

Assessment of Index Properties and Compaction Characteristics of Black Cotton Soil in parts of Wolaita Sodo City, Southern Ethiopia.

Lollo Chande Lollo¹, Muse Gebreselassie Desta²

¹Assistant Professor, ²Lecturer

¹Civil Engineering Department, ²Hydraulic and Water Resource Engineering Department

^{1,2}Wolaita Sodo University

Wolaita Sodo City, Ethiopia.

Abstract: Index properties are the properties of soil that help in identification and classification of soil. This study is aimed at evaluating index properties and compaction characteristic of black cotton soil found in part of Wolaita Sodo City. Four disturbed samples were collected from areas of the city which is covered by black cotton soil. Different laboratory tests such as Particle size distributions, Consistency limits, and Specific gravity and Standard Compaction tests were carried on the samples. All the analysis was carried out in line with the ASTM testing procedures. Particle size distribution test result showed that the fine fraction (<0.075mm) of the investigated soil is in the range of 84.84% to 95.74% and clay fraction is in the range of 44.17% to 51.01%. Consistency limits test result indicated that the liquid limits, the plastic limits and plasticity index of the soil are in the ranges of 78.51% to 87.68%, 36.53% to 36.67% and 40.86% to 51.01% respectively. From standard compaction test it is found that maximum dry density/MDD/ and optimum moisture content/OMC/ of the soil is in the ranges of 1.21g/cm³ to 1.28g/cm³ and 33.33% to 42.39% respectively. Thus the soil in the investigated area is classified as A-7-5 as per American Association of State Highway and Transportation Officials soil classification system and as highly plastic clay (CH) and/or highly plastic inorganic silt (MH) according to unified soil classification system.

Index Terms - Index property, Compaction, Plasticity index, Liquid limit.

1. INTRODUCTION

Soil index properties are the properties of soil that help in identification and classification of soil for engineering purposes. Particle size distribution, Specific gravity, Consistency Limits and relative density are some of the index properties of soil. The particle size distribution analysis shows the range of particle sizes presents in the soil. According to unified soil classification systems (USCS) gravels are soil fraction with particle size of greater than 4.75 mm, sand are soil fraction with particle size between 4.75mm and 0.075mm, while fines (silt and clay) are soil fraction with particle size of less than 0.075mm[1].

The consistency limits are a basic measure of the nature of a fine-grained soil. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state the consistency and behavior of a soil is different and thus so are its engineering properties. Liquid limit divides the liquid state from the plastic state of the soil. The Liquid limit (LL) is the minimum moisture content at which the soil tends to flow as a liquid. The dividing line between plastic states and semi solid states of soil is termed as plastic limit [2]. The plastic limit (PL) is the minimum water content where soil starts to exhibit plastic behavior. Plasticity index is the difference between the liquid limit and plastic limit of soils. The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction.

Compaction is the process of increasing the density of a soil by packing the particles closer together with a reduction in the volume of air only. Compaction increases the dry density and decreases the void ratio. Compaction of soil has great importance for practically achieving the desired strength, permeability and compressibility of soil during the construction. [3]

2. DESCRIPTION OF STUDY AREA

Geographically Wolaita Sodo City is located at latitude of 6°54'N and longitude of 37°45'E with an elevation that ranges between 1600 - 2100 meters above sea level. Wolaita Sodo City possesses a well moderated subtropical highland climate, with a pronounced pattern of wet summers and dry winters. Wolaita Sodo City administration is the second largest city in South Nations Nationality and Peoples Region and its population is 254, 294 in 2018.

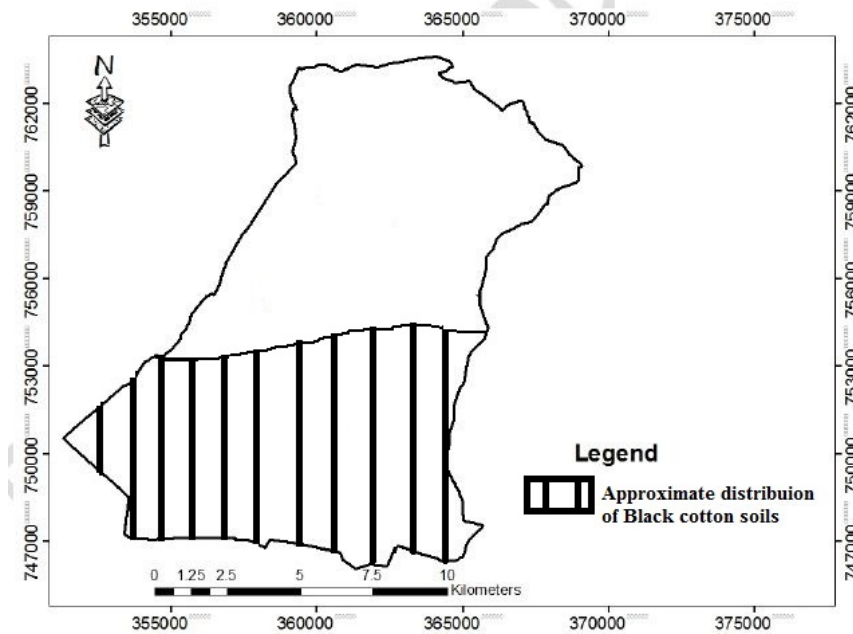


Figure 1: Wolaita Sodo City Map

3. MATERIALS AND METHODS

Disturbed soil samples were collected from areas covered by black cotton soils. The samples were taken from four test pit at 2m depth. Different laboratory tests such as particle size distributions (sieve size analysis and hydrometer analysis), consistency limits (liquid limit and plastic limit), specific gravity analysis and standard compaction was carried on the samples. All the analysis was carried out in line with the ASTM testing procedures.

4. RESULTS AND DISCUSSION

4.1. PARTICLE SIZE DISTRIBUTION TEST

The particle size distribution curves of the soil samples are presented in figure 2 and table 1 shows the percentages of different soil fractions present in the soil. Particle size distribution analysis showed that the investigated soil is predominantly fine grained (<0.075mm) soil.

Table 1: Particle Size Analysis Result

Sample	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	0.05	10.79	44.99	44.17
2	0.41	14.75	37.09	47.75
3	0.15	9.20	39.64	51.01
4	0.25	4.01	41.86	53.88

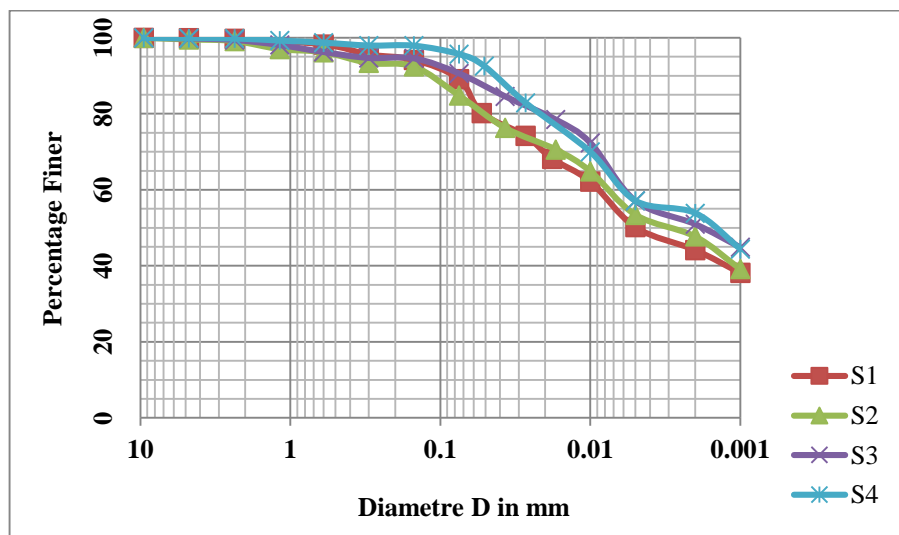


Figure 2: Particle size distribution curves of soil samples.

4.2. CONSISTENCY LIMITS TEST

Result of consistency limits of the soil in the study area is presented in table 2. The liquid limit and plasticity index of the investigated soil lies within ranges of 78.51% to 87.68% and 41.89% to 51.01% respectively. Thus the soil in the investigated area is categorized as highly plastic soil.

Table 2: Consistency Limits Test Result

Sample	Liquid Limits (LL) (%)	Plastic Limits (PL) (%)	Plasticity Index (PI) (%)
1	87.68	36.67	51.01
2	78.51	36.62	41.89
3	80.07	36.53	43.54
4	85.74	38.75	46.99

4.3. SPECIFIC GRAVITY TEST

The specific gravity of the soil depends on the amount of sand and also depends on their mineral constituents and mode of formation of the soil.[4] The specific gravity of the studied soil samples are presented in table 3. In this study the specific gravity of soil samples is within the range of 2.65 to 2.68. Soil investigation done in Addis Ababa city showed that the specific gravity of such soil lies in the ranges of 2.48 to 2.78[5] and in Woliso town the specific gravity of black cotton soils was reported to be in the range of 2.65 to 2.75.[6] These results shows that the tested soil in this study have specific gravity values that are typical for black cotton soils.

Table 3: Specific Gravity Test Results.

Sample	Specific Gravity (Gs)
1	2.68
2	2.65
3	2.66
4	2.65

4.4. STANDARD COMPACTION TEST

Density moisture relation of the investigated soil is shown figure 3 and standard compaction test result is summarized in table 4. The Maximum dry density (MDD) and optimum moisture content (OMC) of the investigated soil lies within ranges 1.21g/cm³ to 1.28g/cm³ and 33.63% to 42.39% respectively.

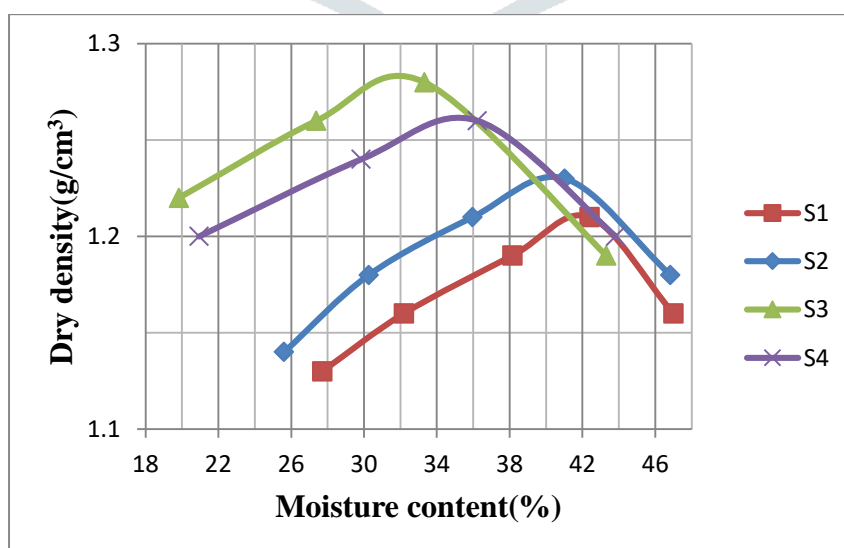


Figure 3: Dry Density Vs Moisture Content Graph

Table 4: Summary of Compaction Test Results.

Sample	Optimum Moisture Content (OMC) %	Maximum Dry Density (MDD) g/cm ³
1	42.39	1.21
2	41.03	1.23
3	33.63	1.28
4	36.23	1.26

4.5. SOIL CLASSIFICATION

4.5.1. Soil Classification Based on Unified Soil Classification System (USCS).

The basis for unified soil classification system is the liquid limit and plasticity index of a soil. To classify the soil in the investigated area as per USCS system; plasticity index and liquid limit of the samples were put on Casagrande plasticity chart as shown in figure 4 below.

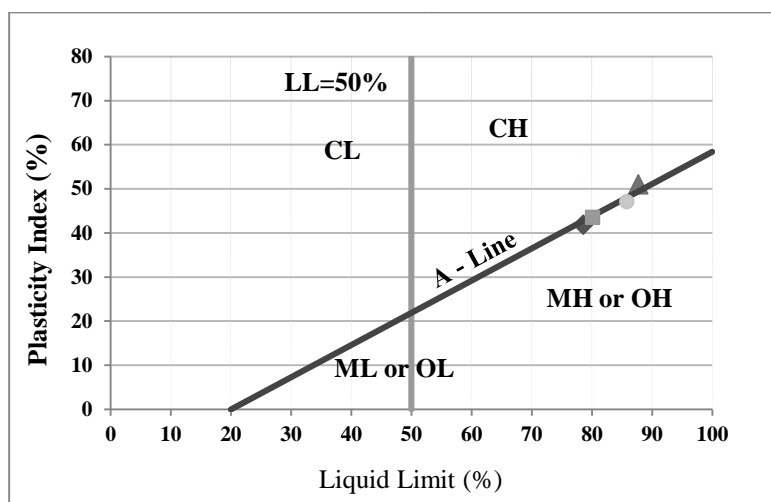


Figure 4: Casagrande Plasticity Chart.

According to unified soil classification system the soil in the investigated area is classified as highly plastic clay (CH) and/or highly plastic inorganic silts (MH).

4.5.2. Soil Classification Based on American Association of State Highway and Transportation Officials (AASHTO) System

In order to classify the investigated soil as per AASHTO soil classification system, plasticity chart based on AASHTO soil classification system were drawn as shown in figure 5 below.

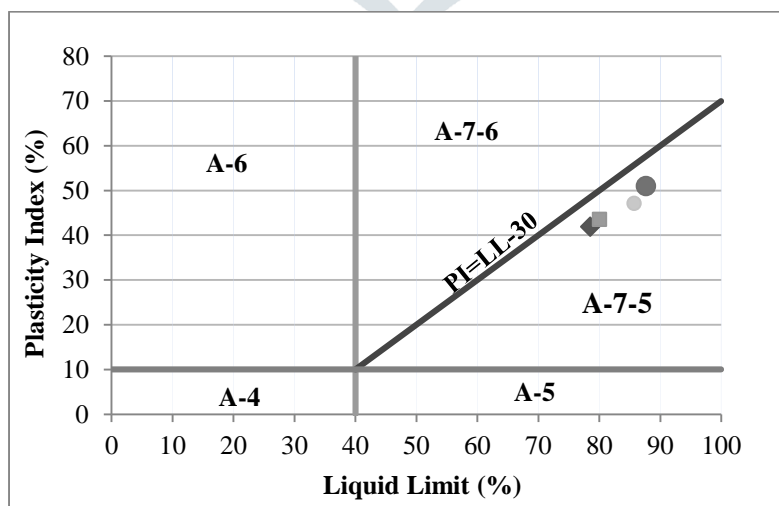


Figure 5: Plasticity Chart based on AASHTO soil classification system

This showed that the soil in the investigated area is classified as A-7-5 soil according to AASHTO soil classification system.

4.5.3. Soil Classification Based on Colloidal Activity.

Activity is defined as the ratio of the plasticity index of the soil to the percent of clay fraction. Activity has been used as an index property to determine the swelling potential of clays [1]. Colloidal activity values for the soils under investigation are calculated and summarized in table 5.

Table 5: Summary of Activity Values.

Sample	Clay Fraction (%)	Plasticity Index (%)	Activity
1	44.17	51.01	1.15
2	47.75	41.89	0.88
3	51.01	43.54	0.85
4	53.88	46.99	0.87

Based on their activity values clays are classified as inactive, normal and active as given in table 6[7]. Activity values of the investigated soil are in the range of 0.85 to 1.15. Thus the investigated soil is classified as normal soil.

Table 6: Degree of Colloidal Activity

Activity	Soil Nature
< 0.75	Inactive
0.75-1.25	Normal
> 1.25	Active

4.6. CONCLUSION

The liquid limit and plasticity index of the investigated soil lies within ranges of 78.51% to 87.68% and 41.89% to 51.01% respectively. Thus the soil in the study area is highly plastic soil. Particle size distribution test result showed that the investigated soil is predominantly fine grained soil. From standard compaction test it is found that maximum dry density/MDD/ and optimum moisture content/OMC/ of the soil is in the ranges of 1.21g/cm³ to 1.28g/cm³ and 33.33% to 42.39% respectively. According to unified soil classification system (USCS) the soil in the investigated area is classified as highly plastic clay (CH) and/or highly plastic inorganic silts (MH) and according to American Association of State Highway and Transportation Officials (AASHTO) soil classification system soil in the investigated area is classified as A-7-5 soil. Based on its activity values, soil in the investigated area is classified as normal soil and such soil is expected to have some potential for swelling.

REFERENCES

- [1] Das, B.M. 1997. Advanced Soil Mechanics, 2nd ed. Washington DC.
- [2] Liu, C. and Evett, J. B. 2000. Soil properties testing, measurement, and evaluation, 4th ed. Prentice Hall, Upper Saddle, New Jersey.
- [3] Lollo, L.C. and Lambebo, B.A. 2019. Geotechnical Characterization of Selected Soil for use as Sub base Materials for Low Volume Road Construction: A case study of Bilate quarry site, southern Ethiopia. International Journal of Scientific Engineering and Research, 7(2):139-142.
- [4] Oluyinka, L.G. and Olubunmi, O.C. 2018. Geotechnical properties of lateritic soil as subgrade and base material for roads construction in Abeokuta, southwest Nigeria. International journal of Advanced Geosciences, 6(1): 78-82.
- [5] Teferra, A and Yohaness, S. 1986. Investigation on expansive soil of Addis Ababa. Journal of EAEA, 7:1-9.
- [6] Haile, B. 2014. Investigation into some of the Engineering properties of soils found in Woliso town. Unpublished M.Sc Thesis, AAU.
- [7] Skempton, A.W.1953. The Colloidal Activity of Clays. Proceeding 3rd International Conference on Soil Mechanics and Foundation Engineering, Switzerland, 1: 57-61.