Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Investigation of Some Engineering Characteristics of Soils in Burao Town, Somaliland

Ali Ahmed Hussein

ali@ogaansho.org

University of Burao

Ahmed Abdirahman Farah

Ogaansho Research and Consultancy Center

Mohamed Hussein Eggeh

Ogaansho Research and Consultancy Center

Hamda Jama Yousof

Ogaansho Research and Consultancy Center

Research Article

Keywords: Engineering properties of soil, Moisture content, Specific gravity, Atterberg limits, Grain-size distribution, Compaction characteristics

Posted Date: March 20th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9157197/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

Soils are essential for supporting civil engineering structures like roads and buildings. Making a thorough investigation of underground conditions is crucial for successful and cost-effective substructure design, as inadequate geotechnical investigations can lead to poor designs, construction delays, costly modifications, environmental damage, remedial work, and potential structural failures with legal repercussions.

This research assesses the engineering properties of soil in Burao town, focusing on vulnerable areas prone to weak soils due to water infiltration. Sampling from two locations near the Togdheer dry river involved excavation to 2.5 meters, yielding disturbed and undisturbed samples for laboratory testing. Findings indicated fine sand as the predominant soil type, with natural moisture contents of 12.77% and 17.25%, specific gravities of 2.50 and 2.63, and varying Atterberg limits. Grain size analysis revealed sand dominance (91.63% – 91.84%) and low silt and clay content.

Compaction tests identified maximum dry densities ranging from 1.71 to 1.95 g/cm³ and optimum moisture content between 13.5% and 14%. Soil classifications indicate that it is well-graded sand (SW) according to the Unified Soil Classification System, making it suitable for drainage-oriented construction projects, even though it has a lower load-bearing capacity compared to clay or gravel soils.

In this research, limitations observed included the absence of essential tests like California Bearing Ratio and triaxial shear strength at the Burao University laboratory; future research should include these tests for better soil behavior understanding. Additionally, a regulatory framework is needed in Somaliland to mandate geotechnical investigations for construction permitting, ensuring projects rely on accurate soil data to improve safety and integrity.

2 Background

Soil is a complex heterogeneous material containing different types of minerals which is the results of weathering or disintegration of the rock. The properties of soil vary from one location to another since they are naturally occurring materials. Soils are porous materials created on the earth’s surface through the processes of weathering. It is a multi-phase material that contains solids, liquids, and gases (Sorsa et al., 2020). According to (Das, 2006), the mineral grains that form the solid phase of a soil aggregate are the product of rock weathering. The size of individual grains varies over a wide range. Many of the physical properties of soil are dictated by the size, shape and chemical composition of the grains. To better understand these factors, one must be familiar with the basic types of rocks that form the earth’s crust, the rock forming minerals, and the weathering process.

Investigation of the underground soil conditions at a site is prerequisite to the performance and economical design of the substructure elements. It is also necessary to obtain sufficient information for feasibility and economic studies of the proposed project. Public building officials may require soil data together with the recommendations of the geotechnical consultant prior to issuing a building permit, particularly if there is a chance that the project will endanger the public health or safety or degrade the environment (Debebe, 2011).

Inadequate geotechnical investigation, inaccurate interpretation, or a failure to present result information in a clearly understandable manner; may lead to improper designs, building schedule delays, expensive alterations, use of substandard borrowed materials, site or environmental damage, post-construction remedial work, and even a structure's failure and subsequent litigation as indicated by (Debebe, 2011). Hence, geotechnical investigations should be carried out on the soil and rock beneath (and occasionally adjacent to) a site of proposed structures to gain information on the type, properties, and distributions of a soil.

Geotechnical research on the engineering properties of soil is therefore crucial in a nation like Somaliland, which is expanding quickly and will require a lot of construction work in the future, since civil engineers utilize these data to build foundations, pavements, retaining walls, and other components for upcoming construction projects around the nation.

There are no frequent studies that relate to investigations of the engineering properties of soil that have been conducted in the majority of the nation's major cities, including Hargeisa, Burao, Borame, etc. Therefore, this study focuses on the investigation of engineering characteristics of soils in Burao town, Somaliland, based on laboratory analysis.

As stated by (Abdilahi, 2024), the population of Burao, a major city in Somaliland, has been rising gradually due to conflict, drought, and other disasters. Burao is one of the fastest growing cities in the country and there is a big volume of construction works. Since it is the transit way between the Western and Eastern regions of Somaliland, the growth of trade and commerce is very high in the city.

Furthermore, Burao is known for its production of livestock, meanwhile the viability of Somaliland economy after destruction of socio-economic infrastructure in civil wars was began when the livestock export has restarted in 1991 immediately after declaration of Somaliland independence (Hassan, 2020).

Due to its location and near distance to the port, which is around 120km from Berbera port, industries and other investors are attracted to construct in Burao town and the nearby areas. However, the engineering properties of the soil in the city are not studied yet. Therefore, this research is directed to study the physical and mechanical property of soils i.e. investigation of engineering characteristics of soils in Burao town, Somaliland, based on laboratory analysis of soil’s natural moisture content, specific gravity, grain size distribution, Atterberg limits, and compaction characteristics.

3 Methods

3.1.1 Description of the study area

This study was conducted in Burao city, the capital city of Togdheer region, Somaliland. Officially, the Republic of Somaliland has been a de facto sovereign state in the Horn of Africa since 1960. Somaliland locates in the Horn of Africa, on the southern coast of the Gulf of Aden. It borders Djibouti to the northwest, Ethiopia to the south and west, and Somalia to the east. Its claimed territory has an area of 176,120 square kilometers (68,000 sq. mi), with approximately 5.7 million residents as of 2021. The government of Somaliland regards itself as the successor state to British Somaliland, with latitude 9.4117 and longitude 46.8253 (Abdi & Hareru, 2024).

As mentioned on (Farah, 2019), Burao city is located 270 km east of Hargeisa the capital city of Somaliland, and lies on Latitude 9° N and Longitude 45° E. The city is situated in the northern part of the Hawd plateau, at an elevation of around 1,040 meters above sea level, and gently slopes to the south-east. The intermittent Togdheer River is the main natural element in the city, with the built-up area concentrated on its southern banks (UN-HABITAT, 2009).

3.1.2 Geography and climate

Burao has a hot, semi-arid climate. Annual rainfall is only 200 millimeters, falling in the two wet seasons of April to June and October to November (UN-HABITAT, 2009). Weather in Burao, much like other inland towns in Somaliland, is very warm to hot and dry year-round. The city has a hot arid climate in common with most of Somaliland, although Burao's weather is moderated by altitude. The average daytime temperatures during the summer months of June and August can rise to 31°C or 87.8°F, with a low of 20°C or 68°F at night. The weather is cooler the rest of the year, averaging 27°C or 80.6°F during the day and 13°C or 55.4°F at night-time.

3.1.3 Sample and sampling technique

A laboratory experimental program was designed to conduct the investigation of the fundamental engineering properties of the soil. Four representative (disturbed and undisturbed) soil samples were collected from two selected sampling areas. pits were excavated to a maximum depth of 2.5 meters. The disturbed soil samples were first air-dried and laboratory tests were conducted according to the American Society for Testing and Materials (ASTM) and American Association of State Highway and Transportation Officials (AASHTO) soil testing procedures. The laboratory tests that were conducted for this study include natural moisture content, specific gravity, grain size distribution, Atterberg limits, and compaction characteristics. However, the study was limited to two test pits that may not represent the whole study area. Therefore, the findings should be considered as indicative, rather than definitive, for the entire study area.

3.1.4 Data collection procedure

The different activities that were carried out in this research work can be classified into three main phases: pre-fieldwork, fieldwork, and post-fieldwork. The primary tasks conducted before fieldwork are a literature review, collection of supplementary materials such as geological and geographical maps of the study area, identification of the availability and functioning of laboratory and field soil sampling apparatus, and site selection. For this study, two study areas were randomly selected while using field observation and some literature that showed areas where weak soils may exist near the dry river of Togdheer in the center of the town to understand the engineering properties of very weak soil in that area.

During the fieldwork stage, visual identification of soils around the study area were observed,

and the soil samples were extracted, and two sampling areas were selected from the two sides of the Togdheer dry river. The two pits were excavated to a depth of 2.5 meters, and two representative disturbed and undisturbed soil samples were collected from each pit. The disturbed samples were obtained using a hand shovel, and the undisturbed samples were obtained using an HMA-90L 100mm Cutting Sample Ring using a mechanical method. The undisturbed samples are for natural moisture content. The disturbed samples are for specific gravity, grain size distribution, Atterberg limits, and compaction characteristics tests.

During post-fieldwork, a laboratory test program for the collected soil samples was conducted. The results from laboratory tests and visual identification from field surveys were interpreted, and they are reported in this paper. For this study, the disturbed and undisturbed soil samples were collected based on ASTM and AASHTO sampling procedures.

3.1.5 Data Processing and analysis

Data processing and analysis represent critical components of the research investigating the engineering characteristics of soils in Burao town, Somaliland. This phase entails the systematic organization and interpretation of data collected from laboratory tests. Initially, raw data including measurements of natural moisture content, specific gravity, grain size distribution, Atterberg limits, and compaction characteristics were meticulously compiled. Statistical methods were employed to analyze this quantitative data, allowing researchers to discern patterns, trends, and correlations pertinent to the study's objectives. Such rigorous data processing is essential for ensuring that the findings accurately reflect the inherent properties of the soil and its suitability for various construction applications. By synthesizing this quantitative data, the research aspires to provide a comprehensive understanding of how the engineering characteristics of soils influence construction performance in Burao. The resulting analysis were documented clearly and coherently, ultimately contributing valuable knowledge to the field of geotechnical engineering in Somaliland and informing future construction practices in the region.

4 Results

4.1.1 Index Properties of soil

4.1.1.1 General

Before selecting sampling areas, visual site investigations and information from residents and construction firms were collected to consider the different soil types and to take samples evenly through the whole town. Accordingly, to get areas where weak soils may exist in the town to understand their engineering properties of very weak soil, two sampling areas were selected from the two sides of the Togdheer dry river, which were selected to be the most vulnerable areas that have weak soil, as studied in literature, construction firms, and information from residents. The two pits were excavated to a depth of 2.5 meters, and two representative disturbed and undisturbed soil samples were collected from each pit. The global coordinates of the sampling location, i.e. northing, easting, and elevations are shown in Table 4.1.

Table 1
Global coordinates of sampling areas

Test Pit	Location	Northing	Easting	Elevation (m)
Sample A	Near Ilays Enterprise Building (Maxadka Village)	9°31'35.85"N	45°32'23.28"E	1042.42
Sample B	Near Plaza Hotel (Plaza village)	9°30'51.66"N	45°33'32.60"E	1033.58

The various properties of soils that are considered as index properties include natural moisture content, specific gravity, Atterberg limits, particle size distribution, and compaction characteristics. In this study, the index property laboratory tests were performed in accordance with ASTM standard testing procedures. The details of each laboratory test conducted are described in the following sections.

4.1.1.2 Standard Testing Procedures

The laboratory specifications used for this study were from ASTM and AASHTO standards that are presented in Table 2 below:

Table 2
Standard Testing Procedures

No	Name of the test	ASTM	AASHTO	Test condition
1	Moisture Content	D4643-00	-	Undisturbed
2	Specific Gravity	D 854-02	-	Air-dried
3	Grain Size Analysis	D 422 – 63	-	Air-dried
4	Atterberg Limits	D 4318-00	-	Air-dried
5	Compaction characteristics	D698	-	Air-dried

4.1.2 Moisture Content

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 volumes (Dr. K. R. Arora, 2006).

The natural (in-situ) moisture content of the soil samples was determined from the undisturbed soil samples using oven drying method of *ASTM D 4643-00*. The soil sample is taken as undisturbed using HMA-90L 100mm Cutting Sample Ring. Part of the undisturbed sample was filled with laboratory cans and the mass of the sample and that of the can are obtained using accurate weighing balance. The soil sample in the can is the dried in an oven at a temperature of $110^{o} \pm 5\ ^{o}C$ for 24 hours.

The laboratory results of the moisture contents of the samples are presented in Table 3.

For Sample A (Maxadka Village), the average moisture content is approximately 17.25%, with individual replicate measurements of 17.20% and 17.29%. This relatively high moisture content suggests that the soil may exhibit plastic behavior, which can affect its load-bearing capacity and structural integrity. As outlined in ASTM standards, soils with higher moisture content may require considerations for drainage and stabilization techniques to ensure adequate performance in construction applications.

Conversely, Sample B (Plaza Village) demonstrates a lower average moisture content of 12.77%, with consistent replicate values of 12.75% and 12.79%. This reduced moisture level indicates that the soil may possess better compaction characteristics, aligning with ASTM guidelines that emphasize the importance of moisture content in achieving optimal soil density. Lower moisture content typically correlates with increased soil strength and reduced susceptibility to deformation under load.

In conclusion, the variations in moisture content between the two samples underscore the necessity for careful consideration in geotechnical assessments. The findings highlight the implications of moisture levels on soil behavior, reinforcing the importance of adhering to ASTM standards for accurate soil characterization and effective construction practices.

Table 3
Laboratory test results of the natural moisture content of the samples

Item	Test number			
Field Sample Designation	Sample A (Maxadka Village)		Sample B (Plaza village)	
Can No.	1	2	1	2
Mass of can, W1 (gm)	24.77	24.63	34.21	34.08
Mass of can + wet soil, *W2* (gm)	46.57	51.15	47.3	49.6
Mass of can + dry soil, *W3* (gm)	43.37	47.24	45.82	47.84
Mass of moisture, *W2* - *W3* (gm)	3.2	3.91	1.48	1.76
Mass of dry soil, *W3* - WI (gm)	18.6	22.61	11.61	13.76
Moisture content, w (%) = (W2 - W3)*100 / W3 -WI	17.2	17.29	12.75	12.79
	Average Moisture Content = 17**.25**		Average Moisture Content = 12**.77**	

4.1.3 Specific gravity

Specific gravity is defined as the ratio of the unit weight of a given material to the unit weight of water. The specific gravity of soil solids is often needed for various calculations in soil mechanics. It can be determined accurately in the laboratory. Most of the values fall within a range of 2.6 to 2.9. The specific gravity of solids of light-colored sand, which is mostly made of quartz, may be estimated to be about 2.65; for clayey and silty soils, it may vary from 2.6 to 2.9 (Das, 2006).

using (ASTM Standards, 2002), the specific gravity of the two samples was determined in a laboratory using a pycnometer filled with a stopper. The pycnometer is cleaned and dried at a temperature of 105^{o} and cooled. The mass of the pycnometer is taken and a sample of air-dried soil is taken in to the pycnometer and weighed.

To avoid particles with large size, the sample was grounded to pass 2-mm sieve before test and tap water is then added to the sample. The sample is allowed to soak water for about two hours and more water is added until the pycnometer is full. The stopper is inserted in to the pycnometer and its mass is taken. The pycnometer is emptied, washed and then refilled with distilled water. The pycnometer was filled to the same mark as in the previous case. The mass of the pycnometer filled with water is taken.

The specific gravity of the studied soils, as shown in Table 4, provides valuable insights into the physical characteristics of the samples from Maxadka Village (A) and Plaza Village (B). Sample A exhibits a specific gravity of 2.5, while Sample B has a slightly higher value of 2.63. These results suggest that sample A falls within the typical range for organic soils, which generally spans from 2.2 to 2.5, while sample B falls within the typical range for soil solids, which generally spans from 2.6 to 2.9 as outlined in ASTM standards. The specific gravity values indicate the density of the soil particles; a higher specific gravity in Sample B may imply a denser composition, potentially enhancing its load-bearing capacity.

Table 4
Specific gravity results for studied soils.

No		Sample A	Sample B
1	Weight of pycnometer, gm	180	180
2	Weight of Sample, gm	120	142
3	Weight of pycnometer + Sample, gm	300	322
4	Weight of pycnometer with Full of Water, gm	746	762
5	Weight of pycnometer + Sample + Water, gm	674	674
6	Volume of Sample (2 + 4–5)	48	54
7	**Specific Gravity (2/6)**	**2.5**	**2.63**

4.1.4 Grain-Size Distribution

The distribution of particle sizes or average grain diameter of course-grained soils is obtained by screening a known weight of soil through a stack of sieves of progressively finer mesh size. Each sieve is identified by a number of square holes per linear inch of mesh. The particle diameter in the screening process, often called sieve analysis, is the maximum particle dimension to pass through the square hole of a particle mesh. A known weight of dry soil is placed on the largest sieve (the top sieve) and the nest of sieves is then placed on a vibrator, called a sieve shaker, and shaken. The soil retained on each sieve is weighed and the percentage of soil retained on each sieve is calculated. The results are plotted on a graph of percent of particle finer than a given sieve (not the percent retained) as the ordinate versus the logarithm of the particle sizes.

The following series of sieves, of square-mesh woven-wire cloth, was used for sieve analysis based on the maximum particle size.

Table 5
Series of sieves used for grain size distribution testing

Sieve No.	Sieve Size (mm)
4	4.75
8	2.36
16	1.88
30	0.6
60	0.25
100	0.15
140	0.105
200	0.075

The combined results for grain size distribution curve for coarse grained soils is shown in Fig. 7 below.

The grain size distribution graph depicted in Fig. 4, provides a comprehensive analysis of the particle size distribution for two soil samples, identified as Sample A (Maxadka Village) and Sample B (Plaza Village). The x-axis represents the particle size in millimeters (mm), ranging from 4.75 mm, indicative of coarse sand, to 0.075 mm, representing silt. The y-axis indicates the percentage of particles passing through the sieves, spanning from 0% to 100%.

Sample A demonstrates a higher concentration of larger particles, with approximately 80% passing through the 4.75 mm sieve. The curve exhibits a steady decline as particle size decreases, suggesting a predominance of coarser materials within this sample. In contrast, Sample B shows a more gradual decrease in the percentage of particles passing through the sieves, indicating a finer grain composition relative to Sample A. By the time it reaches the 0.075 mm sieve, around 80% of Sample B's particles are passing, highlighting a significant presence of silt-sized particles. The gradation of soils in the study

area varies considerably (Table 6). From the grain size analysis result silt & clay content ranging from 2.79–5.44%, sand fraction 91.62–91.84% and gravel content from 2.72–5.58%.

Table 6
Summary of grain size analysis result

Designation	Depth	Percentage amount of particle size		
		Gravel %	Sand %	Silt & Clay %
Sample A	2.5 m	2.72	91.84	5.44
Sample B	2.5 m	5.58	91.63	2.79

4.1.5 Atterberg limits

When clay minerals are present in fine-grained soil, the soil can be remolded in the presence of some moisture without crumbling. This cohesive nature is caused by the adsorbed water surrounding the clay particles. In the early of 1990s, a Swedish scientist called Atterberg developed a method to describe the consistency of fine-grained soils with varying moisture contents. At a very low moisture content, soil behaves more like a liquid. Hence, an arbitrary basis, depending on the moisture content, the behavior of soil can be divided in to four basic states – *solid, semisolid, plastic and liquid.* The moisture content, in percent, at which the transition from solid to semi-solid state takes place is called as the *shrinkage limit.* The moisture content at the point of transition from semi-solid to plastic state is the *plastic limit* and from plastic to liquid state is the *liquid limit.* These parameters are also known as Atterberg limits (Das, 2006).

4.1.5.1 Liquid limit

The moisture content, in percent, at which the transition from plastic to liquid state takes place is called as the liquid limit (Das, 2006). Liquid Limits were determined for air-dried samples. It was done based on the Standard Reference: ASTM D 4318-00 –Standard Test Method for Liquid Limit. The air- dried samples were prepared by spreading the specimen in the air until it dried. The portions of the samples sufficient to provide 150 to 200 g of material passing the No. 40 (0.425mm) sieve were used for the preparation of the sample for this test.

4.1.5.2 Plastic limit

The plastic limit is defined as the moisture content in percent, at which the soil crumbles, when rolled into threads of 3.2 mm (1/2 in.) in diameter. The plastic limit is the lower limit of the plastic stage of soil. The plastic limit test is simple and is performed by repeated rollings of an ellipsoidal-size mass by hand on a ground glass plate. The procedure for the plastic limit test is given by ASTM in test designation D-4138 (Das, 2006).

Table 7 presents the Atterberg limit test results for two soil samples in Burao town, revealing significant differences in their plasticity characteristics. Sample A has a liquid limit of 39.75% and a plastic limit of 28.19%, resulting in a plasticity index of 11.56. This indicates that Sample A exhibits a higher plasticity, which suggests greater susceptibility to deformation under load, potentially compromising the stability of structures built on it. In contrast, Sample B, with a liquid limit of 21.75% and a plastic limit of 17.78, has a lower plasticity index of 3.93. This lower plasticity implies that Sample B is more stable and less prone to deformation, making it more suitable for construction applications where structural integrity is crucial. The variance in plasticity highlights the importance of selecting appropriate soils to ensure optimal construction performance and minimize risks of structural failure.

Table 7
Laboratory Atterberg limit test result of the soil samples

Field Sample No.	Liquid Limit (%)	Plastic Limit (%)	Plasticity index (LL - PL)
Sample A	39.75	28.19	11.56
Sample B	21.75	17.78	3.93

4.1.6 Compaction test

Compaction means pressing the soil particles close to each other by mechanical methods. Air is expelled from the void space in the soil mass during compaction and the mass density is increased. Compaction of a soil is done to improve its engineering properties of the soil. Compaction generally increases the shear strength of the soil, and hence the stability and bearing capacity. It is also useful in reducing the compressibility and permeability of the soil (Dr. K. R. Arora, 2006)(7).

Compaction, in general, is the densification of soil by removal of air, which requires mechanical energy. The degree of compaction of a soil is measured in terms of its dry unit weight. When water is added to the soil during compaction, it acts as a softening agent on the soil practices. The soil particles slip over each other and move into a densely packed position. The dry unit weight after compaction first increases as the moisture content increases. Any increase in the moisture content tends to reduce the dry unit weight. This phenomenon occurs because the water takes up the spaces that would have been occupied by the solid particles. The moisture content at which the maximum dry unit weight is attained is generally referred to as the optimum moisture content (Das, 2006).

Procedure

There are two types compaction tests are routinely performed;

- Standard proctor compaction test
- Modified proctor (or modified AASHTO) compaction test

In the proctor test, the soil is compacted in a mold that has a volume of 944 cm^3 (1/30 ft^3). The diameter of the mold is 101.6 mm (4 in). During the laboratory test, the mold is attached to a base plate at the bottom and to an extension at the top. The soil is mixed with varying amounts of water and then compacted in three equal layers bay hammer that delivers 25 blows to each layer. The hammer has a mass of 2.5 kg (5.5 lb.) and has a drop of 30.5 mm (12 in) (Das, 2006). Figure 4.6 shows the laboratory equipment required for conducting a standard proctor test.

With the development of heavy rollers and their use in field compaction, the standard proctor test was modified to better represent field condition. This revised version is sometimes referred to as the *modified proctor test* (ASTM Test Designation D-1557 and AASHTO Test Designation T-180). For conducting the modified proctor test the same mold is used with a volume of 944 cm^3 (1/30 ft^3) as in the case of standard proctor test. However, the soil is compacted in five layers by a hammer that has a mass of 4.54 kg (10 lb.). The drop of the hammer is 457 mm (18 in). The number of hammer blows for each layer is kept at 25 as in the case of standard proctor test (Das, 2006).

Due to its increase in the compactive effort, and its results in an increase in the maximum dry unit weight of the soil, the modified proctor test is preferred, and this study were used by the modified one. The summary of the test result is shown in Table 8.

Table 8 summarizes the compaction test results for the soil samples, detailing their maximum dry density (MDD) and optimum moisture content (OMC). Sample A (Maxadka Village) shows a MDD of 1.71 g/cm^3 and an OMC of 13.50%, indicating that it requires a specific moisture level to achieve optimal compaction. Conversely, Sample B (Plaza Village) has

a higher MDD of 1.95 g/cm³ and an OMC of 14.00%, suggesting a denser soil composition that is likely to enhance its load-bearing capacity. The higher density of Sample B implies that it can better resist deformation and provide improved stability for construction projects. Therefore, the compaction characteristics of these soils are critical for determining their suitability in construction, as they directly influence the strength and durability of structures. Understanding these properties allows engineers to make informed decisions about soil selection and treatment to ensure construction performance meets safety and quality standards.

Table 8
Maximum dry density and optimum moisture content results

Designation	Depth(m)	MDD (g/cm3)	OMC (%)
Sample A	2.5 m	1.71	13.50
Sample B	2.5 m	1.95	14.00

4.2 Classification of the Soils

4.2.1 General

Soil in nature rarely exist separately as gravel, sand, clay, silt or organic matter, but are usually found as mixtures with varying proportions of these components. Grouping of soil on the bases of certain definite principles would help the engineer to rate the performance of a given soil either as a sub-base material for roads and airfield pavements, foundations of structures, etc (Murthy, 1990).

Soil classification is the arrangement of soil into different groups such that the soil in a particular group have similar behavior. It is a sort of labelling of soils with different labels. As there is a wide variety of soils covering earth, it is desirable to systematize or classify the soil into broad groups of similar behavior. It is more convenient to study the behavior of groups than that of individual soils (Dr. K. R. Arora, 2006).

Soil classification is used to specify a certain type that is best suitable for a given application. There are two main classification schemes which are available. Each was devised for a specific use. For example, American association of State Highway and Transport official (AASHTO) developed one scheme that classifies soil according to their usefulness in roads and highways while the unified soil classification system (USCS) was originally developed for use in airfield construction but was later modified for general use (Budhu, 2007)

There are several methods of classifying soils. The most widely used classification systems by engineers are described here. The soils under investigation have been classified according to USCS and AASHTO M-145.

4.2.2 Unified soil classification system (USCS)

The unified classification system is based on recognition of the type and predominance of the constituents considering grain size, gradation, plasticity and compressibility. It divides soil into three major divisions; coarse-grained soils, fine-grained soils, and highly organic (peaty) soils. In the laboratory, the Grain-Size curve and the Atterberg limits can be used for identification. The peat soils are readily identified by color, odor, spongy feel and fibrous texture (Murthy, 1990)(13).

The name and symbols used to distinguish between the typical and boundary soil groups are GW, GP, GM, GC, SW, SP, SM and SC. The symbols that started with a prefix G stand for gravel or gravelly soil and symbol that started with S are sand or sandy soil. 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 symbol “O” indicating the presence of organic material.

Table 9
Classifications of soils based on USCS Classification system

Designation	Depth (m)	LL (%)	PI (%)	Percentage amount of particle size			Classification according to USCS
				Gravel (%)	Sand (%)	Silt & Clay (%)	
Sample A	2.5 m	39.75	11.56	2.72	91.84	5.44	SW-SM
Sample B	2.5 m	21.75	3.93	5.58	91.63	2.79	SW

According to USCS classification scheme most of the soil of the study area falls in well-graded sand (SW) region. From the plot of plasticity chart in Fig. 11 and the classification soils on Table 9, the soils found in Burao town is well-graded sand.

4.2.3 AASHTO Classification System

The AASHTO classification system of soil classification was developed in 1929 as the public road administration classification system. It has gone several revisions. With the present version proposed by the committee on classification of materials for sub-grades and granular type roads of the highway research board in 1945 (ASTM designation D-3283; AASHTO method M145).

According to (Das, 2006), the soil in this system 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 pass 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 types materials. The classification system is based on the following criteria:

1. Grain size:

a. Gravel: fraction passing the 75-mm (3-in) sieve and retained on the No. 10 (2-mm) U.S. sieve

b. Sand: fraction passing the No.10 (2-mm) sieve and retained on the No. 200 (0.075-mm) U.S. sieve

c. Silt and clay: fraction passing the No.200 (0.075-mm) sieve

2. Plasticity: the term silty is applied when the fine fraction of the soils have a plasticity index of 10 or less. The term clayey is applied when the fine fractions have a plasticity index of 11 or more

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

Table 10
Classifications of soils based on AASHTO Classification system

Designation	Depth (m)	Percentage Passing on Sieve			LL (%)	PI (%)	Group Index	Group classificat-ion	Usual types of significant Constituent material	General Rating as sub-grade material
		No.10	No.40	No.200						
Sample A	2.5 m	88.10	57.14	5.44	39.75	11.56	0.0	A-3	Fine sand	Excellent to good
Sample B	2.5 m	76.00	29.48	2.79	21.75	3.93	0.0	A-2-4	Silty or clayey gravel and sand	Excellent to good

As presented in Table 10 and Fig. 12, indicate that Sample A is categorized as A-3, characterized as fine sand with a high percentage of particles retaining excellent to good subgrade material properties. In contrast, Sample B is classified as A-2-4, indicating a silty or clayey gravel composition. This classification highlights the differing engineering characteristics and suitability for construction applications, emphasizing Sample A's superior performance in terms of load-bearing capacity compared to Sample B, which, while still classified as good, demonstrates a lower overall plasticity and moisture retention capacity.

5 Discussions

The natural Moisture content test results for oven-dried samples at a temperature of 105 + 5 ^{o}c are summarized in Table 3. The moisture content test results for soil samples from Sample A and Sample B reveal distinct differences, with Sample A exhibiting an average moisture content of 17.25% compared to Sample B's 12.77%. According to ASTM D 2216, which outlines the laboratory determination of moisture content in soils, moisture levels significantly influence soil behavior in engineering applications. Sample A's higher moisture content suggests increased plasticity, which may impair its stability and load-bearing capacity, while Sample B’s lower moisture content aligns with ASTM guidelines for optimal compaction, indicating a more stable soil structure.

The specific gravity is an important parameter in identifying the soil type, classification, and its suitability as a construction material. The test results for specific gravity are mentioned in Table 4 and indicate that the specific gravity of soils in the study area falls within the range of 2.5–2.63, which is in the range of typical inorganic soils.

The grain size analysis result is shown in Fig. 4 and the summary of grain size analysis result is shown on Table 6. The results obtained from the grain size analyses indicate that the dominant proportion of soil particle in the research areas is sand, which has a content ranging from 91.62–91.84%, gravel fraction 2.72–5.58% and silt & clay content of 2.79–5.44%.

The Atterberg Limits, or the soil index property test, involves the determination of the plastic limit (PL), liquid limit (LL) and plasticity index (PI) of the soil. The liquid limit and the plastic limit are moisture contents that correspond to the liquid and plastic state thresholds of the soil, respectively. The result of Atterberg Limit of the soil samples on oven dried is shown on Table 7. From these testes the soil under investigation is inorganic. The soil in the research area has liquid limit ranging from 21.75–39.75%, plastic limit ranging from 17.78–28.19% and plastic index from 3.93–11.56%.

Optimum moisture content and the maximum dry density of the study area is summarized in Table 8. From the test results the maximum dry density (MDD) for sample A and Sample B are 1.71 & 1.95 g/cm3 respectively and their optimum moisture content are 13.5 & 36.5 percent respectively.

Classifications of soils in the study area based on USCS classification scheme, most of the soil of the study area falls in well-graded sand (SW) region. From the plot of plasticity chart in Fig. 11 and the classification soils on Table 9 the soils found in Burao town is well-graded sand. On the other hand, the classification of soil based on AASHTO classification is shown in Table 10. And also, Fig. 12. From this table and chart, it can be observed that soil in the study area is classified in group A-3 and A-2-4.

5.1 Comparison of Current Research Findings with Regional Studies

This section compares the findings of the current study on soil engineering characteristics in Burao town with research conducted in neighboring countries, as there are no prior studies specifically investigating engineering soil properties in Somaliland. As mentioned on Table 11, by examining variations in soil properties such as soil type, specific gravity, and plasticity indices, this comparison provides a contextual framework for understanding local soil behavior. This approach not only highlights gaps in the existing literature but also emphasizes the relevance of regional studies in informing construction practices in Somaliland.

Table 11
Comparison of Current Research Findings with Regional Studies

Name of Previous Researchers	Debebe, 2011	Wanyonyi Otando et al, 2004	Nega, 2016	Shemiye S, 2020)	Current Research
Soil type	Silt & silt sand	Red friable clays	Clay & Silt sand	highly plastic clay and low plastic silt	Fine sand
Location	Adama, Ethiopia	Nairobi, Kenya	Haromaya, Ethiopia	Fiche town, Ethiopia	Burao town, Somaliland
Clay Content (%)	5.4–40 5	90% and over	1.6-65.75	12.2-20.73	2.79–5.44
Liquid Limit (%)	29–73	-	32-87.3	62–88	21.75–39.75
Plasticity Index (%)	5–34	-	14.7–63.4	32–54	3.93–11.56
Specific gravity	2.4–2.7	-	2.65–2.84	2.67–2.83	2.5–2.63
Maximum dry density (g/cm^3)	1.20–1.62	-	1.39–1.52	-	1.71 & 1.95
Optimum moisture content (%)	17.5–36.5	-	1.39–1.52	-	13.5 & 14

6 Conclusion

This study investigated the existence and the basic engineering properties of soil, which are important for understanding of the soil behavior in Burao, Somaliland, for the safety of civil engineering structures, particularly foundations and pavements. The laboratory tests that were conducted for this study were natural moisture content, specific gravity, grain size analysis, Atterberg limits and Modified proctor compaction test.

The test procedures were based on ASTM and AASHTO test standards. From the study, the natural moisture content of soils of the study area ranges from 12.77–17.25% that shows most of sample soils are sand, that cannot grasp more water. Due to some organic and solid matters in the sample the specific gravity of the soil samples is low but mostly the specific gravity of the two samples is 2.5 and 2.63 respectively.

The Grain Size Distribution indicates majority samples have fine-sand material. Therefore, sand type of soil which have a percentage ranging 91.63–91.84% is dominantly located in the study area. From consistency limit test result, liquid limit of soil ranges from 21.75–39.75%, plastic limit ranges from 17.78–28.19% and plasticity index ranges from 3.93–11.56%.

According to AASHTO soil classification system, the two soil samples of study are categorized as A-3 and A-2-4, while on USCS classification system; both the two soil samples of study are categorized as well-graded sand. Therefore, both the two samples indicates that the majority samples are sand material, which can be utilized as foundation material for civil engineering structures.

The lack of previous studies on soil characteristics in Burao underscores the necessity for systematic geotechnical investigations to support sustainable development. This gap in knowledge points to potential risks in construction practices, emphasizing the importance of localized research.

The study highlights that variations in soil properties, particularly moisture content and plasticity, significantly influence the performance of construction projects in Burao. Higher moisture content correlates with lower stability, indicating a critical need for moisture management strategies in construction planning.

Declarations

Funding and Supports

The authors declare that this work was supported by the laboratory technician of Civil engineering lab for Burao University. We also declare that no funds, grants, or other support were received during the preparation of this manuscript.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Ali Ahmed Hussein, and Ahmed Abdirahman. The first draft of the manuscript was written by Mohamed Hussein & Hamda Jama Yousof and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets generated during and/or analyzed during the current study are laboratory test results.

References

1. Sorsa A, Senadheera S, Birru Y. Engineering characterization of subgrade soils of Jimma town, Ethiopia, for roadway design. Geosciences (Switzerland). 2020 Mar 1;10(3).
2. Das BM. Principles of Geotechnical Engineering FIFTH EDITION [Internet]. 2006. Available from: www.thomsonrights.com
3. Debebe D. Investigation On Some Of The Engineering Characteristics Of Soils In Adama Town, Ethiopia. 2011.

4. Abdilahi HA. Influence of Cash Transfer Program on Socio-Economic Empowerment of Communities in IDPS of Burao, Somaliland. International Journal of Poverty, Investment and Development [Internet]. 2024 Sep 24;5(3):25–39. Available from: https://ajpojournals.org/journals/index.php/IJPID/article/view/2442
5. Hassan MR. Evaluating Economic Stability in Somaliland: The Impact of Livestock Export. 2020.
6. Abdi MA, Hareru WK. Assessment of Factors Affecting the Implementation of Occupational Health and Safety Measures in the Construction Industry in Somaliland. Advances in Civil Engineering. 2024;2024.
7. Farah MJ. Challenges of Solid Waste Management and factors influencing its effectiveness: A case study in Burao Municipality. 2019.
8. UN-HABITAT. Burao Profile - first steps towards strategic planning. 2009;
9. Dr. K. R. Arora. Soil mechanics and foundation engineering. Revised and Enlarged. 2006;
10. ASTM Standards. Appendix A American Society for Testing and Materials (ASTM) Standards. 2002.
11. Murthy VNS. Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering. 1990.
12. Budhu M. Soil Mechanics and Foundation 2nd. Edition. 2007.
13. Shemiye S. INVESTIGATION ENGINEERING PROPERTIES OF SOIL IN FICHE TOWN JUNE 2020 Addis Ababa Ethiopia. 2020.

Figures



Figure 1

inserting samples in the oven for drying



Figure 2

Reading mass of the pycnometer for specific gravity test



Figure 3

Sieve shaker & series of sieves used for grain size distribution testing

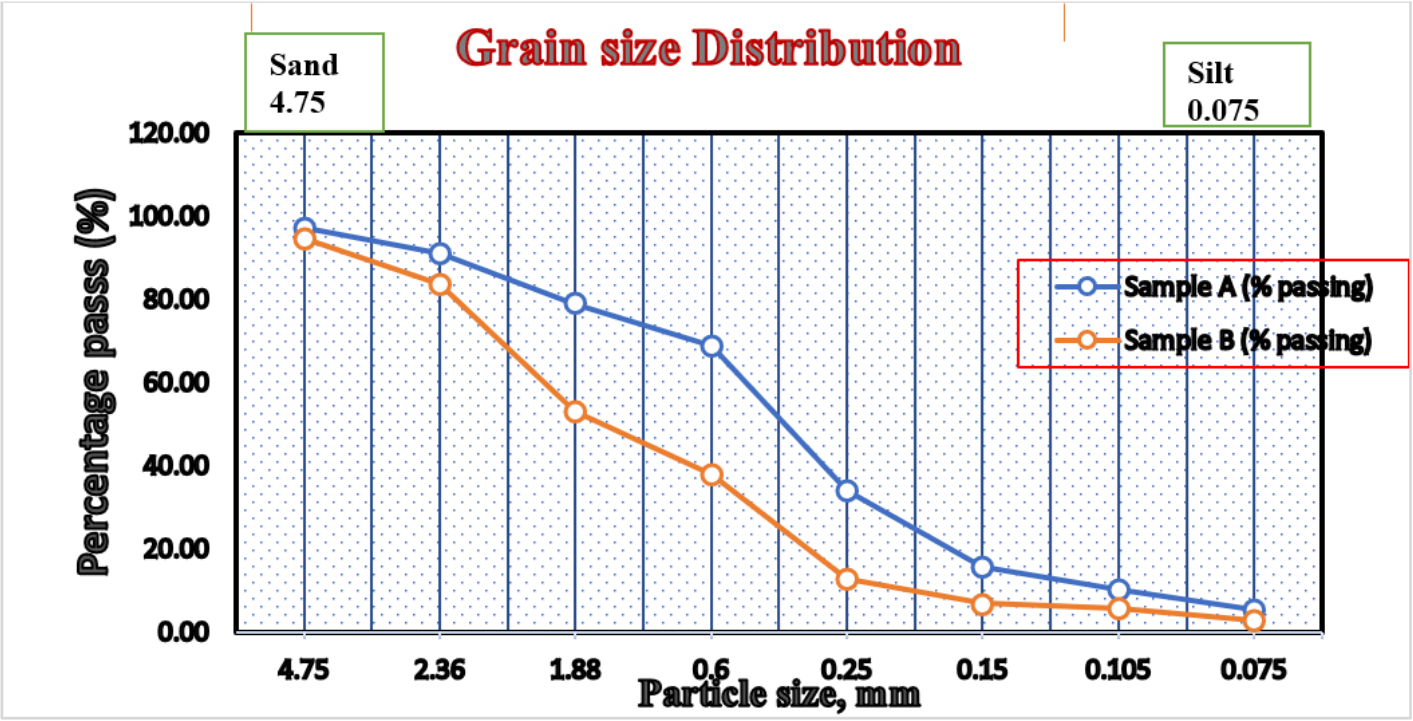


Figure 4

Grain size distribution cure for the two samples



Figure 5

Soil pat after groove has closed

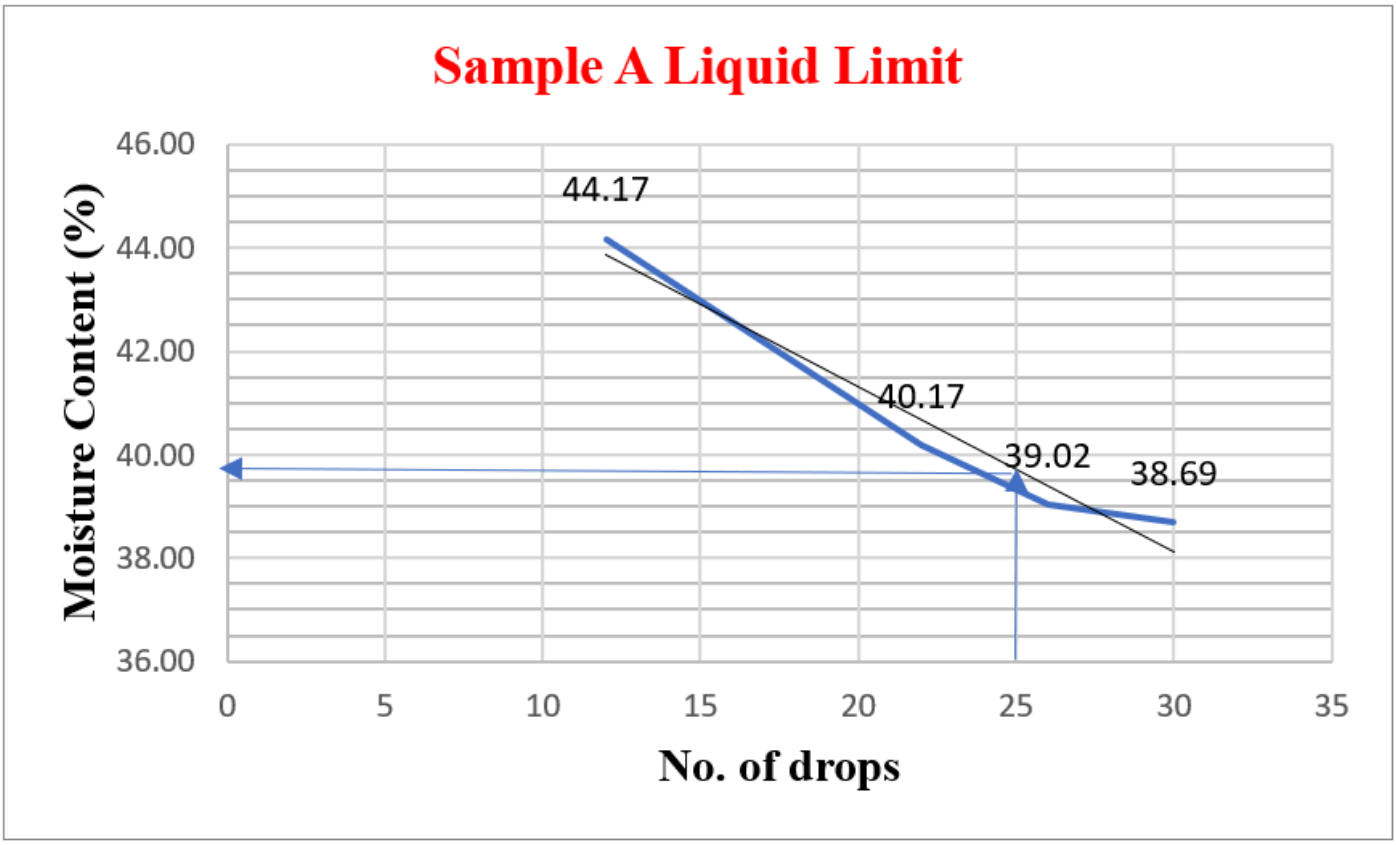


Figure 6

Typical liquid limit result for Sample A

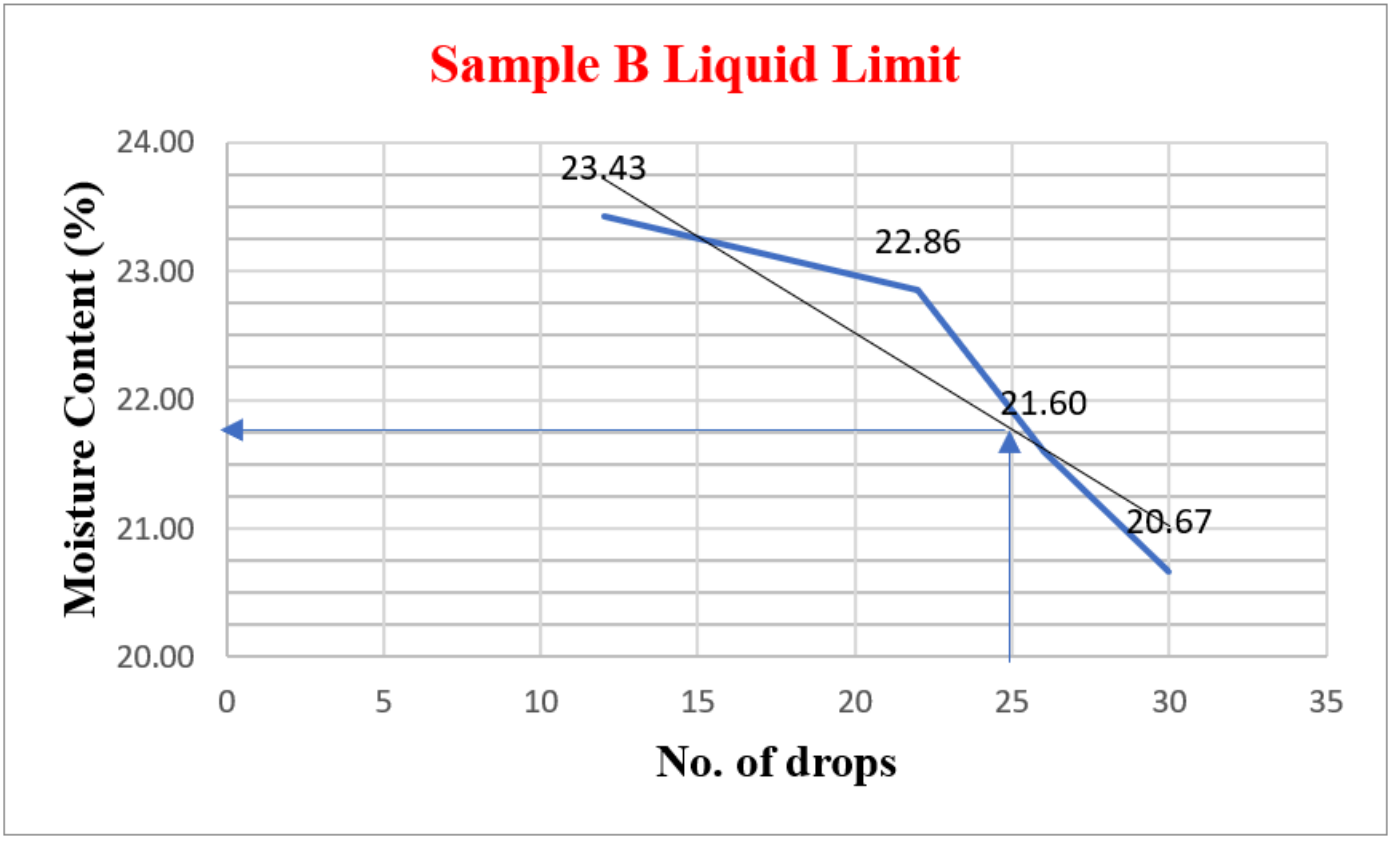


Figure 7

Typical liquid limit result for Sample B



Figure 8

Plastic limit test (ellipsoidal soil mass)

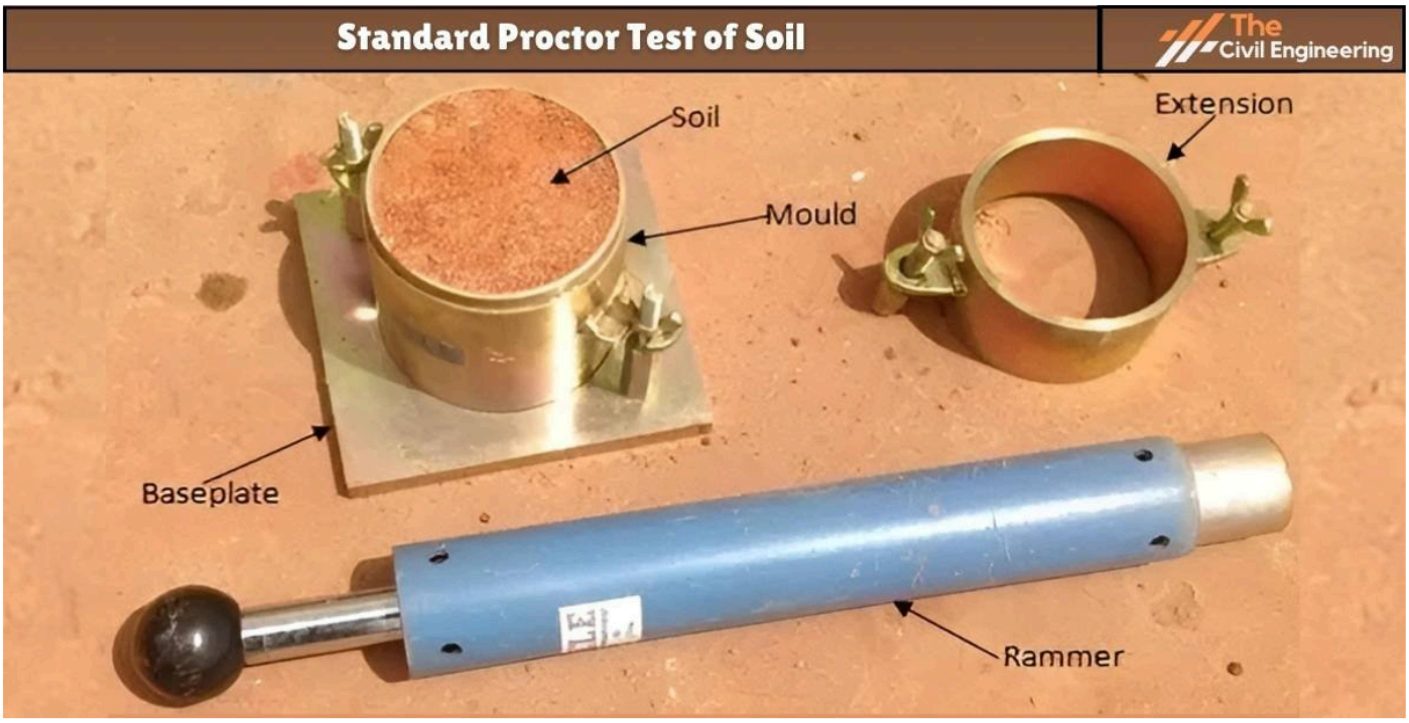


Figure 9

Standard proctor test apparatus (Wikipedia)



Figure 10

Compaction test using modified proctor test

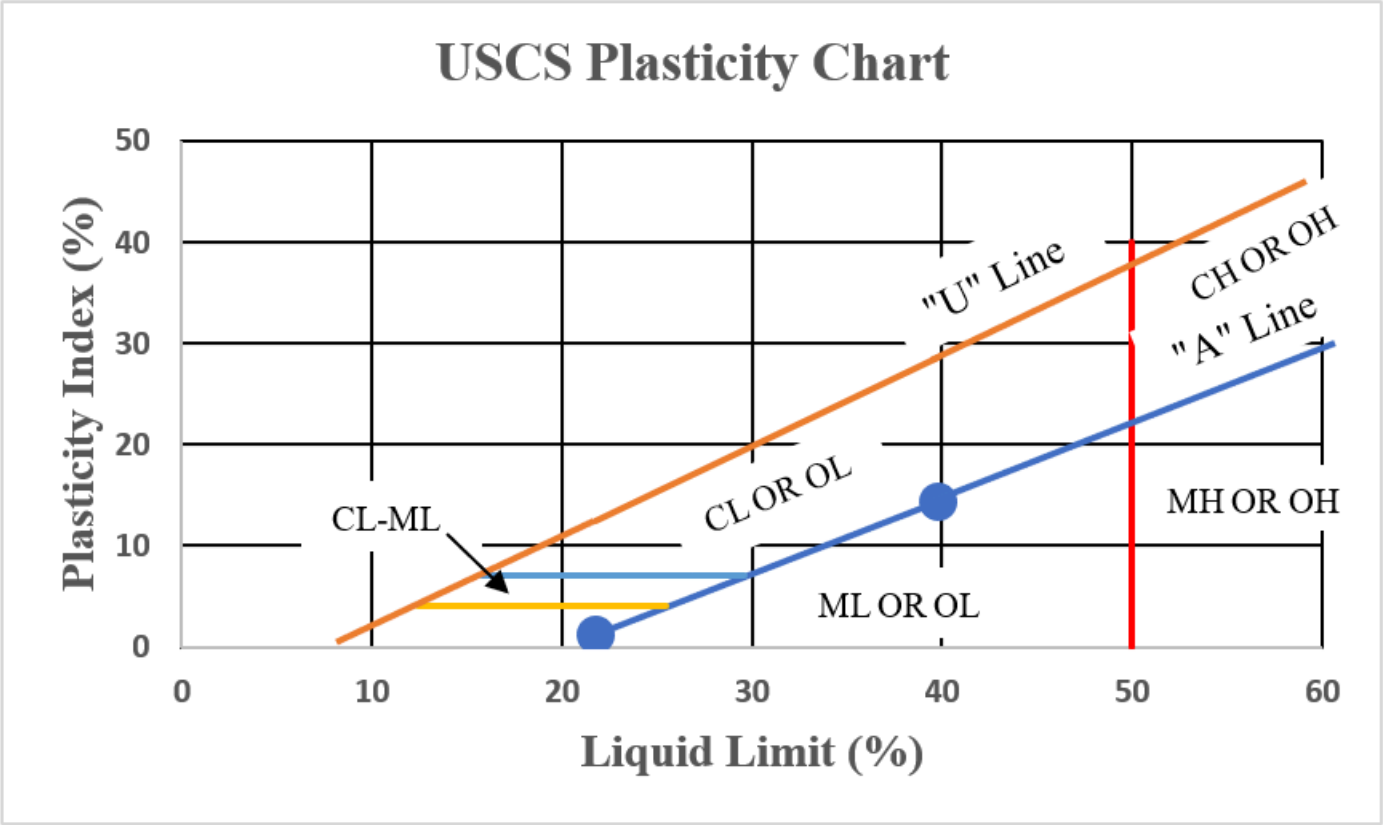


Figure 11

Plasticity chart of the study area according to Unified Soil Classification System

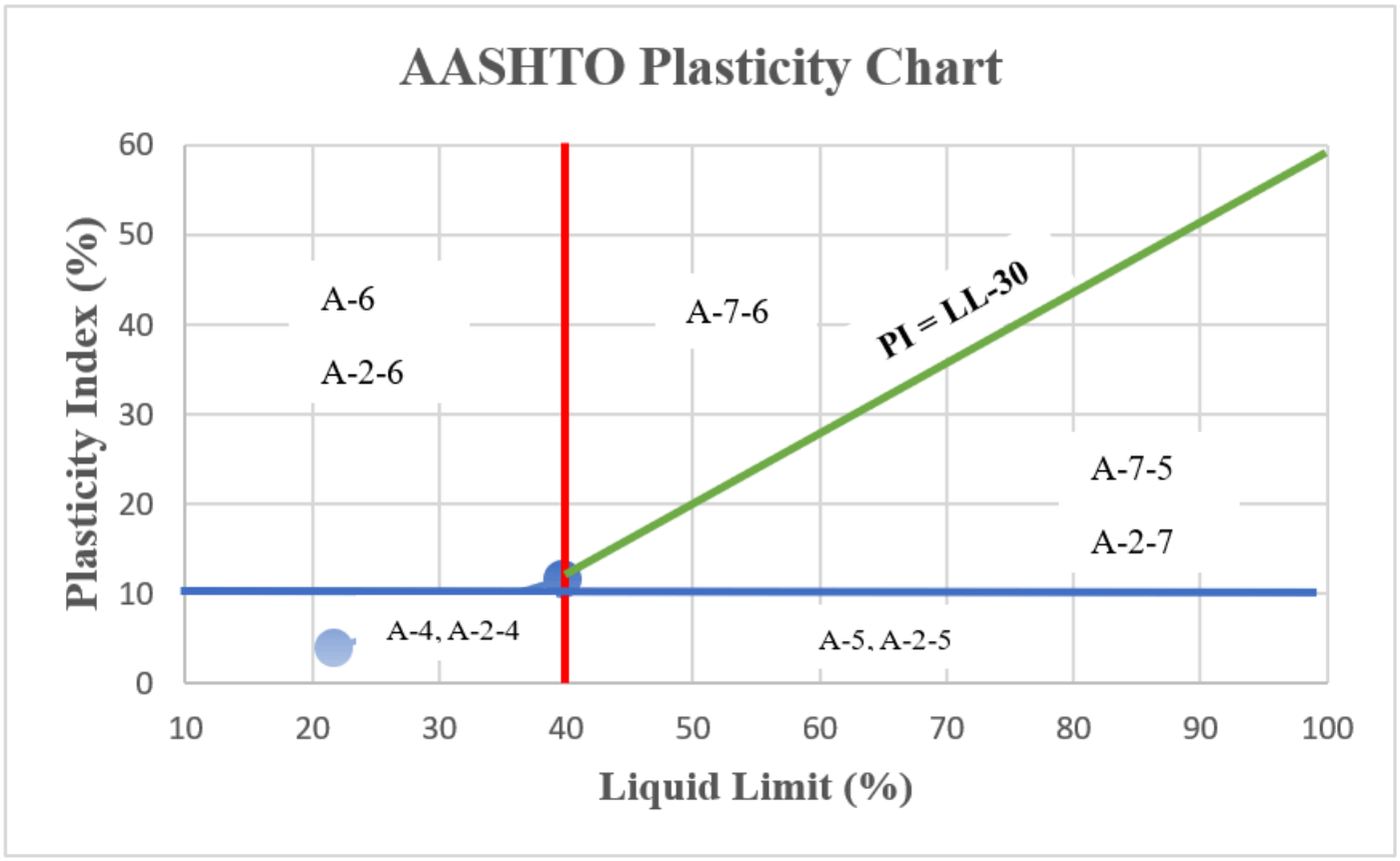


Figure 12

Plasticity chart of soil in the study area according to AASHTO system of classification