6.0 | | | | | 85.6 | 70.41 | 93.93 | 87.88 |
| Silt | 57.6 | | | | | 5.8 | 0.06 | 0.1 | 0,19 |
| Clay | 36.4 | 25.9 | 5 | 6.7 | - | 8.6 | 3.390 | 5.43 | 8.65 |
| Clay Activity | 1.37 | | | | | 0.58 | 3.24 | 1.66 | 1.04 |
| **3.Soil classification** | | | | | | | | | |
| BSCS | CE | | Sandy clay | | | SM | SW | SC | SC |
| USCS | MH | | | | | SM | SW | SP-SC | SW-SC |
| ASCS | A-7-5 | | | | | A-2-4 | A-2-6 | A-2-4 | A-2-4 |

**Result of Vane shear test:**

S1:

| | |
|---|---|
| Deflection of spring, $\theta_f$ | 26° |
| Rotation of vane | 17° |
| Rotation of spring mounting | 43° |

By interpolation;

$$\frac{0.098 - M}{31 - 26} = \frac{0.098 - 0.074}{31 - 23}$$

$$M = 83 \text{ Nmm}$$

Vane shear strength, $T_v$ = $\frac{M}{4.29}$ kN/m²

$$= \frac{83}{4.29}$$

$$= 19.35 \quad \text{kN/m}^2$$

**Moisture content :**

| | |
|---|---|
| Weight of container (g) = | 17.2 |
| Weight of container + sample (g) = | 143.4 |
| Weight of container + dry sample (g) = | 112.4 |
| Weight of sample (g) = | 126.2 |
| Weight of dry sample (g) = | 95.2 |
| Moisture content (%) = | 32.6 |

S2:

| | |
|---|---|
| Deflection of spring, $\theta_f$ | 20° |
| Rotation of vane | 15° |
| Rotation of spring mounting | 35° |

By interpolation;

$$\frac{0.074 - M}{23 - 20} = \frac{0.074 - 0.049}{23 - 16}$$

$$M = 63 \text{ Nmm}$$

Vane shear strength, $T_v = \dfrac{M}{4.29}$ kN/m$^2$

$$= \frac{63}{4.29}$$

$$= 14.7 \text{ kN/m}^2$$

**Moisture content :**

| | |
|---|---|
| Weight of container (g) = | 19.7 |
| Weight of container + sample (g) = | 171.8 |
| Weight of container + dry sample (g) = | 128.4 |
| Weight of sample (g) = | 152.1 |
| Weight of dry sample (g) = | 108.7 |
| Moisture content (%) = | 39.9 |

S3:

| | |
|---|---|
| Deflection of spring, $\theta_f$ | 21° |
| Rotation of vane | 15° |
| Rotation of spring mounting | 36° |

By interpolation;

$$\frac{0.074 - M}{23 - 21} = \frac{0.074 - 0.049}{23 - 16}$$

$$M = 67 \text{ Nmm}$$

Vane shear strength, $T_v = \dfrac{M}{4.29}$ kN/m$^2$

$$= \frac{67}{4.29}$$

$$= 15.62 \quad \text{kN/m}^2$$

**Moisture content :**

| | |
|---|---|
| Weight of container (g) = | 16.7 |
| Weight of container + sample (g) = | 172.8 |
| Weight of container + dry sample (g) = | 129.5 |
| Weight of sample (g) = | 156.1 |
| Weight of dry sample (g) = | 112.8 |
| Moisture content (%) = | 38.4 |

S4:

| | |
|---|---|
| Deflection of spring, $\theta_f$ | 19° |
| Rotation of vane | 16° |
| Rotation of spring mounting | 35° |

By interpolation;

$$\frac{0.074 - M}{23 - 19} = \frac{0.074 - 0.049}{23 - 16}$$

$$M = 60 \text{ Nmm}$$

Vane shear strength, $T_v = \dfrac{M}{4.29}$ kN/m$^2$

$$= \frac{60}{4.29}$$

$$= 13.98 \quad \text{kN/m}^2$$

**Moisture content :**

| | |
|---|---|
| Weight of container (g) = | 19.2 |
| Weight of container + sample (g) = | 175.0 |
| Weight of container + dry sample (g) = | 131.4 |
| Weight of sample (g) = | 155.8 |
| Weight of dry sample (g) = | 112.2 |
| Moisture content (%) = | 38.9 |