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Investigating Some of the Engineering Properties of the Soil Found in Segen Town

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ABSTRACT

To become safe from any failure of civil structure due to geotechnical problem investigation and analyzing the engineering properties of a soil is a key. Therefore this research is aimed to give a clue on the engineering properties of soil found in Segen town. These studies has addressed analyzing the visual identification, index property determination, compaction, consolidation and shear strength analysis by taking both the disturbed and undisturbed samples from ten test pits. The sampling procedure and apparatus for all conducted sample is based on American society for testing material (ASTM) manual standards.

The in situ bulk density test undertaken shows that the dry unit weight value ranging from 11.36kN/m^3 to 13.72kN/m^3 for the investigated sample. Also the specific gravity done by pycnometer method indicates that the Segen soil has specific gravity between 2.51-2.74.

The grain size analysis undertaken by wet sieve analysis shows that out of the investigated samples 86.67% sample has categorized as fine grained soils with percentage finer greater than No, 200 sieves opening of more than 70% and the sample grouped under coarse grained soil has percent finer value of 7.3% and 10.0%.

From the Attergberg limit test result the liquid limit of the investigated sample ranges from 42%-62%, the plastic limit of 20%-35% and the plasticity index value in between 11%-27%.

The classification of the Segen soil by using the grain size and Attergberg limit result shows that the soil is mostly inorganic clay of medium plasticity (CH) and Inorganic clay of high plasticity (MH) according to Unified soil classification system. On the other hand American Association of Highway and Transportation Officials (AASHTO) classification system has grouped the studied soil as A-7-6 and A-7-5 which is clayey soil with fair to good quality rating as subgrade material.

Based on the free swell index result most of the town soil experience None Expansive *behavior except one sample* around TVET collage at a depth of 1.8m which has a moderate degree of expansiveness with the free swell index value of 65%.. *The liquidity index result shows the area soil has the liquidity index value less than zero describing the soil as high strength, brittle fracture expecting. And few investigated soil has experienced with intermediate strength, soil deforms like plastic material since their determined liquidity index value is less than zero and greater than one.*

The investigated sample has the undrained shear strength value ranging from 45.23kPa-78.65kPa as the unconfined compression strength test shows.

Within the depth of the exploration the compaction test shows that the maximum dry density of the Segen soil is in between 1.22-1.53g/cm3 and the optimum moisture content ranging from 25.00%-32.5%

[Key words; Investigation, disturbed sample, undisturbed sample, engineering properties]

1. INTRODUCTION

1.1. Background

Among fourteen zones of the SNNPRG of Ethiopia Segen Zone is one of the youngest zone which is established in 2003 E.C. (Combination of five special woreda's; Konso, Burji, Amaro Derashe and Alle) by the government of Ethiopia.

Since its establishment, the Segen Town which is the administration center of the Zone is trying to fulfill the infrastructural requirements for the development of town. Currently on the city except small district hospital and

TVET building the rest infrastructural constructions both road and building (huge project) are as planned by the zone administration.[11]

As the city has only age of seven year there is no any research done on investigation of soil in the area. So it is necessary and critical issue to investigate the city soil because of investigation of the soil helps any project that can built on soil; and to select the soil material that is used for the proposed task. Since Geotechnical engineers apply their expertise about soil and rocks to the development of foundations for a variety of structures. In advance of any design or construction, they conduct environmental site assessments in areas proposed for development and make suggestions based on soil properties. They learn about the composition and condition of soil in an area and predict the long-term effects of that soil on walls, foundations, septic systems and countless other structures that are integral to our daily lives. For example, some clay soils have a tendency to shrink and swell as their water content changes, often triggered by changes in seasons and precipitation. This expansive property can put pressure on the walls of structures and damage them.[12]

According to many researchers' idea and generality soil investigation is an essential part of the design and construction of a proposed structural system (buildings, dams, roads and highways, etc.). Soils are identified, observed, and recovered during investigation of a proposed site. Usually soil investigations are conducted only on a fraction of a proposed site because it would be prohibitively expensive to conduct an extensive investigation of a whole site. One then makes estimates and judgments based on information from a limited set of observations, and from field and laboratory test data that will have profound effects on the performance and costs of structures constructed at a site.[10]

Therefore; site investigation is performed in order to gather data about the subsoil conditions of the soil which is needed for: [13]

- ✓ The planning and constructing the new projects.
- ✓ It is also used to investigate the reasons of the failure of the previous facility and what remedial processes can be executed on it.
- ✓ It is also used to calculate the exact measurements of the construction material such as sand, concrete, clay, gravel etc.

The aim of these Thesis is to provide maximum information about the type, characteristics and distributions of a soil in the Segen town.

1.2. Statement of problem

Insufficient geotechnical investigations, faulty interpretation of results or failure to portray results in a clearly understandable manner may contribute to inappropriate designs; delays in construction schedules, costly construction modifications, and use of substandard material, environmental damage to the site and even failure of a structure.

Therefore, to obtain information on type, characteristics and distributions of a soil, geotechnical investigations should be done on soil and rock underlying (and sometimes adjacent to) a site of proposed structures. [5]

For developing countries like Ethiopia which is developing at high growth rate the construction industry is also growing rapidly. Detailed geotechnical investigation on the Engineering property of soil is very essential.

As Segen town is newly established zonal administration town the construction activity shall be expected to develop in recent time. As the result of these investigating into engineering properties of soil is the very beginning task to safe guard the geotechnical failure of any structure. This research is directed to study investigation in to some of engineering properties of soils like determining the strength of soil, investigating index properties, characterizing the compaction and consolidation nature of soil, and also describing the expansiveness of the soil.

1.3. Objective

1.3.1. General Objective

The main objective of this research is to investigate some of the Engineering properties of the soil found in Segen Town.

1.3.2. Specific Objectives

The specific objective of this project includes:-

1. To determine the index properties
2. To classify the soil in the study area
3. To determine the consolidation characteristics of the soil
4. To determine the unconfined compressive strength of soil
5. To describe the compaction characteristics of the soil

1.4. Research Question

Based up on the main as well as specific objectives the following form of Research question shall be formulated.

- ❖ How can improper data of soil affect the construction?
- ❖ What are the methods used to specify and conduct the soil investigation in laboratory?
- ❖ How we know which soil type is appropriate for the proposed projects?

1.5. Scope of the study

The scope of the study is limited to investigating in to some of the engineering properties of soil like index property, shear strength parameter, compaction, consolidation and explaining the expansive behavior of soil. In this study ten sampling pits are identified and selected up on the geologic nature of soil. The sample is taken from Segen town where the major construction activities are planned and the pit depth is limited up to three meter.

2. LITERATURE REVIEW

2.1. General

Soil is defined as a natural aggregate of mineral grains, with or without organic constituents that can be separated by gentle mechanical means such as agitation in water. Soils are formed by the process of weathering of the parent rock. The weathering of the rocks might be by (physical) mechanical disintegration, and/or chemical decomposition. The process of weathering of the rock decreases the cohesive forces binding the mineral grains and leads to the disintegration of bigger masses to smaller and smaller particles. When rock surface gets exposed to atmosphere for an appreciable time, it disintegrates or decomposes into small particles and thus soils are formed. Physical weathering involves reduction of size without any change in the original composition of the parent rock. The main agents responsible for this process are exfoliation, unloading, erosion, freezing, and thawing. Chemical weathering causes both reductions in size and chemical alteration of the original parent rock. The main agents responsible for chemical weathering are hydration, carbonation, and oxidation. Often, chemical and physical weathering takes place in concert [13]

2.2. General soil type and formation

It has been discussed on section (2.1) earlier that soil is formed by the process of physical and chemical weathering. The individual size of the constituent parts of even the weathered rock might range from the smallest state (colloidal) to the largest possible (boulders). This implies that all the weathered constituents of a parent rock cannot be termed soil. According to their grain size, soil particles are classified as cobbles, gravel, sand, silt and clay. Grains having diameters in the range of 4.75 to 76.2 mm are called gravel. If the grains are visible to the naked eye, but are less than about 4.75 mm in size the soil is described as sand. The lower limit of visibility of grains for the naked eyes is about 0.075 mm. Soil grains ranging from 0.075 to 0.002 mm are termed as silt and those that are finer than 0.002 mm as clay. This classification is purely based on size which does not indicate the properties of fine grained materials [13].

On the basis of origin of their constituents, soils can be divided into two large groups these are Residual soils, and Transported soils.

2.3. Soil mineralogical composition

Soil minerals are inorganic particles which are derived from weathered parent material and decayed plants and animals. Gravels are pieces of rocks with occasional particles of quartz, feldspar and other minerals. Sand particles are made of mostly quartz and feldspar. Silts are the microscopic soil fractions that consist of very fine quartz grains and some flake-shaped particles that are fragments of micaceous minerals. Clays are mostly flake-shaped microscopic and submicroscopic particles of mica and other minerals. Clays are defined as those particles "which develop plasticity when mixed with a limited amount of water"[7] Clay minerals are almost always the result of chemical weathering of rock particles and are hydrates of aluminum, iron or magnesium silicate combined to create sheet-like structures. These sheets are built from two basic units, the tetrahedral unit of silica and the octahedral unit of the hydroxide of aluminum, iron or magnesium.

The three main groups of clay minerals are as follows:

I. Kaolinite group

This is the most dominant part of residual clay deposits and is made up from large stacks of alternating single tetrahedral sheets of silicate and octahedral sheets of aluminum. Kaolinites are very stable with strong structure and absorb little water. They have low swelling and shrinkage responses to water content variation

II. Illite group

This mineral consists of a series of single octahedral sheets of aluminum sandwiched between two tetrahedral sheets of silicon. Illites tend to absorb more water than kaolinites and have higher swelling and shrinkage characteristics.

III. Montmorillonite group

This mineral has a similar structure to Illite group but, in the tetrahedral sheets, some of the silicon is replaced by iron, magnesium and aluminum. Montmorillonite exhibit extremely high water absorption, swelling and shrinkage characteristics [15]

2.4. Index properties of soil

As an aid for the soil and foundation engineer, soils have been divided into basic categories based upon certain physical characteristics and properties. The categories have been relatively broad in scope because of the wide range of characteristics of the various soils that exist in nature. For a proper evaluation of the suitability of soil for use as foundation or construction material, information about its properties, in addition to classification, is frequently necessary. Those properties which help to assess the engineering behavior of a soil and which assist in determining its classification accurately are termed 'Index Properties'. The tests required to determine index properties are in fact 'classification tests'. Index properties include indices that can be determined relatively quickly and easily, and which will have a bearing on important aspects of engineering behavior such as strength or load-bearing capacity, swelling and shrinkage, and settlement. These properties may be relating to individual soil grains or to the aggregate soil mass. The former are usually studied from disturbed or remolded soil samples and the latter from relatively undisturbed samples, i.e. from soil in-situ.

Some of the important physical properties, which may relate to the state of the soil or the type of the soil, include soil color, soil structure, texture, particle shape, grain specific gravity, water content, in-situ unit weight, density index, particle size distribution, and consistency limits and related indices. [16]

3. STUDY AREA DESCRIPTION AND RESEARCH METHODOLOGY

3.1. Study area description

The study is carried out in Segen town which is the administrative city of Segen Area peoples, zone located at southern part of Ethiopian under the SNNPRG region. Segen Area People's zone covers a total area 7738.42 km^2. It lies between 5^{0}32'-5^{0}61'latitude and 37^{0} 26'-37^{0}80' longitude with an elevation ranging (501—3061) meters above sea level. The zone has 5 woredas with a total population (in 2011) is estimated about 654,176. Segen town is the capital town of Segen Area People's zone located at a distance of 330km from Hawassa city and 580km away from south of Addis Ababa.[11]

In Segen area people's zone of Segen town eight ethic groups are living together in diversity in which each ethnic group has its own culture, custom, beliefs and language's. Almost all languages are from Cushitic group; (burijigna, Darashigna, Halinte, Afana Konso, Kusumigna, Mashiltata and Mostata from Burji, darashe, Ale, Konso, Kusume, Mashole and Mosiye ethinic groups respectively) and Omotic group of Korate from Kore ethinic group. Apart from the listed ethnic groups as native peoples the town is also composed of every nation and nationalities of Ethiopia.[2] Since, there are many tourism places including Konso New York and other monuments the town will have a great opportunity of investment for governmental and non-governmental sectors and the town shall be the destiny of tourism center.

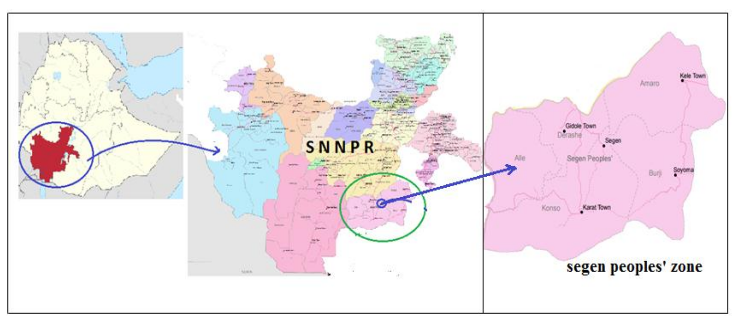

Figure 3:1 Segen peoples' zone and town location on Ethiopian map. [22]

Climatic condition

3.1.1.1. **Temperature**

The Segen area peoples zone which covers the total area of 6312 square kilometer can experience the minimum and maximum mean annual temperature of 12.5^{0}c and 27.5^{0}c respectively as stated on annual statically analysis of the zone in 2011.

3.1.1.2. **Rain fall**

As per the record of national meteorological Agencies of 2011 the Segen Towns with the average altitude of 1627m above mean sea level the average mean annual minimum rain fall is 601mm while the maximum is 1600mm which is recorded in 2009-2010.[2]

According to Ethiopian treasure report Ethiopia is laying between the equator and tropics of cancer. It has three different climate zones according to elevation. The first zone is Kola (tropical zone); is below 1830m elevation and has an average annual temperature of about 27^{0}C with annual rainfall of about 510mm. while waina dega(subtropical zone); is the second climatic division and includes the Highland areas of 1830-2440 meters in elevation and experience an average temperature about 22^{0}C with annual rain fall between 510 and 1530mm. Dega(cool zone) is the last one with elevation above 2440meters and an average annual temperature of 16 ^{0}C and average annual rainfall between 1270 and 1280mm.[20]

As per the above data of Ethiopian treasure Segen town is under the Kola (Tropical zone) with elevation, temperature and average annual rainfall as mentioned earlier under these section.

3.2. Study design

A study design is a process that guides a researcher on how to collect analyses and interpret the observation. This study was designed for investigating the nature of the soil found in the area and then after describing the classification, strength characteristic, consolidation and compaction, and also to specify the swelling nature of the soil by taking the sample and performing laboratory test for the selected sample.

3.3. Sample size & sampling procedure

Sampling is the process by which respondents are picked out of the population to represent that population. This process can either be done through probability or non-probability methods [12]

Qualitative research involves non-probability sampling where little attempt is made to generate a representative sample. A form of judgmental sampling technique is thus employed to identify respondent organizations, sample members are chosen on the basis of the researcher's purpose as to what constitute a representative sample for the population of interest [8].

3.3.1. Sample Size and procedure

Depending on the standard which describes the sample size (number of test pits) for a given area shall be the sample size for this research. From different area of the town ten test pits have been selected.

The ASTM sampling procedures have been followed on selected sites; to disturbed and undisturbed samples for laboratory analysis. After carefully conducting the laboratory test the data are organized and tabulated.

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4. IN SITU SOIL PROPERTIES AND LABORATORY TEST RESULTS

4.1. In situ properties

The soil sample was taken from the different areas of Segen town. While sampling the first steps that I followed is to visually reconnaissance the town soil and identify the geological inspection of the area. Following visual identification I have refereed literature's and contacts those firms that work in construction office of the municipality; they have proposed the areas that are prior to them regarding to construction activities. Since the town is young they pointed out those areas that are planned for the construction. Accordingly, I have selected ten sampling pits and excavated up to a depth of three meter. Regarding to their function (purpose of test) disturbed and undisturbed samples were taken and transported to Arba Minch institute of technology laboratory. The global coordinates of sampling location and their corresponding visual textural classification is tabulated below in table 4:1 below and specified on the map on figure 4:1.

Table 4:1 the global coordinates and visual color description of the soil

S. No	Test pit designation	Test pit location	Depth of sampling	Latitude	Longitude	Elevation(m)	Visual Color Description
1	TP-1@1.9m	Area proposed for condominium	1.9m	5^{0}35'50.562''	37^{0}32'55.52''	1604.800	Red
2	TP-1@3m		3m	5^{0}35'50.562''	37^{0}32'55.52''	1604.800	Reddish brown
3	TP-2@1.7m	Municipality	1.7m	5^{0}35'14.322''	37^{0}32'51.46''	1635.100	Brown
4	TP-3@3m	Around stadium	3m	5^{0}35'37.067''	37^{0}32'34.66''	1590.100	Red
5	TP-4@2.1m	High school	2.1m	5^{0}35'31.087''	37^{0}33''0.73''	1633.600	Red
6	TP-4@3m		3m	5^{0}35'31.087''	37^{0}33''0.73''	1633.600	Reddish brown
7	TP-5@1.8m	TVET collage	1.8	5^{0}35'49.29''	37^{0}33'21.01''	1621.100	black soil
8	TP-5@3m		3m	5^{0}35'49.29''	37^{0}33'21.01''	1621.100	Reddish black
9	TP-6@1.7m	Bus station	1.7m	5^{0}35'30.222''	37^{0}33'14.42''	1595.400	black soil
10	TP-6@3m		3m	5^{0}35'30.222''	37^{0}33'14.42''	1595.400	yellowish black
11	TP-7@2m	Konso Mewucha	2m	5^{0}34'59.17''	37^{0}32'41.78''	1607.200	Brown
12	TP-8@3m	Arba Minch mewucha	3m	5^{0}35'27.28''	37^{0}32'37.67''	1611.900	Red
13	TP-9@1.5m	Police station	1.5m	5^{0}37'32.55''	37^{0}33'1.85''	1611.100	black soil
14	TP-9@3m		3m	5^{0}37'32.55''	37^{0}33'1.85''	1611.100	Reddish black
15	TP-10@3m	Behind national bank of Ethiopia	3m	5^{0}35'19.89''	37^{0}32'47.52''	1630.700	Red

4.2. Index properties of soil

4.2.1. Natural moisture contents

The water content of a soil is an important parameter that controls its behavior. It is a quantitative measure of the wetness of a soil mass. The water content of a soil can be determined to a high degree of precision, as it involves only mass which can be determined more accurately than volume. The water content of soil is determined as a routine matter in most of the other tests. [4]

The purpose of this test is to determine the water (moisture) content of soils. The water content is the ratio, expressed as a percentage, of the mass of "pore" or"free" water in a given mass of soil to the mass of the dry soil solids.in these report the water content determination is done according to ASTM D 2216 standard test Method for determination of water (moisture) content of soil, Rock, and soil –agregtae mixture.

The signficance of the test is that for many soils, the water content may be an extermilly important index used for estabilishing the relationship beteween the way a soil behaves and its properties. The consistence of fine grained soil largely depends on its water content. The water content is also used in expressing the phase relationship of air, water and soilids in a given volume of soil.

The water content calculation by Oven drying method using ASTM D 2216 test procedure for the investigated soil are tabulated as follows

Table 4:2 water content results for all test pits

S. No	Test pit Designation	Test Pit Location	Depth of Sampling	Natural Moisture Content	Visual Color Description
1	TP-1@1.9m	AREA PROPOSED for condominium	1.9m	24.00	Red
2	TP-1@3m		3m	32.18	Reddish brown
3	TP-2@1.7m	MUNCIPALITY	1.7m	18.76	Brown
4	TP-3@3m	STADIUM	3m	22.96	Red
5	TP-4@2.1m	High school	2.1m	26.40	Red
6	TP-4@3m		3m	29.69	Reddish brown
7	TP-5@1.8m	TVET collage	1.8	27.96	Black
8	TP-5@3m		3m	31.66	Reddish black
9	TP-6@1.7m	bus station	1.7m	36.32	Black
10	TP-6@3m		3m	27.68	Yellowish black
11	TP-7@2m	Konso Mewucha	2m	20.31	Brown
12	TP-8@3m	Arba Minch Mewucha	3m	23.17	Red
13	TP-9@1.5m	police station	1.5m	27.52	Black
14	TP-9@3m		3m	31.94	Reddish black
15	TP-10@3m	Behind national bank of Ethiopia	3m	23.19	Red

4.2.2. Specific gravity

The specific gravity of a soil is the ratio of the mass of a given volume of the material at a stated temperature to the mass of an equal volume of de-aired or gas-free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil.

The significance of these test is in relating a weight of soil to its volume and in calculation of phase relationship, i.e. the relative volume of solids to water and air in a given volume soil. The specific gravity is used in the computations of most of the laboratory tests, and is needed in nearly all pressure, settlement, and stability problems in soil engineering. In this attachment the specific gravity of soli is calculated by using ASTM D854-00 standard test for specific gravity of soil solids by water pycnometer. [1]

The specific gravity calculation by water pycnometer method using ASTM D854-00 for the investigated soil is presented as follows.

Table 4:3 Specific gravity results for all test pits

Ser. no	Test pit Designation	Test Pit Location	Depth of Sampling	Specific Gravity	Visual Color Description
1	TP-1@1.9m	Area proposed for condominium	1.9m	2.65	Red
2	TP-1@3m		3m	2.65	Reddish brown
3	TP-2@1.7m	municipality	1.7m	2.51	Brown
4	TP-3@3m	stadium	3m	2.74	Red
5	TP-4@2.1m	High school	2.1m	2.69	Red
6	TP-4@3m		3m	2.65	Reddish brown
7	TP-5@1.8m	TVET collage	1.8	2.77	Black soil
8	TP-5@3m		3m	2.64	Reddish black
9	TP-6@1.7m	Bus station	1.7m	2.62	Black soil
10	TP-6@3m		3m	2.60	Yellowish black

4.2.3. Grain size analysis

The purpose of this test is to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

In these document the grain size analysis is conducted by wet sieve analysis (by washing the soil sample). 1-2kg of soil sample passing No, 4(4.75mm) sieve size soil sample is soaked for 24 hours. By using No, 200(0.075mm) sieve size the washing shall be continued until clean water is passing from the washed sample. The mass retained and passed on sieve No, 200 is taken to oven dry for 24 hours at tempreture of 105^{0}c and the mass retained at sieve No, 200 undergo sieve analysis; while the later one can be conducted by sedimetation anlysiss by taking 50 gram of soil sample from the toal mass; that is passed over No,200 sieve openning.[4]

Below Table 4:4 shows the percentage finer and coarser after washing and weghing the sample for the study sample.

Table 4:4 the percentage finer and coarser

S. No	Test Pit Designation	Test Pit Location	Depth of Sampling	Total Mass Soaked(g)	Mass Retained @0.075mm(g) (0.075mm< soil size>4.75mm)	Mass Passing 0.075mm(g) soil size<0.075mm	Per. Finer (%)	Visual color Description
1	TP-1@1.9m	Area proposed for	1.9m	1000.000	97.5 00	883.0	90.056	Red
2	TP-1@3m		3m	1500.000	121.600	1378.400	91.893	Reddish Brown

		Condominium						
3	TP-2@1.7m	Municipality	1.7m	2000.000	585.360	142.080	7.104	Brown
4	TP-3@3m	Stadium	3m	2000.000	513.790	1486.210	74.311	Red
5	TP-4@2.1m	High school	2.1m	1000.000	112.500	887.500	88.750	Red
6	TP-4@3m		3m	2000.000	135.000	1865.000	93.250	Reddish Brown
7	TP-5@1.8m	TVET collage	1.8	1500.000	230.000	1270.000	84.667	Black soil
8	TP-5@3m		3m	1000.000	230.500	757.500	76.670	Reddish Black
9	TP-6@1.7m	Near bus station	1.7m	1000.000	91.980	908.020	90.802	Black soil
10	TP-6@3m		3m	1000.000	288.960	692.00	70.610	Yellowish Black
11	TP-7@2m	Konso Mewucha	2m	1500.00	1349.25	150.75	10.05	Brown
12	TP-8@3m	Arba Minch Mewucha	3m	1500.00	343.575	1156.425	77.095	Red
13	TP-9@1.5m	Police station	1.5m	1000.00	145.01	854.99	85.499	Black
14	TP-9@3m		3m	1500.00	415.74	1084.26	72.284	Reddish Black
15	TP-10@3m	Behind NBE	3m	1000.00	249	751	75.1	Red

4.2.3.1. Sieve Analysis

The sieve analysis is carried out by sieving a known dry mass of sample through the nest of sieves placed one below the other so that the openings decrease in size from the top sieve downwards, with a pan at the bottom of the stack. The whole nest of sieves is given a horizontal shaking for about 10 minutes (if required, more) till the mass of soil remaining on each sieve reaches a constant value (the shaking can be done by hand or using a mechanical shaker, if available).[13]

In my analysis the sample that is remained at sieve number 200(0.075mm) after washing and drying is conducted for determining the percentage fine at each sieve size.

4.2.3.2. Hydrometer analysis

Hydrometer analysis is based on the principle of sedimentation of soil grains in water. When a soil specimen is dispersed in water, the particles settle at different velocities, depending on their shape, size, and weight. For simplicity, it is assumed that all the soil particles are spheres, and the velocity of soil particles can be expressed by Stokes' law as it is explained in section 2.4.4.1 above.

The test is conducted by the procedure explained in ASTM D 422-63, D 2419-74 sedimentation analysis of soil by hydrometer. The test is analysed by using 151H hydromrter see apendex. E for detail.

The result of sieve analysis and hydrometer can also be presented by combining the two results together as illustrated in the graph below. Then the parameters that are Cc(coefficient of curvature) and Cu(uniformity coefficient) is calculated from the value; D10, D30 and D60 which are the values taken from the graph of the combined analysis of percentage finer(y-axis) to particle size (x-axis as log scale)

10% particle finer, 30% particle finer and 60% particle finer respectively.

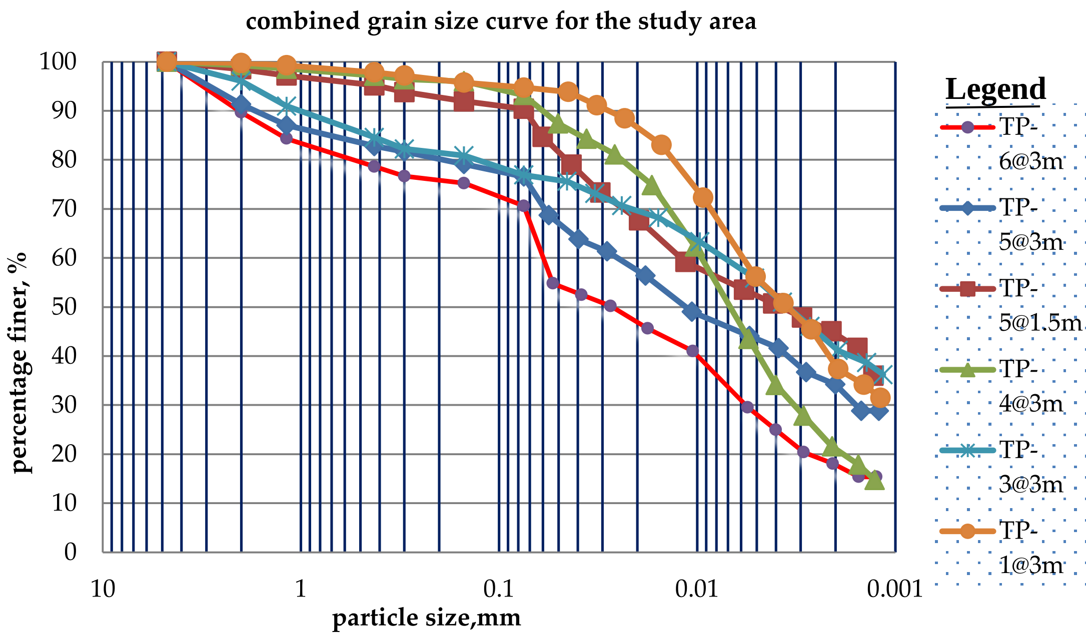

Figure 4:1 combined grain size curve for the study area

4.2.4. Attergberg limit

When clay minerals are present in fine-grained soil, that soil can be remolded in the presence of some moisture without crumbling. At very low moisture content, soil behaves more like a brittle solid. When the moisture content is very high, the soil and water may flow like a liquid. Hence, on an arbitrary basis, depending on the moisture content, the nature of soil behavior can be broken down into four basic states: solid, semisolid, plastic, and liquid. [6]

The purpose of Attergberg limit test is to determine the plastic and liquid limit of fine grained soil. the liquid limit (LL) is arbitrary defined as the water content, in percent at which a part of soil in standard cup by groove of standard dimensions will flow together at the base of the groove for a distance of 13mm (1/2 in) when subjected to 25 shocks from the cup being dropped 10mm in standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content in a percent at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in) diameter threads without crumbling.

The significance of the test is that a wide variety of soil engineering properties have been correlated to the liquid and plastic limit, and these Attergberg limit are also used to classify a fine grained soil according to Unified soil classification system or AASHTO system.

The plastic limit, liquid limit, plasticity index, and liquidity index for the entire test are presented in table 4:5 below

Table 4:5 plastic limit, liquid limit, plasticity index and liquidity index of all test pit of study area

S. No	Test Pit Designation	Test Pit Location	Depth of Sampling	Liquid Limit	Plastic Limit	Plasticity Index	Moisture Content	Liquidity Index	Visual Color Description
1	TP1@1.9m	Area proposed for Condominium	1.9m	49	20	28	24.004	0.131	Red
2	TP-1@3m		3m	43	28	16	32.176	0.296	Reddish Brown
3	TP-3@3m	Stadium	3m	45	30	15	22.962	-0.477	Red
4	TP4@2.1m	High School	2.1m	44	33	11	26.401	-0.558	Red
5	TP-4@3m		3m	42	30	12	29.690	-0.060	Reddish Brown
6	TP5@1.8m	TVET Collage	1.8	57	32	25	27.955	-0.152	Black soil
7	TP-5@3m		3m	62	35	28	31.658	-0.105	Reddish Black
8	TP6@1.7m	bus station	1.7m	49	31	18	36.318	0.284	Black soil
9	TP-6@3m		3m	54	32	22	27.679	-0.180	Yellowish Black
10	TP-8@3m	Arba Minch Mewucha	3m	44	31	13	23.17	-0.588	Red
11	TP9@1.5m	Police Station	1.5m	56	33	23	9.50	-1.026	Black soil
12	TP-9@3m		3m	62	35	27	31.94	-0.122	Reddish Black
13	TP10@3m	Behind NBE	3m	46	31	15	23.19	-0.491	Red

4.2.5. Free Swell Test

Free swell, also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water.[21]

The test procedure includes; Taking two specimens of 10g(10ml) each of pulverized soil passing through 425μm IS Sieve and oven-dry; Pour each soil specimen into a graduated glass cylinder of 100ml capacity; Remove entrapped air by gently shaking or stirring with a glass rod. Allow the suspension to attain the state of equilibrium (for not less than 24hours). Then the free swell can be calculated from the equation.

$$\text{Free swell index} = \frac{Vd-Vk}{Vk}\times \mathbf{100} \ldots\ldots\ldots\ldots 4:1$$

Where;

- V_d = volume of soil specimen read from the graduated cylinder containing distilled water.
- V_k = volume of soil specimen read from the graduated cylinder containing kerosene.

Holtz and Gibbs suggested that soils having a free-swell value as low as 100 percent can cause considerable damage to lightly loaded structures and soils heaving a free swell value below 50 percent seldom exhibit appreciable volume change even under light loadings. [13] The degree of expansiveness is described in terms of free swell, plastic limit and liquid limit values as follows for the study area

Table 4:6 degree of expansiveness for study area based on free swell

S. No	Test pit Designation	Depth of Sampling	LL	PL	Free Swell Index,%	Degree of Expansiveness
1	TP-1@1.9m	1.9m	48.020	20.381	27.500	None Expansive
2	TP-1@3m	3m	42.937	27.662	35.000	None Expansive
3	TP-2@1.7m	1.7m			27.500	None Expansive
4	TP-3@3m	3m	44.676	29.974	20.000	None Expansive
5	TP-4@2.1m	2.1m	43.741	32.842	32.500	None Expansive
6	TP-4@3m	3m	41.503	30.945	45.000	None Expansive
7	TP-5@1.8m	1.8m	57.152	31.818	65.000	Moderate
8	TP-5@3m	3m	62.310	34.579	47.500	None Expansive
9	TP-6@1.7m	1.7m	49.763	30.990	45.000	None Expansive
10	TP-6@3m	3m	53.732	31.657	42.500	None Expansive

4.1. Shear Strength of Soil

4.1.1. Unconfined compression tests

The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. According to the ASTM standard, the unconfined compressive strength (qu) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area. The test is conducted according to ASTM D 2166 -Standard Test Method for Unconfined Compressive Strength of Cohesive Soil in which the writer has followed those step.

4.1.1.1. Significance of the test

For soils, the undrained shear strength (s_u) is necessary for the determination of the bearing capacity of foundations, dams, etc. The undrained shear strength (s_u) of clays is

commonly determined from an unconfined compression test. The undrained shear strength (s_u) of a cohesive soil is equal to one-half the unconfined compressive strength (q_u) when the soil is under the $\phi = 0$ condition (ϕ = the angle of internal friction). The most critical condition for the soil usually occurs immediately after construction, which represents un drained conditions, when the un drained shear strength is basically equal to the cohesion(C).[14]

Since unconfined compression test is conducted on a remolded or undisturbed saturated clay sample (taken by Shelby tube); in my analysis the sample is taken by Shelby tube from the study area and extruded, then after trimmed with length to diameter ratio of 2.

The calculated result for investigated soil is presented below with its axial strain vs. axial load diagram followed by determining the undrained shear strength of the specimen from the plotted graph.

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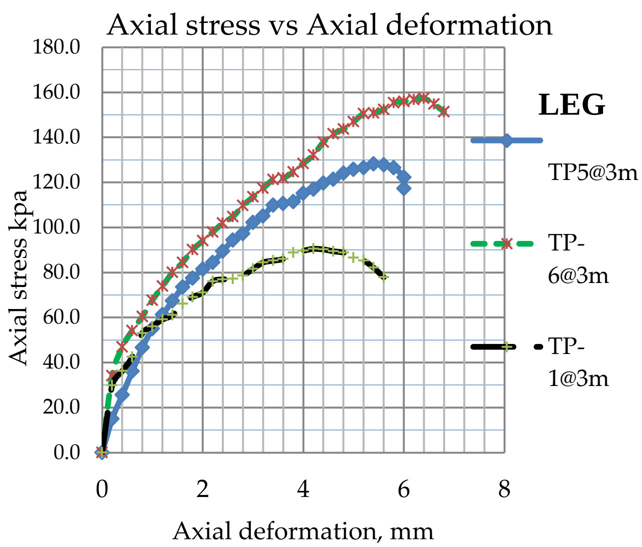

Figure 4:2 axial stresses vs. axial deformation

Table 4:7 undrained shear strength of the soil in the study area

Test Pit Designation	Unconfined Compressive Strength(q_u)	Undrained Shear Strength(S_u)
TP-1@3m	90.46	45.23
TP-5@3m	128.12	64.06
TP-6@3m	157.29	78.65

4.2. Compaction Test

Compaction is an economical and popular technique for improving soils. The soil fabric is forced into a dense configuration by the expulsion of air using mechanical effort with or without the assistance of water.

A laboratory test, called the standard Proctor compaction test, was used in this report to deliver a standard amount of mechanical energy (compactive effort) to determine the maximum dry unit weight of a soil by ASTM D 698 standard test procedure. In the standard Proctor compaction test, a dry soil specimen is mixed with water and compacted in 3 layers in a cylindrical mold 4 in. internal diameter and 4.584 in. high. The volume of the standard Proctor mold is 1/30 ft^3 (944 cm^3). Each layer is subjected to 25 blows from a 5.5 lb hammer falling freely from a height of 12 in. The energy imparted by the hammer is12,400 ft.lb/ft^3 (600 KN-m/m^3). Four or more tests are conducted on the soil using different water contents. The last test is identified when additional water causes the bulk unit weight of the soil to decrease. The results are plotted as dry unit weight (ordinate) versus water content (abscissa). Typical dry unit weight Vs. water content plots are shown in Figure 4.5:1 which is sample analysis result for TP-4@1.5m.

The water content at which the maximum dry unit weight, ($\gamma_{d(max)}$), is achieved is called the optimum water content (OMC). On the same chart the zero air voids line is drawn which is the combination of moisture and density that produce complete saturation of the soil or the γ_d obtained when there is no air in the void spaces. The compaction curve theoretically does not cross this line but becomes parallel to it. Remember that the values of water content, wet unit weight and specific gravity are not constant throughout the soil. Since G_s and γ_w are constants for a given soil the zero airline is a linear function of water content.[14]

Table and chart below shows the calculation of dry density and moisture content for the investigated soil, Then moisture content (X-axis) vs. dry density (Y-axis) is plotted to now the maximum dry density and optimum moisture content of the sample.

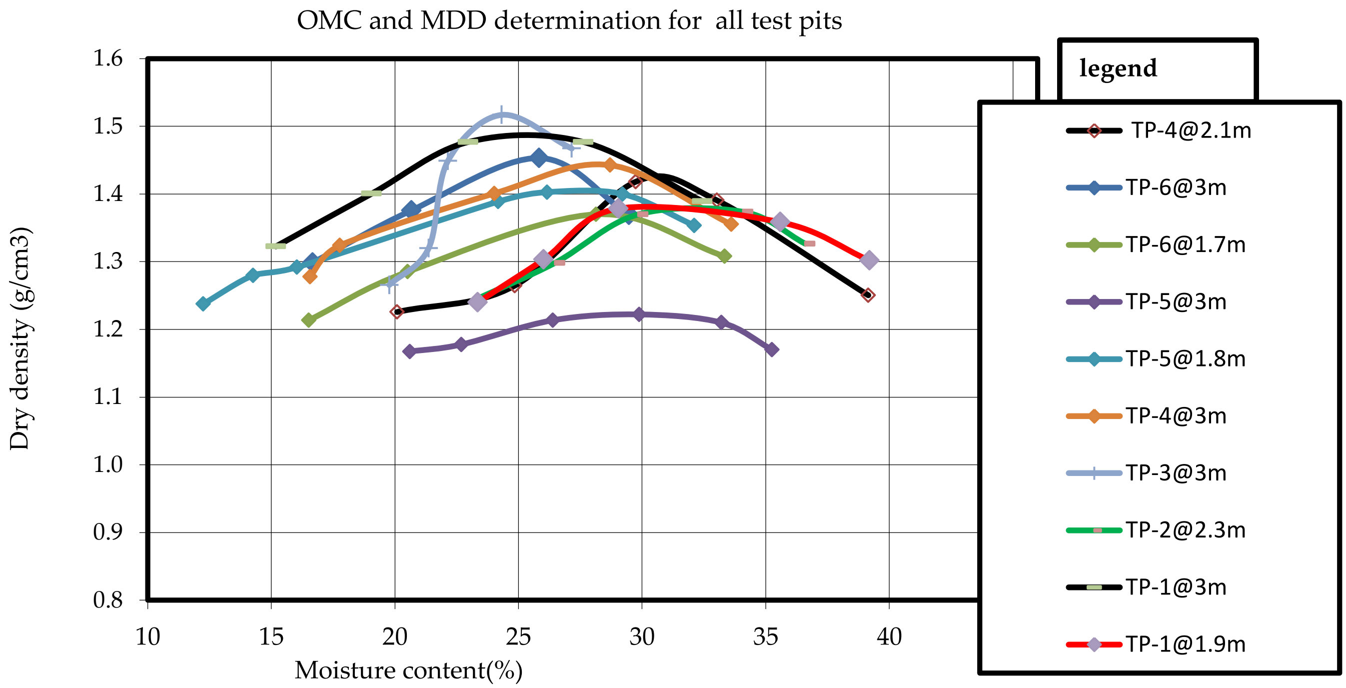

Figure 4:3 OMC and MDD determination curve for the study area

Table 4:8 optimum moisture content and maximum dry density of study area

S. No	Test pit Designation	Test pit Location	Depth of Sampling	OMC(optimum moisture content)	MDD(maximum dry density)
1	TP-1@1.9m	Area proposed for Condominium	3m	30.000	1.38
2	TP-1@3m		3m	25.000	1.49
3	TP-2@2.3m	Municipality	2.3m	32.500	1.53
4	TP-3@3m	Stadium	3m	24.320	1.52
5	TP-4@2.1m	High school	2.1m	31.250	1.42
6	TP-4@3m		3m	28.710	1.44
7	TP-5@1.8m	TVET Collage	1.8	26.160	1.40
8	TP-5@3m		3m	29.880	1.22
9	TP-6@1.7m	Bus station	1.7m	28.130	1.37
10	TP-6@3m		3m	25.840	1.45

4.3. Consolidation Test

4.3.1. General

In order to evaluate the suitability of a foundation or earth structure, it is necessary to design against both bearing capacity failure and excessive settlement. For foundations on cohesive soils, the principal design criterion is typically the latter the control of expected settlements within the limits considered tolerable for the structure. As a result, once allowable foundation displacements have been established, the estimate of total settlement over the service life of the structure is a major factor in the choice of foundation design. [6]

The data obtained from the one-dimensional (odometer) consolidation test are as follows:

- ✓ Initial height of the soil, H_0, which is fixed by the height of the ring.
- ✓ Current height of the soil at various time intervals under each loading (time–settlement data).
- ✓ Water content at the beginning and at the end of the test, and the dry weight of the soil at the end of the test.

This test is performed to determine the magnitude and rate of volume decrease that a laterally confined soil specimen undergoes when subjected to different vertical pressures. From the measured data, the consolidation curve (pressure-void ratio relationship) can be plotted. This data is useful in determining the compression index, the recompression index and the pre consolidation pressure (or maximum past pressure) of the soil. In addition, the data obtained can also be used to determine the coefficient of consolidation and the coefficient of secondary compression of the soil. [6]

The odometer test result for TP-6@3m is presented in table 4:20and graph 4:12 below for determining the coefficient of consolidation by using log time (Casagrande's) method.

Below is the summery of all the loading and unloading result in tabular form for each pressure

Table 4:9 coefficient of consolidation analysis for TP-6@3m

Pressure	Time for 50% Consolidation	D_0	D_{100}	D_{50}	ΔH	∑ΔH	H_d	Coefficient of Consolidation(Cv)	Hv(Void Height)	Void Ratio(e)
2.834	0	20	20	20	0	0	10	0	9.599	0.9230
28.34	0.336	19.92	19.64	19.78	0.36	0.35	9.89	2.39E-01	9.241	0.8885
56.69	1.632	19.64	19.27	19.45	0.73	1.08	9.72	4.76E-02	8.871	0.8720
113.36	8.846	19.27	19.06	19.16	0.93	1.66	9.58	8.52E-03	8.665	0.8332
226.72	0.359	18.95	18.62	18.79	1.37	2.30	9.39	2.02E-01	8.227	0.7911
453.44	1.349	18.54	18.19	18.36	1.89	3.26	9.18	5.13E-02	7.709	0.7412
453.44	6.25	18.23	18.25	18.24	1.83	3.71	9.12	1.09E-02	7.772	0.7473
226.72	6.42	18.40	18.45	18.43	1.64	3.46	9.21	1.09E-02	7.964	0.7658
113.36	1.5	18.49	18.54	18.51	1.28	2.90	9.25	4.69E-02	8.332	0.8011
56.69	18.789	18.58	18.66	18.62	1.16	2.42	9.31	3.79E-03	8.444	0.8119
28.34	50.833	18.69	19.0	18.84	0.81	1.96	9.42	1.43E-03	8.786	0.8448

''$H_v=(H_i-H_s)-\sum\Delta H$; $e=H_v/H_s$; $Cv=0.197[\, H_d^2/t_{50}$; $\sum\Delta H=\sum\Delta H$ for previous loading + ΔH under applied pressure''

From the above table we can observe that the coefficient of consolidation varies from 0.00143 to 0.239 depending on the applied load. To evaluate other parameters of consolidation such as coefficient of compression index (Cc) and pre consolidation pressure the plot of pressure (Y-axis) vs. Time (on X-axis with log scale) is drawn as shown in figure diagram 4:5 below; the analysis of pre consolidation pressure is done by the Casagrande's method as it is explained in section 2.6.1 above.

Table 4:10 the consolidation test output result for examined samples

S. No	Test pit Designation	Depth of sampling	C_c	C_v		sc	s0	OCR
1	TP-3@3m	3m	0.17	0.13	0.00202	125 kPa	34.667358	3.605
3	TP-5@3m	3m	0.15	0.24	0.00141	72.5 kPa	39.46563	1.837
4	TP-6@3m	3m	0.14	0.24	0.00143	65.5 kPa	41.02542	1.596

From Table 4:10 the study area soil has the over consolidation (OCR) ratio greater than 1 indicating the soil is experienced with higher stress than the present stress it has.

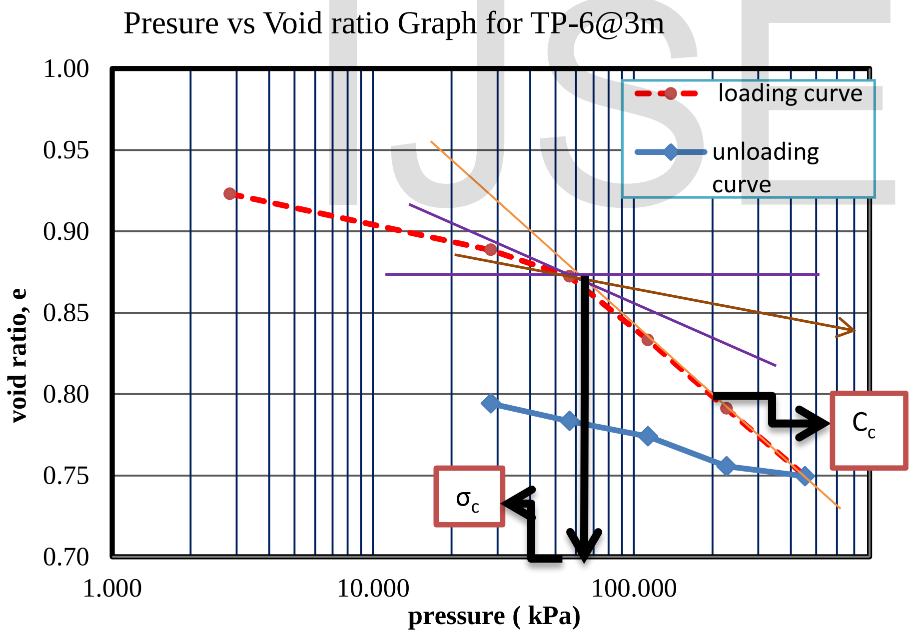

Figure 4:4 pressures vs. void ratio graph for TP-6@3m

5. DISCUSSION ON LABORATORY TEST RESULT

Natural moisture content

The water content of the fine grained soil such as silts and clays in generally are more than that of the coarse grained soils, such as gravels and sands. The water content of the fine grained soil may be even more than 50% of the total mass is that of water [4]. Table 4:2 shows that the soil around town municipality and Konso Mewucha has lower natural water content values of 18.77% and 19.65%

respectively indicating that the soil around that area is coarser than the other pit. On the other hand the soil around bus station and TVET collage has the highest natural water content value indicating the finer behavior of the soil in relative.

Specific gravity

The specific gravity of the solids for most of natural soils falls in the range of 2.65-2.80 the smaller values are for the coarse grained soils [4]. [Table 4:3 in the above section shows the test results of the specific gravity for the study area and the value calculated lies on the range of 2.512 to 2.742 which indicates almost all the study area soils in inorganic soils range.

Grain size analysis

Particle size or grain size is a method of separation of soils into different fractions based on the particle size. It explains quantitatively the proportion by mass of varies sizes of particle present in a soil and can be shown graphically on a particle size distribution curve [4]. Table 4:4 which shows the wet sieve analysis for differentiating the percentage of coarser and finer. It indicates that except the soil around town municipality and Konso Mewucha which has percent finer value less than 0.075mm of 7.3% and 10.0% respectively, all the rests study area soil has the percent finer of more than 70% categorizing the study area soil under silt and clay.

Free swell

Table 4:6 above describes the increase in volume of soils without any external constraint when subjected to submergence in water. Accordingly except the soil at 1.5m around TVET collage which has free swell index of 65% indicating the degree of expansiveness as Moderate the rest study area soil none expansiveness behavior as the test result shows.

Classification of Soil

Many systems are in use that is based on grain size distribution and Attergberg limits of soil. The systems that are quite popular amongst engineers are the AASHTO Soil Classification System and the Unified Soil Classification System in which both are described under these sections.

Unified soil classification system

The system uses both the particle size analysis and plasticity characteristics of soil like AASHTO system. The soils are classified into two categories.

a) *Coarse–grained soils*: - if more than 50% of the soil is retained on No, 200(0.075mm) sieve, it is designated as coarse grained soils and it comprises 8 groups. The course grained soils are designated as gravel(G) if 50% or more of course fraction(plus 0.075mm) is retained on No,4(4.75mm) sieve; otherwise it is termed as sand(S). if the course grained soils contains less than 5% fines and well-graded (W) they are given the symbols GW and SW, and if poorly graded(P) symbols are GP and SP. The criteria for well graded and poor graded is defined in section 2.4.4 above. If the course grained soils contain less than 12% fines, these designated as GM, GC, SH and or SC as per the criteria given. If the percentage of fines is between 5 to 12% dual symbols such as GW-GM, SP-SM are used.

b) *Fine grained soils*: - if more than 50% of the soil passes No, 200 sieve and there are 6 groups of fine grained soils. Finer grained soils are further classified as (I) soils of low compressibility (L) if the liquid limit is 50% or less. These are given the symbols ML, CL, and OL. (II) Soils of high

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compressibility (H) if the liquid limit is more than 50%. These are given the symbols MH, CH and OH. The exact type of the soil is determined from the plasticity chart as described in figure 5:1 for the study are soil. The A-line has the equation PI=0.73(LL-20) it separates the clay from silt. When the plasticity index and the liquid limit plots in the hatched portion of the plasticity chart, the soil is given the double symbol CL-ML.

The classification of the study area soil is described in table and figure below.

Table 5:1 unified soil classification system of the study area

S. No	Test Pit Designation	Depth of Sampling	Percent amount of particle size				L L	PI	Soil Classification	Usual type of soil
			%gravel	% sand	% silt	%clay				
1	TP1@1.5m	1.9m	0	19.07	80.93		49	28	CH	Inorganic clay of medium plasticity
2	TP-1@3m	3m	0	5.25	52.01	42.74	43	16	CH	Inorganic clay of medium plasticity
3	TP-3@3m	3m	0	23.08	40.52	36.4	45	15	CH	Inorganic clay of medium plasticity
4	TP4@1.5m	2.1m	0	25.76	74.24		44	11	CH	Inorganic clay of medium plasticity
5	TP-4@3m	3m	0	6.797	72.623	20.58	42	12	CH	Inorganic clay of medium plasticity
6	TP5@1.5m	1.8	0	9.59	45.94	44.47	57	25	MH	Inorganic clay of High plasticity
7	TP-5@3m	3m	0	23.43	40.21	36.36	62	28	MH	Inorganic clay of High plasticity
8	TP6@1.5m	1.7m	0	9.2	91.8		49	18	CH	Inorganic clay of medium plasticity
9	TP-6@3m	3m	0	29.39	43.56	27.05	54	22	MH	Inorganic clay of High plasticity
10	TP-8@3m	3m	0	22.9	77.095		44	13	CH	Inorganic clay of medium plasticity
11	TP9@1.5m	1.5m	0	14.501	85.499		56	23	MH	Inorganic clay of High plasticity
12	TP-9@3m	3m	0	27.716	72.284		62	27	MH	Inorganic clay of High plasticity
13	TP10@3m	3m	0	24.87	75.256		46	15	CH	Inorganic clay of medium plasticity

From the above table most of study area soil has the liquid limit value of greater than 30% and less than 50% which categorizes the soil as in organic clay of medium plasticity except the soils found Around Police Station, Near Bus Station and TVET Collage area which is categorized as inorganic clay of High plasticity, since their liquid limit value is greater than 50% as the test result indicates.

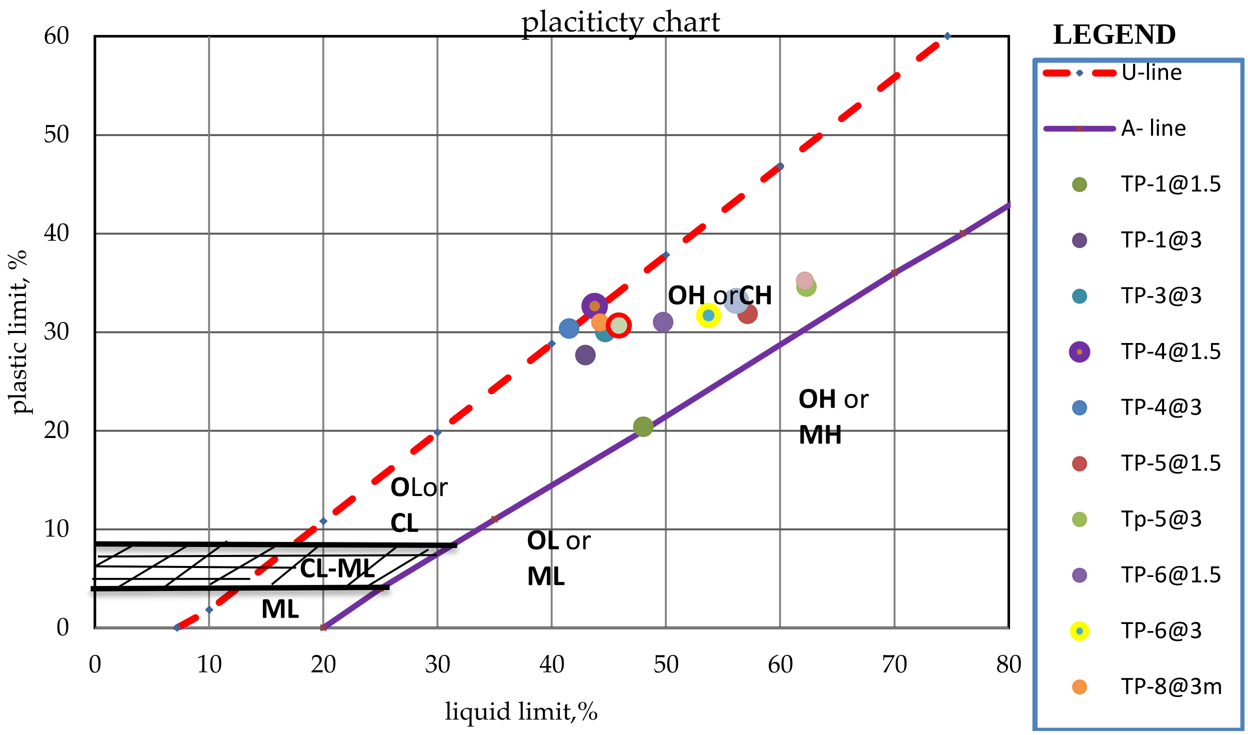

Figure 5:1 plasticity chart for fine grained soil (Murthy, P-96) (unified soil classification)

AASHTO Soil Classification System

The AASHTO (American Association of State Highway and Transportation Officials) System (ASTMD-3242, AASHTO Method M145) comprises seven groups of inorganic soils; A-l to A-7 with 12 sub-groups in all. The system is based on the following three soil properties; [13]

- ✓ Particle-size distribution
- ✓ Liquid Limit
- ✓ Plasticity Index.

According to AASHTO, granular soils are soils in which 35% or less are finer than the No. 200 sieve (0.075 mm). Silt-clay soils are soils in which more than 35% are finer than the No. 200 sieve.[7] Table and graph below showing the AASHTO classification of soil for the study area.

Table 5:2 AASHTO Soil Classifications

S. No	Test Pit Designation	Depth of Sampling	Percent amount of particle size				LL	PI	Group Classification	General Rating as Sub Grade	Usual Type of Soil
			%Gavel	%Sand	%Silt	%Clay					
1	TP1@1.9m	1.9m	0	19.07	80.93		49	28	A-7-6	Fair to Good	Clayey Soil
2	TP-1@3m	3m	0	5.25	52.01	42.74	43	16	A-7-6	Fair to Good	Clayey Soil
3	TP-3@3m	3m	0	23.08	40.52	36.4	45	15	A-7-5	Fair to Good	Clayey Soil

4	TP4@2.1m	2.1m	0	25.76	74.24		44	11	A-7-5	Fair to Good	Clayey Soil
5	TP-4@3m	3m	0	6.797		20.58	42	12	A-7-5	Fair to Good	Clayey Soil
6	TP-5@1.8m	1.8	0	9.59	45.94	44.47	57	25	A-7-5	Fair to Good	Clayey Soil
7	TP-5@3m	3m	0	23.43		36.36	62	28	A-7-5	Fair to Good	Clayey Soil
8	TP-6@1.7m	1.7m	0	9.2	90.8		49	18	A-7-5	Fair to Good	Clayey Soil
9	TP-6@3m	3m	0	29.39	43.56	27.08	54	22	A-7-5	Fair to Good	Clayey Soil
10	TP-8@3m	3m	0	22.9	77.095		44	13	A-7-5	Fair to Good	Clayey Soil
11	TP-9@1.5m	1.5m	0	14.501	85.499		56	23	A-7-5	Fair to Good	Clayey Soil
12	TP-9@3m	3m	0	27.716	72.284		62	27	A-7-5	Fair to Good	Clayey Soil
13	TP-10@3m	3m	0	24.87	75.826		46	15	A-7-5	Fair to Good	Clayey Soil

From the table 5.2 and plasticity chart all the soils in the study are is classified as clayey soil. Accordingly when rating as the sub grade material the study area soil is identified as fair to good behavior and group classification is grouped all the study area soil under A-7-5 except the investigated soil on the area proposed for condominium building which is A-7-6.

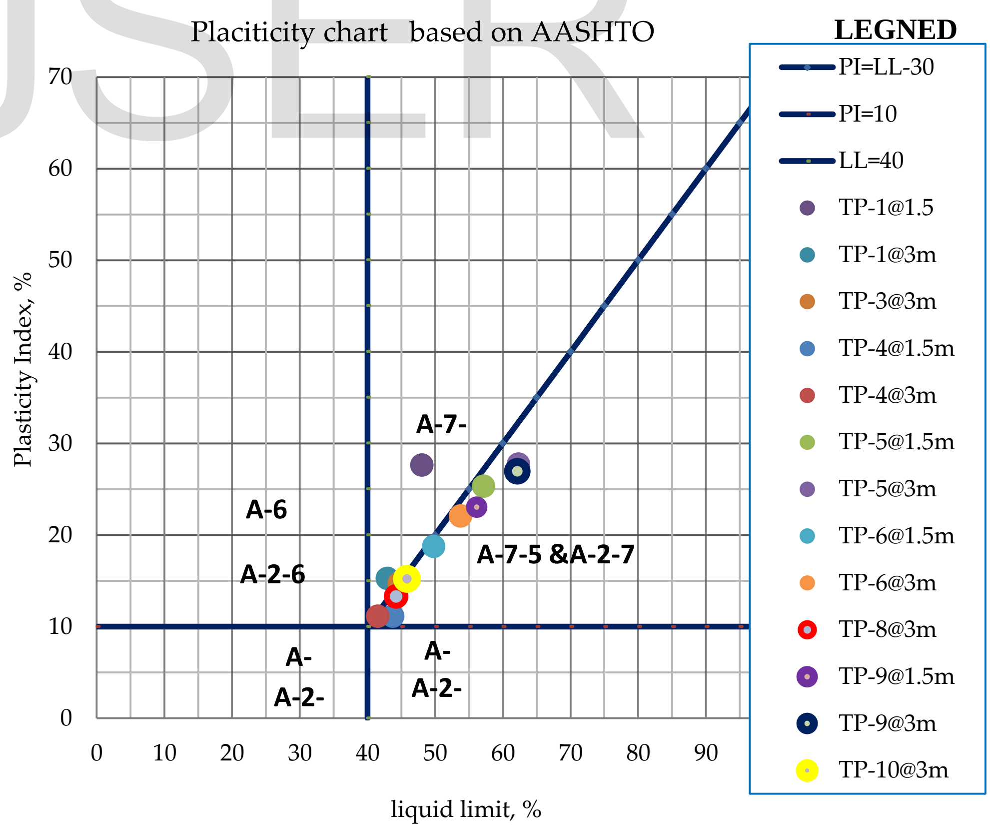

Figure 5:2 plasticity charts for soil classification by AASHTO

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Liquidity index

The classification of soil can be also described by using the liquidity index (LI), of soil; which is the ratio of the difference in water content between the natural or in situ water content of a soil and its plastic limit to its plasticity index as described in section 4.2.4 above. The description standard is also briefed on table 5:3. Below is the soil category description for the study area based on the liquidity index of soil.

Table 5:3 soil classification based on liquidity index

S. No	Test Pit Designation	Depth of Sampling	Natural Moisture Content	PL	PI	LI	Usual Type of Soil
1	TP1@1.9m	1.9m	24.004	20	28	0.1278	Semisolid state: high strength, brittle (sudden) fracture is expected
2	TP-1@3m	3m	32.176	28	16	0.2879	Semisolid state: high strength, brittle (sudden) fracture is expected
3	TP-3@3m	3m	22.962	30	15	-0.4743	Plastic state: intermediate strength, soil deforms like a plastic material
4	TP4@2.1m	2.1m	26.401	33	11	-0.5608	Plastic state: intermediate strength, soil deforms like a plastic material
5	TP-4@3m	3m	29.690	30	12	-0.0574	Plastic state: intermediate strength, soil deforms like a plastic material
6	TP-5@1.8m	1.8	27.955	32	25	-0.1539	Plastic state: intermediate strength, soil deforms like a plastic material
7	TP-5@3m	3m	31.658	35	28	-0.1048	Plastic state: intermediate strength, soil deforms like a plastic material
8	TP-6@1.7m	1.7m	36.318	31	18	0.3005	Semisolid state: high strength, brittle (sudden) fracture is expected
9	TP-6@3m	3m	27.679	32	22	-0.1794	Plastic state: intermediate strength, soil deforms like a plastic material
10	TP-8@3m	3m	23.17	31	13	-0.6042	Plastic state: intermediate strength, soil deforms like a plastic material
11	TP-9@1.5m	1.5m	27.520	33	23	-0.2436	Plastic state: intermediate strength, soil deforms like a plastic material
12	TP-9@3m	3m	31.94	35	27	-0.1231	Plastic state: intermediate strength, soil deforms like a plastic material
13	TP-10@3m	3m	23.19	31	15	-0.4914	Plastic state: intermediate strength, soil deforms like a plastic material

From liquidity index table above except soil that are found around the site which is proposed for condominium building and the area near bus station at shallow depth which has the LI value greater than zero and less than 1 getting the soil description as semi solid state with high strength, brittle (sudden) fracture is expected. The rest of study area soil has the LI of less than zero characterizing the behavior as plastic state with intermediate strength, soil deforms like a plastic material.

Activity of cay

Activity can be determined from the results of the standard laboratory tests such as the wet analysis, liquid limit and plastic limit. Clays containing kaolinite will have relatively low activity and those containing montmorillonite will have high activity. [16]The activity of clay can be described as normal soil if activity value is less than 0.75, normal soil type if activity value is greater than 0.75 and less than 1.25 and for those soils that have activity value of greater than 1.25; the category considers as active soils. Below is the plot of the study area soil to identify activity of the soil as tabular and graph form.

Table 5:4 Soil Classification according to activity

S. No	Test Pit Designation	Depth of Sampling	Clay Fraction, %	PI	Activity(A)	Remark /Soil Description
1	TP-1@3m	3m	42.740	15	0.35740	in active
2	TP-3@3m	3m	36.400	15	0.40391	in active
3	TP-4@3m	3m	20.580	11	0.51303	in active
4	TP-5@1.5m	1.8	44.470	25	0.56970	in active
5	TP-5@3m	3m	36.360	28	0.76268	normal
6	TP-6@3m	3m	27.080	22	0.81517	normal

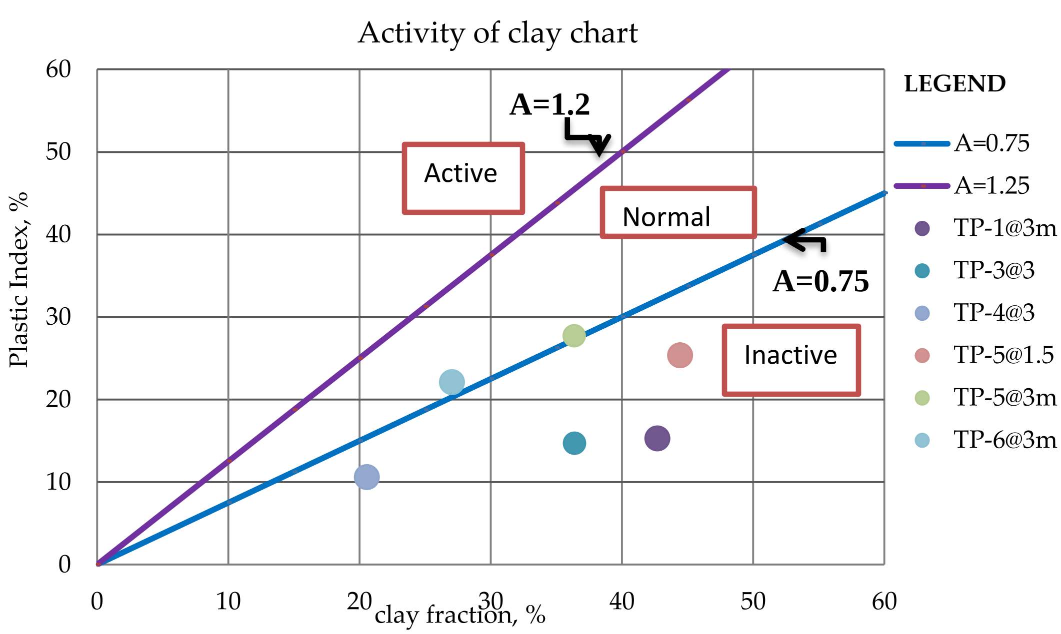

Figure 5:3 Soil classification based on activity of clay

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The graph and chart above indicates the soil around Bus station and TVET collage area are in the normal range and the rest investigated soil shall be grouped under inactive side.

Shear strength

Table 4.7 shows that the unconfined compressive strength of Segen town soil is ranging from 90.46kPa-157.29kPa with the undrained shear strength value with in the range of 45.23-78.65kpa.

Compaction

Knowledge of the optimum water content and the maximum dry unit weight of soils are very important for construction specifications of soil improvement by compaction. Specifications for earth structures (embankments, footings, etc.) usually call for a minimum of 95% of Proctor maximum dry unit weight. So compaction increase the shear strength & bearing capacity; it also reduces the compressibility and permeability of soil [16]. From Table 4.8 the maximum dry density varies from 1.22-1.53g/cm^3 depending on the behavior of soil. On the other hand the study area soil has the optimum moisture content of 25%-32.5%. The result implies that the soil can be under the clay category.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The visual classification for the color description of the study area soil categorizes most of soil as Red, Reddish brown, Black and Yellow black. The natural moisture content of the Segen town at shallow depths i.e., at 1.5m is lower than that of 3m indicating the soil at deeper depths is more moist than the shallow.

From the in situ bulk density result the dry unit weight of the investigated Segen soil is in between 11.36 -13.72 kN/m^3 indicating the area soil is light.

The grain size distribution result shows the Segen town soil is fine soils with percentage finer more than 70% except for the soil around town municipality and Konso Mewucha with less percent finer value of 7.33% and 10.046% respectively.

From the free swell index result the soil around *TVET* collage at a depth of 1.8m has a moderate degree of expansiveness with the with the free swell index value of 65%. On the other hand the rest of the study area soil experience none expansiveness behavior with free swell index value of less than 50%.

Based on the Unified Soil Classification the Segen town soil is predominantly inorganic clay of medium plasticity (CH) and Inorganic clay of high plasticity (MH) while the town soil is clayey soil with fair to good quality when rating as subgrade material. These reveals that the investigated soil has poor quality when using as sub grade material and needs stabilization or other techniques if recommended for using as sub grade material.

From the liquidity index result the soil around bus station at 1.7 m and in the area proposed for condominium at 3 m depth has the liquidity index value of less than zero describing the soil as high strength, brittle (sudden) fracture is happened. The rest soil in Segen town is characterized with intermediate strength, soil deforms like plastic material.

6.2. Recommendations

1. As Segen is newly established city and zonal administration town the construction activity will be expect to expand in recent years. As the result of these further in depth investigation in to engineering properties by increasing the number of sample shall be recommended to depict the soil map of the area.
2. Since the town soil from this study is described as clay soil for further it is recommended if the swelling characteristic is investigated and the correlation of index property to relate the shear strength is also recommendable.
3. To generalize the full description of the engineering properties for future the dynamic properties shall be studied in the town.

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