COMPARISON BETWEEN SIEVE ANALYSIS & HYDROMETER WITH LASER PARTICLE ANALYZER TO DETERMINE PARTICLE SIZE DISTRIBUTION

ROHAYA BINTI RASMIN

UNIVERSITI MALAYSIA PAHANG

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COMPARISON BETWEEN SIEVE ANALYSIS & HYDROMETER WITH LASER PARTICLE ANALYZER TO DETERMINE PARTICLE SIZE DISTRIBUTION

ROHAYA BINTI RASMIN

A thesis submitted in fulfillment of the
requirements for the award of the degree of
Bachelor of Civil and Environmental Engineering

Faculty of Civil & Environmental Engineering
Universiti Malaysia Pahang (UMP)

NOVEMBER 2009

“I hereby declare that I have read this thesis and in my
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I declare that this thesis entitled "*COMPARISON BETWEEN SIEVE ANALYSIS & HYDROMETER WITH LASER PARTICLE ANALYZER TO DETERMINE PARTICLE SIZE DISRTIBUTION OF SOILS*" 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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SPECIAL TO MY BELOVED

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BROTHERS
AHMAD FAKHRI BIN RASMIN
AHMAD FAIZ BIN RASMIN

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ABSTRACT

Determination of soil particle size distribution (PSD) by sieving, hydrometer as well as by laser particle analyzer suffers from inherent flaws, mainly due to the difficulty in defining the size of irregularly shaped particles. Therefore these methods yield only estimates of particle size distribution. The objective of this study was to determine a functional relationship exists between the PSDs obtained by the combined sieve-hydrometer method and those obtained by laser particle analyzer. Samples from 3 different places in Kuantan were analyzed. For the laser particle analyzer CILAS Particle analyzer were used employing the Mie theory. Values of 1.5 and 0.2 for the real part and the imaginary term of the reflective index, respectively, gave satisfactory results for the optical model calculations. Volume percentage of the clay-size fraction obtained by laser particle analyzer was generally lower than mass percentage of the clay fraction derived by the combined sieve & hydrometer method. The opposite trend was noted for the silt-size fraction. Coefficient of determination for the regression equations for the clay, silt, and sand fractions determined by the two methods were 0.702, 0.689, and 0.821, respectively. Good agreement between measured and calculated laser particle analyzer values for one size class was accompanied by poor agreement between measured and calculated values for the other. The laser particle analyzer method provides a continuous particle size distribution curve, which enables a detailed data analysis and a flexible application of different particle size distribution dependent classification system.

ABSTRAK

Penentuan agihan saiz zarah tanah menggunakan kaedah ayakan, hidrometer juga menggunakan laser menghadapi masalah yang dialami secara semulajadi, terutamanya disebabkan oleh masalah dalam menentukan saiz zarah yang tidak sama bentuknya. Oleh yang demikian, kaedah-kaedah ini hanya digunakan untuk menentukan agihan saiz zarah sahaja. Objektif kajian ini adalah untuk menentukan agihan saiz zarah tanah juga ingin mengenalpasti hubungkait antara kaedah laser dengan kaedah ayakan dan hidrometer. Sampel tanah diambil dari tiga kawasan berbeza sekitar Kuantan – Gambang. Untuk Kaedah Laser, mesin CILAS diguna pakai dan untuk pengiraannya pula, Teori Mie telah diguna pakai. Nilai bagi 1.5 dan 0.2 yang digunakan untuk bahagian sebenar dan terma imaginasi memberikan keputusan yang memuaskan untuk kiraan model optikal. Peratus isipadu untuk tanah liat bagi kaedah laser adalah lebih kecil berbanding dengan kaedah ayakan dan hidrometer. Tren berlawanan pula didapati di bahagian pecahan tanah lumpur atau kelodak. Pemalar yang digunakan dalam kaedah-kaedah menentukan jenis tanah samaada tanah liat, tanah liat lembut, lumpur atau pasir adalah 0.702, 0.689, dan 0.821 berturut-turut. Hubung kait yang baik dapat dilihat antara ukuran dan kiraan yang dilakukan dalam kaedah laser manakala hubungkait yang kurang baik didapati daripada kaedah ayakan dan hydrometer. Kaedah laser memberikan lengkung agihan saiz partikel yang sentiasa bersambung yang memudahkan proses pembahagian jenis-jenis dan klasifikasi tanah mengikut kelas masing-masing.

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LIST OF SYMBOLS

BS - British Standard

BSCS - British Soil Classification System

C_m - Meniscus correction

D - Particle diameter

G_S - Specific gravity

H_R - Effective depth

JKR - Jabatan Kerja Raya

K - Percent finer (%)

L_O - Initial length

L_D - Oven-dried length

LL - Liquid limit

LS - Linear shrinkage

M_t - Temperature correction

m - Mass

PI - Plasticity index

PL - Plastic limit

R - Fully corrected reading

R_h - True reading

R_h’ - Hydrometer reading

SL - Shrinkage limit

η - Viscosity of water

x - Dispersant correction

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CHAPTER 1

INTRODUCTION

1.1 Background of project

Soils are a vital resource in every country of the world. An understanding of the soil properties begins at the simple level of what can be observed for example the particle size distribution. Particle size distribution is a list of values or a mathematical function that defines the relative amounts of particles present, sorted according to size. Particle Size Distribution is also known as grain size distribution (Frieden, B. J., & Sagalyn, L. B. (1989).

The method used to determine Particle Size Distribution is called particle size analysis and the apparatus in conversional method will be sieve analysis and hydrometer test while more advanced, fasters, reliable and accuracy method is laser particle size analyzer.

The result obtained from this laboratory assessment then will be used to classify the soil. Generally soil can be divided into three major groups which are coarse, fine and organic soil. The British Soil Classification System (BSCS) will be use to classify the soil sample.

Soil consists of individual particles, or grains. Particles are three-dimensional objects for which three parameters (the length, breadth and height) are required in order to provide a complete description. Most sizing techniques therefore assume that the material being measured is spherical, as a sphere is the only shape that can be described by a single number (its diameter).

1.2 Problem Statement

Particle size distribution is one of the most fundamental physical properties of a soil, defining, for example the soil texture, and strongly affecting many physical and chemical soil properties. It is typically presented as percentage of the total mass of soil occupied by a given size fraction.

In soil mechanic and geotechnical engineering it is really important to know the particle size distribution in order to know the soil condition content in percentage of clay, silt or sandy sand. Problem in soil mechanics had begun to be identified and addressed analytically by the beginning of the eighteenth century (Heyman, 1972). Limitations of traditional methods for particle-size analysis warrant the investigation of new techniques.

This study will compare finding from particle size distribution of soil sample by using sieve analysis & hydrometer and laser particle analyzer. This study also will identify suitable method to determine the particle size distribution. This study will explore two types of test which are sieve analysis & hydrometer test and laser particle analyzer.

1.3 Objectives

To achieve this study, several of objectives has stated:-

1. To determine the particle size distribution of soils by using two different methods which is sieve analysis & hydrometer test and laser particle analyzers;

2. Comparison the result from sieve analysis & hydrometer with laser particle analyzer to give the suite of suitability for particle size distribution analysis; and

3. To determine the soil type in accordance to British Soil Classification System (BSCS).

1.4 Scope of study

In this academic study, scopes of the studies are:

a) The location site are several places in Kuantan,Pahang.
b) Sample are collected from several places in Kuantan,Pahang for the testing which label sample 1, sample 2, and sample 3.
c) Conduct two testing on the same type of soil which are sieve analysis & hydrometer test and laser particle diffraction analyzer to determine the particle size distribution.
d) Differentiate those two tests by using graph of percentage of the particle size distribution to know which test gives more suitability.

1.5 Significance of study

It is necessary to know the particle size distribution of soils to determine whether they are suitable for particular applications that we need to use either in concrete mixing, designing soil or geotechnical structure. Sieve analysis & hydrometer testing and also laser particle size analyzer are very important in order to know which test are more suitable and also it will make the contractor to know the soil properties as well as the soil conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the review of soil and the soil classification system that will be use to classify the soil sample after running the laboratory testing will be presented. More than that, the testing that use to determine the particle size distribution also will be presented.

Particle size distribution in soil is one of the more interesting soil physical properties. The information provided by Particle Size Distribution are often used to infer soil functioning and use. The traditional method of characterizing particle sizes in soils is to divide the array of possible particle sizes into three arbitrary separable size ranges: sand, silt and clay (Lin-Sien Lum, 2001).

An alternative to this approach is to measure and display the complete distribution of particle sizes. Sieves can be used to separate and determine the content of the relatively large particles of sand and coarse silt.

However the common source of Particle Size Distribution data is the process of sedimentation of particles in water and the most popular techniques are the hydrometer method, this method is based on the Stoke’s law and employs the relationship among time, travel distance, and the diameter of a sphere subject to sedimentation in a viscous liquid (Sivakugan N,,2000)

According to Bouyoucos (1925), for many years, sedimentation methods have been used for measuring soil particle- size distributions. In the hydrometer method, first described by Bouyoucos (1925), the floatation depth of a hydrometer is measured as a function of time, providing an indication of the solution density.

The sieve analysis is a determination of the proportions of particles lying within certain size ranges in a granular material by separation on sieves of different size openings. Sieve analysis is also known as screen analysis. Combined sieve-and hydrometer method is one of the two conventional methods commonly used in research and practice in all branches of science and engineering dealing with soils while laser diffraction is a modern method.

Laser diffraction is measurements one obtains information about particle size distribution through measurements of scattering intensity as a function of the scattering angle and the wavelength and polarization of light based on applicable scattering models.

The instrument measures particle size over the range of 0.045 to 2000 µm. The laser beam accurately measures particles of an apparent cross-sectional diameter greater than 0.4 µm (Buurman et al., 1997). The calculation module offers the use of two optical modes, the Fraunhoffer diffraction model and the Mie theory. It should be borne in mind that the Mie theory applies rigorously to spherical, homogeneous particles and fits less satisfactorily nonspherical or nonhomogeneous particles (Jonasz, 1991). In this study, several tests will be conducted to compare between these three tests.

2.2 Definition of soil

Soil is the term given to the unbounded, granular material which covers much of the surface of the Earth that is not under water (William Powrie, 1997). Soil consists primarily of solid particles, which range in size from less than a micron to several millimeters. Soil is used as a construction material in various civil engineering projects, and it supports structural foundations (Braja M.Das, 2002).

Much of the work of foundation and geotechnical engineers involves soil. It is imperative therefore to know the definition of the soil. A simple definition of soil is that it is a particulate medium, with particles resulting from a variety of geologic processes, and is composed of a variety of minerals, with particle size ranging from the order of magnitude of 1 μ to 1 m (Rodrigo Salgado, 2008). The space between soil particles, referred to as the pore space, is filled with one or more of the following: air, some other gas, water, or some other liquid.

Beyond the amazing range of soil particle sizes, soil is complex in other ways. Soil particles may be arranged in densely packed states or very loose ones. Soils at depth exist under large stresses; soils close to the surface exists under small stresses. Particle arrangements can vary not only in terms of how dense they are but also in the way particles are in contact with each other (Rodrigo Salgado, 2008). The pore fluid chemistry can vary. In some soils, particles interact physicochemical with the pore fluid; any changes in pore fluid chemistry can affect soil behavior.

2.2.1 Soil description

Soil description deals with the systematic categorization of soils based on distinguishing characteristics as well as criteria that dictate choices in use. Four information fields are provided for recording and determining the soil description which are; terrain texture, surficial material, surface expression and geomorphological process, respectively (Howes and Kenk, 1997).

2.3 Physical properties of soil

Soil engineers usually classify soils to determine whether they are suitable for particular applications (Sam Helwany, 2007). For instance, borrowing soil from other sites, the properties that need to be considered:

i. The particle size distribution
ii. The consistency of each soil
iii. The classification of the soil

Soils are porous and open bodies, yet they retain water. They contain mineral particles of many shapes and sizes and organic material which is colloidal (particles so small they remain suspended in water) in character. The solid particles lie in contact one with the other, but they are seldom packed as closely together as possible.

The size distribution of primary mineral particles, called soil texture, has a strong influence on the properties of a soil. Particles larger than 2 mm in diameter are considered inert. Little attention is paid to them unless they are boulders that interfere with manipulation of the surface soil. Particles smaller than 2 mm in diameter are divided into three broad categories based on size. Particles of 2 to 0.05 mm diameter are called sand; those of 0.05 to 0.002 mm diameter are silt; and the <0.002 mm particles are clay.

The texture of soils is usually expressed in terms of the percentages of sand, silt, and clay. To avoid quoting exact percentages, 12 textural classes have been defined. Each class, named to identify the size separate or separates having the dominant impact on properties, includes a range in size distribution that is consistent with a rather narrow range in soil behavior. The loam textural class contains soils whose properties are controlled equally by clay, silt and sand separates. Such soils tend to exhibit good balance between large and small pores; thus, movement of water, air and roots is easy and water retention is adequate. Soil texture, a stable and an easily determined soil characteristic, can be estimated by feeling and manipulating a moist sample, or it can be determined accurately by laboratory analysis. Soil horizons are sometimes separated on the basis of differences in texture.

2.3.1 Particle Size Distribution

Civil engineers describe and classify soils according to the particle size, rather than according to their age, origin or mineralogy (William Powrie, 1997). Different particle sizing techniques may produce different results depending upon the properties of the particles being measured.

Methods such as sedimentation and cascade impaction are based on the surface area of the particles and will vary with roughness and shape. Sieving measures the smaller dimensions of a sample, therefore rod-shaped particles will be difficult to measure accurately. Suitable particle sizing must consider the volume of the particle being measured.

There are several methods to determine Particle Size Distribution which is called sieve analysis, hydrometer and laser particle analyzer. Furthermore, Particle size distribution is used for the prediction of soil hydraulic properties (Bloeman, 1980; Arya and Paris, 1981).

The standard analysis of particle size distribution involves the dispersion of mineral particles after destroying the organic matter (D.L Rowell, 1994). The size classes are the separated using sieves and by sedimentation and the mass in each particles class is determined. The method also serves separates the different size fraction for observation and analysis. The effects of sedimentation on the separation of soil particles in a field situation can be seen where soil has been puddle by cattle or machinery during a wet period around a drinking trough or in a gateway. After this disturbance the sand settles quickly followed by silt and the clay to form a layered skin when the soil subsequently dries out (Reith J.W.S, 1962).

2.3.2 Soil consistency

A system called Atterberg Limits is used to describe the Liquid Limits (LL), Plastics Limit (PL), and Shrinkage Limit (SL) of a soil. According to this system as water is added to a dry soil, the soil changes from solid to semi-solid to plastic to liquid. (Das, B.M., 2002)

The moisture content in the soil at the threshold between semi-solid and plastic is called the plastic limit. The moisture content in the soil at the threshold between plastic and liquid is called the liquid limit. Liquid limit is determined by forming a groove in a dish of soil and impacting the dish until the groove closes. The test is done following the ASTM procedure D-4318. The plastic limit is determined by rolling a thread of soil on a glass plate until the 1/8-inch-diameter thread begins to crumble. This technique is also explained in ASTM procedure D-4318. A large liquid limit indicates high compressibility and high shrinks swell tendencies. Subtracting the plastic limit from the liquid limit yields the plasticity index. A large plasticity index indicates low shear strength. (Das, B.M., 2002)

2.3.3 Soil classification

Soil classification deals with the systematic categorization of soils based on distinguishing characteristics as well as criteria that dictate choices in use (Braja.M.Das). Soil is classified into different groups or categories so that relationships are better understood between different soils. The different groupings help determine the usefulness of any soil for any particular use. Soil classification is the separation of soil into classes or groups each having similar characteristics and potentially similar behavior. A classification for engineering purposes should be based mainly on mechanical properties, for example; permeability, stiffness, strength. The class to which a soil belongs can be used in its description.

One of the first classification systems was developed by the Russian scientist Dokuchaev around 1880, it was modified a number of times by American and European researches and developed into the system commonly used until the 1960's.

It was based on the idea that soils have a particular morphology based on the materials and factors that form them. In the 1960's a different classification system began to emerge that stressed just soil morphology and relied less on soil parental materials and soil forming factors. Since then it has undergone further modifications.

The two most widely used classification systems are the American Association of State Highway and Transportation Officials (AASHTO) and the Unified Soil Classification System (USCS).

2.4 British Soil Classification System (BSCS).

The soil classification is one of the important data that need in the soil mechanics and geotechnical engineering. Soil Classification Systems have been developed to provide scientists and resource managers with generalized information about the nature of a soil found in a particular location.

In general, environments that share comparable soil forming factors produce similar types of soils. This phenomenon makes classification possible. Numerous classification systems are in use worldwide. There are many projects from all over the world doing research and experiment to classify the soil type. Different soils with similar properties may be classified into groups and sub-groups according to their engineering behavior (Rodrigo Salgado, 2008).

The soil classification that broadly used are such as AASHTO classification system, the Unified Soil Classification System and soil classification based on British Soil Classification System (BSCS). The Unified Soil Classification System (ASTM 2004: Designation D-2487) classifies soils based on their grain size distribution curves and their Atterberg limits. The system uses the symbol W for well-graded gravel, SP means poorly graded sand, and so on.

Again, to determine the exact designation of a soil using the Unified Soil Classification System, the curve and the Atterberg limit. In this project the British Soil Classification System for Engineering purposes will be use.

The British Soil Classification System (BSCS) which was introduced in the British Standard Code of Practice for Site Investigations, BS 5930:1981 is reviewed. An account is given of the development of the BSCS from the previous British system of CP 2001; the reasons for changes are explained, and comparison is made with similar systems in use in America, France, Germany, Switzerland, and Japan. New features of the system are that it is metricated, its groups are fully defined, description of the grading of coarse materials is improved, fuller description is possible of coarse soils containing an appreciable proportion of fines and of fine soils containing an appreciable proportion of gravel or sand, the classification of fine soils is extended to provide for materials of very high and extremely high plasticity, the presence of organic matter can be indicated in any type of soil, and materials containing boulders and cobbles can be classified (Dumbleton, M. J, 2007).

With reference to BS 5930:1981, 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 425 µm BS sieve. This may be done on the basis of estimation (field or rapid method) or from laboratory tests (full laboratory procedure) described in BS 5930:1981.

Besides that, according to this classification, soil can be divided into three major group that are course soil, fine soil and organic or peat soil. For more detailed classification, the groups may be divided into sub-groups on the basis of laboratory tests. The classification is carried out on material nominally finer than 60mm (passing a 63mm test sieve complying with the requirements of BS 410).

The names and descriptive letters for grading and plasticity characteristics are shown in Table 2.1. In Table 2.2, it is showed how the soil groups are formed from combinations of the ranges of characteristics, and gives both the names of the groups and the symbols which may be used for them. In the group symbol, the letter describing the dominant size fraction is placed first, e.g. CS, sandy CLAY; SC, very clayey SAND; S-C (spoker S' dash C'), clayey SAND. Any group may be qualified as 'organic' if organic matter is a significant constituent, in which case the letter 'O' is sufficed to the group symbol, e.g. CHO, organic CLAY of high plasticity; CHSO, organic sandy CLAY of high plasticity. The most important group of organic soil, however, is that plotting below the A-line, MO, and comprising most M-soil of high liquid limit and above.

Classification may be carried out to a lesser or greater degree of sub-division, according to requirements. When the field or rapid method is used, only the main soil groups need be identified. The particle-size distribution of the soil may be plotted on a grading chart as shown in Appendix A. This will assist in designating soil as well or poorly-graded, and, if poorly graded, whether uniform or gap-grad.

Table 2.1: Names and descriptive letters for grading and plasticity characteristics (BS 5930: 1981)

		Descriptive name	Letter
Coarse components	Main terms	GRAVEL	G
		SAND	S
	Qualifying terms	Well graded	W
		Poorly graded	P
		Uniform	Pu
		Gap graded	Pg
Fine components	Main terms	FINE SOIL, FINES May be differentiated into M or C	F
		SILT (M-SOIL) Plots below A-line of plasticity chart of figure 31 (of restricted plastic range)	M
		CLAY Plots above A-line (fully plastic)	C
	Qualifying terms	Of low plasticity	L
		Of intermediate plasticity	I
		Oh high plasticity	H
		Of very high plasticity	V
		Of extremely high plasticity	E
		Of upper plasticity range * incorporating groups I, H, V and E	U
Organic components	Main term	PEAT	Pt
	Qualifying term	Organic (may be suffixed to any group)	O

* This term is a useful guide when it is not possible or not required to designate the range of liquid limit more closely, e.g. during the rapid assessment of soils.

Table 2.2 (a): British Soil Classification System for Engineering Purposes
(BS 5930: 1981)

Soil groups (see note 1)			Subgroups and laboratory identification			
GRAVEL and SAND may be qualified Sandy GRAVEL and Gravelly SAND, etc. where appropriate			Group symbol (see notes 2&3)	Subgroup symbol (see note 2)	Fines (% < 0.06 mm)	Liquid limit %
SOARSE SOILS less than 35% of the materials is finer than 0.06 mm	GRAVELS More than 50% of coarse materials is of gravel size (coarser than 2 mm)	Slightly silty or clayey GRAVEL	GW	GW	0	
			G		To	
			GP	GPu GPg	5	
		Silty GRAVEL	G-M	GWM GPM	5	
			G-F		To	
		Clayey GRAVEL	G-C	GWC GPC	15	
		Very silty GRAVEL	GM	GMS, etc		
			GF		15	
		Very clayey GRAVEL	GC	GCL	To	
				GCI	35	
				GCH		
				GCV		
				GCE		
	SANDS More than 50% of coarse materials is of sand size (finer than 2 mm)	Slightly silty or clayey SAND	SW	SW	0	
			S		To	
			SP	SPu SPg	5	
		Silty SAND	S-M	SWM SPM	5	
			S-F		To	
		Clayey SAND	S-C	SWC SPC	15	
		Very silty SAND	SM	SML, etc		
			SF		15	
		Very clayey SAND	SC	SCL	To	
				SCI	35	
				SCH		
				SCV		
				SCE		

Table 2.2 (b): continued

Subgroups and laboratory identification			
Group symbol (see notes 2&3)	Subgroup symbol (see note 2)	Fines (% < 0.06 mm)	Name
GW	GW	0	Well graded GRAVEL
G		To	
GP	GPu GPg	5	Poorly grded/Uniform/Gap graded GRAVEL
G-M	GWM GPM	5	Well graded/Poorly graded silty GRAVEL
G-F		To	
G-C	GWC GPC	15	Well graded/Poorly graded clayey GRAVEL
GM	GMS, etc		Very silty GRAVEL; subdivide as for GC
GF		15	
GC	GCL	To	Very clayey GRAVEL (clay of low,
	GCI	35	intermediate,
	GCH		high,
	GCV		very high,
	GCE		extremely high plasticity)
SW	SW	0	Well graded SAND
S		To	
SP	SPu SPg	5	Poorly graded/Uniform/Gap graded SAND
S-M	SWM SPM	5	Well graded/Poorly graded silty SAND
S-F		To	
S-C	SWC SPC	15	Well graded/Poorly graded clayey SAND
SM	SML, etc		Very silty SAND; subdivided as for SC
SF		15	
SC	SCL	To	Very clayey SAND (clay of low,
	SCI	35	intermediate,
	SCH		high,
	SCV		very high,
	SCE		extremely high plasticity)

Table 2.2 (c): continued

Soil groups (see note 1)			Subgroups and laboratory identification			
GRAVEL and SAND may be qualified Sandy GRAVEL and Gravelly SAND, etc. where appropriate			Group symbol (see notes 2&3)	Subgroup symbol (see note 2)	Fines (% < 0.06 mm)	Liquid limit %
FINE SOILS more than 35% of the materials is finer than 0.06 mm	Gravelly or sandy SILTS and CLAYS 35% to 65% fines	Gravelly SILT	MG	MLG, etc		
			FG			
		Gravelly CLAY (see note 4)	CG	CLG		35
				CIG		35 to 50
				CHG		50 to 70
				CVG		70 to 90
				CEG		> 90
	SILTS and CLAYS 65% to 100% fines	Sandy SILT (see note 4)	MS	MLS, etc		
			FS			
		Sandy CLAY	CS	CLS, etc		
		SILT (M-SOIL)	M	ML, etc		
			F			
		CLAY (see note 5 & 6)	C	CL		35
				CI		35 to 50
				CH		50 to 70
				CV		70 to 90
				CE		> 90

Table 2.2 (d): continued

Subgroups and laboratory identification			
Group symbol (see notes 2&3)	Subgroup symbol (see note 2)	Liquid limit %	Name
MG FG	MLG, etc		Gravelly SILT; subdivide as for CG
CG	CLG	35	Gravelly CLAY of low,
	CIG	35 to 50	intermediate,
	CHG	50 to 70	high,
	CVG	70 to 90	very high,
	CEG	> 90	extremely high plasticity)
MS FS	MLS, etc		Sandy SILT; subdivide as for CG
CS	CLS, etc		Sandy CLAY; subdivide as for CG
M F	ML, etc		SILT; subdivide as for C
C	CL	35	CLAY of low,
	CI	35 to 50	intermediate,
	CH	50 to 70	high,
	CV	70 to 90	very high,
	CE	> 90	extremely high plasticity)

ORGANIC SOILS	Descriptive letter ‘O’ suffixed to any group of sub-group symbol	Organic matter suspected to be a significant constituent. Example MHO: Organic SILT of high plasticity
PEAT	Pt	Peat soil consists predominantly of plant remains which may be fibrous or amorphous.

NOTE 1. The name of the soil group should always be given when describing soils, supplemented, if required, by the group symbol, although for some additional applications (e.g. longitudinal sections) it may be convenient to use the group symbol alone

NOTE 2. The group symbol or sub-group symbol should be placed in brackets if laboratory methods have not been used for identification, e.g. (GC)

NOTE 3. The designation FINE SOIL or FINES, F, may be used in place of SILT, M, or CLAY, C, when it is not possible or not required to distinguish between them.

NOTE 4. GRAVELLY if more than 50% of coarse materialis of gravel size. SANDY if more than 50% of coarse material is of sand size.

NOTE 5. SILT (M-SOIL), M, is material plotting below the A-line, and has a restricted plastic range in relain to its liquid limit, and relatively low cohesion. Fine soils of this type include clean silt-sized materials and rock flour, micaceous and idatomaceaous soils, pumice, and volcanic soils, and soils containing halloysite. The alternative term ‘M-soil’ avoids confusion with materials of predominantly silt size, which form only a part of the group.

Organic soils also usually plot below the A-line on the plasticity chart, when they are designated ORGANIC SILT, MO.

NOTE 6. CLAY, C, is material plotting above the A-line, and is fully plastic in relation to its liquid limit.(BS 5930:1981)

2.5 Laser particle analyzer

Laser particle analyzer are used by adding sample to the circle pool, then the results will be obtained just after running the test. Moreover, its software system is more powerful and flexible, and makes this laser particle size analyzer highly automatic, much more convenient to use and performance better.

It adopts imported semiconductor lasers of power, long life and good monochrome; using specially designed large-size high-sensitivity photo detector array by large-scale integrated circuit manufacturing process; sample feeding using centrifugal pumps and micro-sample pool. It adopts Milosevic (Mie) Theory and the free distribution model as the data-processing methods. High-precision data transmission and processing circuitry and a series of advanced technologies and manufacturing processes are adopted to ensure the equipment accurate and reliable, high test speed, good repeatability, easy operation and so on.

The set of particle size analyzer integrates laser technology, computer technology and photonics technology, is particularly suitable to be used by colleges and universities, research institutes and laboratory of large enterprise.

2.5.1 Laser particle analyzer invention and theory

The present invention provides a particle-size distribution measuring apparatus and method for suspending a sample containing particles in a fluid and introducing the sample into a sample cell. The sample cell is then illuminated with a light, such as laser beams, and the diffracted laser beams or light from the particles are then appropriately measured at positions around the sample cell. The specific particle-size and distribution of particles are then computed and can be provided in the form of a plurality of graphs over a predetermined time period. This graph information can then be visually displayed so that the graphs are juxtapositionedly arranged to enable an observer to distinguish between variations in adjacent graphs. In this regard, a video display can create a simulated three-dimensional display on the screen for particle-size being a first coordinate, distribution percentage or rate being a second coordinate and time being a third coordinate.

The observer can then monitor the stacked or progressive array of graphs and determine when the system is stable enough to commence meaningful measurements. Thus, the measurement cycle will start at a point of time when no change is perceived between the stacked series of particle-size distribution graphs and it is assumed that the suspension has arrived at a stationary condition suitable for such measurements.

CHAPTER 3

METHODOLOGY

3.1 Particle Size Distribution Determination

In order to determine the particle size distribution of a soil, two test can be conducted which are sieve analysis & hydrometer test and laser particle analyzer. From this two testing, the percentage of the size can be determined as well as the particle size distribution. The procedures that were carried out in this assessment can be described as below:

i. Sieve Analysis Test
ii. Hydrometer Analysis Test
iii. Plastic Limit (Atterberg Limit) Test
iv. Liquid Limit (Atterberg Limit) Test
v. Laser Particle Analyzer Test

The properties that were tested are described in accordance to BS 1377:part2:1990. Clause 9 for determination of particle size distribution (sieve analysis and hydrometer analysis), BS 1377:part2:1990. Clause 4 for determination of the liquid limit (Cone Penetrometer Method), BS1377:part2:1990. Clause 5 for determination of the plastic limit and plasticity index, and lastly the Fraunhofer theory for Laser Particle Analyzer.

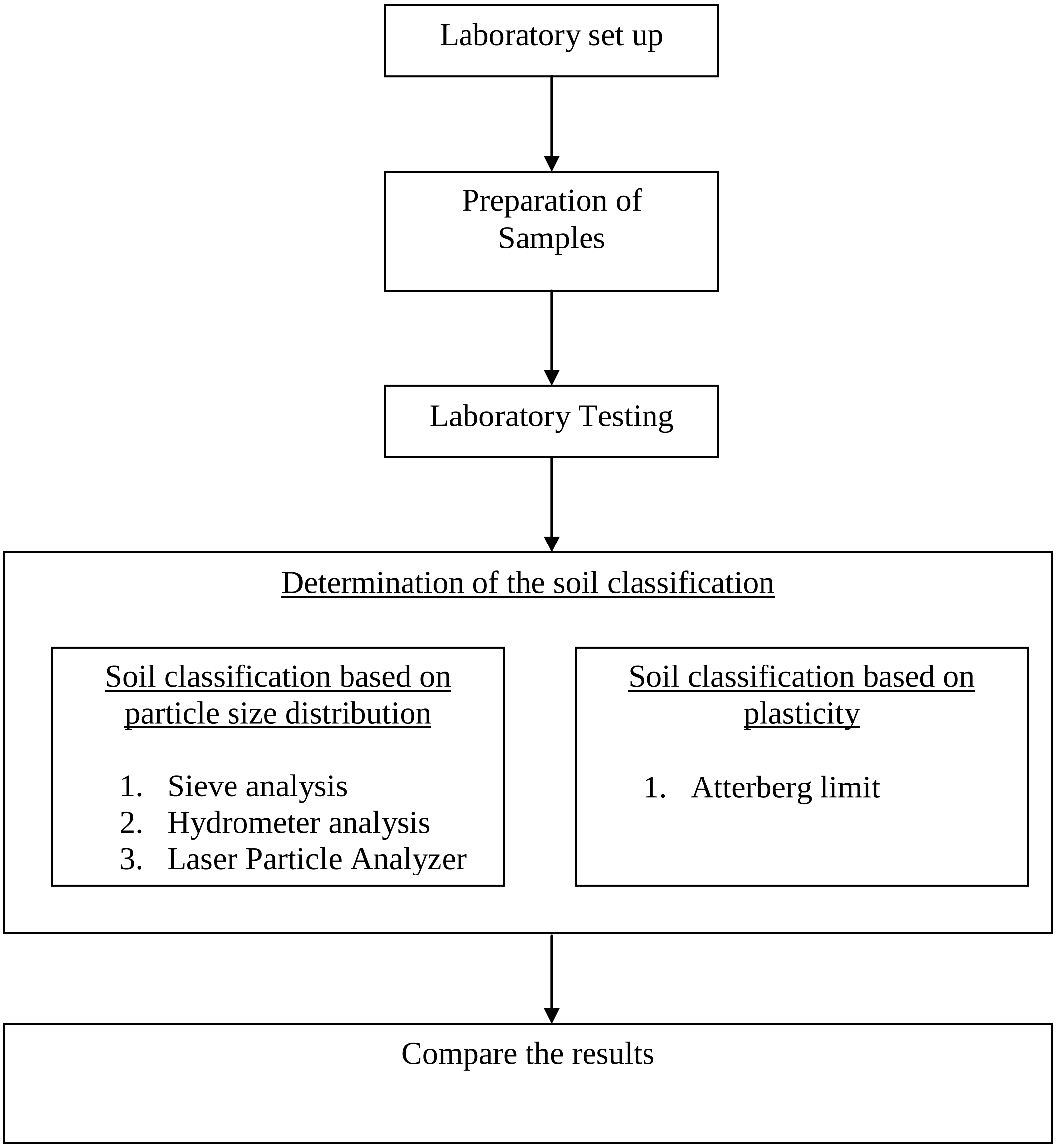

Figure 3.1: Project Methodology Flow Chart

3.2 Material

The material used for laboratory test is residual soil which consists of fine soil and silt soil and clay soil. Fine soil is soil where more than 35% of the materials are finer than 0.06mm. Meanwhile silt soil and clay soil is soil finer than 0.06 mm and soil finer than 0.002mm respectively. There are three soil samples that will be used and each label as sample 1, sample 2, and sample 3. Each sample was taken at Bukit Gambang Resort, SK Gambang and Kelinik Kesihatan Chermai. For initial observation soil sample 1 is brownish in color, gravelly and clayey, soil sample 2 is Yellowish brown in color, residual soil and clayey, and soil sample 3 is dark brown, gravelly and clayey.

Figure 3.1: Soil sample

Figure 3.2: Oven dried for all samples

3.3 Sample Preparation

After the samples have been collected, it has been brought to the laboratory to be tested. In laboratory, before doing the tests, the weight of the sample is taken. This is very important since the percent of each particle size distribution is calculated using the soil mass.

3.4 Laboratory Tests

When designing a soil structure, the particle size distribution of a soil is very important to be determined. There are several methods to determine the particle size distribution of a soil. The method for example sieve analysis & hydrometer and laser particle analyzer will give the information of the soil strata and the percentage of clay, silt or sand of the soil. Other than that, these two methods can also give the information of the soil condition, whether it is homogenous of non-homogeneous.

After the samples have been prepared it has been brought to the laboratory to be tested. In order to analyze the particle distribution of soil sample an extensive laboratory test has been performed throughout the research project. The test included the follows:

a. Sieve analysis
b. Hydrometer testing
c. Laser particle analyzer

3.4.1 Sieve analysis

To know the soil particle size distribution, sieve analysis test is conducted. A sieve analysis test is a procedure to separate fine material from course material by means of a series of woven or perforated surfaces. The proportion of different size particles is recorded. This record is the conclusion of the analysis.

In order to perform the test, a sample of the aggregate must be obtained from the source. To prepare the sample, the aggregate should be mixed thoroughly and be reduced to a suitable size for testing. The total weight of the sample is also required

3.4.1.1 Testing Procedure

A gradation test is performed on a sample of aggregate in a laboratory. A typical sieve analysis involves a nested column of sieves with wire mesh cloth (screen). A representative weighed sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. At the base is a round pan, called the receiver.

The column is typically placed in a mechanical shaker. The shaker shakes the column, usually for some fixed amount of time. After the shaking is complete the material on each sieve is weighed. The weight of the sample of each sieve is then divided by the total weight to give a percentage retained on each sieve. The size of the average particles on each sieve then being analysis to get the cut-point or specific size range captured on screen.

The results of this test are used to describe the properties of the aggregate and to see if it is appropriate for various civil engineering purposes such as selecting the appropriate aggregate for concrete mixes, asphalt mixes, and foundations. The results of this test are provided in graphical form to identify the type of gradation of the aggregate. The complete procedure for this test is outlined in the American Society for Testing and Materials (ASTM) C 136 and the American Association and State Highway and Transportation Officials (AASHTO) T 27.

The results are presented in a graph of percent passing versus the sieve size. On the graph the sieve size scale is logarithmic. To find the percent of aggregate passing through each sieve, first find the percent retained in each sieve. To do so, the following equation is used,

$$\%\text{Retained} = \frac{W_{Sieve}}{W_{Total}} \times 100\%$$

Where W_{Sieve} is the weight of aggregate in the sieve and W_{Total} is the total weight of the aggregate. The next step is to find the cumulative percent of aggregate retained in each sieve. To do so, add up the total amount of aggregate that is retained in each sieve and the amount in the previous sieves. The cumulative percent passing of the aggregate is found by subtracting the percent retained from 100%.

$$\%\text{Cumulative Passing} = 100\% - \%\text{Cumulative Retained}.$$

The values are then plotted on a graph with cumulative percent passing on the y axis and logarithmic sieve size on the x axis

3.4.2 Hydrometer Testing

A hydrometer is an instrument used to measure the specific gravity (or relative density) of liquids; that is, the ratio of the density of the liquid to the density of water. A hydrometer is usually made of glass and consists of a cylindrical stem and a bulb weighted with mercury or lead shot to make it float upright. The liquid to be tested is poured into a tall jar, and the hydrometer is gently lowered into the liquid until it floats freely. The point at which the surface of the liquid touches the stem of the hydrometer is noted. Hydrometers usually contain a paper scale inside the stem, so that the specific gravity can be read directly.

The operation of the hydrometer is based on the Archimedes principle that a solid suspended in a liquid will be buoyed up by a force equal to the weight of the liquid displaced. Thus, the lower the density of the substance, the lower the hydrometer will sink. ASTM committee D 18 developed the ASTM hydrometer specifically for particle size analysis of soils. The Hydrometer Test Set is used to indirectly measure particles smaller than No. 200 present in a suspension at a given time. The stem of the ASTM hydrometer is scaled to read either specific gravity of the suspension (most preferred) or grams per liter of suspension.

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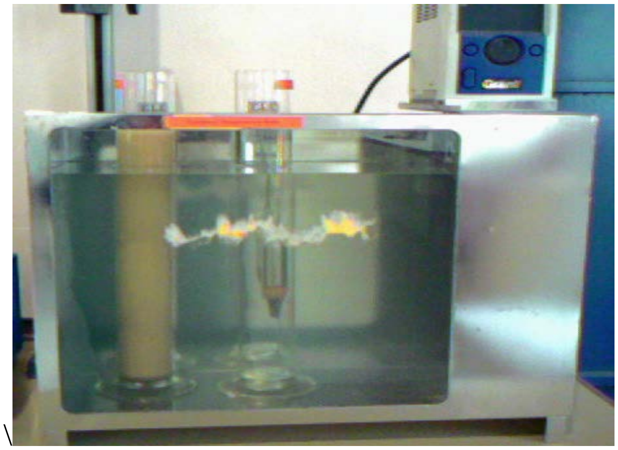

Figure 3.3: Hydrometer analysis

3.4.2.1 Testing Procedures

Firstly, Carried out on material passing the number10 sieve. Then Sample size 115g for sandy soil 65g for silts or clay. Take 15g more and determine moisture content**.**

Prepare a 4% solution of sodium hexametaphosphate (Calgon) is used. (add 40g Calgon in 1000 cc of distilled water and mixing thouroughly).

Determine the composite correction for Hydrometer reading due to specific gravity error by taking a 1000-cc graduate cylinder and adding 875 cc of distilled water plus 125 cc of the dispersing agent in it. Put the hydrometer in the cylinder (from step 6). Record the reading (top of meniscus). This is the zero correction (F_z). Also observe the meniscus correction ($F_m \approx 1$). Record the temperature, T and calculate Temperature correction:

$$F_T = -4.85 + 0.25T \text{ (for T between } 15^o \text{ and } 28^o\text{)}$$

$$\text{Composite correction} = F_z + F_m + F_T$$

For most purposes it has been found that sodium hexametaphosphate (known commercially as Calgon) is one of the most suitable and convenient dispersants. The the stock solution recommended by the British Standard is made up of

33 g sodium hexametaphosphate
7 g sodium carbonate
Distilled water to make 1 litre of solution.

The suspension of pretreated soil passing the 63 µm sieve, obtained as described in stage 1, is transferred from the receiver into a 1000ml sedimentation cylinder without losing any soil. The suspension is made up exactly to the 1000ml mark with distilled water.

The sedimentation cylinder is placed in the constant-temperature bath, and setted at 25°C. The second cylinder containing distilled water then placed in the constant-temperature bath; this is for holding the hydrometer between readings.

Allow the cylinders to stand in the bath until they have reached the bath temperature; about 1hour is usually sufficient. Several sedimentation cylinders (up to six or eight) may be tested at the same time. When all cylinders are in the constant-temperature bath, the water level in the bath should just reach the 1000ml graduation marks.

A rubber bung is inserted into the sedimentation cylinder. This must be pushed in sufficiently to obtain a watertight fit, but undue force must not be applied, as otherwise the glass may split and cause serious injury to the hand. The cylinder is then shaken vigorously to obtain a uniform suspension. The sediment is stirred with a glass rod so that is all goes into suspension. The cylinder is inverted for a few seconds, and is then stood in the constant-temperature bath without delay. As soon as it is in the upright position, the stop-watch is started (zero time, $t = 0$).

1) Hydrometer readings

The rubber bung was removed, and the hydrometer then inserted steadily and allowed to float freely. It must not be allowed to bob up and down, or to rotate, when let go. However, a quick rotational twist with the fingers on the end of the stem will dislodge any air bubbles which may adhere to the side.

Readings of the hydrometer are taken, in the manner described in stage 4, at the top of meniscus level at the following times from zero, 0.5, 1, 2, 4 min. The hydrometer then removed slowly, rinsed in distilled water and placed in the separate cylinder of distilled water in the constant temperature bath.

The hydrometer was inserted for further readings at the following times from zero, and removed and placed it back in the distilled water cylinder after each reading: 8, 15, 30 min;1, 2, 4, 8 hour; overnight (about 16hour); thereafter (if necessary) twice daily. It is not essential to keep rigidly to these times, provided that the actual time of each reading is recorded on the hydrometer test sheet.

Insertion and withdrawal of the hydrometer into the suspension must be done carefully. Each operation should take about 10s, and when released the hydrometer should be in its steady floating position. Disturbance of the suspension, either by the hydrometer or by vibration, must be avoided. If a heater/stirrer unit is fitted to the constant-temperature bath, this must be mounted so that no vibration is transmitted to the sedimentation cylinder.

The temperature of the suspension is checked at intervals, but if a reliable constant-temperature bath is used, there should normally be no significant change in temperature throughout the test. A constant temperature of 25°C is preferable to out of 20°C, partly because it eliminates the necessity of cooling in all but the hottest climates, and also because it is convenient for the reason given in stage (4)

2) Correction of hydrometer readings

Each density reading taken on the hydrometer must first be expressed as a hydrometer reading R_h corresponding to the level of the upper rim of the meniscus. This is done by subtracting 1 from the density and moving the decimal point tree places to the right (i.e. multiply by 1000). For example, a density of 1.0325 would be a hydrometer reading of $R_h = 32.5$

To each reading R_h must now be apply four corrections. As follows:

1. Meniscus correction, C_m
2. Temperature correction, M_t
3. Dispersing agent correction, x
4. Water density correction, C_w.

The first three corrections referred to are explained in the British Standard. The fourth follows form the specification for the calibration of the hydrometer (Head, 1976), but is not explained in the Standard. The way these corrections are obtained is described below.

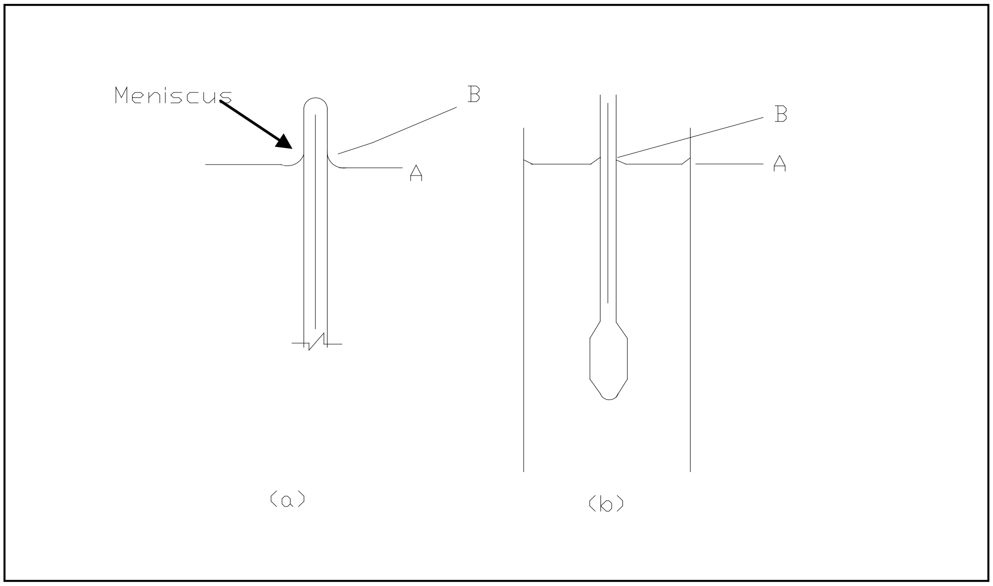

Figure 3.4: Reading a hydrometer

a) Meniscus correction A hydrometer is calibrated to read correctly at the surface of the liquid in which it is immersed (level A in Figure 3.4a). Since soil suspensions are not transparent enough to permit a reading to be taken at this level, the scale has to be read at the upper rim of the meniscus. This is shown at B in Figure 3.4a. It is therefore essential that the meniscus be fully developed, which means that the hydrometer stem must be perfectly clean.

The meniscus correction (C_m) has to be added to R_h in order to obtain the true reading R_h because the density readings on the stem increase downwards. The correction C_m is a constant for a given hydrometer, and is determined as follows.

The hydrometer is inserted in a 1000ml cylinder about three-quarters full of distilled water. The plane of the surface of the liquid is seen as an ellipse from just below the surface. The eye is raised until the surface is seen as a straight line, and the scale marking at which this plane intersects the hydrometer stem is noted (reading A in Figure 3.4b). By looking from just above the plane of the liquid surface, the scale marking at the level of the upper unit of the meniscus is noted (reading B). The difference between the two scale readings, multiplied by 1000, is the meniscus correction:

$$C_m = (B - A) \times 1000 \tag{3.1}$$

For example: if reading A = 0.9985

Reading B = 0.9990

(B - A) = 0.0005

$C_m = + 0.5$

This is a typical value for C_m, but it must be determined for every hydrometer. The true hydrometer reading R_h is given by;

$$R_h = R'_h + C_m \tag{3.2}$$

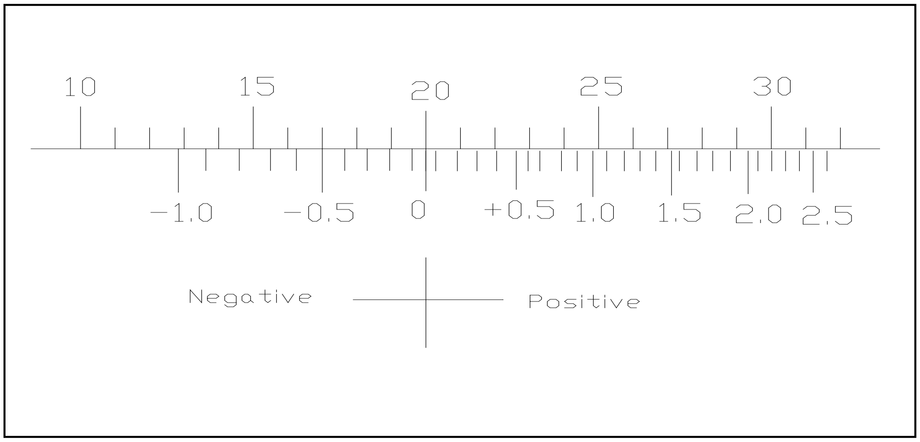

Figure 3.5: Temperature correction chart

b) **Temperature correction** Hydrometers are usually calibrated at 20°C. If a test is carried out at a different temperature, both the density of water and density of the hydrometer lowing the thermal expansion of glass will be different. These factors are allowed for in the temperature correction chart (Figure 3.5).

The value of M_t given on the chart at the appropriate temperature is added to the true hydrometer reading R_h.

Examples:

At 27°C, $M_t = 1.5$; Add 1.5 to R_h

At 17°C, $M_t = -0.5$; Subtract 0.5 from R_h

c) **Dispercing agent correction** The addition of the dispersing agent results in the density of the liquid in which sedimentation takes places being greater than that of water. To determine the correction x, a volume of exactly 50ml of the dispersing agent solution (i.e. the stock solution) is placed in a weighed bottled or evaporating dish. The water is evaporated by drying in the oven at 105-110°C, and the mass of dispersing agent m_dg remaining in the container is determined. The correction x to be applied to R_h is given by

$$x = 2m_d \tag{3.3}$$

The correction is independent of temperature, and is typically 3.5 – 4.0 for the standard dispersing agent. The value should be checked periodically, and always measured if a non-standard dispersant solution is used. The x correction is always subtracted from the R_h value.

d) **Water density correction** The 1975 British Standard specifies that the scale of the hydrometer shall be calibrated in g/ml to read 1000 at 20°C. The density of pure water is exactly 1.000 only at 4°C, at which temperature the density is at its maximum. At higher temperatures it is less than this, as shown in Table 3.1. At 20°C the density is 0.9982, which would correspond to an R_h value on the hydrometer of –1.8. This is the reading which a normal hydrometer shows when immersed in pure water at 20°C, because hydrometers are calibrated to read true density in g/ml. there are as yet no hydrometers available which read exactly as required by the British Standard.

Table 3.1: Viscosity and density of water

Temperature, °C	Dynamic viscosity, η (mPa s)	Density, ρ_w (Mg/m^3)
15	1.1369	0.99909
20	1.0019	0.99820
25	0.8909	0.99704
30	0.7982	0.99565
40	0.6540	0.99222

Table 3.2: Hydrometer reading corrections.

Temperature (°C)	C_m	M_t	C_w	x	Total correction Calculated	Total correction rounded
15	+0.5	- 0.75	+1.8	- 3.5	- 1.95	- 2
20	+0.5	0	+1.8	- 3.5	- 1.20	- 1
25	+0.5	+ .10	+1.8	- 3.5	- 0.2	0
30	+0.5	+2.3	+1.8	- 3.5	+1.1	+ 1

To comply with the standard, therefore, all hydrometer readings must be increased by 1.8 when used at 20°C. At any other temperature the same correction is applied, together with the appropriate M_t correction referred to above.

The fully corrected hydrometer reading R is given by;

$$R = R'_h + C_m + M_t - x + 1.8 \qquad (3.4)$$

The total of the four corrections at different temperatures is given in Table 3.2. This is based on a meniscus correction $C_m = 0.5$ and a dispersant correction $x = 3.5$.

It is interesting to observe that at 25°C the total correction is -0.2, which for most practical purposes may be taken as zero. Thus, at 25°C, provided that the standard dispersant is used, together with a standard hydrometer, the observed top of meniscus readings may be taken to be the same as the fully corrected readings R. This is one advantage of conducting the test at 25°C as the standard constant temperature.

As explained in stage (5), the fully corrected reading R is used only for calculation of percentages of particles smaller than a given size. The value of $R_h = R'_h + C_m$ (i.e. meniscus correction only) is used at all temperatures for computing the particle diameter D, whether by calculation, by using tables or from the nomographic chart, because here the hydrometer is acting as a measuring rd to determine the effective depth at which the density reading applies.

3) Calculations

a) **Equivalent particle diameter D** The equivalent particle diameter at a known depth and after a certain time interval from the start of sedimentation can be calculated from the following equation;

$$D = 0.005\,531 \sqrt{\frac{\eta H}{(G_S - 1)t}} \qquad (3.5)$$

Where D = equivalent particle diameter (mm); η = viscosity of water at test temperature (mPas); H = effective depth (mm); Gs = specific gravity of particles; t = elapsed time (min). Values of η at various temperatures are given in Table 3.1.

This equation can be solved without tedious repetitive calculations by using the nomographic chart, devised by casagrande (1931), which is shown here in Appendix C.

Before the chart can be used, the calibration of the hydrometer used for the test must be added. This consists of a scale of R_h values corresponding to the printed H_r figures at the extreme right-hand side of the chart. The procedure is described in Stage 7.

The nomograph chart is used as follows. The procedure is illustrated by the skeleton diagram in Figure 3.6.

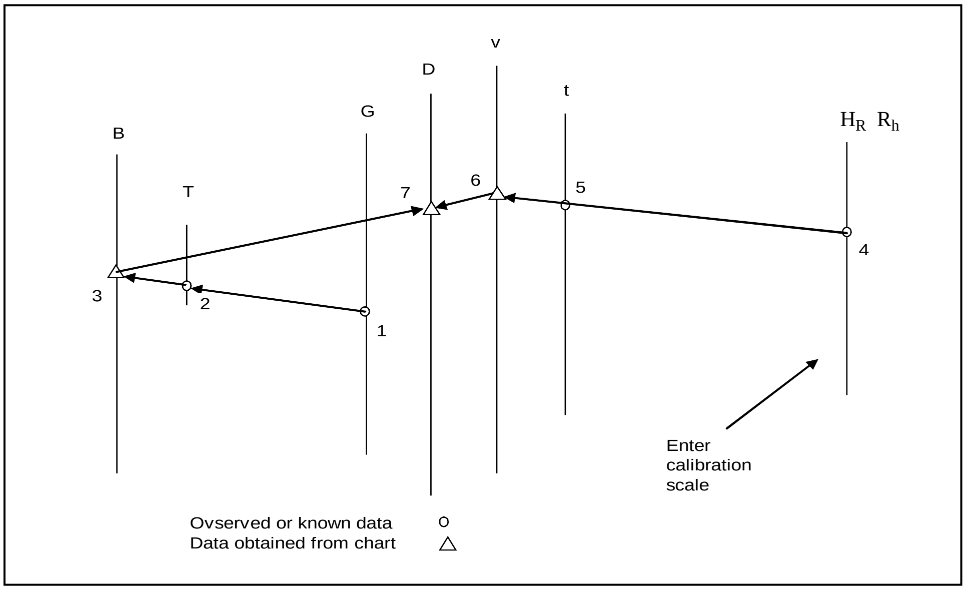

Figure 3.6: Use of nomographic chart

Find the specific gravity of the soil particles on the Gs scale (1), and the test temperature on the T scale (2). Place a straight-edge between them and extrapolate the line to intersect the B scale at (3). Find the corrected hydrometer reading on the Rh scale for the particular hydrometer (4), using Rh = R'h + Cm. find the time at which that reading was taken on the t scale (5). Place a straight-edge between (3) and (6) and read off the diameter where this line intersects the D scale at (7). This is the particle diameter relevant to the hydrometer reading.

The nomograph chart was devised before the days of electronic calculators. The advent of programmable computers renders the chart obsolete in many laboratories, since the Stokes Law equation can be solved almost instantaneously with a computer. The hydrometer calibration curve, if linear, can be easily incorporated into the computer program. The percentage calculation (see below) can also be included. It is then necessary to enter only the hydrometer reading and the time in order to obtain immediately the particle size and percentage. If linked to an X-Y plotter, the particle size curve can be drawn automatically.

b) **Percentage smaller than D** The percentage, by mass, of particles smaller than the equivalent diameter, D, is denoted by K. This percentage is equivalent to the percentage passing in sieve analysis. It is given by the equation;

$$K = \frac{G_S}{m\,(G_S - 1)} \times R \times 100\% \qquad (3.6)$$

Where Gs = Specific gravity of soil particles; m = mass of dry soil after pretreatment; R = fully corrected hydrometer reading = $R'_h + C_m + M_t - x + 1.8$

The value of K is calculated for each hydrometer reading, and is plotted against the corresponding particle size, drawn to a logarithmic scale exactly as for a grading curve determined by sieving. The same graph sheet is used, the sizes of particles being extended downwards to about 1µm. Usually, the test is terminated at about 2 µm, which is the lower limit of the silt size range. The intersection of the particle size curve with the 2µm ordinate gives the percentage which is referred to as the ‘clay fraction’.

The significance of the correction for the density of water ($C_m = + 1.8$) becomes clear at the fine end of the scale. In the early stages of the test, when the hydrometer reading R'_h are 20 or more, this correction amounts to less than 10% of the reading used in the calculation. But towards the end the value of R'_h falls to 5 or less, and this correction is then of the same order of magnitude as the reading. Without this correction the derived value of the clay fraction can be seriously underestimated, and could be only half the correct value.

4) Presentation of result

Calculated percentages finer than each determined sizes are plotted against the corresponding particle diameter on the same sheet as the used for a sieving analysis. A smooth curve is drawn through the plotted points.

Details of pretreatment, the size of sample used and the S_G of particles used in the calculations are added to the particle size distribution sheet, together with a visual description of the soil.

7) Calibration of Hydrometer.

The hydrometer must be calibrated in the cylinder in which it si to be used. This is because the cross-sectional area, A, of the cylinder comes into the calibration calculation. In practice, the sectional area varies but little between similar measuring cylinders of one batch; nevertheless each cylinder used should be checked.

To determine the sectional area A, measure the distance, L, in millimeters between two well spaced graduations (such as 100 and 900 ml) on the cylinder. The volume included between these two marks is800 ml, so the sectional area, A, is given by

$$A = [800/L] \times 1000\text{mm}^2 \tag{3.7}$$

The sides of the cylinder must be parallel, so that the sectional area is constant throughout its length.

On the hydrometer itself the distance from the neck of the bulb to the lowest calibration mark is measured, to the nearest millimeter, with a steel ruler. This is denoted by N in Figure 3.7, the distances l_1, l_2, etc., from this calibration mark to each of the other major marks are measured as shown, to the nearest millimeter, and tabulated. The distance H corresponding to each reading R_h is given by $(N+l_1)$, $(N+l_2)$, etc.

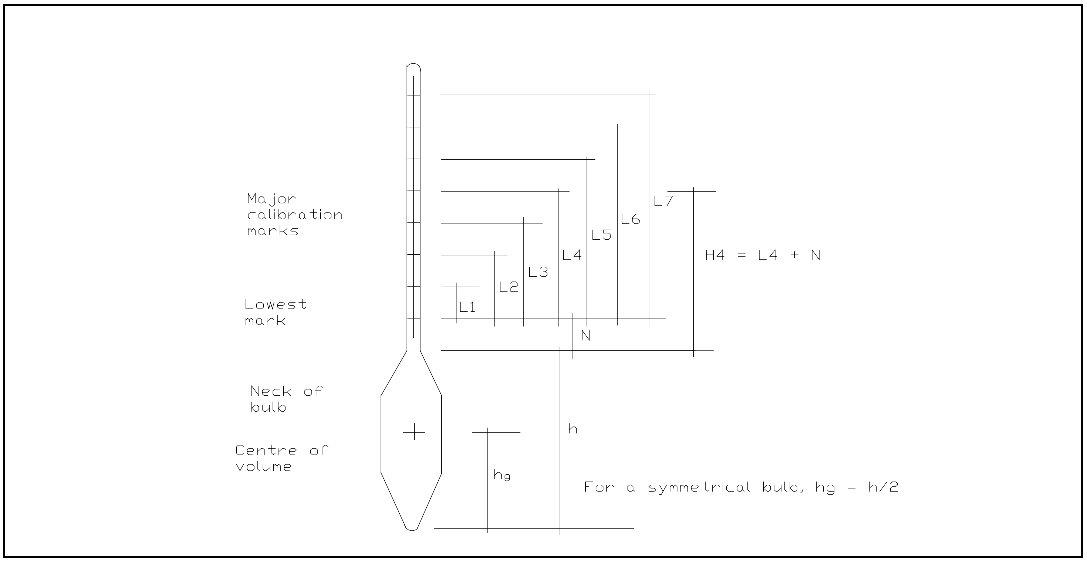

Figure 3.7: Measurement for calibration of hydrometer

The distance from the neck to the bottom of the bulb is measured, in millimeters, and is denoted by h. this measurement can be made either by laying the hydrometer flat on a sheet of paper and projecting down on to the paper using a set-square, or by holding the hydrometer vertically and projecting across with a square to a meter-stick held vertically by a burette stand.

The volume of the hydrometer bulb, V_h, can be measured by weighing the hydrometer to the nearest 0.1 g and equating the mass in grams to its volume in ml. alternatively, the rise in level of water in a 1000ml cylinder, initially filled to the 800ml mark, can be measured. In both methods there is a small error due to the inclusion of the stem or part of it, but this can be neglected for practical purposes.

If the hydrometer bulb is of symmetrical shape, no further measurements are necessary, but if it is not symmetrical, the position of the centre of volume of the bulb must be determined. This can be done with sufficient accuracy by projecting the shape of the bulb on to a sheet of paper and estimating the position of the centre of gravity of the outline the distance of the centre of gravity of the bulb from the bottom is denoted by h_g (Figure 3.9), and for a symmetrical bulb $h_g = ½ h$

The effective depth H_R (mm), corresponding to each major calibration mark R_h, is calculated from the equation

$$H_R = H_1 + h_g - (V_h / 2A) \qquad (3.8)$$

If the hydrometer bulb is symmetrical, this equation becomes;

$$H_R = H_1 + ½ [h- (V_h/A)] \qquad (3.9)$$

Values of H_R are plotted against R_h on ordinary graph paper, and a smooth curve is drawn through the points as shown in Appendix D**.** The curve usually approximates to a straight line over the range used. This relationship takes into account the effective depth of the suspension at the level being considered at a given time, and allows for the rise of liquid in the cylinder due to displacement by the hydrometer.

By measuring the slope of the calibration line, and reading off its intercepts on the H_R axis, the equation of the calibration line can be written in the form

$$H_R = 214 - 4.1\ R_h \qquad (3.10)$$

Which is the equation to the calibration curve shown in Appendix D. This relationship between H_R and R_h can be used in a programmable computer for the calculation of the particle diameter, D, corresponding to each hydrometer reading.

The calibration curve is added to the H_R scale at the extreme right of the nomographic chart as follows. For each of the main hydrometer scale markings (30, 25, 20, etc.) the corresponding value of effective depth Hr is read off from the calibration curve. The R_h value is marked against H_R on the printed scale. Note that the H_R values printed in the British Standard are given in centimeters, and must be multiplied by 10 to express them millimeters. Intermediate values of R_h can be added by subdividing each main division on the scale. This automatically incorporates the hydrometer calibration. If a different hydrometer is used, a new R_h scale must be constructed on the chart.

The R_h scale shown in Appendix C is derived from the calibration curve in Appendix D.

3.4 Atterberg limit test

The condition of a clay soil can be altered by changing the moisture content; the softening of clay by the addition of water is a well-known example. For every clay soil there is a grange of moisture contents within which the clay is of a plastic consistency, and the Atterberg limits provide a means of, measuring and describing the plasticity range in numerical terms.

3.4.1 Liquid limit (Cone penetrometer) test

This is the British standard preferred method for determining the liquid limit of soils. It is based on the measurement of penetration into the soil of a standardized cone of specified mass. At the liquid limit the cone penetration is 20mm. The method was developed at TRRL from various cone tests which have been in use in other countries, and was adopted by the BSI with a few modifications. It requires the same apparatus as is used for bituminous material testing, (BS 4691:1974), but fitted with a special cone.

3.4.1.1 Objective

The objective of this test is to determine the liquid limit of a soil.

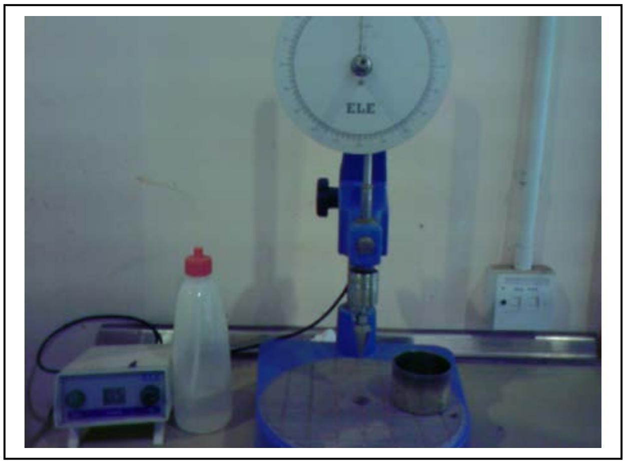

Figure 3.8: Cone penetrometer method

3.4.1.2 Apparatus

Cone penetrometer, flat glass plate, metal cups, spatula, moisture content tins, and distilled water.

3.4.1.3 Procedure

The apparatus was checked so that the mass of falling cone assembly to ± 0.1 g, stem falls freely when released and the tip of cone can be felt through gauge when brushed with finger.

The soil is mixed (paste with the spatulas for at least 10 minutes, distilled water must be added in successive stages to give a cone penetration of about 15 mm and mix well in. Thorough mixing and kneading is the most important feature of the test and must never be overlooked. Then, the soil paste was pressed against the side of the cup to avoid trapping air. More paste well is pressed into the bottom of the cup without an air pocket. The small spatula is convenient for these operations. The top surface is finally smoothed off level with the rim using the straight edge.

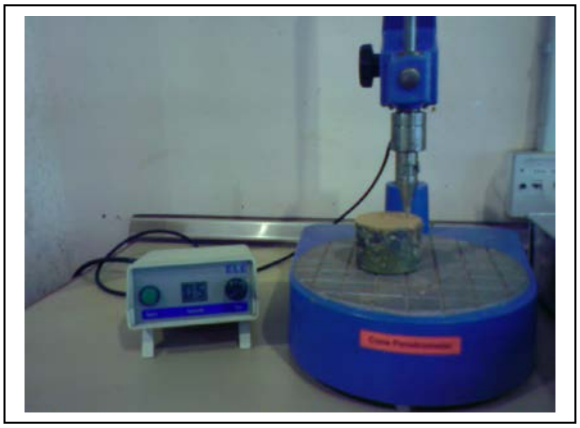

Figure 3.9: Soil sample before penetration.

The tip of the cone is adjusted with a few millimeters of the surface of the soil in the cup (Figure 3.9). The cone was holed, the release button was pressed and the height of the cone was adjusted so that the tip just touches the soil surface. The stem of the dial gauge is lowered to make contact with the top of the cone shaft. The reading of the dial gauge then recorded to the nearest 0.1 mm (R_1). Alternatively if the pointer is mounted on a friction sleeve, adjust the pointer to read zero (i.e. $R_1 = 0$).

The timer is sated to 5second, the button is pressed and the pointer is released immediately. Automatic re-locking of the stem is indicated by a click. The apparatus must remain steady and must not be jerked. The dial reading is recorded to the nearest 0.1 mm (R_2). The difference between R_1 and R_2 was recorded as the cone penetration. If the pointer was initially set to read zero, the reading R_2 gives the cone penetration directly.

The cone then lifted out and cleaned carefully. Avoid touching the sliding stem. A little more wet soil is added to the cup, without entrapping air, smooth off and the procedure (5), (6) and (7) is repeated. Two consecutive penetrations should be within 0.5 mm or three within 1 mm. A moisture content sample of about 10 g was taken from the area penetrated by the cone, using the tip of a small spatula. Placed in a numbered moisture content container, which is weighed, oven dried and weighed as in the standard moisture content procedures.

The soil remaining in the cup is remixed with the rest of the sample on the glass plate together with a little more distilled water, until a uniform softer consistency is obtained. Penetration range of the soil sample should be within 15 – 25 mm. Repeat the procedure (3) – (10) with different volume of water to get at least 4 points evenly spaced.

The moisture content of the soil from each penetration reading is calculated from the wet and dry weighing as in the moisture content test. Each cone penetration (mm) is plotted as ordinate, against the corresponding moisture content (%) as abscissa, both to linear scales. The best straight line fitting these points is drawn.

From the graph, the moisture content corresponding to a cone penetration of 20 mm is read off to the nearest 0.1%. The result is reported to the nearest whole number as the liquid limit (cone test).

3.4.2 Plastic limit test

This test is to determine the lowest moisture content at which the soil is plastic. It can be carried out only on soils with some cohesion, on the fraction passing a 425µm sieve. The test may be carried out either on soil in its natural state or on air-dried soil which has been remixed with water. The test is usually carried out in conjunction with the liquid limit test.

3.4.2.1 Objective

The objective of this test is to determine the plastic limit of a soil.

Figure 3.10: Plastic limit test.

3.4.2.2 Apparatus

Glass plate, a separate glass plate for rolling of threads, spatulas, and moisture content apparatus.

3.4.2.3 Procedure

About 20 g of the prepared soil paste was taken and spread on glass mixing plate so that it can partially dry. Mix occasionally to avoid local drying out. When the soil is plastic enough, it is well kneaded and then shaped into a ball. The ball is molded between the fingers and rolled between the palms of the hands so that the warmth of the hands slowly dries it.

When slight cracks begin to appear on the surface, the ball is divided into two portions each of about 10 g. Further, each ball divided into four equal parts, but kept each set of four parts together. One of the parts is kneaded by the fingers to equalize the distribution of moisture, and then formed into a thread about 6 mm diameter, using the first finger and thumb of each hand.

The thread then rolled between the fingers of one hand and the surface of the glass plate by uniform pressure. The pressure should reduce the diameter of the thread from 6 mm to about 3 mm after between five and ten back-and-forth movements of the hand. Noted that it is important to maintain a uniform rolling pressure throughout; do not reduce pressure as the thread approaches 3 mm diameter.

The soil further dried by moulding between the fingers again, not by continued rolling which gives a dried crust. From it into a thread and roll out again as before, this procedure is repeated until the thread crumbles when it has been rolled to 3 mm diameter. Crumbling of the thread include falling apart in small pieces; breaking into a number of short pieces tapered towards the ends; longitudinal splitting from the ends towards the middle and then falling apart. Crumbling must be the result of the decreasing moisture content only and not due to mechanical breakdown caused by excessive pressure, or oblique rolling or detachment of an excessive length beyond the width of the hand.

As soon as the crumbling stage is reached, the crumbled threads were gathered and placed into a weighed moisture content container. The lid is replaced immediately. Procedure (4) – (8) then repeated for the other pieces of soil, and placed in the same container. The container and soil is weighed as soon as possible, dried in the oven overnight, cooled and weighed dry, as in the standard moisture content procedure.

Procedure (4) – (9) is repeated on the other set of four portions of the soil, and a second moisture content container is used. The moisture content of the soil in each of the two containers was calculated. The average of the two results was taken. If they differ by more than 0.5% moisture content, the test should be repeated. The average moisture content referred to above is expressed to the nearest whole number and reported as the plastic limit (w_1) of the soil. The method of preparation of the soil is reported, and so is the percentage of material passing the 425 μm sieve if it was sieved. The result is usually reported on the same sheet as the liquid limit test.

The difference between the liquid limit and the plastic limit is calculated to give the plasticity index (PI) of the soil:

$$PI = LL - PL \qquad (3.11)$$

This value is also reported to the nearest whole number. If it is not possible to perform the plastic limit test, the soil is reported as non-plastic (NP). This also applies if the plastic limit is equal to or greater than the liquid limit: the latter can occur in some soils with high mica content (**Tubey and Webster, 1978**).

3.4.3 Laser particle analyzer

Laser diffraction based particle size analysis relies on the fact that particles passing through a laser beam will scatter light at an angle that is directly related to their size. As particle size decreases, the observed scattering angle increases logarithmically. Scattering intensity is also dependent on particle size, diminishing with particle volume. Large particles therefore scatter light at narrow angles with high intensity whereas small particles scatter at wider angles but with low intensity.

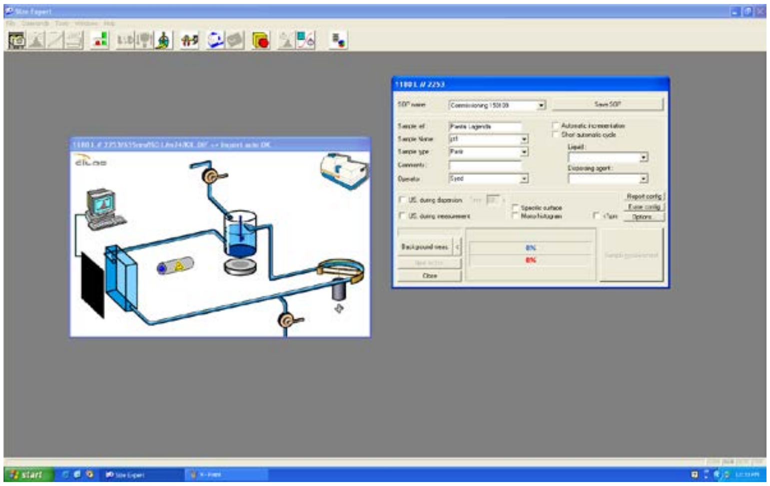

Figure 3.11: Key in the basic data

3.4.3.1 Testing Procedure

It is this behavior that instruments based on the technique of laser diffraction exploit in order to determine particle size. A typical system consists of a laser, to provide a source of coherent, intense light of fixed wavelength; a series of detectors to measure the light pattern produced over a wide range of angles; and some kind of sample presentation system to ensure that material under test passes through the laser beam as a homogeneous stream of particles in a known, reproducible state of dispersion. The dynamic range of the measurement is directly related to the angular range of the scattering measurement, with modern instruments making measurements from around 0.02 degrees through to beyond 140 degrees. The wavelength of light used for the measurements is also important, with smaller wavelengths (e.g. blue light sources) providing improved sensitivity to sub-micron particles.

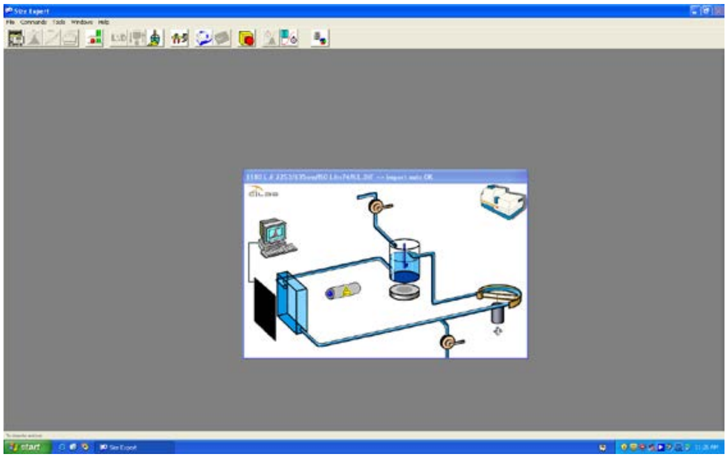

Figure 3.12: First phase in the particle sizer

3.5 Particle Size Calculations

In laser diffraction, particle size distributions are calculated by comparing a sample’s scattering pattern with an appropriate optical model. Traditionally two different models are used: the Fraunhofer Approximation and Mie Theory.

The Fraunhofer approximation was used in early diffraction instruments. It assumes that the particles being measured are opaque and scatter light at narrow angles. As a result, it is only applicable to large particles and will give an incorrect assessment of the fine particle fraction.

Mie Theory provides a more rigorous solution for the calculation of particle size distributions from light scattering data. It predicts scattering intensities for all particles, small or large, transparent or opaque. Mie Theory allows for primary scattering from the surface of the particle, with the intensity predicted by the refractive index difference between the particle and the dispersion medium. It also predicts the secondary scattering caused by light refraction within the particle – this is especially important for particles below 50 microns in diameter, as stated in the international standard for laser diffraction measurements (ISO13320-1 (1999)).

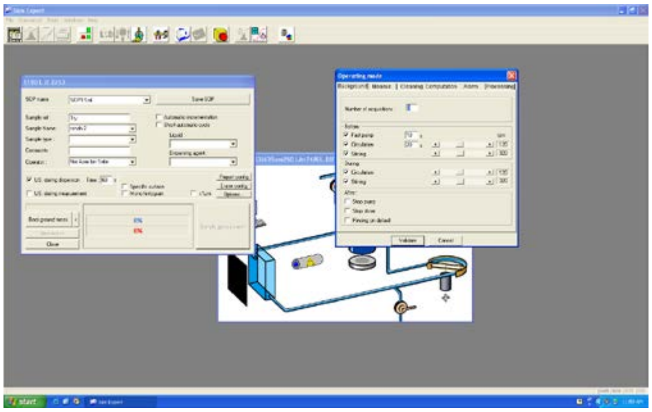

Figure 3.13: The results and graph obtained just after the test

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This chapter will discuss relatively about presented testing and results achieved that can be presented as plotted graph. All the results achieved are presented in this chapter for the analysis and determination of particle size distribution, analysis including comparison between particle size distribution form sieve & hydrometer with laser particle analyzer and the soil classification for each sample. There were three different soils sample have been collected in Kuantan to conducting testing and analysis.

4.2 Particle size distribution (Hydrometer analysis& sieve analysis) results

All the results of particle size distribution are tabulated and presented in Appendix E1. Below are the results for particle size distribution obtained from the hydrometer analysis test and sieve analysis test in accordance to British Standard for soil sample 1, soil sample 2, and soil sample 3.

4.2.1 Results for soil sample 1

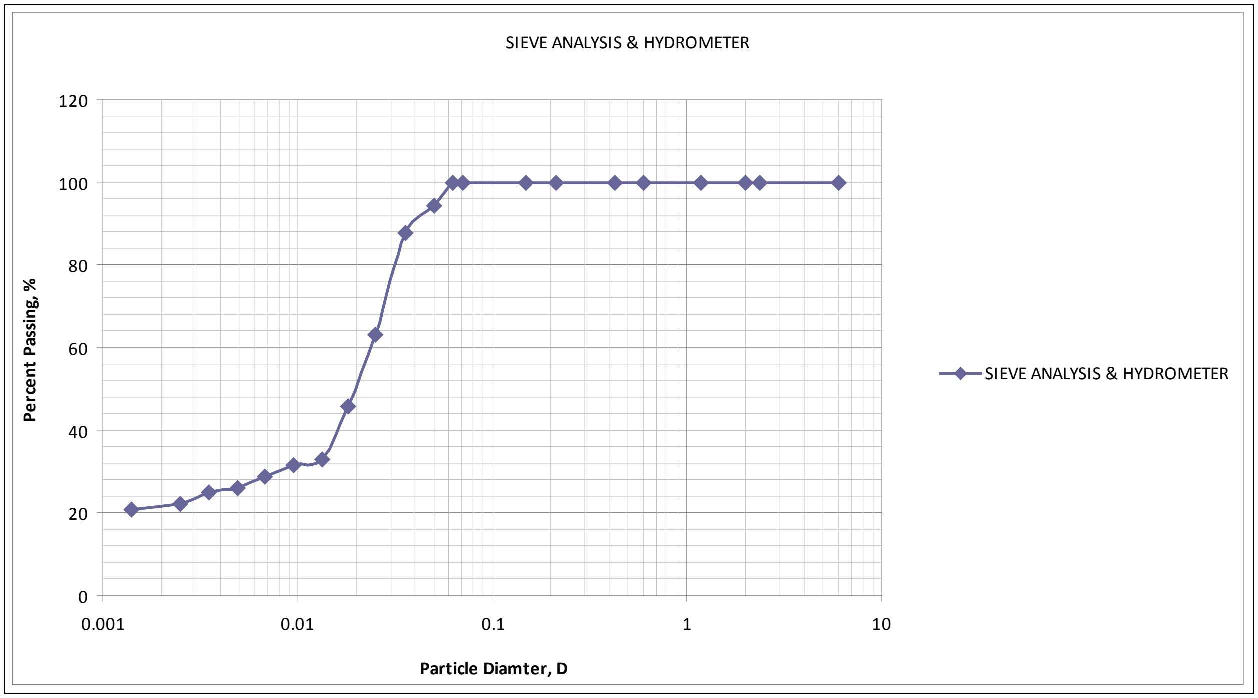

Figure 4.1: Particle size curve from hydrometer test and related sieving for soil sample 1.

Figure 4.1 above showed the percent finer (%) versus Equivalent particle size (mm) for Sieve & Hydrometer analysis test to determine the particle size distribution for sample 1. Based on the graph; it is showed that the percent finer than 0.002 mm is 21%, percent finer than 0.06 mm is 100 %, and percent finer than 2mm is 100%. Besides that, this graph also showed that the percent finer than 0.063 mm is 100 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

4.2.2 Results for soil sample 2

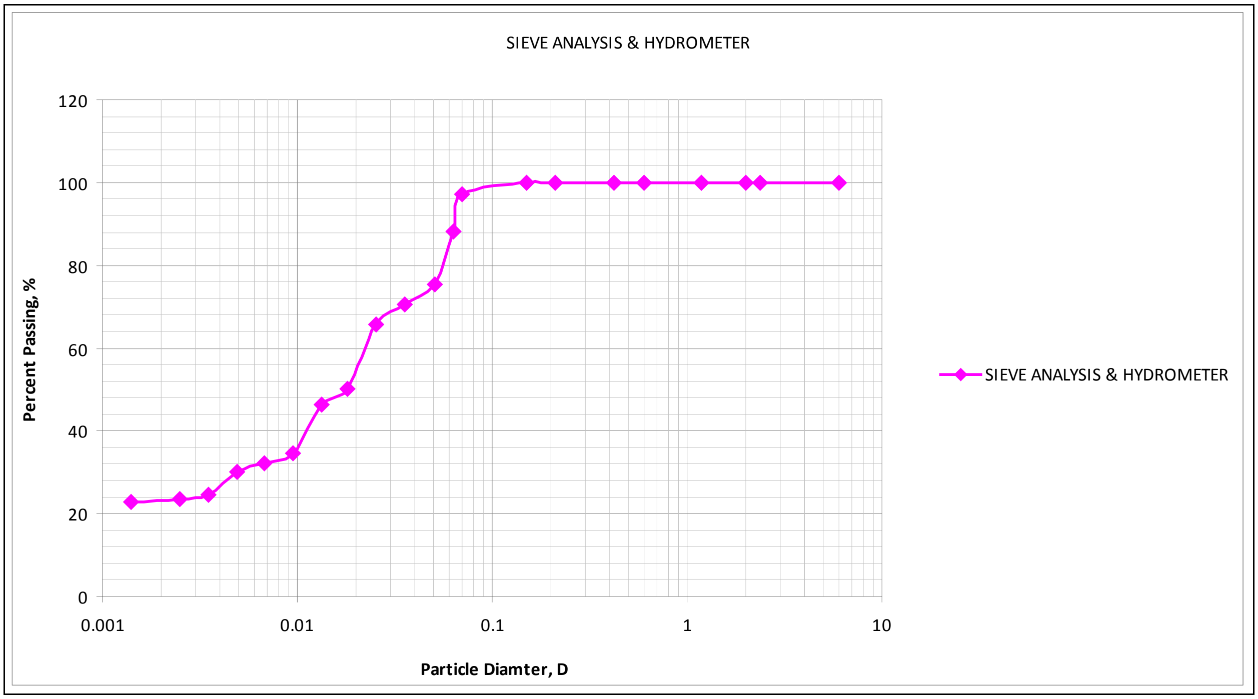

Figure 4.2: Particle size curve from hydrometer test and related sieving for soil sample 2.

Figure 4.2 above showed the percent finer (%) versus Equivalent particle size (mm) for sieve & hydrometer analysis test to determine the particle size distribution for soil sample 2. Based on the graph, it is showed that the percent finer than 0.002 mm is 23 %, percent finer than 0.06 mm is 87 %, and percent finer than 2mm is 100 %. Besides that, this graph also showed that the percent finer than 0.063 mm is 88.05 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

4.2.3 Results for soil sample 3

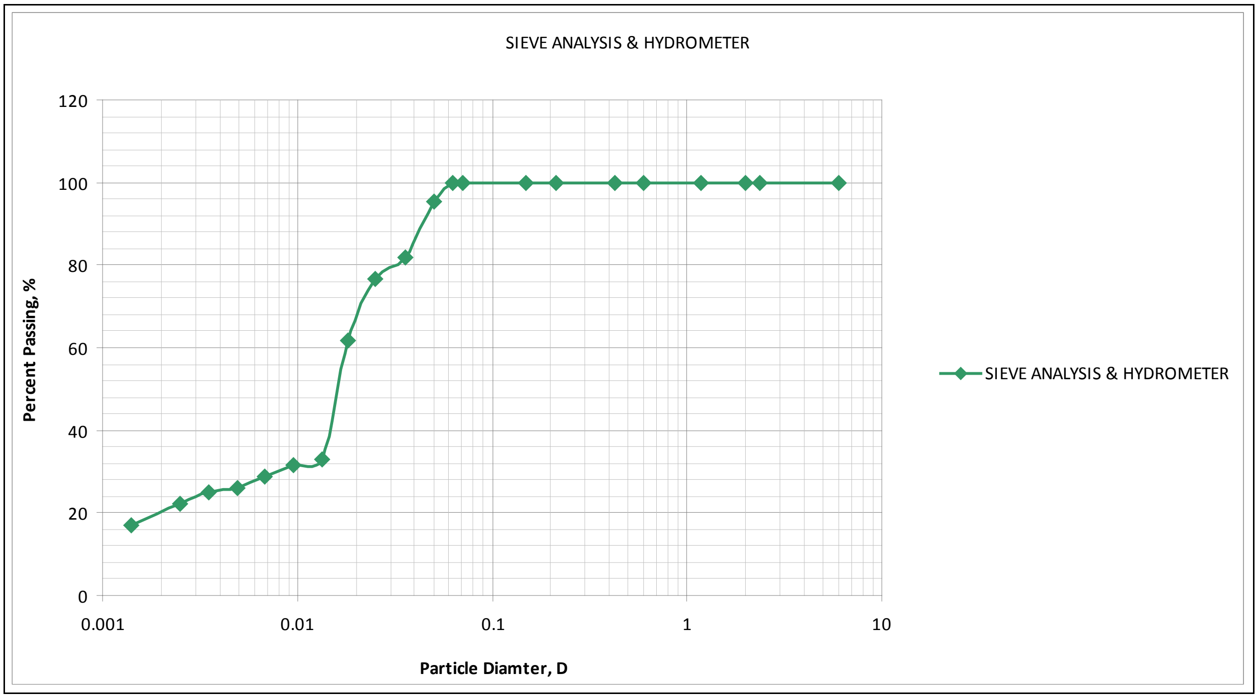

Figure 4.3: Particle size curve from hydrometer test and related sieving for soil sample 3.

Figure 4.3 above showed the percent finer (%) versus Equivalent particle size (mm) for sieve & hydrometer analysis test to determine the particle size distribution for soil sample 3. Based on the graph, it is showed that the percent finer than 0.002 mm is 21.2 %, percent finer than 0.06 mm is 100 %, and percent finer than 2mm is 100 %. Besides that, this graph also showed that the percent finer than 0.063 mm is 100 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

Based on the graph plotted in Figure 4.1, Figure 4.2, and Figure 4.3, it is showed that the percent finer than 0.002 mm for soil sample 1, 2, and 3 is 21%, 23%, and 21.2% respectively. This is followed by percent finer than 0.06 mm that is 100 %, 87 %, and 100 % correspondingly. The percent finer than 2mm for soil sample 1 is 100%, soil sample 2 is 100 %, and soil sample 3 is 100 %. Meanwhile, the percent finer than 0.063 mm is 100 %, 82 %, and 100 % for soil sample 1, 2, and 3 respectively.

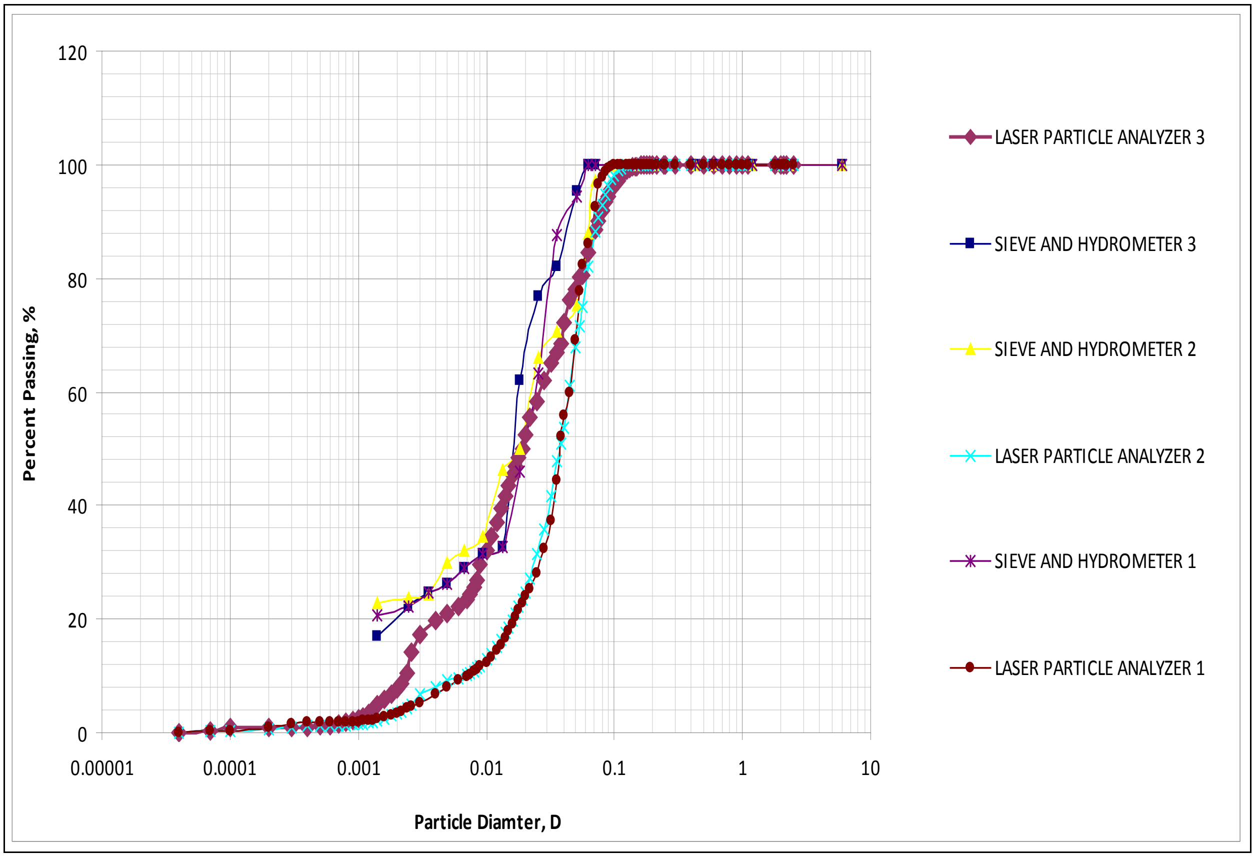

Figure 4.4: All results combined from three different soil samples.

4.3 Laser Particle Analyzer results

All the results of particle size distribution are tabulated and presented in Appendix E2. Below are the results for particle size distribution obtained from the laser particle analyzer test for soil sample 1, soil sample 2, and soil sample 3.

4.3.1 Results for soil samples 1

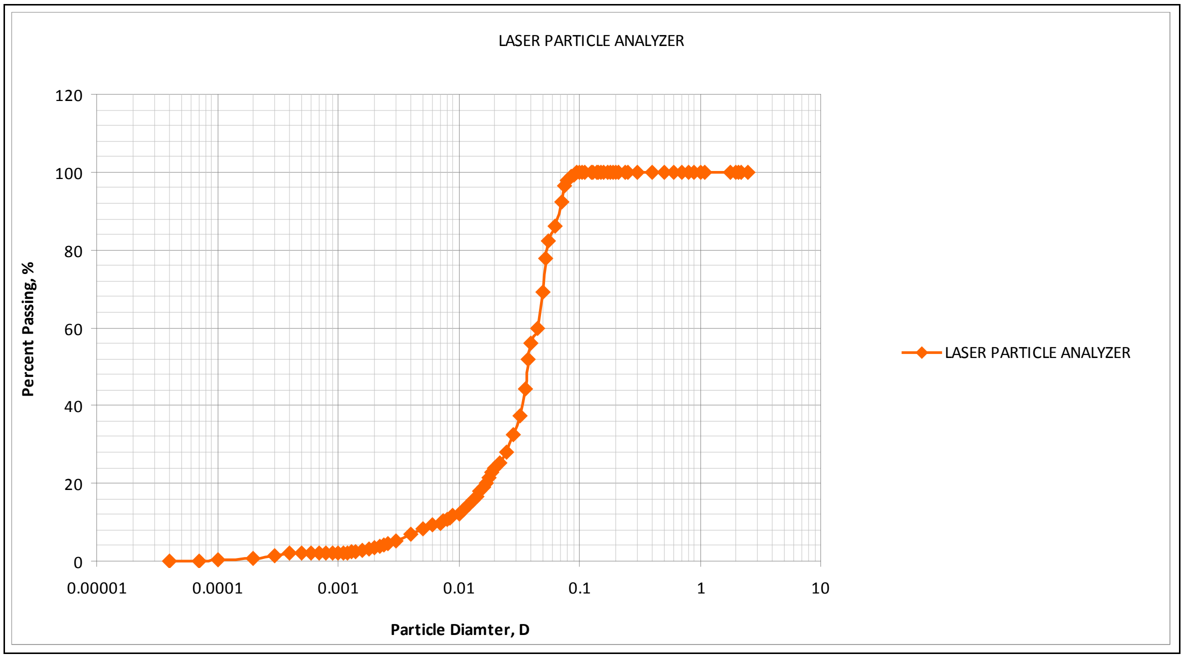

Figure 4.5: Particle size curve from laser particle analyzer for soil sample 1.

Figure 4.5 above showed the percent finer (%) versus Equivalent particle size (mm) for laser particle analysis test to determine the particle size distribution for soil sample 1. Based on the graph, it is showed that the percent finer than 0.002 mm is 3.39 %, percent finer than 0.06 mm is 82.28 %, and percent finer than 2mm is 100 %. Besides that, this graph also showed that the percent finer than 0.063 mm is 86.09 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

4.3.2 Results for soil samples 2

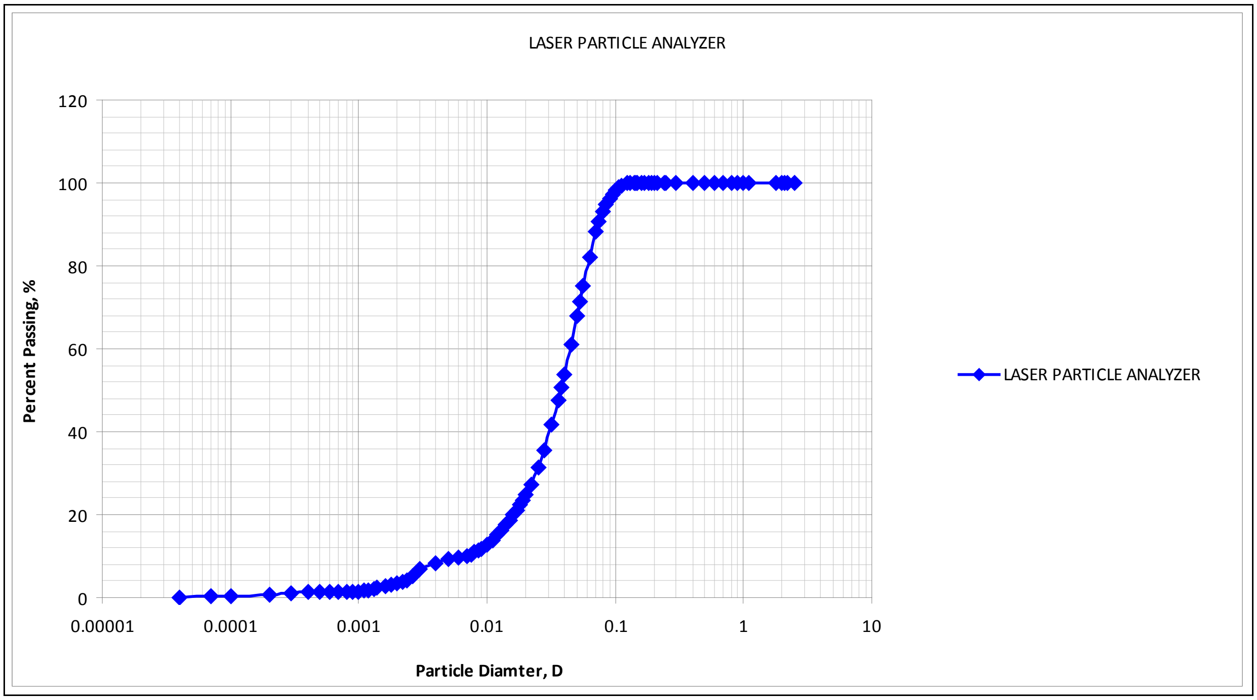

Figure 4.6: Particle size curve from laser particle analyzer for soil sample 2.

Figure 4.6 above showed the percent finer (%) versus Equivalent particle size (mm) for laser particle analysis test to determine the particle size distribution for soil sample 2. Based on the graph, it is showed that the percent finer than 0.002 mm is 3.4 %, percent finer than 0.06 mm is 75.01 %, and percent finer than 2mm is 100 %. Besides that, this graph also showed that the percent finer than 0.063 mm is 82.09 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

4.3.3 Results for soil samples 3

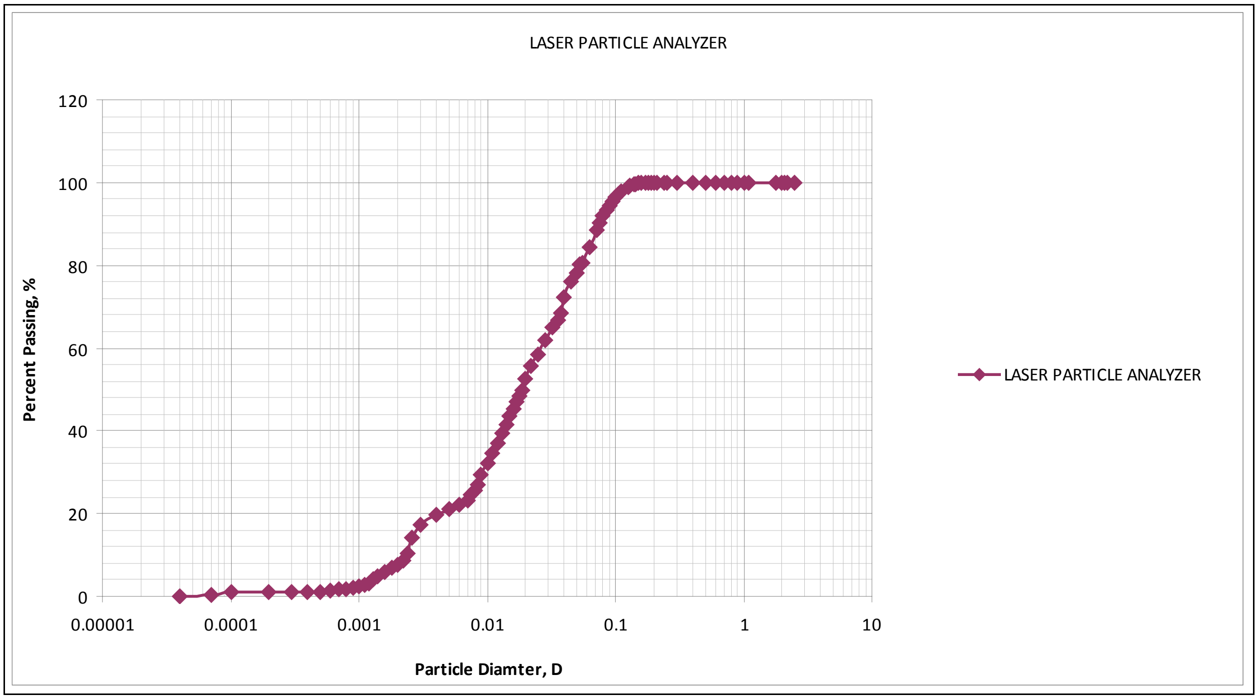

Figure 4.7: Particle size curve from laser particle analyzer for soil sample 3.

Figure 4.7 above showed the percent finer (%) versus Equivalent particle size (mm) for laser particle analysis test to determine the particle size distribution for soil sample 3. Based on the graph, it is showed that the percent finer than 0.002 mm is 1.05 %, percent finer than 0.06 mm is 80.23 %, and percent finer than 2mm is 100 %. Besides that, this graph also showed that the percent finer than 0.063 mm is 84.51 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

4.4 Comparison between sieve & hydrometer with laser particle analyzer

4.4.1 Comparison results for soil samples 1

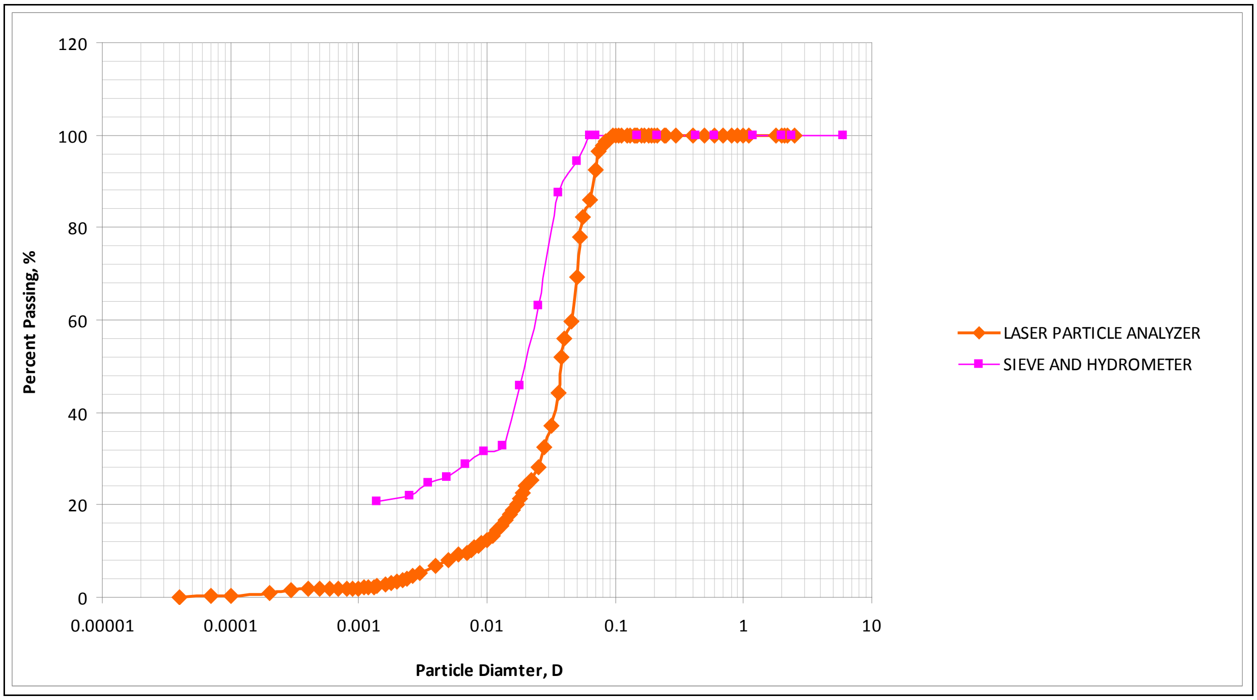

Figure 4.8: Particle size curve from sieve & hydrometer and laser particle analyzer for soil sample 1.

Figure 4.8 above showed the percent finer (%) versus Equivalent particle size (mm) for both Sieve & Hydrometer and laser particle analysis test to determine the particle size distribution for soil sample 1. Based on the graph, it is showed that the percent finer than 0.002 mm is 21 % for sieve & hydrometer while for laser particle analyzer is 3.39 %, percent finer than 0.06 mm is 100 % for sieve & hydrometer while for laser particle analyzer is 82.28%, and percent finer than 2mm is 100 % for both test. Besides that, this graph also showed that the percent finer than 0.063 mm is 100% for sieve & hydrometer while for laser particle analyzer is 86.09 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

4.4.2 Comparison results for soil samples 2

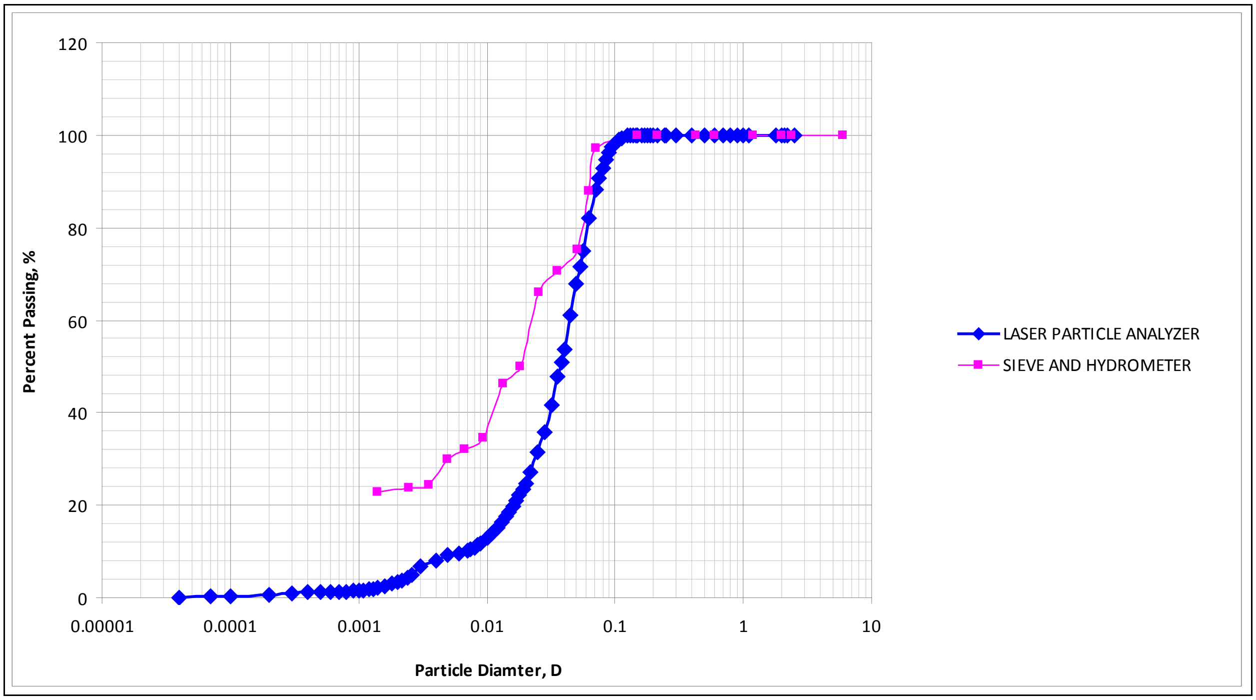

Figure 4.9: Particle size curve from sieve & hydrometer and laser particle analyzer for soil sample 2.

Figure 4.9 above showed the percent finer (%) versus Equivalent particle size (mm) for Sieve, hydrometer and laser particle analysis test to determine the particle size distribution for soil sample 2. Based on the graph, it is showed that the percent finer than 0.002 mm is 23 % for sieve & hydrometer while for laser particle analyzer is 3.4 %, percent finer than 0.06 mm is 87 %, for sieve & hydrometer while for laser particle analyzer is 75.01 % and percent finer than 2mm is 100 % for both analysis. Besides that, this graph also showed that the percent finer than 0.063 mm which is 88.05 % for sieve & hydrometer analysis while for laser particle analyzer is 82.09 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

4.4.3 Comparison results for soil samples 3

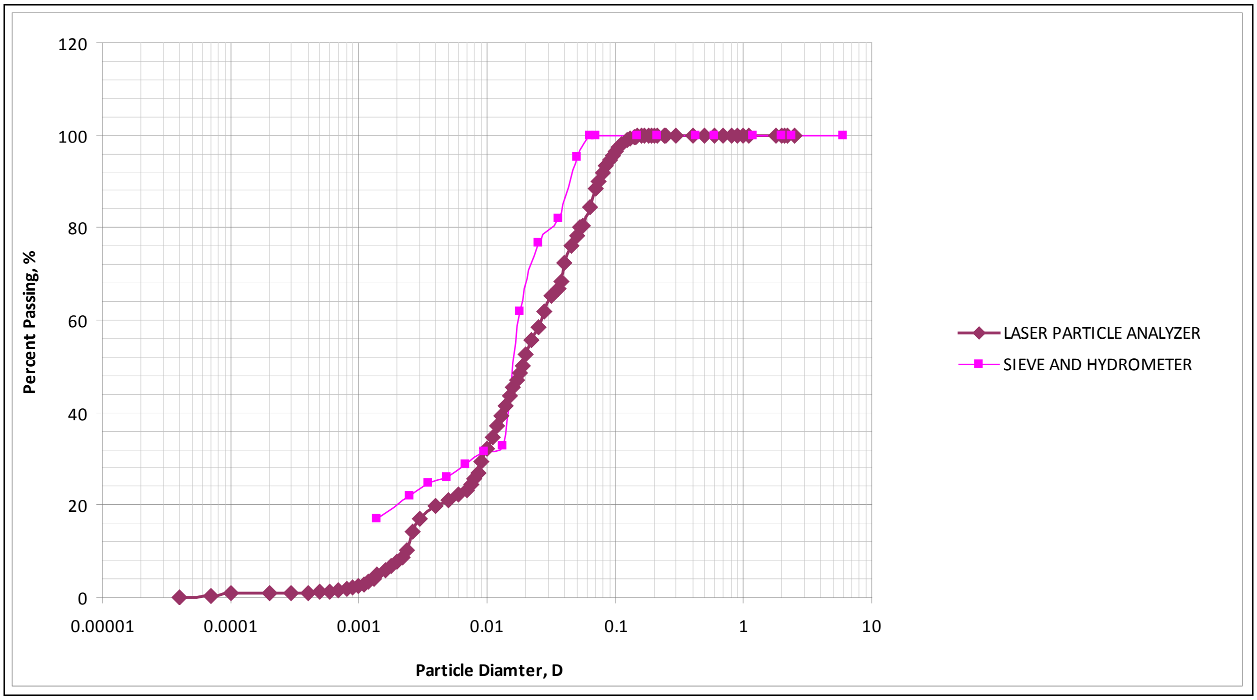

Figure 4.10: Particle size curve from sieve & hydrometer and laser particle analyzer for soil sample 3.

Figure 4.10 above showed the percent finer (%) versus Equivalent particle size (mm) for Sieve, Hydrometer and laser particle analyzer analysis test to determine the particle size distribution for soil sample 3. Based on the graph, it is showed that the percent finer than 0.002 mm is 21.2 % for sieve & hydrometer while for laser particle analyzer is 1.05 %, percent finer than 0.06 mm is 100 % from sieve & hydrometer while from laser particle analyzer is 80.23 %, and percent finer than 2mm is 100 % for both analyses. Besides that, this graph also showed that the percent finer than 0.063 mm is 100 % for sieve & hydrometer while for laser particle analyzer is 84.51 %. The soil particle size smaller than 0.002 mm was classified as clay soil meanwhile the soil particle size in range between 0.002 mm to 0.06 mm is Silt soil.

4.5 Soil classification

With reference to BS 5930:81, the soil classification for soil sample 1, soil sample 2, and soil sample 3 were determined. All the data and results that have been collected were used for soil classification purposes. The soil classification of all sample will be determine as in clause 4.5.1 for soil sample 1, clause 4.5.2 for soil sample 2, and clause 4.5.3 for soil sample 3. The summary then made.

Table 4.1: Particle composition of soil for soil sample 1, soil sample 2, and soil sample 3.

SOIL TYPE	SAMPLE 1		SAMPLE 2		SAMPLE 3	
TEST	Sieve & Hydrometer	Laser Particle Analyzer	Sieve & Hydrometer	Laser Particle Analyzer	Sieve & Hydrometer	Laser Particle Analyzer
CLAY (finer than 0.002 mm)	21%	3.39%	23%	3.4%	21.02%	1.05%
SILT (0.002 mm to 0.06 mm)	100%	82.28%	87%	75.01%	100%	80.23%
SAND (0.06 mm to 2 mm)	100%	86.09%	88.05%	82.09%	100%	84.51%
GRAVEL (2 mm to 60 mm)	100%	100%	100%	100%	100%	100%

4.5.1 Soil classification for soil sample 1

In accordance to BS 5930:81 for soil classification purpose, all results obtained from laboratory test that have been carried out was used to classified the soil sample 1. Based on all analysis, the percent finer than 0.06 mm (60 µm) is 100% and 82.28 % for samples 1 and when referred to Table 2.2 (a), we know that soil sample 1 is fine soils where more than 35 % of the material is finer than 0.06 mm. This results also in range more than 35 % that is either gravelly or sandy silts or clays. With reference BS 5930:1981, gravelly if more than 50% of coarse material is of gravel size(coarser than 2mm) and sandy if more than 50% of coarse material is of sand size (finer than 2mm). There for, we knew that soil sample 1 is sandy because the percent finer than 2mm is 100 %. Besides that, according to Atterberg limit results the percent of liquid limit is 56% that is in range between 50% to 70% represent soil of high plasticity. When plotted to Appendix A, for liquid limit, LL is 56% and plasticity index, PI is 26%, the soil sample is plotted below the A-line that is classified as SILT soil (M-SOIL). According to the information collected we can classified the soil sample as Sandy SILT (MS) and its subgroup is Sandy SILT of high plasticity (MHS).

4.5.2 Soil classification for soil sample 2

In accordance to BS 5930:81 for soil classification purpose, all results obtained from laboratory test that have been carried out was used to classified the soil sample 2. Based on all analysis, the percent finer than 0.06 mm (60μm) is 87 %, 75.01 % and when referred to Table 2.2 (a), we know that soil sample 2 is fine soils where more than 35 % of the material is finer than 0.06 mm. This results also in range greater than 35 % that is either gravelly or sandy silts or clays. With reference to BS 5930:1981, gravelly if more than 50% of coarse material is of gravel size(coarser than 2mm) and sandy if more than 50% of coarse material is of sand size (finer than 2mm). There for, we knew that soil sample 2 is sandy because the percent finer than 2mm is 100 %. Besides that, according to Atterberg limit results the percent of liquid limit is 65% that is in range between 50% to 70% represent soil of high plasticity. When plotted to Appendix A, for liquid limit, LL is 65% and plasticity index, PI is 45%, the soil sample is plotted above the A-line that is classified as CLAY . According to the information collected we can classified the soil sample as Sandy CLAY (CS) and its subgroup is Sandy CLAY of high plasticity (CHS).

4.5.3 Soil classification for soil sample 3

In accordance to BS 5930:81 for soil classification purpose, all results obtained from laboratory test that have been carried out was used to classified the soil sample 3. Based on all analysis, the percent finer than 0.06 mm (60 µm) is 100 %, 80.23 % and when referred to Table 2.2 (a), we know that soil sample 3 is fine soils where more than 35 % of the material is finer than 0.06 mm. This results also in range greater 35% to 65% that is either gravelly or sandy silts or clays. With reference to BS 5930:1981, gravelly if more than 50% of coarse material is of gravel size(coarser than 2mm) and sandy if more than 50% of coarse material is of sand size (finer than 2mm). Therefore, we knew that soil sample 3 is sandy because the percent finer than 2mm is 100 %. Besides that, according to Atterberg limit results, the percent of liquid limit is 55% that is in range between 50% to 70% represent soil of high plasticity. When plotted to Appendix A, for liquid limit, LL is 55% and plasticity index, PI is 22%, the soil sample is plotted below the A-line. In addition, the existing of large amounts of roots, grass and other vegetable matter showed that it is containing high organic compound. According to the information collected we can classified the soil sample as Sandy SILT (MS) and its subgroup is Organic Sandy SILT of high plasticity (MHSO).

4.5.4 Summary of soil classification

According to analysis that have been done, it is showed that the soil classification for soil A is sandy SILT of high plasticity (MHS), and the soil classification for soil B is sandy CLAY of high plasticity (CHS). The soil classification for soil C is Organic sandy SILT of high plasticity (MHSO).

SILT (M-SOIL), M, plots below A-line
CLAY, C, plots above A-line } M and C may be combined as FINE SOIL, F

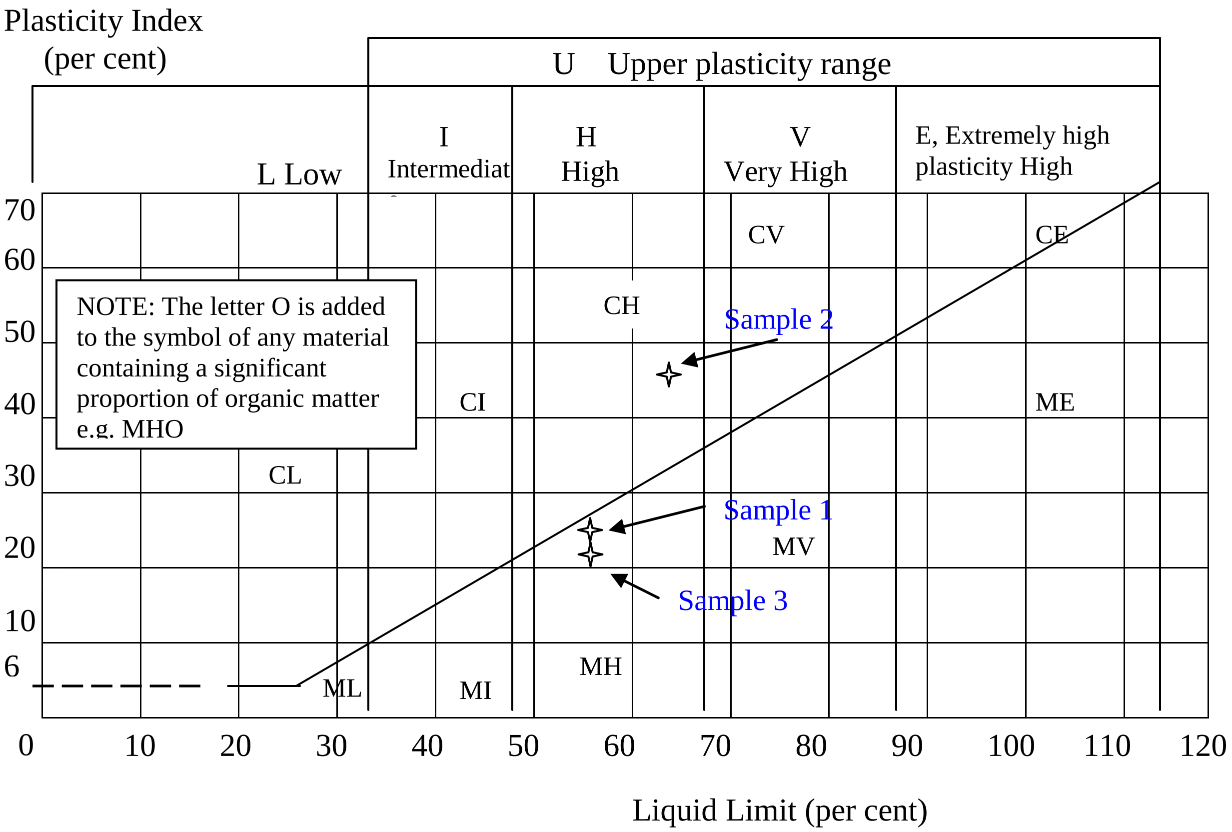

Figure 4.11: Plasticity chart for the classification of soil sample 1, soil sample 2, and soil sample 3.

4.6 Discussion

In order to explain the analysis made, these discussions were made. Some results can be explained based on theory from other researcher before. All data collected from the tests are tabulated and analyzed.

4.6.1 Discussion of particle size distribution results

Based on Figure 4.1, Figure 4.2, and Figure 4.3, it is showed that the first point from the sieve and hydrometer test does not lie on the smooth curve connecting the sieving curve with the remaining points. This is partly because in the early stage of the sedimentation test, the assumption made in the theory based on stoke's law may not strictly valid (Casagrande, 1934).

In addition, some of the coarse silts particles are retained on the 63 µm sieve when wet sieved, owing to the effects of surface tension. This particle reappears when dry sieved and unless they are added to the sedimentation cylinder, there is a small deficiency in this size range (Gee and Bauder, 1986).

This initial reading should be ignored if they do not lie on a smooth curve continued from the sieving curve. When transferred the figure into a table, this is the percent of particle composition for all three samples. This composition of soil particle can be discussed according to atterberg limit results (Syvitski et al,1991).

While if we see the graph obtained for laser particle analyzer yielded a smaller clay fraction than the sieve & hydrometer method. Conversely, the Laser particle analyzer yielded, in general, a higher proportion of silt than did the sieve & hydrometer test. Although relationships were found between the laser particle analyzer derived and sieve & hydrometer data for the three different size fractions, the scatter of the points around the fitted line for each size fraction was fairly wide. This type of scatter clearly implies that attempts to convert laser particle analysis derived volume percentage of a given size fraction to mass percentage will not be accurate and thus be of limited value (Topp et al, 1980).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this chapter, the objectives of the project that are to determine the particle size distribution and to determine the soil type in accordance to British Soil Classification System (BSCS) will be presented.

According to the sieve & hydrometer and laser particle analyzer tests results, with reference to BS 5930:81 and Mie's Theory, the soil classification for soil sample 1, soil sample 2, and soil sample 3 were determined. When plotted to Appendix A, for liquid limit, LL is 56% and plasticity index, PI is 26%, the soil sample 1 is plotted below the A-line that is classified as SILT soil (M-SOIL). According to the information collected we can classified the soil sample as Sandy SILT (MS) and its subgroup is Sandy SILT of high plasticity (MHS).

Meanwhile, for soil sample 2, for liquid limit, LL is 65% and plasticity index, PI is 45%, the soil sample B is plotted above the A-line that is classified as CLAY soil (C) and its subgroup is Sandy CLAY of high plasticity (CHS).

For soil sample 3, that having liquid limit, LL is 55% and plasticity index, PI is 22%, the soil sample 3 is plotted below the A-line. In addition, the existing of large amounts of roots, grass and other vegetable matter showed that it is containing high organic compound. There fore, we can classify the soil sample 3 as Sandy SILT (MS) and its subgroup is Organic Sandy SILT of high plasticity (MHSO).

Even though the results and plotted graph shown beyond satisfactory results, it still show the relationship between sieve analysis & hydrometer with laser particle analyzer. It also can be seen that the results from the size below 0.02 mm to smaller size have a perpendicular line for three cases.

It is also can be seen that laser particle analyzer gave more results especially when it comes to smaller particle size below 0.02 mm to smaller size. It gave more data and information compared to combined sieve & hydrometer. But the decision whether to use the traditional method or the alternative method are based upon the pros and cons.

5.2 Recommendation

From the experimental result, the following recommendations are proposed;

1. Conducting more laboratory test to get a more accurate classification.
2. Compared the soil classification obtained from the BSCS with other soil classification method such as ASTM and AASHTO and see the difference between these methods of soil classification.
3. Use sieve brush to clean the sieve before start the process to avoid the unwanted particles that can affect the result.
4. Make sure that the arrangement of the sieve with different sizes is correctly in the right place. Start with the largest aperture sieve and ending with smallest aperture sieve which remaining pan at the bottom.
5. An unduly long period of sieving must be avoided, because this would give particles additional opportunity to pass through any openings, which may be slightly oversize.
6. The hydrometer must be in good condition and ensure all reading taken is almost accurate.
7. The comparison should be done for several time and ensure that the soils samples are in the same condition for both tests.

I compared the sieve analysis & hydrometer with laser particle analyzer method for three soils samples. For the purpose of conversion of data from one type of measurement to the other, the relationship between sieve & hydrometer and laser particle analyzer data for different size fractions was less than satisfactory. In addition, the relationship between the sieve & hydrometer and laser particle analyzer derived clay fraction. Furthermore, in many of the soils that exhibited good agreement between measured and calculated value existed for the silt or sand fraction.

It should be realized that there is no method for particle size distribution determination of soil materials that can serve as a universal yardstick, because all available methods whether classic (e.g., sieve & hydrometer) or new (e.g., laser particle analyzer), suffer from some inherent flaws. The choice between methods depends, therefore, on the balance between the pros and cons of each. Advantages of the laser particle analyzer procedure over the sieve & hydrometer method include (i) need for only a small sample, (ii) short time of analysis, and (iii) a continuous particle size distribution curve. It is shown in previous chapter that the laser particle analyzer used smaller sample and gave more data and results compared to traditional method.

The difference between a particle size distribution obtained by laser particle analyzer and the one obtained by traditional method for a given soil is dependent in a complex fashion on the properties of the soil and especially on its mineralogy (that determines, e.g. the density) and morphology (that effects the shape, or deviation from sphericity) of the soil particles.The overall consequence of the predictable, procedure-dependent sources of error inherent in the particle size distribution determinations by the two methods and the harder to estimate soil-dependent sources of error is that no consistent relationship between particle size distribution derived by laser particle analyzer and particle size distribution derived by traditional methods can be formulated.

Compared with the sieve & hydrometer method, the laser particle analyzer procedure suffers from two main disadvantages; one is the high cost of the instrumentation. However, with the increase in cost of labor and constant pressure for greater reliability, reproducibility, and speed of analysis, the attractiveness of laser particle analyzer apparatus is expected to grow. The second disadvantages is the lack of a database that correlates laser particle analyzer derived particle size distributions with soil properties, similar to the very expensive database existing for sieve & hydrometer derived particle size distributions. Nonetheless, should the laser particle analyzer method become more accepted in the soil science community, the well needed database will gradually be established.

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