Jimma University

School of Graduate Studies

Jimma Institute of Technology

Department of Civil Engineering

(Geotechnical Engineering Stream)

INVESTIGATION ON INDEX PROPERTIES OF SOIL IN SHASHEMENE TOWN.

M.SC.Thesis

By: Fraol Amare

August, 2016

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A thesis submitted to the school of Graduate Studies of Jimma Institute of Technology in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Geotechnical Engineering).

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August, 2016

Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis is my original work performed under the supervision of my research advisor Dr. Yoseph Birru, and has not been presented as a thesis for a degree in any other university. All sources of materials used for this thesis have also been duly acknowledged.

Name	Signature	Date
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This thesis has been submitted for examination with my approval as university supervisor

Name	Signature	Date
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2. _________________ Advisor	_______________	_____ /____ /___
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5. _________________ External Examiner	______________	_____ /____ /___

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ABSTRACT

This work focuses mainly on identifying Index properties of soil in Shashemene Town. Shashamane is the capital of West Arsi, which is developing rapidly both in horizontal and vertical construction. Rapid urbanization in the city area has led to an increased interest in the basic properties of soils which are present within the city area. Geotechnical information of the subsoil in an urban area is important for various civil engineering development purposes. Non-availability of the proper geotechnical information of the subsoil makes foundation and engineering works expensive, difficult and sometimes hazardous. Index properties of soil are thus properties, which are used to characterize soils and determine their basic properties.

In this study a total of 20 bulk samples were taken from ten test pits, then stored in labeled plastic bags and transported by truck to Hawasa University for testing. Samples from each test pit were collected at 1.5 m and, 3 m depth and investigated for their Index properties with a view to classifying and identifying the soil of the study area. All tests were carried out using ASTM and BS standard procedure of testing.

According to the study, Moisture content ranges in the area from 26 – 36%, liquid limit ranges from 39 – 50%, plastic limit ranges from 27 – 36%, plasticity Index ranges from 8 – 16%, linear shrinkage limit ranges from 4 – 6%, free swell ranges from 21 – 35% and specific gravity ranges from 2.43 - 2.60.

Based on visual observation and the test results obtained from the laboratory, comparison were made with some standard specifications and it was revealed that soil samples of the areas are reddish brown, clayey silt soils. Though this research work is limited in its time and budget, it is believed that the finding would serve as a good starting point for further study in the future.

ACRONOMY

Designation

Tp - Test Pit

LL - Liquid limit

PL - Plastic limit

PI - Plasticity Index

LS - Linear shrinkage

FS - Free Swell

Sg - Specific gravity

W - Moisture content

AASHTO - American Association of State Highway and Transportation Officials

USCS - unified soil classification system

ASTM - American Society for testing and Materials

BS - British Standard

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1. INTRODUCTION

1.1. Background

Soils are naturally complex, multiphase materials. They are generally assortment of particles (solids), fluids, and gases. Each influences the behavior of the soil mass as a whole. Unless we understand the composition of a soil mass, we will be unable to estimate how it will behave under loads and how we can use it as a construction material. Geoengineers have devised classification systems based on the results of simple, quick soil tests. These systems help us make decisions about the suitability of particular types of soils for typical geoengineering systems [1]. These simplified tests which are indicative of the engineering properties of soils are called index properties. Index properties of cohesive soils are used to characterize the physical and mechanical behavior of soils by making use of parameters such as moisture content, specific gravity, particle size distribution, Atterberg limits. Such parameters are useful to classify cohesive soils and provide correlations with engineering soil properties [2].

Proper understanding of properties of soil will help to understand the actual cause of failure of structure and will lead to proper designing and construction by avoiding or minimizing the failure and maintenance of the structure [3].

Misunderstanding of soils and their properties can lead to construction errors that are costly in effort and material. Though different disciplines find a soil classification based purely on particle-size classification satisfactory for their professional needs, the Civil Engineer requires classification that has engineering applications. The demand led to the development of number of engineering soil classifications. All widely used engineering soil classifications involve a combination of particle size and measures of plasticity and texture [3].

This research work examined index property of soil, identification and classification of soil. Index properties of soil are properties, which are to be used to characterize soils and determine their basic properties such as moisture content, specific gravity, particle size distribution, Atterberg limits, Shrinkage limit and free swell.

The suitability of a soil for particular use should be determined based their on engineering characteristics. For this reason, this study may have contribution for Shashemene city Administration in the development of infrastructure facilities.

1.2. Statement of the problem

Soil characterization plays a vital role in early stages of planning and design of an infrastructure projects such as buildings bridges, highways, airports, seaports and railways etc., due to the fact that Soil is diverse in formation and in character, it needs accurate prediction of its engineering behavior is of research interest in geotechnical engineering . As the engineering behavior of soils vary from place to place and even with time, accurate prediction of parameters that properly characterize it is necessary.

1.3. Research Question

1. What are the Index Properties of soils of Shashemene?
2. What type soil is found in Shashemene Town?

1.4. Purpose and Objectives of the study

1.4.1. Purpose of the study

The purpose of study is to find out the index properties of the sub-soil over which the structure has to be built. Soil characteristics vary both with respect to depth from the ground surface and stretch in horizontal direction .Therefore this study may help to identify soil characteristics of the town both with respect to depth from the ground surface and stretch in horizontal direction.

1.4.2. General objective

To make investigation on index properties of soil in Shashemene Town.

1.4.3. Specific objectives

- To investigate: moisture content, particle size distribution, Atterberg limit, specific gravity and free swell tests.

- To determine and classify soil of the selected research area both according to AASHTO and USCS classification method
- To determine the range of values of index property of soil in different parts of the city.

1.5. Scope and limitation

1.5.1. Scope of the study

This research addresses the above goals by undertaking investigation on the index properties of soil. For this intended purpose, disturbed samples were collected from different location of Shashemene Town and investigations on the index property of soil were conducted.

1.5.2. Limitation of the study

The research is limited to the index property tests on samples collected from different location of Shashemene Town using randomly scattered test pit. Due to unavailability of test equipment, it was not possible to conduct mineralogical tests.

1.6. Structure of the thesis

The research report is divided in to five Chapters, each Chapter covers specific topic in the research work. In Chapter one, background, statement of the problem, purpose and objective, scope and limitation of the study are presented. Chapter two deals with a brief literature review of Index property of the soil. In Chapter three, description of the study area, materials and methods of study. Chapter four covers results and discussion of test results. The last chapter presents conclusion and recommendation.

2. LITRATURE RIVEW

2.1 Soil formation and soil deposit

Soils are formed by the process of in-situ weathering and decomposition of parent rock. The three major weathering processes are physical, chemical and biological processes. In the weathering process, the parent rock and rock minerals break down, releasing internal energy and forming soils of lower internal energy that are stable. The properties of soil materials depend up on the properties of the rock materials which they are derived from. Physical processes increase surface area and fractures so that chemical attack takes place whereas biological phenomena include both of them [4].

The varieties of soil materials encountered in engineering problems is almost limitless ranging from hard, dense, large pieces of rock through to gravel, sand, silt, and clay to organic deposit of soft compressible organic peat. At any given site, a number of different soil types can be present, and the composition may vary over intervals of a little as a few inches [3].

The major factors influencing the formation of soil are described as follows:-

2.1.1. Parent materials

Parent material constitute during the early and immediate stage of the Soil forming factors such as, parent rock, vegetation conditions, climate, topography and drainage conditions, chemical process weathering stages processes determine the type of soil formed. The nature of the parent materials is much more important during the above weathering stages than after intense weathering for long period of times.

There are two main variables in parent materials that affect soils: grain size and composition. Grain size is the main determinant of soil texture. Soil texture influences the soil structure, consistency, cation exchange capacity, profile drainage, moisture retaining capacity, and organic content [4].

2.1.2. Vegetation conditions

Vegetation condition is highly dependent with climate (precipitation, soil, and air) and topography nature of the area. Areas with highly vegetation cover have less susceptibility to erosion. This means the probability of formation of residual tropical soil is less.

2.1.3. Climate

In mountainous tropical countries like Ethiopia, altitude is by far the most important factor Controlling climate. It affects distribution of both temperature and rainfall. Generally, regions between 1500-2300 meter a.m.s.l (categorized as "woina dega" or sub-tropical climate) have temperature that range between 15-20^{0}c, areas between 500-1500 meters a.m.s.l ("kola" tropical climate) have 20-30^{0}c and areas below 500 meters a.m.s.l ("bereha" or desert climate) have a temperature 30^{0}c and above [4].

Climate is the major factor governing the rate and type of soil formation .The major components of climate are the amount and distribution of precipitation, and temperature. Physical weathering is more pronounced in dry climates, while the extent and rate of chemical weathering is largely controlled by the availability of moisture and temperature. The temperature variation is adequately represented by mean annual temperature, which is nearly constant temperature. The clay minerals of the soil of the world changed in predictable way with distance from the equator. According to Van Hoff"s principle, the velocity of chemical reaction increases by a factor of 2 to 3 for every 100c rise in temperature.

Climate has a further effect on the properties of tropical residual soil. In sub humid tropical and subtropical areas, water tables are often deeper than 5 to 10m and the effect of unsaturation; desiccation and seasonal or long term rewetting have to be taken into account in geotechnical design.

The two main rainfall parameter most widely available are the mean annual total and the length of dry season. The amount and distribution of precipitation affect the availability of moisture and relative humidity of the soil atmosphere; it influences the concentration or chemical activities of solution in the system [5].

2.1.4. Topography and drainage condition

Topography has a major influence on drainage characteristics, which in turn is known to have a major effect on soil mineralogy. Topography controls the rate of weathering by partly determining the amount of available water and the rate at which it moves down through the zone of weathering. It also controls the effective edge of the profile by controlling the rate of erosion of a weathered material from the surface. Hence, deeper profiles will generally be found in valleys and on gentle slopes rather than high ground or steep slopes [5].

Soil profiles developed from basic igneous rocks on hillsides the depth of weathering increases down the slopes whereas kaolinite/hallosite are the predominant clay minerals at the top of the slope and smectite at the bottom of the slope.

2.2. Chemical weathering process:

2.2.1. Decomposition:

This includes the physical breakdown of the rock fabric and the chemical break down of the Constitute minerals, usually rock forming minerals. Typical products are being clay minerals, Oxides, hydroxides, and free silica. Under tropical condition, reaction may occur more relatively quickly so that recently transported soils may subsequently be modified into soil materials. Decomposition is physio-chemical breakdown of primary minerals and release of constitute elements (SiO2, Al2O3, Fe2O3, CaO, MgO, K2O, Na2O), which appear in simple ionic forms [6].

2.2.2. Leaching and Re-deposition:

This includes laterization process; involves removal of combined silica, alkaline earth, and alkalies. There is a consequent accumulation of oxides and hydroxides of sesquioxides and the leached materials may be redeposited and accumulated elsewhere in the soil profile.

Under condition of low chemical and soil-forming activity, physio-chemical weathering does not continue beyond the clay-forming stage and tends to produce end products consisting of clay minerals predominantly represented by kaolinite and occasionally by hydrated and hydrous oxide of iron and aluminum [7].

2.2.3. Dehydration/desiccation:

Process that the composition and distribution of the sesquioxides-rich minerals in a manner, which is generally not reversible upon wetting. Dehydration also influences the formation of clay minerals. That is, in the case of total dehydration, strongly cemented soils with a unique granular soil structure may be formed.

2.3. General types of soil

According to their grain size, soil particles are classified as cobbles, gravel, sand, silt and clay. Grains having diameters in the range of 4.75mm to 76.2mm are called gravel. If the grains are visible to the naked eye, but are less than about 4.75mm in size the soil is described as sand. The lower limit of visibility of grains for the naked eyes is about 0.075mm. Soil grains ranging from 0.075mm to 0.002mm are termed as silt and those that are finer than 0.002mm as clay. This classification is purely based on size, which does not indicate the properties of fine-grained materials.

2.4. Soil particles size and shape

The size of particles may range from gravel to the finest possible. Their characteristics vary with size. Soil particles coarser than 0.075mm are visible to the naked eye or may be examined by means of a hand lenses. They constitute the coarser fraction of the soil. The coarser fraction is constituted of gravel and sand. The individual particles of gravel, fragments of rock, are composed of one or more minerals, whereas sand grains contain mostly one mineral material, which is usually quartz. The individual grains of sand and gravel may be angular, sub angular, sub-rounded or well rounded. Gravel may contain flat. Some sands contain a high percentage of mica flakes that give them the properties of elasticity. Silt and clay constitute the finer fraction of particle.

2.5. Soil mineralogical composition:

Mineral particles can be inorganic particles derived from rock materials and minerals. They are extremely variable in size and composition. Primary minerals: present in original rock from which soil is formed. These occur predominantly in sand and silt fractions, and are weathering resistant (quartz, feldspars). Secondary minerals: formed by decomposition of primary minerals, and their subsequent weathering and recomposition into new ones (clay minerals). Humus or organic matter: decomposed organic materials [4].

2.6. Index properties

2.6.1 General

This chapter gives an idea about the previous studies of various researchers in the field of soil characteristic. Basically, soil is a more complex material as compared to other man made engineering materials. The complexity is contributed by its existence in almost innumerable varieties, by its combination of solid, liquid and gases, where in many instances the solid particles vary in size ranging from big boulders to colloidal size. Furthermore the relative quantities of solid, liquid and gases in a given soil is bound to change due to any physical cause, such as loading, seasonal variation and change of temperature [8].

Engineering soils are subdivided into two main groups as a function of their Predominant sizes and associated plasticity. The coarse-grained soils are composed of Sand size and larger particles. They are separated into size ranges by sieving of Materials up to cobble size. Except for minor fractions of plastic fines, they characteristically are non-plastic. The fine grained soils consist predominantly of silt and clay-sized particles with differing degrees of plasticity measured by their Atterberg limits rather than by sieving and settling velocity methods.

The most widely used classification schemes are those that divide soils into an orderly, easily remembered system of groups, or classes, that have similar physical and engineering properties and that can be identified by simple and inexpensive tests. These groups ideally provide estimates of both the engineering characteristics and Performance of soils for design and construction [9]. In nature soil occurs in a large variety. Engineers are continually searching for simplified tests. That will increase their knowledge of soils by employing a simple and rapid soil tests. These simplified tests which are indicative of the engineering properties of soils are called index properties [10]. Index properties of cohesive soils are used to characterize the physical and mechanical behavior of soils by making use of parameters such as moisture content, specific gravity, particle size

distribution, Atterberg limits and moisture-density relationships. Such parameters are useful to classify cohesive soils and provide correlations with engineering soil properties [11].
The engineering behavior of soils, whether formed under arctic, temperate or tropical Conditions, is determined by certain physical characteristics designated as engineering properties. Since determination of the engineering properties is usually expensive, index properties, which are simpler and cheaper to evaluate but indicative of the engineering characteristics, are investigated. These properties are mainly used for identification and classification of soils [12].

In nature, Soils occur in a large variety. However, soils exhibiting similar behavior can be grouped together to form a particular group. Engineers are continually searching for simplified tests that will increase their knowledge of soils beyond that which can be gained from visual examination without having to resort to the expense, detail, and precision required with engineering properties tests. These simplified tests provide indirect information about the engineering properties of soils and are, therefore, called index tests. Basic soil properties and parameters can be subdivided into physical, index, and engineering Categories. Physical soil properties include particle size and distribution, specific gravity, and water content. Index parameters of cohesive soils include liquid limit, plastic limit, shrinkage limit, and activity. Such parameters are useful to classify cohesive soils and provide correlations with engineering soil properties [13]. The test for determination of engineering property are generally elaborate and time consuming. Sometime the geotechnical engineer is interested to have some rough assessment of engineering property without conducting elaborate tests. This is possible if index property of soil is determined [2].

A thorough and comprehensive geotechnical investigation is an essential requirement to the Design and construction of civil engineering projects. The proper design of civil engineering Structures like foundation of buildings, retaining walls, high ways, etc. requires adequate Knowledge of sub surface conditions at the sites of the structures. Many damages to buildings, roads and other structures founded on soils are mainly due to the lack of proper investigation of substructure condition [14].

2.6.2 Soil Classification

Soils exhibiting similar behavior can be grouped together to form a particular group under different standardized classification systems. A classification scheme provides a method of identifying soils in a particular group that would likely exhibit similar characteristics. There are different classification devises such as USCS and AASHTO classification systems, which are used to specify a certain soil type that is best suitable for a specific application. These classification systems divide the soil into two groups: cohesive or fine-grained soils and cohesion-less or coarse-grained soils [1].

2.6.3 Grain Size Distribution

For coarse grained materials, the grain size distribution is determined by passing soil sample either by wet or dry shaken through a series of sieves placed in order of decreasing standard opening sizes and a pan at the bottom of the stock. Then the percent passing on each sieve issued for further identifying the distribution and gradation of different grain sizes [16]. Particle size analysis tests are carried out in accordance to ASTM D 422-63. Besides, the distribution of different soil particles in a given soil is determined by a sedimentation process using hydrometer test for soil passing 0.075 mm sieve size. For a given cohesive soil having the same moisture content, as the percentage of finer material or clay content decreases the shear strength of the soil possibly increases.

2.6.4. Moisture Content

Change in moisture content is the most influential parameter that affects the property of soils. Moisture content is defined as the ratio expressed as a percentage of mass of water to mass of soil solids. The purpose of moisture content test is to determine the amount of water present in a quantity of soil in terms of its dry weight and to provide general correlations with strength, settlement, workability and other properties. The moisture content of soils, when combined with data obtained from other tests, produces significant information about the characteristic of the soil. For example, when the in situ moisture content of a sample retrieved from below the phreatic surface approaches its liquid limit, it is an indication that the soil in its natural state is susceptible to larger consolidation settlement. The moisture content test is carried out in the laboratory as per the procedure of AASHTO T 265 or ASTM D 2216 and in the field according to AASHTO T217.

2.6.5 Atterberg limit

Based on their mode of formation and mineralogical composition different soils respond differently for the same moisture content. Albert Atterberg, a Swedish Scientist in 1911 gave an idea of the consistency limit of cohesive soils and proposed a number of tests for defining their properties. The three Atterberg limits which are liquid limit, plastic limit and shrinkage limits are the boundary between each of the two consecutive states of the soil-water phases. Their test is performed only on that portion of a soil which passes the 425 mm (No. 40) Sieve [17]. A description of phases of soil-water system is shown with schematic diagram in figure2.1.

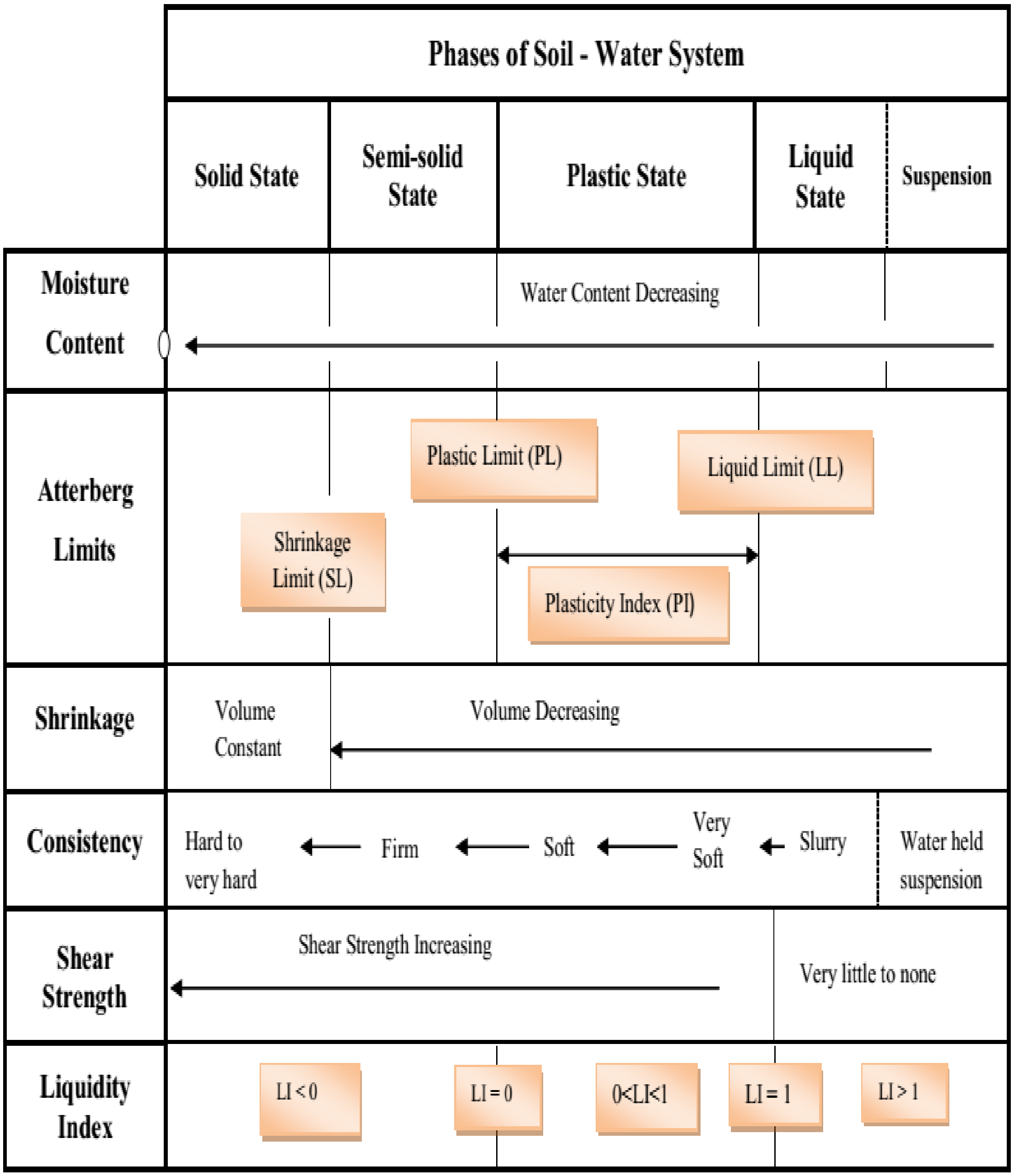

Figure2.1:-Description of Phases of Soil-Water System [17]

Liquid Limit: The liquid limit (LL) is the water content, expressed in percent, at which the soil changes from a liquid state to a plastic state and principally it is defined as the water content at which the soil pat cut using standard groove closes for about a distance of 13 cm (1/2 in.) at 25 blows of the liquid limit machine (Casagrande Apparatus). The liquid limit of a soil highly depends upon the clay mineral present. The conventional liquid limit test is carried out in accordance of test procedures of AASHTO T 89 or ASTM D 4318. A soil containing high water content is in the liquid state and it offers no shearing resistance [16].

Plastic Limit: The plastic limit (PL) is the water content, expressed in percentage, below which the soil stops behaving as a plastic material and it begin to crumble when rolled into a thread of soil of 3.2 mm diameter. The conventional plastic limit test is carried out as per the procedure of AASHTO T 90 or ASTM D 4318. The soil in the plastic state can be remolded into different shapes. When the water content is reduced the plasticity of the soil decreases changing into semisolid state and it cracks when remolded [17].

However, in our country more researches have done on index property of soil: Detail investigation on index property of lateritic soil (the case of Nedjo-Mend-Assosa) [8], Investigating the index property of residual tropical soil of Western Ethiopia (the case of Assosa) [6], Investigating in to the appropriate laboratory testing procedure for the determination of the index properties of the lateritic soil of Western Ethiopia (Nedjo-Jarso-Begi Road area)[18] etc were done. Hence, there are no available data on the geotechnical and Index property of soil within the study area. And also the previous researchers focused only on the Index properties of lateritic soil. This scenario has therefore prompted the need of this research work.

3. MATERIALS AND RESEARCH METHODS

3.1. Description of the study Area

3.1.1. Location and Topography

Shashemene is located in the southern part of the country at a distance of about 250 kms from the capital Addis Ababa in West Arsi Zone of Oromia Regional State. Its geographical coordinate is 7013' North Latitude and 380 37' East Longitudes in the main Ethiopian rift valley between Lake Shala and Lake Hawasa.

The topography of Shashemene is characterized as flat with slope rarely exceeding 3 present particularly along river courses. The slope generally decreases from southeast towards the northwest. The elevation of the city is ranging from 1840 m.a.s.l. to 2025 m.a.s.l. On the average, Shashemene City lies at an elevation of 1940 m.a.s.l.

3.1.2. Geology

The Geology of the Shashemene area is typical of the Nazret Series (Nn) indicated in the 1:2,000,000 geological map of Ethiopia. These series is defined by tuff, ignimbrite, pumice, ash, rhyolite and intercalations of basaltic flows.

The lithological units occurring in Shashemene includes quaternary volcanic rocks and lacustrine sediments. The volcanic rocks comprise ignimbrite and siliceous pyroclastic.

3.1.3. Climate and Hydrology

Although Ethiopia lies within the tropics, temperature is modified considerably by altitude giving rise to five distinct climatic zones that are traditionally recognized throughout the country. Based on the climatic zone classification the catchment falls within WoinaDega zone except at higher altitudes of Abaro hills which will belong to Dega zone. The dry season occur between November and February the other eight months are considered to be rainy months with rainfall concentration increases during April-May and July-September periods.

The Climate of Shashemene City and its surroundings have moderate climatic condition and experiences two distinct wet and dry seasons. The rainfall in the region has a weak bi-modal pattern with first peak in April-May and the second and main peak occurring in July –

September, and the mean annual rainfall is about 945 mm, the dry season is from November to February with very little sporadic rains occur occasionally.

3.2 General characteristics of soil profile

In general in excavated test pits three quasi- homogeneous geotechnical layers were observed. The description of three layers presented as follows.

Figure3.1:- photo of general soil layer of excavated test pit

3.2.1Top soil layer

Top layer soil is characterized predominantly by black clay with little sand and organic matter, moderately plastic and firm. The thickness of this layer is not more than 40 cm and average thickness is about 20 cm. Spatially this soil almost covers the whole area.

3.2.2 Middle soil layer

Middle soil layer is characterized predominantly by light gray and whitish in color, sand and gravel sized material, it is very weak and firm, highly porous material and non-plastic soil

.This layer is found below the top soil and the thickness of this soil as observed is from 30 cm to 100 cm. The thickness of this middle layer soil increases from South to North in area.

3.2.3.Lower soil layer

The lower soil layer is most soil horizon characterized by reddish brown, clayey silt with few sand sized materials, stiff moderately plastic soil.

3.3 Materials

There are different materials used as input for the accomplishment of this thesis work. Those information or data used as inputs are obtained from: Topographic map, geologic and geographical maps

3.3.1. Software's used

Global mapper 10---DEM---digital elevation model, Excel Spread sheet

3.3.2. Laboratory equipment used

- For moisture content determination

  Drying oven, Balance, Moisture can, Spatula

- For Atterberg Limit determination

  Liquid limit device, Porcelain (evaporating) dish, Flat grooving tool with gage, Moisture cans, Balance sensitive to 0.01g, Glass plate, Spatula, Wash bottle filled with distilled water, Drying oven

- For Grain size distribution determination

  Balance sensitive to 0.01g, Set of sieves, Cleaning brush, Sieve shaker, Mixer(blender), 152H Hydrometer, Sedimentation cylinder, Control cylinder, Thermometer, Beaker, Timing device.

- For linear shrinkage determination

  Spatulas, evaporating dish, mold for Liner shrinkage test, petroleum jelly, drying oven, vernier calipers.

- For free swell determination

  100 ml graduated cylinder and water

- For specific gravity determination

  Pycnometer, Balance, Vacuum pump, Funnel, Spoon.

3.4. Research methods

The different activities that were carried out in this research work can be classified into three main phases: pre-field work, field work and post field work. The main activities in the pre-fieldworks include reviewing basic concept about index property of the soil and previously done researches on index property of the soil were revised. During the field work stage, visual identification of soils around the study area and soil sampling (disturbed sample) were made. During post field work, samples collected during field investigation were brought to Hawasa University and the tests were done in order to determine the Index Properties of soils and classify soil of the selected research area. The results from laboratory test and visual identification were interpreted and report preparation followed.

3.5. Sample size & sampling procedure

3.5.1. Sample Size

The soil specimens for this thesis work were collected from Shashemene. Prior to sampling visual site investigation were made to consider the different soil type and to sample evenly in the town. Accordingly ten test pit were chosen from four sub cities and totally of 20 bulk sample were collected from different depth (1.5-3 m) using randomly scattered test pit.

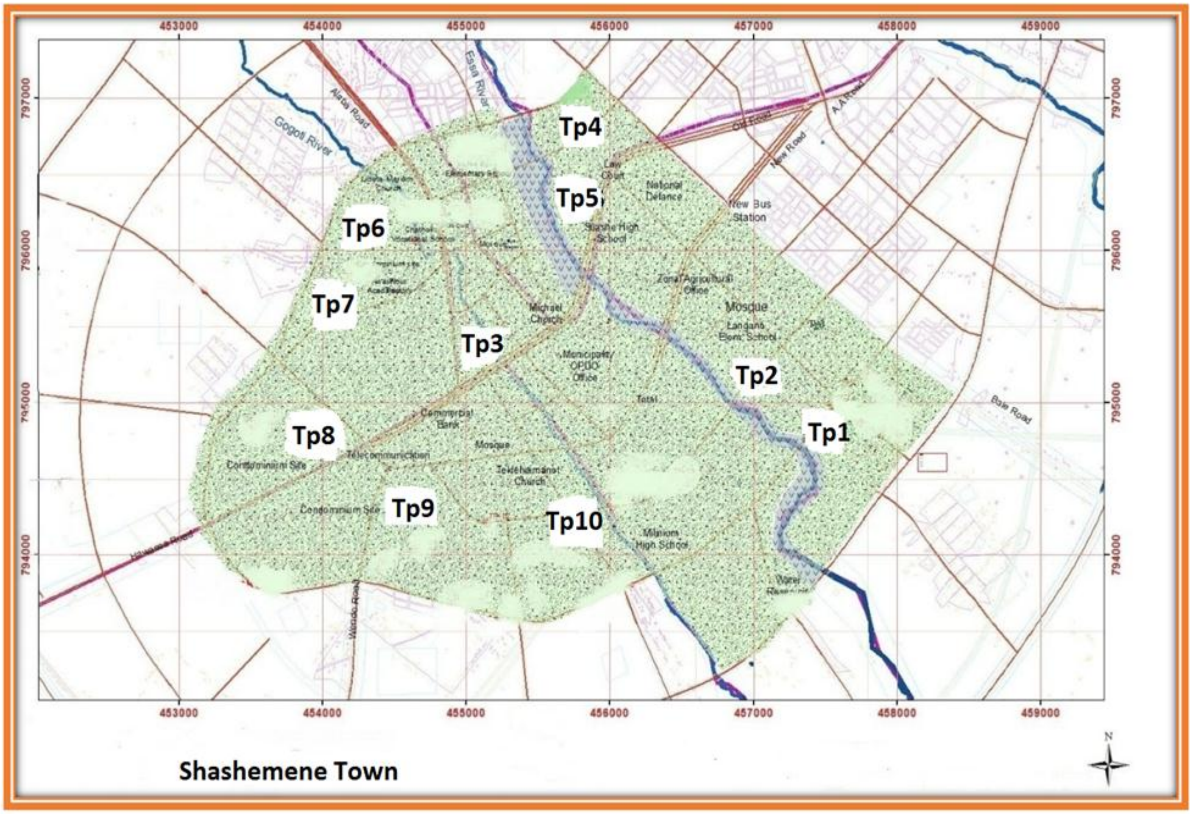

Figure3.5:- Location of the sample taken in Shashemene Town

Table 3.1. Sampling Procedure and tests

Index parameters analyzed	Standard followed for test
Grain size analysis	AASHTO T 88 or ASTM D 422
Moisture content	AASHTO T 265 or ASTM D 2216
Liquid limit	AASHTO T 89 or ASTM D 4318
Plastic limit	AASHTO T 90 or ASTM D 4318
Linear shrinkage limit	BS:1377: part 2: 1990
Specific gravity	AASHTO T 100 or ASTM D 854

3.6. Data processing and analysis

Soil sampling were analyzed for particle size distribution, moisture content, specific gravity, liquid limit, plastic limit, shrinkage limit, free swell and plastic index. These parameters determine the structural properties of soil.

3.7. Ethical considerations

Before continuing the study acceptance should be given from local authorities. The purpose of the study were clearly described to the organization and to the concerning local communities.

3.8. Data quality assurance

Laboratory test and field work manual were prepared in order to avoid error in sample collection. The training is given for sample collectors to handle the sample carefully. To check reliability and accuracy of samples all samples were properly identified with tags, labels, and all samples were preserved and transported in tight, moisture proof plastic bag. laboratory instruments were calibrated.

4. RESULT AND DISCUSSION

Most of the laboratory tests in this research were carried out in accordance with the ASTM Procedures for soil testing. The laboratory tests conducted are explained in the following section.

4.1. Index Property Tests

4.1.1. Moisture content determination

For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The Water content is also used in expressing the phase relationships of air, water, and Solids in a given volume of soil. The obtained test results summary is shown in table4.1below.

Table 4.1. Moisture Content test result

Sample designation	Depth (m)	Natural moisture content (%)
TP1	1.5	36
	2.8	32
TP2	1.5	30
	3.0	29
TP3	1.5	34
	3.0	30
TP4	1.5	28
	3.0	39
TP5	1.5	34
	3.0	32
TP6	1.5	30
	3.0	34
TP7	1.5	28
	2.7	30
TP8	1.5	32
	3.0	33
TP9	1.5	29
	3.0	32
TP10	1.5	31
	3.0	26

4.1.2. Specific gravity

Specific gravity is used to calculate parameters such as void ratio, porosity, soil particle size distribution by means of the hydrometer and degree of saturation. According to ASTM D 854-98, two procedures for performing specific gravity are provided. These are Method-A, procedures for oven dried specimen and Method-B, procedure for moist specimen. For specimens of organic soils and highly plastic, fine-grained soils, Procedure B shall be the preferred method. But in this research the specific gravities are determined using method A. The specific gravity tests were carried out and summarized for the soil samples under investigation. The test results summary is shown in table 4.2 below.

. Table 4.2. Specific gravity test result.

Sample designation	Depth (m)	Specific gravity
TP1	1.5	2.45
	2.8	2.49
TP2	1.5	2.45
	3.0	2.46
TP3	1.5	2.46
	3.0	2.51
TP4	1.5	2.45
	3.0	2.46
TP5	1.5	2.53
	3.0	2.60
TP6	1.5	2.45
	3.0	2.52
TP7	1.5	2.43
	2.7	2.44
TP8	1.5	2.45
	3.0	2.52
TP9	1.5	2.43
	3.0	2.46
TP10	1.5	2.48
	3.0	2.56

The specific gravity of Shashemene soils ranges from 2.43 to 2.60. According to Arora [2] the specific gravity of silt soil ranges from 2.66 to 2.7, the specific gravity of clay soil ranges from 2.68 to 2.8. So that, the specific gravity of Shashemene soil is low. This is may be because the soils in the study area much derived from light weighted rocks

4.1.3. Grain size analysis

A soil consists of an assemblage of discrete particles of different of various shapes and sizes. For the other entire engineering test to be effective, determination of the particle sizes is important due to its strong relationship with the engineering behavior. Some relevant and useful information can be obtained from a grain size distribution curve. Such information includes the percentage larger or finer than a given size and their uniformity or the range in grain size distribution.

Particle size distribution of the samples from ten different test pits are listed in table 4.3 and graphical presentations are shown in figure4.1 for typical ones and appendix-B for the rest..

Table 4.3. Percentage amount of particle-sizes test result

Sample designation	**Depth (m)**	**Percentage amount of particle sizes**			
		Gravel (%)	Sand (%)	Silt (%)	Clay (%)
TP1	1.5	7.3	25.1	40.1	26.3
	2.8	8.3	19.9	43.0	28.8
TP2	1.5	5.6	21.1	48.9	24.4
	3.0	4.5	20.2	49.8	25.4
TP3	1.5	9.8	18.3	45.3	26.6
	3.0	3.7	16.9	51.0	28.4
TP4	1.5	8.9	21.0	46.5	23.6
	3.0	6.4	15.1	52.6	25.9
TP5	1.5	7.4	18.9	50.0	23.7
	3.0	4.8	12.1	52.1	30.8
TP6	1.5	3.9	21.8	50.8	23.4
	3.0	5.3	16.1	53.0	25.6
TP7	1.5	2.9	19.2	53.3	24.6
	2.7	1.9	17.6	54.1	26.3
TP8	1.5	5.1	20.0	52.6	22.3
	3.0	3.7	16.1	53.9	26.7
TP9	1.5	4.5	14.9	62.5	18.1
	3.0	6.2	17.3	55.5	21.1
TP10	1.5	4.0	19.6	54.9	21.4
	3.0	3.7	21.7	44.7	30.1

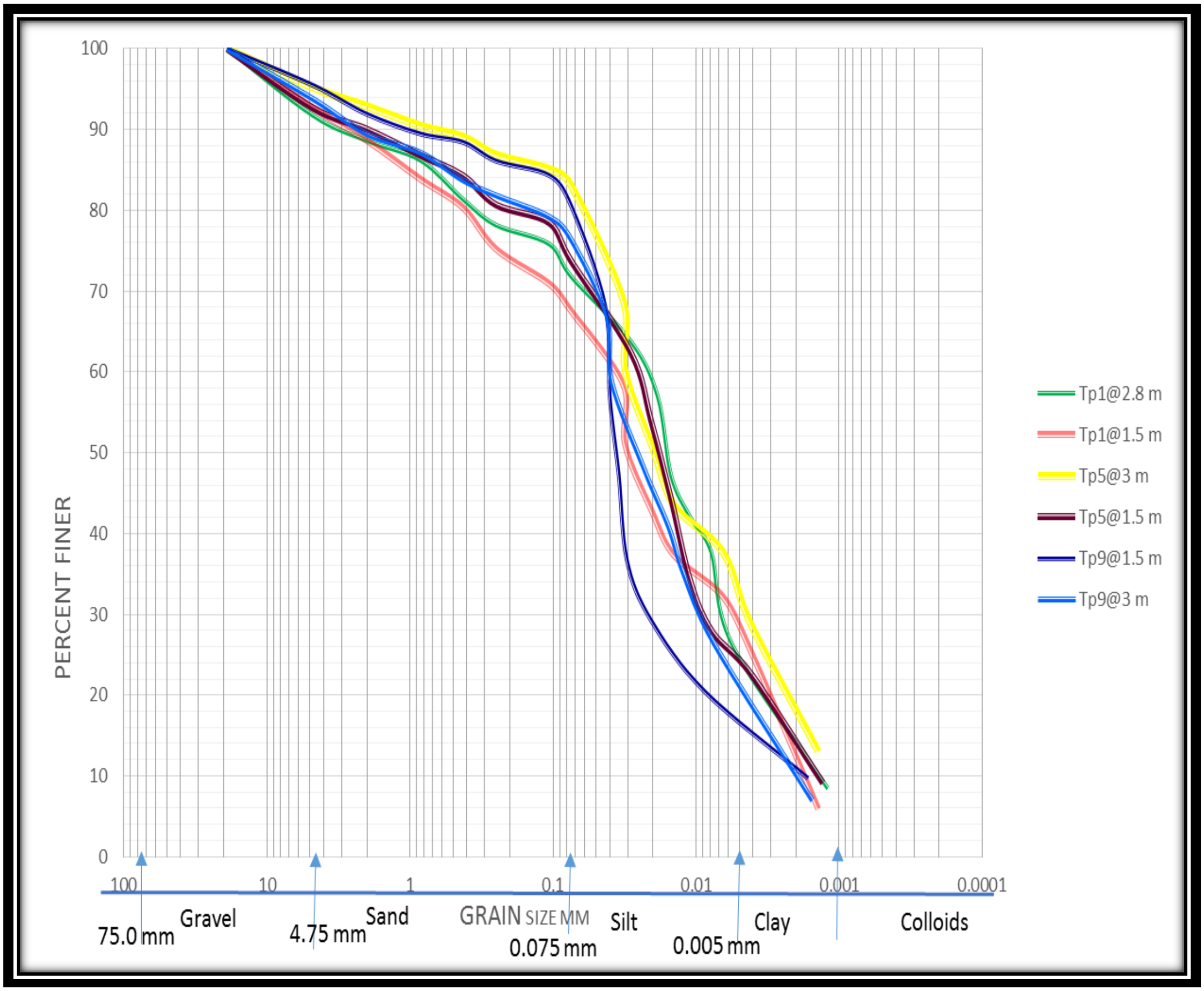

Figure4.1:- typical grain size distribution curve for the combined sieve and hydrometric analysis.

4.1.4. Atterberg limits

The Swedish soil scientist Albert Atterberg originally defined seven "limits of Consistency" to classify fine-grained soils, but in current engineering practice only two of the limits, the liquid and plastic limits are commonly used. (A third limit, called the shrinkage limit, is used occasionally) [19]. The obtained results are shown in table 4.4 below**.**

Table 4.4. plastic limit, liquid limit and plastic index test result

Sample designation	Depth(m)	Liquid limit (LL %)	Plastic limit (PL %)	Plastic index (PI %)
TP1	1.5	46	35	11
	2.8	48	35	13
TP2	1.5	39	30	9
	3.0	41	31	10
TP3	1.5	47	36	12
	3.0	49	34	15
TP4	1.5	36	27	9
	3.0	40	29	11
TP5	1.5	45	35	10
	3.0	49	34	15
TP6	1.5	39	30	10
	3.0	42	31	11
TP7	1.5	44	35	9
	2.7	45	36	9
TP8	1.5	46	33	12
	3.0	48	34	14
TP9	1.5	46	36	11
	3.0	48	36	12
TP10	1.5	45	34	11
	3.0	50	34	16

4.1.5. Shrinkage limit

The shrinkage limit is the dividing line between the semisolid and solid states. It is quantified for a given soil as specific water content, and from a physical standpoint, it is the water content that is just sufficient to fill the voids when the soil is at the minimum volume it will attain on drying. Below the shrinkage limit, any water content change will not result in volume change; above the shrinkage limit, any water change will result in accompanying volume change.

Shrinkage limit, SL can be calculated as follows.

$$\mathrm{SL} = \omega - \left\{ \left(\frac{V - V_o}{W_o} \right) \gamma_\omega \times 100 \right\} \quad \text{……………………………………………… (4.1)}$$

Where: SL= shrinkage limit (expressed as a percentage)

ω= water content of wet soil in the shrinkage dish, %

V = volume of wet soil pat (same as volume of shrinkage dish), cm^3

V_o = volume of oven-dried soil pat, cm^3

W_o = weight of oven-dried soil pat, g

γ_ω = unit weight of water, 1 g/cm^3

Another soil parameter that often determined in conjunction with the shrinkage limit is the shrinkage ratio, which is an indicator of how much volume change may occur as changes in water content above the shrinkage limit takes place. The shrinkage ratio is defined as the ratio of a given volume change, expressed as a percentage of the dry volume, to the corresponding change in water content above the shrinkage limit, expressed as a percentage of the mass of oven-dried soil. In equation form,

$$R = \left\{ \frac{\Delta V / V_o}{\Delta \omega / W_o} \right\} = \frac{W_o}{V_o} \quad \text{……………………………………………… (4.2)}$$

Where: R = Shrinkage ratio

$\Delta\omega = (\Delta V)(\gamma_\omega)$ =Change in water content (gm), where unit weight of water is g/cm^3

ΔV = soil volume change (cm^3)

V_o = volume of oven-dried soil (cm^3)

W_o= weight of oven-dried soil pat (gm)

The shrinkage limit and shrinkage ratio are particularly useful in analyzing soils that undergo large volume changes with changes in water content (such as Montimorillonite and Illite clays). The shrinkage ratio gives an indication of how much volume change may occur as changes in water content above the shrinkage limit takes place. Test procedure can be seen in ASTM D427-83, ASTM D 4943 and AASHTO T-92. These test methods uses mercury or wax to determine shrinkage limit. Due to unavailability these material ,for this research work a linear shrinkage values were determined according to British Standard, BS: 1377: part 2:1990. in order to determine the shrinkage characteristics of the soils. This method is an alternative to the volumetric shrinkage limit.

Linear shrinkage (LS) can be calculated as follows:

$$Ls = \frac{\text{Lo}-\text{Lf}}{\text{Lo}} \times 100 \quad \text{.........} \quad (4.3)$$

Where: LS = linear shrinkage

L_o = length of wet soil bar

L_f = length of dry soil bar

The obtained results are shown in table 4.5 below.

Table 4.5. Linear shrinkage limit test result.

Sample designation	Depth(m)	Linear Shrinkage limit(LS) %
TP1	1.5	5
	2.8	5
TP2	1.5	4
	3.0	5
TP3	1.5	4
	3.0	6
TP4	1.5	4
	3.0	5
TP5	1.5	5
	3.0	4
TP6	1.5	5
	3.0	4
TP7	1.5	4
	2.7	6
TP8	1.5	5
	3.0	5
TP9	1.5	4
	3.0	5
TP10	1.5	4
	3.0	6

4.1.6. Free swell

Simple soil property tests, Atterberg limit tests, linear shrinkage tests, and free swell tests can be used for the evaluation of the swelling potential of expansive soils. However, the free swell test is Very crude and was used in the early days when refined testing methods were not available [21]. The test is performed by placing 10 ml dry soil specimen, passing through 425μ sieve, into 100 ml graduated cylinder and filled with water. The swelled volume was noted after the soil left to settle for about 24hrs.

$$\text{Free swell}(\%) = \frac{\text{Final volume} - \text{Initial volume of the soil}}{\text{Initial volume of soil}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.4)$$

Free swell test results for all samples are summarized in table 4.6.

Table 4.6. Free swell test result.

Sample designation	Depth (m)	Free swell (%)
TP1	1.5	34
	2.8	33
TP2	1.5	32
	3.0	30
TP3	1.5	31
	3.0	35
TP4	1.5	29
	3.0	30
TP5	1.5	26
	3.0	31
TP6	1.5	28
	3.0	29
TP7	1.5	24
	2.7	26
TP8	1.5	22
	3.0	28
TP9	1.5	21
	3.0	26
TP10	1.5	27
	3.0	31

From the test result one can see that the free swell of the soil under investigation ranges from 21% - 35%. Those soils having a free swell less than 50% are considered as low in degree of expansion. While, soils having free swell values between 50 and 100% shows medium degree of expansion and above 100% it shows high degree of expansion [22]. Hence, all soil samples on this study are non-expansive soils which are in agreement with the other supplementing physical test results.

4.2. Soil classification

4.2.1. General

The purpose of any classification system is to categorize soils by relating their appearance and behavior with previously established engineering properties and performance. Attributes of a good classification system include simplicity, reproducibility under variable conditions, and applicability to all soils likely to be encountered. A good system should make distinctions of practical importance to local designs.

The most widely used classification schemes are those that divide soils into an orderly, easily remembered system of groups, or classes, that have similar physical and engineering properties and that can be identified by simple and inexpensive tests. These groups ideally provide estimates of both the engineering characteristics and performance of soils for design and construction engineers. The descriptions of soils within the groups of a given classification typically are represented by alphabetical or alphanumeric symbols for rapid identification in written material, graphic boring logs, and on engineering drawings. The continued use of a few engineering soil classification systems is the result of the provision in each for the needs of the Civil Engineer as well as the adaptability of the classification to the variety of soils encountered in engineering practice [23].

Soil classification is an important aspect to know the characteristic of the soil under consideration. There are different methods of classification based on the identification tests performed on the soil. Unified Soil Classification System (USCS) and the American Association of State Highway Transport Officials (AASHTO) methods are among the widely used schemes of soil Classification. The soils under study have been classified according to USCS and AASHTO M-145. Average grain size classification according to ASTM [24].

Gravel	76.2mm – 4.75mm
Sand	4.75mm – 0.075mm
Coarse sand	4.75mm – 2mm

Medium sand	2mm - 0.425mm
Fine sand	0.425 – 0.075
Silt size	0.074 to 0.005 mm
Clay size	<0.005 mm
Colloids	<0.001 mm

Average grain size classification according to USCS [3].

Gravel	75mm - 4.75mm
Sand	4.75mm - 0.075mm
Silt	0.075mm - 0.002mm
Clay	< 0.002mm

Average grain size classification according to AASHO [22].

Gravel	>2mm
Sand	2mm - 0.05mm
Silt	0.05mm - 0.002mm
Clay	< 0.002mm

4.2.2. USCS Classification Method

The Unified Soil Classification System is based on the recognition of the type and predominance of the constituents considering grain-size, gradation, plasticity and compressibility. It divides soil in to three major divisions: coarse-grained soils, fine gained soils and highly organic (peaty) Soils. In the field, identification is accomplished by visual examination for the coarse-grained soils and a few simple hand tests for the fine-grained soils. In the laboratory, the grain-size curve and the Atterberg limits can be used [25].

The USCS uses symbols for particular size groups. These symbols and their representations are: G–gravel, S–Sand, M–Silt, and C–Clay. These are combined with other symbols expressing gradation characteristics–W for well-graded and P for poorly graded and plasticity characteristics – H for high and L for low, and a symbol O for the presence of Organic material.

Experimental results of soils tested from different parts of the world were plotted on a graph of plasticity index (ordinate) versus liquid limit (abscissa). It was found that clays, silts, and organic soils lie in distinct regions of the graph called the plasticity chart, figure4.2.

The A-line separates clays from silts and the U-line indicates the upper limit of the relationship Between PI and LL. Accordingly, the soil under study is plotted on the plasticity chart.

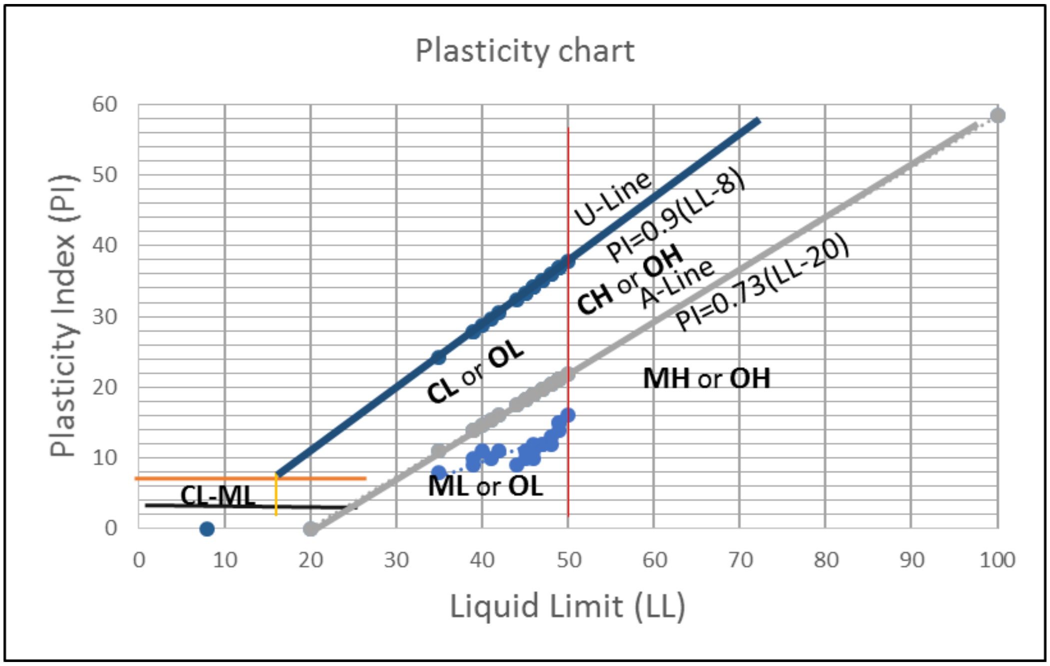

Figure4.2:- Plasticity chart of the area according to USCS

Table 4.7. USCS Classification of Shashemene soil samples

Sample designation	Depth(m)	Percent passes No.200(0.075) Sieve	Liquid limit (LL %)	Plastic index (PI %)	Classification according to USCS
TP1	1.5	67.6	46	11	ML
	2.8	71.8	48	13	ML
TP2	1.5	73.3	39	9	ML
	3.0	75.4	41	10	ML
TP3	1.5	71.9	47	12	ML
	3.0	79.4	49	15	ML
TP4	1.5	70.1	36	9	ML
	3.0	78.5	40	11	ML
TP5	1.5	73.8	45	10	ML
	3.0	83.1	49	14	ML
TP6	1.5	77.2	39	10	ML
	3.0	78.6	42	11	ML
TP7	1.5	77.9	44	9	ML
	2.7	80.4	45	9	ML
TP8	1.5	74.9	46	12	ML
	3.0	80.6	48	14	ML
TP9	1.5	80.5	46	11	ML
	3.0	76.4	48	12	ML
TP10	1.5	75.3	45	11	ML
	3.0	74.1	50	16	ML

The results obtained from grain size analysis indicate that more than 50% of the soil particles passes Sieve no. 200 in all test pits. According to Unified Soil Classification System (USCS) the soil in the study area is fine-grained soil (silt and clayey soils). The combined sieve and hydrometer analysis indicate that the dominant proportion of soil particle in Shashemene Town is silt soils with group name clayey silt.

As shown previously in figure4.2 of plasticity chart of the study area according to Unified Soil Classification System, the soil under investigation lies below the A-line in the region of inorganic silt with low plasticity.

4.2.3 AASHTO Classification System

According to this system, soil is classified into seven major groups: A-1 through A-7. Soils classified under groups A-1, A-2, and A-3 are granular materials of which 35% or less of the particles passing through the No.200 sieve. Soils of which more than 35% pass through the No.200 sieve are classified under groups A-4, A-5, A-6, and A-7. These soils are mostly silt and clay type materials.

Table 4.8. AASHTO Classification of Shashemene soil samples

Sample designation	Depth (m)	Percent passes on Sieve			LL (%)	PI (%)	Group index	Group Classification	Usual type of significant constituent materials
		No.10	N.40	No.200					
TP1	1.5	88.7	80.3	67.6	46	11	9	A-7-5	Clayey soils
	2.8	88.6	81.4	71.8	48	13	10	A-7-5	Clayey soils
TP2	1.5	92.2	85.9	73.3	39	9	7	A-4	Silty soils
	3.0	93.0	86.4	75.2	41	10	8	A-5	Silty soils
TP3	1.5	88.0	82.7	71.9	47	12	10	A-7-5	Clayey soils
	3.0	94.7	90.8	79.4	49	15	14	A-7-5	Clayey soils
TP4	1.5	86.1	81.6	70.1	36	9	5	A-4	Silty soils
	3.0	87.4	80.3	78.5	40	11	9	A-6	Clayey soils
TP5	1.5	90.0	84.3	73.7	45	10	8	A-5	Silty soils
	3.0	92.9	89.1	83.1	49	14	14	A-7-5	Clayey soils
TP6	1.5	90.9	84.6	74.2	39	10	8	A-4	Silty soils
	3.0	89.6	83.4	78.6	42	11	10	A-7-5	Clayey soils
TP7	1.5	95.1	88.8	77.9	44	9	8	A-5	Silty soils
	2.7	96.4	89.9	80.4	45	9	10	A-5	Silty soils
TP8	1.5	91.1	84.3	74.9	46	12	10	A-7-5	Clayey soils
	3.0	92.2	87.0	80.6	48	14	14	A-7-5	Clayey soils
TP9	1.5	91.9	88.4	80.6	46	11	11	A-7-5	Clayey soils
	3.0	89.4	83.7	76.5	48	12	11	A-7-5	Clayey soils
TP10	1.5	90.8	84.1	76.3	45	11	10	A-7-5	Clayey soils
	3.0	89.7	82.9	74.8	50	16	13	A-7-5	Clayey soils

As shown in table 4.8 above, one can see that soil in the study area is classified in group A-7-5, A-6, A-5, and A-4. This groups of soils are clayey and silty soils respectively.

However, as the property of the soil under study is more dependent on particle size distribution, there is a need to appraise other classification system based on grain size

4.2.4 Textural Classification (Modified Triangular Diagram)

The triangular classification system suggested by U.S Bureau of Public Roads is commonly known as the textural classification system. Later, the Mississippi River Commission (USA) proposed a modified triangular diagram (Fig.4.3) so as to eliminate terms which are not used in soil engineering. The term texture issued to express the percentage of the three constituents of Soils, namely, sand, silt and clay [28].

According to MIT textural classification system, the percentage of sand (size 0.06 to 2.0 mm), Silt (size 0.002 to 0.06 mm) and clay (size less than 0.002mm) are plotted along the three sides of an equilateral triangle. If the soil contains a certain percentage of soil particles larger than 2.0 mm, a correction is applied in which the sum of the percentages of sand, silt and clay is increased to 100%. Such a classification is more suitable for describing coarse-grained soils rather than clay soils, whose properties are more dependent on particle size distribution. Hence, according to this Classification system, the soil under study lies in clayey silt part of the triangular chart (Fig.4.3).

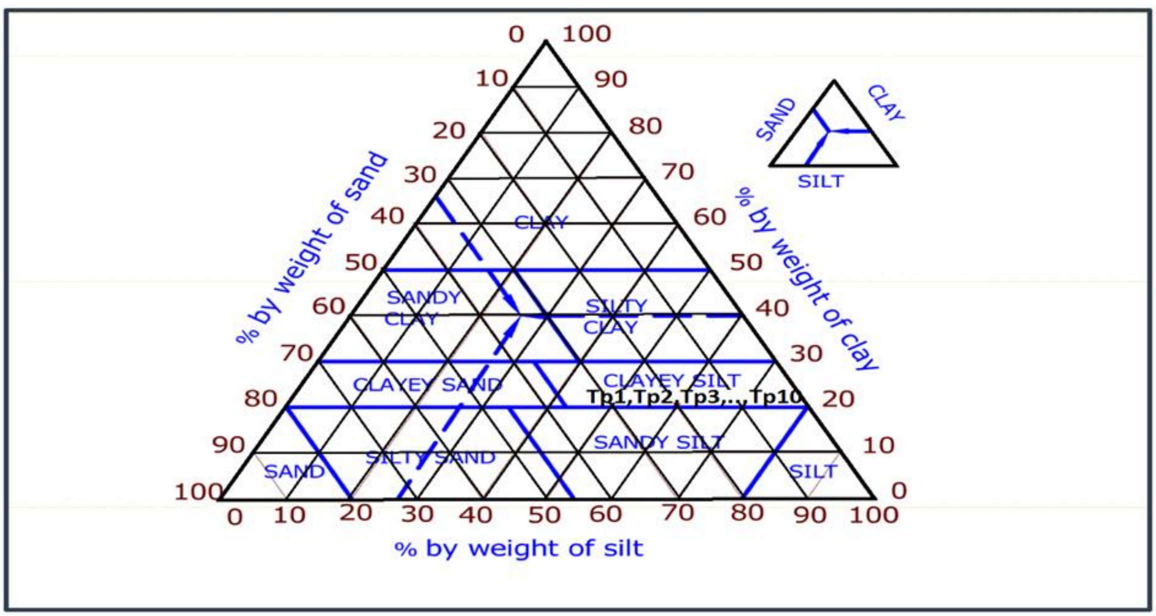

Figure4.3:-Modified Triangular Diagram [23]

4.3. Comparisons with previously done researches

For the soil under investigation; Index property were studied and a comparison was made with Soils with low plasticity inorganic silt. Adama low plastic silty soil and Ziway low plastic silty soil studied by Dagnachew Debebe, [5] and Bezza Tesfaye [4].

Table 4.9. Index property Test Results in different parts of the country

	Thesis by Dagnachew Debebe, [5]	**Thesis by Bezza Tesfaye [4].**	**Current thesis**
Location	Adama	Ziway	Shashemene
Clay content (%)	14-58	6.7-10.9	21.4-30.8
Silt content (%)	14-61	51.4-73.0	40.1-62.5
Sand content (%)	25-56	15.2-40.4	12.1-25.1
Liquid limit (%)	39-49	27-37	39-50
Plastic Limit (%)	26-37	23-29	27-36
Plastic index (%)	10-15	4-8	8-16
Moisture content (%)	25-31	22.6-35.8	26-36
Specific gravity	2.61-2.70	2.40-2.62	2.43-2.60
From plasticity chart	ML	ML	ML

Table 4.14 show the average values of various tests done at different parts of countries, i.e., sieve analysis, liquid limit, plastic index and specific gravities showing different properties. As indicated in the above table Shashemene soils show lower plasticity (clay content) as compared to Adama soil. The data indicate that there is a considerable similarity in the physical properties of Adama and Shashemene town soils

5. CONCULUSION AND RECOMENDATION

5.1. Conclusion

In this study an attempt has been made to examine Index properties of soil in Shashemene town. In order to meet the objective, different laboratory test and visual observation of soil in the field were carried out. Based on the test results the following conclusions were made:

- From the gradation charts and the soil classifications made by using USCS, Shashemene soil is predominantly reddish brown, clayey silt soil. According to AASHTO system of soil classification soil in the study area is classified in group A-7-5, A-6, A-5, and A-4. This groups of soils are clayey and silty soils respectively but the USCS is used for general geotechnical purpose, while AASHTO is Specifically used in road sector.
- The laboratory test result obtained from twenty sample has shown that, moisture content ranges from 26 – 36%, liquid limit ranges from 39 – 50%, plastic limit ranges from 27 – 36%, plasticity index ranges from 8 – 16%, linear shrinkage limit ranges from 4 – 6%, free swell ranges from 21 – 35% and specific gravity ranges from 2.43 – 2.60.
- From the grain Size distribution curve: Gravel size ranging from 1.9 to 9.8%, Sand size ranging from 12.1 to 21.7%, silt size ranging from 44.7 to 60.2%, clay size ranging from 21.4 to 30.8%.

5.2 Recommendation

- Detail investigation has to be done to have reliable data with implementation of geostatistical tools in order to develop proper zoning map of the town. The maximum depth for this investigation was only 3 m, which is far below that influence zone of urban infrastructure and hence more feasible depth shall be considered in the future study.
- Though this research work is limited to index property test due to unavailability of test equipment, it could serve as starting point for further research, which possibly consider other soil engineering parameter such as shear strength and compressibility characteristics.

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APPENDEX-A

A-1 Some of specific gravity test result

For Tp1@ 2.8 m.

Determination No.	1	2
Pycnometer No.	1	2
Mass of pycnometer + soil + water, Mpws(g)	168.48	168.53
Temperature, $T_{t(}{}^{o}C)$	23	23
Mass of pycnometer + water at Tt , Mpw(atTt) (g)	150.58	150.48
Mass of dry soil , Ms (gm)	30	30
Conversion factor , K	0.99933	0.99933
Specific gravity of soil at 20°c.	2.48	2.51
Average specific gravity	2.49	

Where: $G_t = \frac{M_s}{M_{pw,t}-(M_{pws,t}-M_s}$ ………………………………………………………… (4.4)

$G_{20}{}^{o}{}_{C} = K \cdot G_t$ ………………………………………………………….. (4.5)

For Tp2@ 1.5 m.

Determination No.	1	2
Pycnometer No.	1	2
Mass of pycnometer + soil + water, Mpws(g)	168.14	168.43
Temperature, $T_{t(}{}^{o}C)$	23	23
Mass of pycnometer + water at Tt , Mpw(atTt) (g)	150.58	150.48
Mass of dry soil , Ms (gm)	30	30
Conversion factor , K	0.99933	0.99933
Specific gravity of soil at 20°c.	2.41	2.49
Average specific gravity	2.45	

Where: $G_t = \frac{M_s}{M_{pw,t} - (M_{pws,t} - M_s}$

$G_{20^oC} = K \cdot G_t$

For Tp2@ 3m.

Determination No.	**1**	**2**
Pycnometer No.	1	2
Mass of pycnometer + soil + water, Mpws(g)	168.26	168.45
Temperature,$T_{t(^oC})$	23	23
Mass of pycnometer + water at Tt , Mpw(atTt) (g)	150.58	150.48
Mass of dry soil , Ms (gm)	30	30
Conversion factor , K	0.99933	0.99933
Specific gravity of soil at 20°c.	2.43	2.49
Average specific gravity	2.46	

Where: $G_t = \frac{M_s}{M_{pw,t} - (M_{pws,t} - M_s}$

$G_{20^oC} = K \cdot G_t$

For Tp3@ 3m.

Determination No.	**1**	**2**
Pycnometer No.	1	2
Mass of pycnometer + soil + water, Mpws(g)	168.66	168.48
Temperature,$T_{t(^oC})$	23	23
Mass of pycnometer + water at Tt , Mpw(atTt) (g)	150.58	150.48
Mass of dry soil , Ms (gm)	30	30
Conversion factor , K	0.99933	0.99933
Specific gravity of soil at 20°c.	2.52	2.50
Average specific gravity	2.51	

Where: $G_t = \frac{M_s}{M_{pw,t} - (M_{pws,t} - M_s}$

$$G_{20^oC} = K \cdot G_t$$

For Tp6@ 3m

Determination No.	**1**	**2**
Pycnometer No.	1	2
Mass of pycnometer + soil + water, Mpws(g)	168.46	168.78
Temperature,$T_{t(^oC)}$	23	23
Mass of pycnometer + water at Tt , Mpw(atTt) (g)	150.58	150.48
Mass of dry soil , Ms (gm)	30	30
Conversion factor , K	0.99933	0.99933
Specific gravity of soil at 20°c.	2.47	2.56
Average specific gravity	2.52	

Where: $G_t = \frac{M_s}{M_{pw,t} - (M_{pws,t} - M_s}$

$$G_{20^oC} = K \cdot G_t$$

For Tp7@ 1.5 m

Determination No.	**1**	**2**
Pycnometer No.	1	2
Mass of pycnometer + soil + water, Mpws(g)	168.12	168.28
Temperature,$T_{t(^oC)}$	23	23
Mass of pycnometer + water at Tt , Mpw(atTt) (g)	150.58	150.48
Mass of dry soil , Ms (gm)	30	30
Conversion factor , K	0.99933	0.99933
Specific gravity of soil at 20°c.	2.41	2.45
Average specific gravity	2.43	

Where: $G_t = \frac{M_s}{M_{pw,t} - (M_{pws,t} - M_s}$

$$G_{20^oC} = K \cdot G_t$$

For Tp10@ 3 m

Determination No.	**1**	**2**
Pycnometer No.	1	2
Mass of pycnometer + soil + water, Mpws(g)	168.5	168.9
Temperature, $T_{t(^oC)}$	23	23
Mass of pycnometer + water at Tt , Mpw(atTt) (g)	150.29	150.56
Mass of dry soil , Ms (gm)	30	30
Conversion factor , K	0.99933	0.99933
Specific gravity of soil at 20°c.	2.54	2.57
Average specific gravity	2.56	

Where: $G_t = \frac{M_s}{M_{pw,t} - (M_{pws,t} - M_s}$

$$G_{20^oC} = K \cdot G_t$$

APPENDEX-B

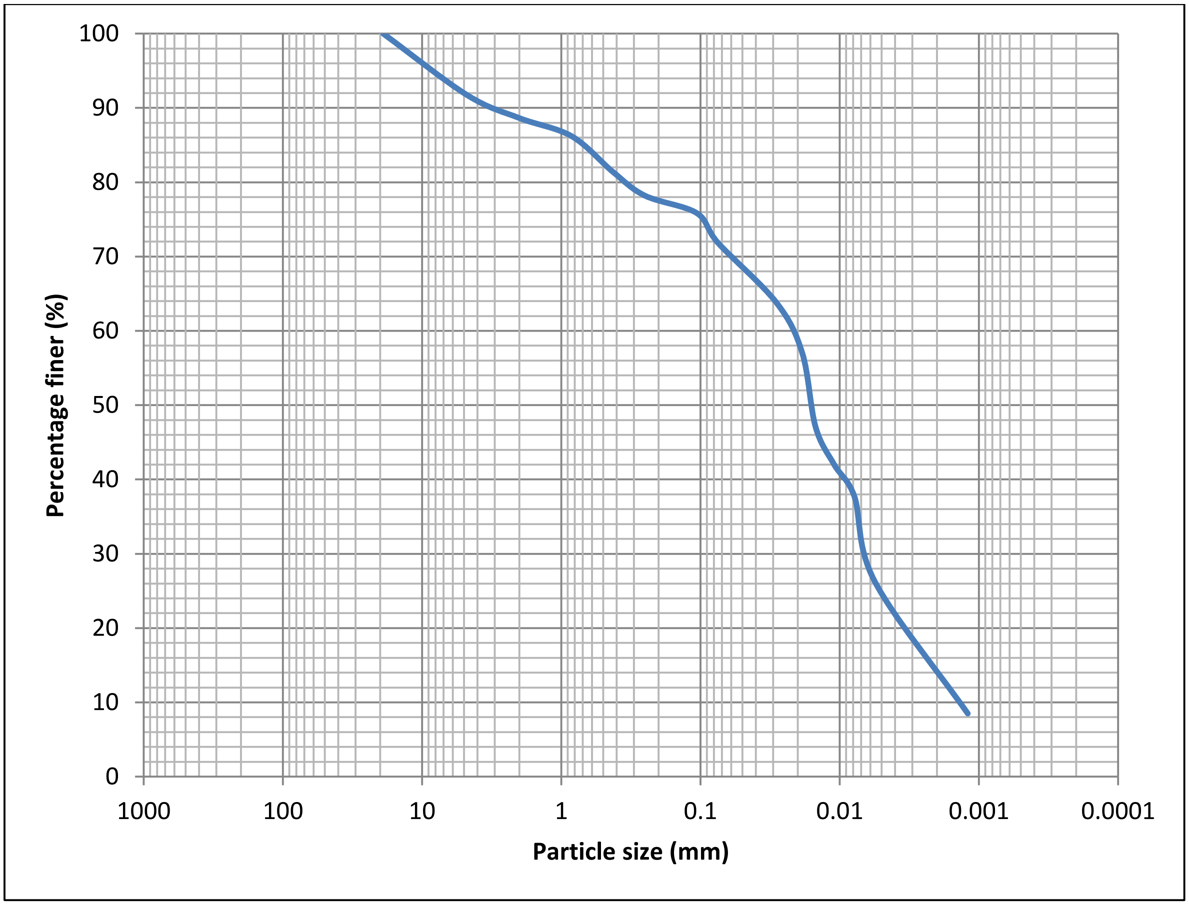
B-1Some of grain size and hydrometer analysis

Sieve Analysis for Tp1@ 1.5 m

Sieve opining(mm)	Mass of Empty Sive(g)	Mass of Sieve +Soil Retained(g)	Soil Retained(g)	percent Retained	Cumulative Percent Passing
19	622.5	622.5	0	0	100
4.75	350.6	391.9	41.3	8.26	91.74
2	400.9	416.4	15.5	3.1	88.64
0.84	372.3	384.55	12.25	2.45	86.19
0.425	305.8	329.8	24	4.8	81.39
0.25	305.3	321.3	16	3.2	78.19
0.106	271.1	282.85	11.75	2.35	75.84
0.075	261.3	281.15	19.85	3.97	71.87
pan	255.7	615.05	359.35	71.87	

Hydrometr Analysis for Tp1 at 1.5 m

Elapsed Time(min)	Temp. o_C	Actual Hydro. Rdg. Ra	Effective Depth L	Coefficient K	Grain Size (mm)	Coefficient C_T	Coefficient a	Corr. Hydr. Rdg. Rc	% Finer p	% Adjusted Finer P_A
2	23	48.5	8.2	0.01404	0.02844	0.70	1.05	43.2	88.7	63.8
5	23	46.5	8.7	0.01404	0.01854	0.70	1.05	37.4	78.6	57.0
8	23	44.5	9	0.01404	0.0149	0.70	1.05	31.2	65.5	47.1
15	23	44	9.1	0.01404	0.01094	0.70	1.05	27.8	58.4	42.0
30	23	42.5	9.3	0.01404	0.00783	0.70	1.05	25.0	52.4	37.7
60	24	40.5	9.8	0.01388	0.00560	1.00	1.05	17.4	36.6	26.3
1440	23	34.5	10.5	0.01404	0.00120	0.70	1.05	5.6	11.8	8.5


100
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Percentage finer (%)
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0.1
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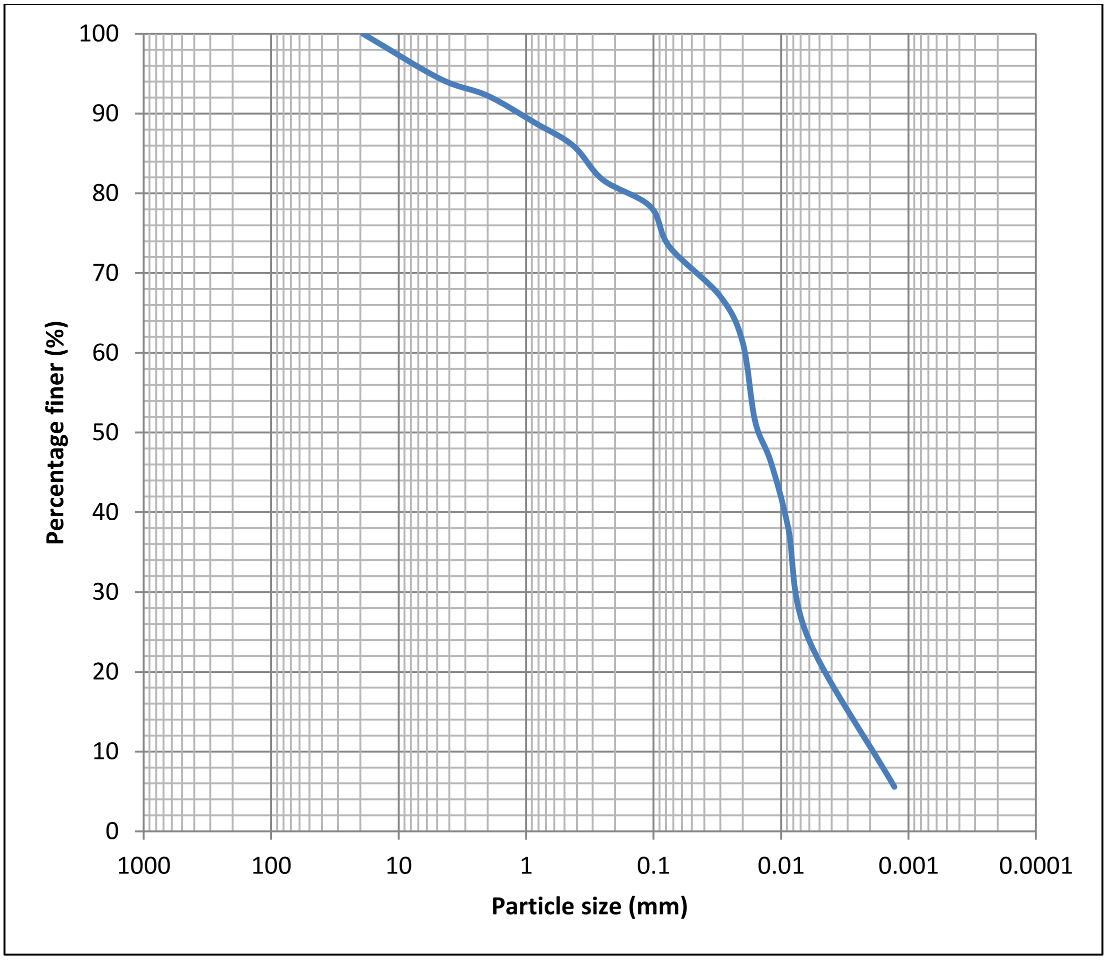
Particle size (mm)

Sieve Analysis for Tp2@ 1.5 m

Sive opining(mm)	mass of Empty Sive(g)	Mass of Sive +Soil Retained	Soil Retained(g)	percent Retaned	Comulative Percent Passing
19	622.5	622.5	0	0	100
4.75	350.6	378.7	28.1	5.62	94.38
2	400.9	411.6	10.7	2.14	92.24
0.84	372.3	389.55	17.25	3.45	88.79
0.425	305.8	320	14.2	2.84	85.95
0.25	305.3	326.55	21.25	4.25	81.7
0.106	271.1	287.85	16.75	3.35	78.35
0.075	261.3	286.55	25.25	5.05	73.3
pan	255.7	622.2	366.5	73.3	

Hydrometer Analysis for Tp2@ 1.5m

Elapsed Time(min)	Temp. o_C	Actual Hydro. Rdg. Ra	Effective Depth L	Coefficient K	Grain Size (mm)	Coefficient C_T	Coefficient a	Corr. Hydr. Rdg. Rc	% Finer p	% Adjusted Finer P_A
2	23	44	9.1	0.01404	0.02844	0.70	1.05	43.6	91.6	67.1
5	23	37	10.2	0.01404	0.01854	0.70	1.05	39.8	83.6	61.3
8	23	36	10.4	0.01404	0.0149	0.70	1.05	33.4	70.2	51.5
15	23	32.5	11	0.01404	0.01094	0.70	1.05	30.1	63.2	46.3
30	23	28	11.7	0.01404	0.00783	0.70	1.05	24.7	51.9	38.1
60	24	27	11.9	0.01388	0.00560	1.00	1.05	15.8	33.3	24.4
1440	23	25	12.2	0.01404	0.00120	0.70	1.05	3.6	7.6	5.6


100
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80
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30
20
10
0
Percentage finer (%)
1000
100
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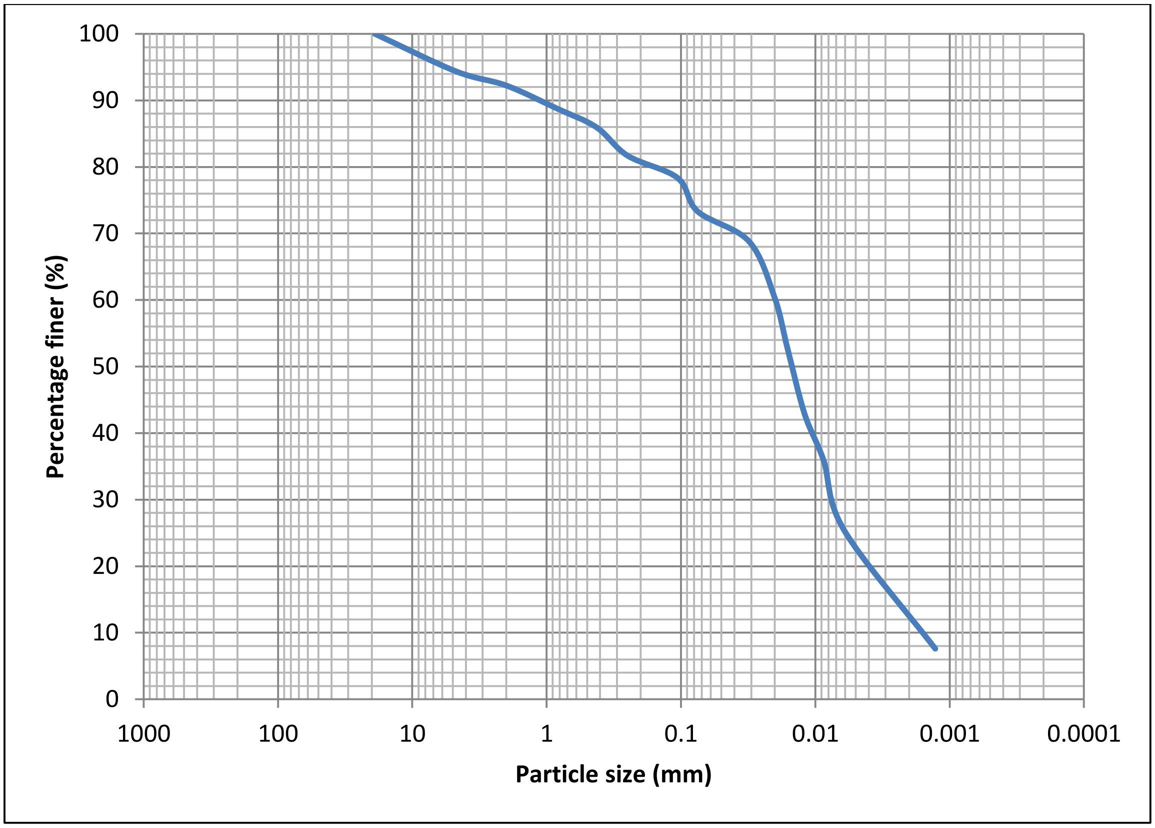
0.1
0.01
0.001
0.0001
Particle size (mm)

Sieve Analysis for Tp2@ 3 m

Sive opining(mm)	mass of Empty Sive(g)	Mass of Sive +Soil Retained	Soil Retained(g)	percent Retaned	Comulative Percent Passing
19	622.5	622.5	0	0	100
4.75	350.6	373	22.4	4.48	95.52
2	400.9	413.6	12.7	2.54	92.98
0.84	372.3	391.35	19.05	3.81	89.17
0.425	305.8	319.9	14.1	2.82	86.35
0.25	305.3	333.4	28.1	5.62	80.73
0.106	271.1	289.65	18.55	3.71	77.02
0.075	261.3	269.95	8.65	1.73	75.29
pan	255.7	632.15	376.45	75.29	

Hydrometer Analysis for Tp2@ 3 m

Elapsed Time(min)	Temp. o_C	Actual Hydro. Rdg. Ra	Effective Depth L	Coefficient K	Grain Size (mm)	Coefficient C_T	Coefficient a	Corr. Hydr. Rdg. Rc	% Finer p	% Adjusted Finer P_A
2	23	39	9.9	0.01399	0.03111	0.70	1.05	43.5	91.4	68.8
5	23	36.5	10.3	0.01399	0.02012	0.70	1.05	38.2	80.2	60.4
8	23	35	10.6	0.01399	0.0161	0.70	1.05	33.3	69.9	52.7
15	23	32	11.1	0.01399	0.01203	0.70	1.05	27.2	57	42.9
30	23	29	11.5	0.01399	0.00868	0.70	1.05	22.7	47.7	35.9
60	24	28	11.7	0.01383	0.0061	1.00	1.05	16.1	33.8	25.4
1440	23	26	12	0.01399	0.00128	0.70	1.05	4.8	10.1	7.6


Percentage finer (%)
100
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30
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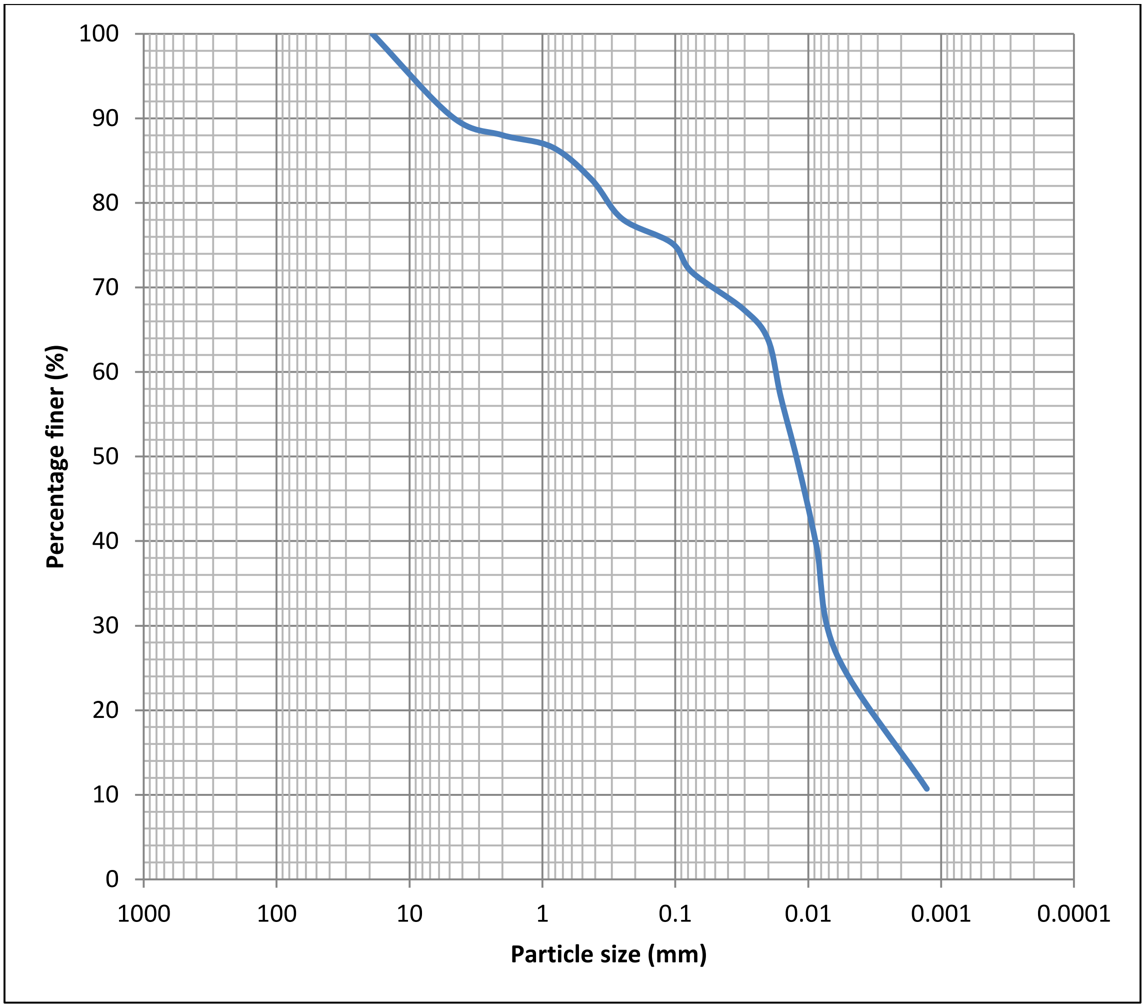
0.1
0.01
0.001
0.0001
Particle size (mm)

Sieve Analysis for Tp3@ 1.5 m

Sive opining(mm)	mass of Empty Sive(g)	Mass of Sive +Soil Retained	Soil Retained(g)	percent Retaned	Comulative Percent Passing
19	622.5	622.5	0	0	100
4.75	350.6	399.8	49.2	9.84	90.16
2	400.9	411.6	10.7	2.14	88.02
0.84	372.3	379.45	7.15	1.43	86.59
0.425	305.8	325	19.2	3.84	82.75
0.25	305.3	328.55	23.25	4.65	78.1
0.106	271.1	285.35	14.25	2.85	75.25
0.075	261.3	278.45	17.15	3.43	71.82
pan	255.7	614.8	359.1	71.82	

Hydrometer Analysis for Tp3@ 1.5 m

Elapsed Time(min)	Temp. o_C	Actual Hydro. Rdg. Ra	Effective Depth L	Coefficient K	Grain Size (mm)	Coefficient C_T	Coefficient a	Corr. Hydr. Rdg. Rc	% Finer p	% Adjusted Finer P_A
2	23	48	8.4	0.0139	0.02871	0.70	1.05	44.8	94	67.5
5	23	37	10.2	0.01399	0.02001	0.70	1.05	42.4	89.1	63.9
8	23	33.5	10.8	0.01399	0.0163	0.70	1.05	37.8	79.5	57.1
15	23	32.5	11	0.01399	0.01199	0.70	1.05	32.7	68.7	49.4
30	23	29	11.5	0.01399	0.00867	0.70	1.05	26.2	54.9	39.5
60	24	27.5	11.6	0.01383	0.00609	1.00	1.05	17.6	36.9	26.6
1440	23	24	12.4	0.01399	0.00130	0.70	1.05	7.1	14.8	10.7


100
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70
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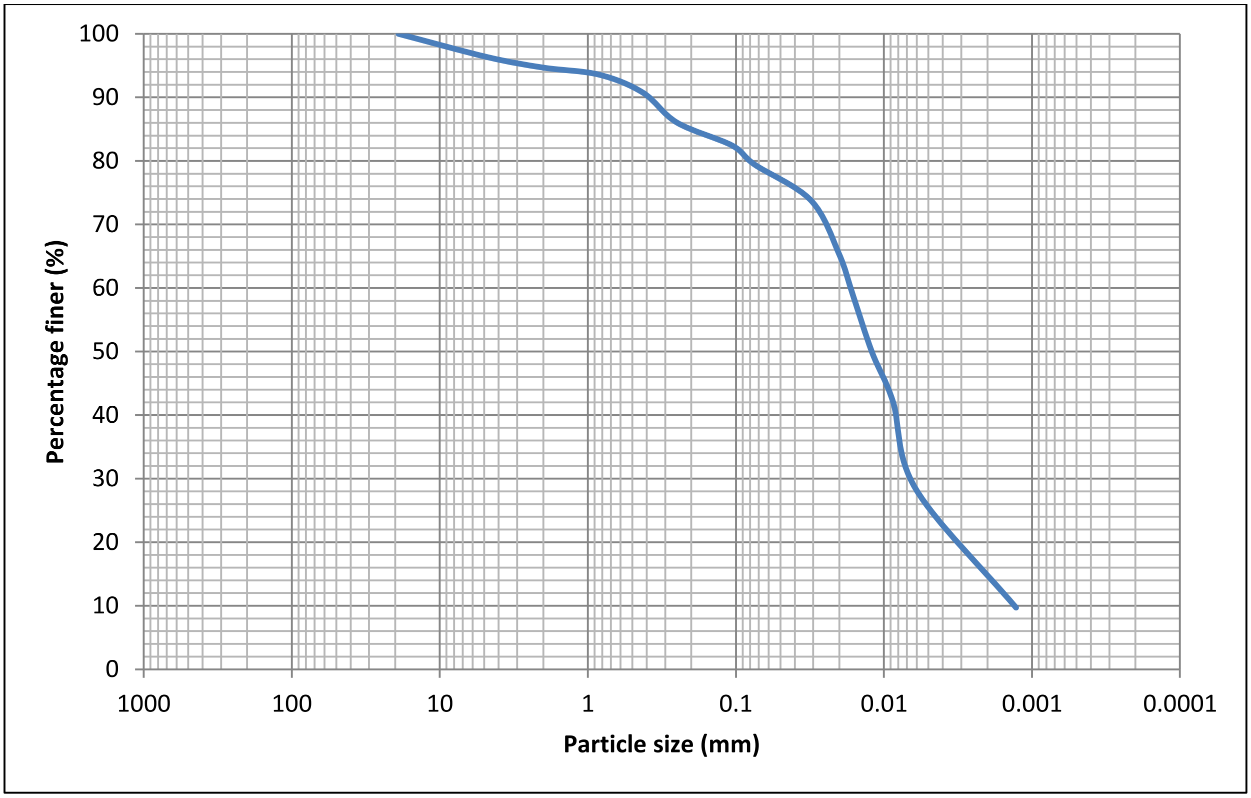
30
20
10
0
Percentage finer (%)
1000
100
10
1
0.1
0.01
0.001
0.0001
Particle size (mm)

Sieve Analysis for Tp3@ 3 m

Sive opining(mm)	mass of Empty Sive(g)	Mass of Sive +Soil Retained	Soil Retained(g)	percent Retaned	Comulative Percent Passing
19	622.5	622.5	0	0	100
4.75	350.6	368.95	18.35	3.67	96.33
2	400.9	409.1	8.2	1.64	94.69
0.84	372.3	377.85	5.55	1.11	93.58
0.425	305.8	319.9	14.1	2.82	90.76
0.25	305.3	328.9	23.6	4.72	86.04
0.106	271.1	289.15	18.05	3.61	82.43
0.075	261.3	276.15	14.85	2.97	79.46
pan	255.7	653	397.3	79.46	

Hydrometer Analysis for Tp3@ 3 m

Elapsed Time(min)	Temp. o_C	Actual Hydro. Rdg. Ra	Effective Depth L	Coefficient K	Grain Size (mm)	Coefficient C_T	Coefficient a	Corr. Hydr. Rdg. Rc	% Finer p	% Adjusted Finer P_A
2	23	50	8.1	0.01376	0.02871	0.70	1.04	44.7	92.9	73.8
5	23	44	9.1	0.01376	0.02001	0.70	1.04	39.6	82.3	65.4
8	23	36.5	10.3	0.01376	0.0163	0.70	1.04	35.5	73.8	58.7
15	23	31	11.2	0.01376	0.01199	0.70	1.04	30.2	62.8	49.9
30	23	28	11.7	0.01376	0.00867	0.70	1.04	25.4	52.9	42.1
60	24	24	12.4	0.01360	0.00609	1.00	1.04	17.2	35.8	28.4
1440	23	21.5	12.8	0.01376	0.001301	0.70	1.04	5.8	12.2	9.7


Percentage finer (%)
100
90
80
70
60
50
40
30
20
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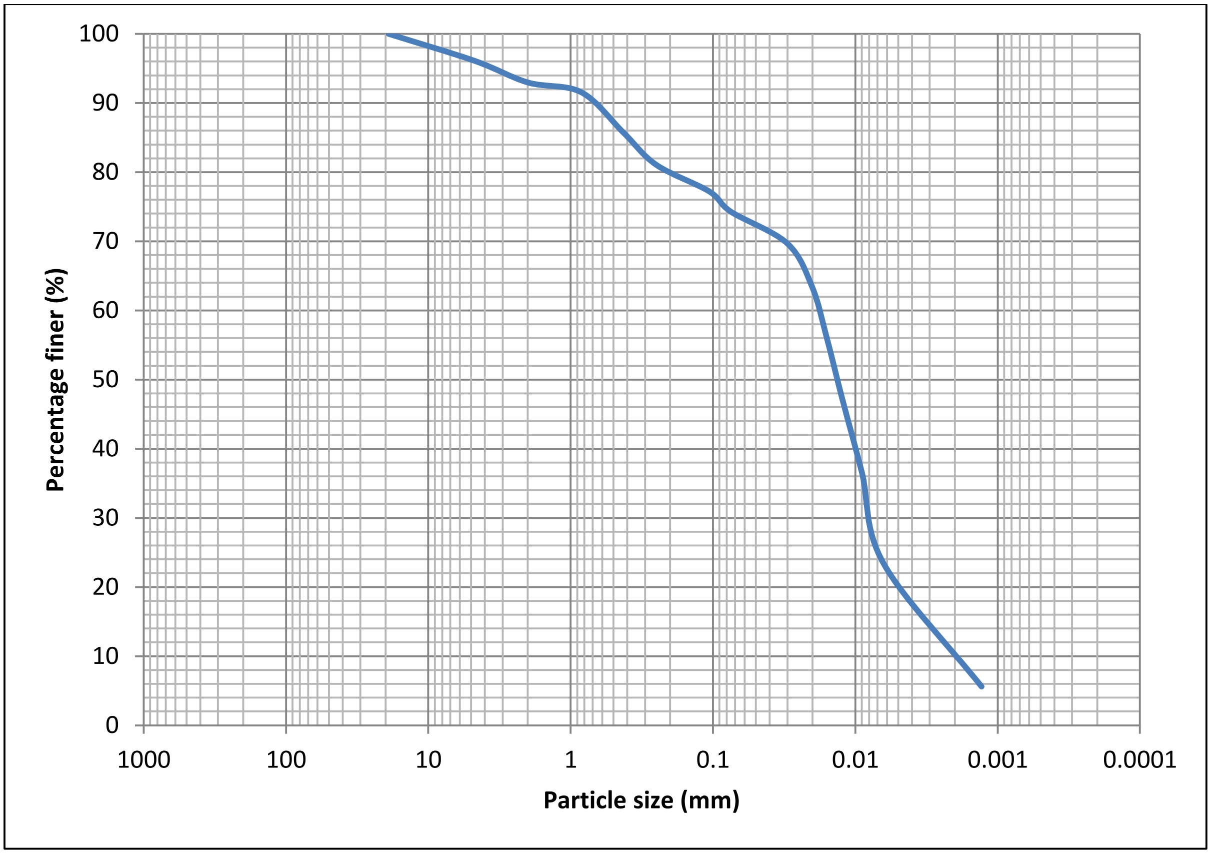
0
1000
100
10
1
0.1
0.01
0.001
0.0001
Particle size (mm)

Sieve Analysis for Tp6@ 1.5 m

Sive opining(mm)	mass of Empty Sive(g)	Mass of Sive +Soil Retained	Soil Retained(g)	percent Retaned	Comulative Percent Passing
19	622.5	622.5	0	0	100
4.75	350.6	370.05	19.45	3.89	96.11
2	400.9	416.6	15.7	3.14	92.97
0.84	372.3	379.45	7.15	1.43	91.54
0.425	305.8	335	29.2	5.84	85.7
0.25	305.3	328.55	23.25	4.65	81.05
0.106	271.1	290.35	19.25	3.85	77.2
0.075	261.3	275.85	14.55	2.91	74.29
pan	255.7	627.15	371.45	74.29	

Hydrometer Analysis for Tp6@ 1.5 m

Elapsed Time(min)	Temp. o_C	Actual Hydro. Rdg. Ra	Effective Depth L	Coefficient K	Grain Size (mm)	Coefficient C_T	Coefficient a	Corr. Hydr. Rdg. Rc	% Finer p	% Adjusted Finer P_A
2	23	44	9.1	0.01404	0.0301		1.05	44.6	93.8	69.7
5	23	37	10.2	0.01404	0.02011	0.70	1.05	40.6	85.4	63.4
8	23	36	10.4	0.01404	0.0159	0.70	1.05	35.9	75.5	56.1
15	23	28.5	11.6	0.01404	0.01235	0.70	1.05	30.3	63.6	47.2
30	23	25	12.2	0.01404	0.00898	0.70	1.05	23.4	49.1	36.5
60	24	24	12.4	0.01388	0.00633	1.00	1.05	15	31.5	23.4
1440	24	22.5	12.6	0.01388	0.001297	1.00	1.05	3.6	7.5	5.6



100
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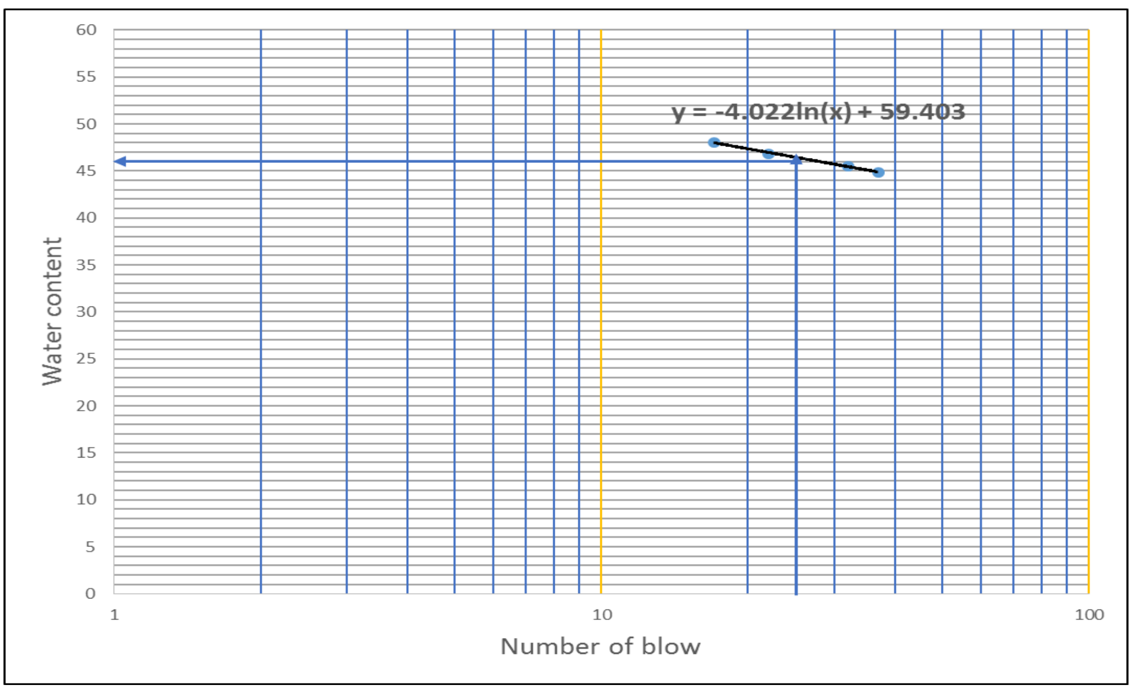
0
Percentage finer (%)
1000
100
10
1
0.1
0.01
0.001
0.0001
Particle size (mm)

APPENDEX-C

C-1 Some of liquid limit result.

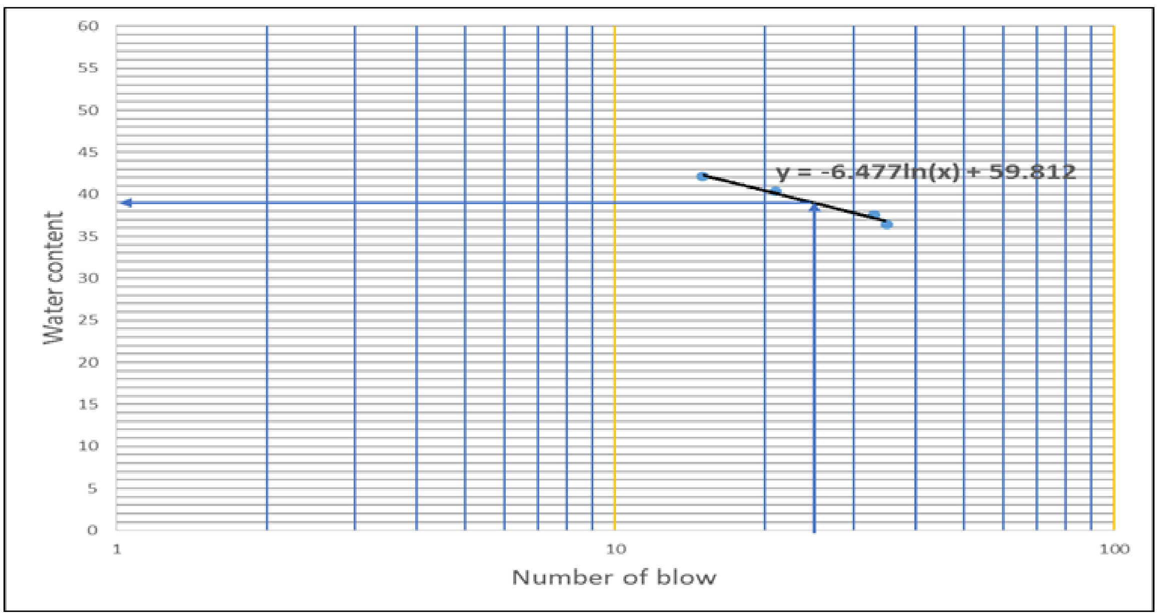
For Tp1@ 1.5 m

Liquid Limit				
Trial No	1	2	3	4
Can No	DV1	DV8	C4	B10
Mass of Can, g	21.50	21	22	19.5
Mass of Can + Wet soil, g	87.41	78.29	68.99	72.7
Mass of Can + Dry soil, g	67	60.5	54	55.5
Mass of Water, g	20.41	17.79	14.99	17.2
Mass of Dry soil, g	45.5	39.5	32	36
NO of Blow	37	32	22	17
Water content, %	44.86	45.04	46.84	47.77
Liquid limit from chart =46				



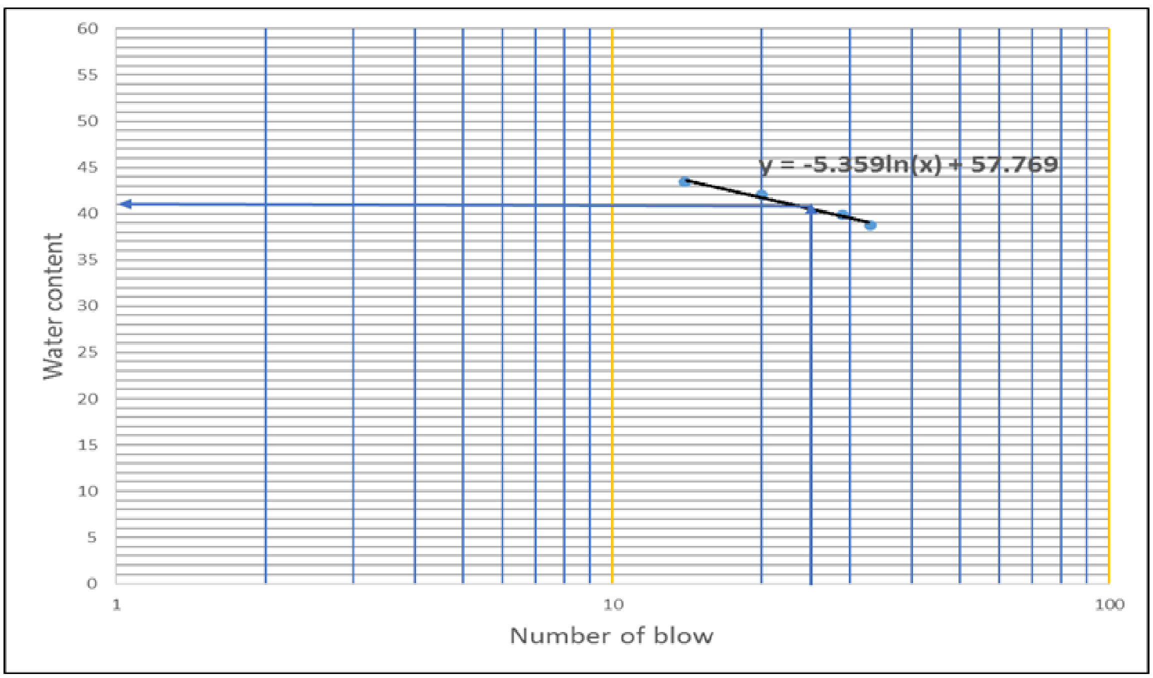
For Tp2@ 1.5 m

Liquid Limit				
Trial No	1	2	3	4
Can No	DV1	DV8	C4	B10
Mass of Can, g	21.5	21	22	19.5
Mass of Can + Wet soil, g	85.74	76.79	65.68	71.7
Mass of Can + Dry soil, g	68.6	61.55	53.13	56.23
Mass of Water, g	17.14	15.24	12.55	15.47
Mass of Dry soil, g	47.1	40.55	31.13	36.73
NO of Blow	35	33	21	15
Water content, %	36.39	37.5	40.31	42.12
Liquid limit from chart =39				



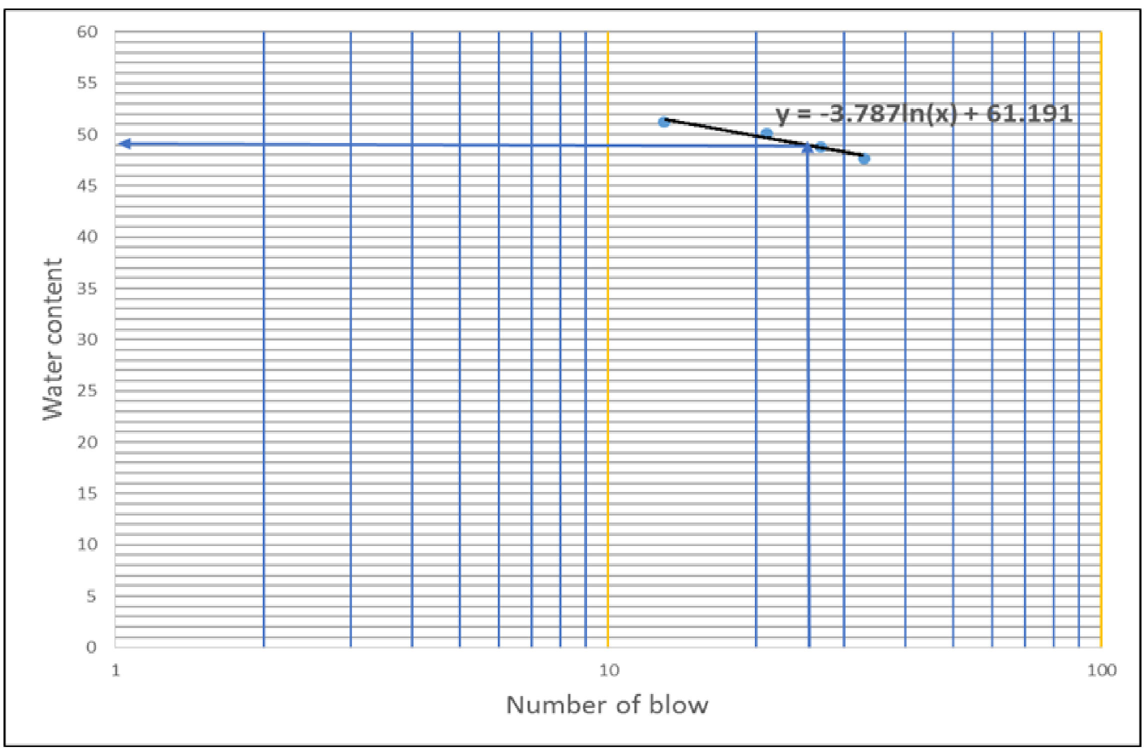
For Tp2@ 3 m

Liquid Limit				
Trial No	1	2	3	4
Can No	DV1	DV8	C4	B10
Mass of Can, g	21.5	21	22	19.5
Mass of Can + Wet soil, g	72.41	76.69	66.68	71.86
Mass of Can + Dry soil, g	58.3	60.8	53.46	56.11
Mass of Water, g	14.11	15.89	13.22	15.75
Mass of Dry soil, g	36.8	39.8	31.46	36.61
NO of Blow	33	29	20	14
Water content, %	38.74	39.92	42.02	43.42
Liquid limit from chart =41				



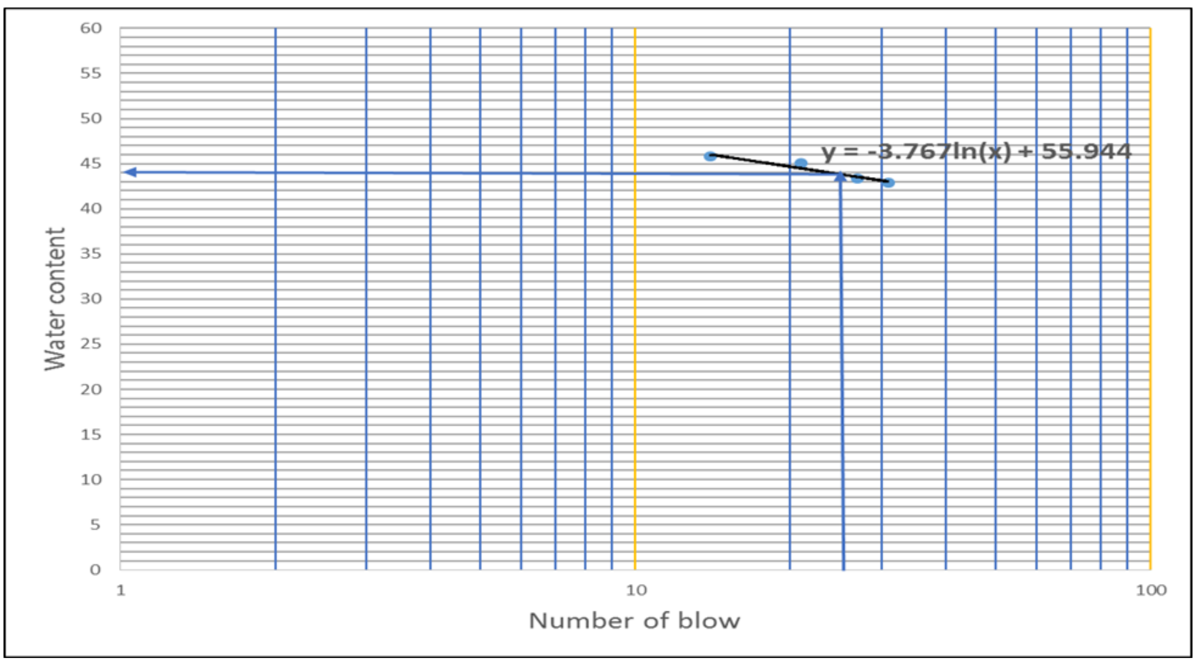
For Tp3@ 3 m

Liquid Limit				
Trial No	1	2	3	4
Can No	DV1	DV8	C4	B10
Mass of Can, g	21.5	21	22	19.5
Mass of Can + Wet soil, g	73.87	78.69	76.28	73.36
Mass of Can + Dry soil, g	57.01	59.78	52.16	55.11
Mass of Water, g	16.86	18.91	15.16	18.25
Mass of Dry soil, g	35.51	38.78	30.16	35.61
NO of Blow	33	27	21	13
Water content, %	47.67	48.76	50.13	51.24
Liquid limit from char =49				



For Tp7@ 1.5 m

Liquid Limit				
Trial No	1	2	3	4
Can No	DV1	DV8	C4	B10
Mass of Can, g	21.5	21	22	19.5
Mass of Can + Wet soil, g	73.84	67.49	63.66	62.79
Mass of Can + Dry soil, g	58.13	53.43	50.73	49.2
Mass of Water, g	15.71	14.06	12.93	13.59
Mass of Dry soil, g	36.63	32.43	28.73	29.7
NO of Blow	31	27	21	14
Water content, %	42.88	43.35	45.01	45.77
Liquid limit from chart =44				



For Tp7@ 2.7 m

Liquid Limit				
Trial No	1	2	3	4
Can No	DV1	DV8	C4	B10
Mass of Can, g	21.5	21	22	19.5
Mass of Can + Wet soil, g	72.87	67.79	64.24	63.73
Mass of Can + Dry soil, g	57.12	53.23	50.78	49.55
Mass of Water, g	15.75	14.56	13.46	14.18
Mass of Dry soil, g	35.62	32.23	28.78	30.05
NO of Blow	31	26	21	16
Water content, %	44.22	45.17	46.76	47.20
Liquid limit from chart =45