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INDEX AND ENGINEERING PROPERTIES OF RESIDUAL TROPICAL SOILS OF SOUTHWESTERN ETHIOPIA

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Abstract - *Civil engineering structures are designed from the knowledge of soil properties at the given site. This research work is for the Investigation of Engineering Properties of Konso town soils. To investigate the engineering properties of Soils found in Konso town, eight test pits were selected based on the expansion potential of the town and the current distribution of the dwellings and buildings according to the municipality of Konso town. The soil samples per pit depth, were collected from pits by direct manual excavation.During field testing, field density and natural moisture content tests were done.The laboratory tests that were carried out include physical properties, index properties, shear strength and consolidation tests. With the aid of these results, analysis were made to determine some characteristics of silty clay soils.To this effect the geotechnical and geo-chemical characteristics of soils sampled from Konso town were investigated.*

From the results that were obtained for grain size analysis, Atterberg limits and from soil classification systems, it was found out that the soil dominant in Konso town was found tobe MH .The activity number was below 0.75, which confirmed the soil was inactive. According to the results of this research, Moisture content ranged between 15 - 43%, Plasticity Index between 18.05 – 25.21%, Clay fraction between 33- 57.6, free swell between 13-43% and Specific Gravity ranges between 2.61-2.86. The shear strength parameters (C, Φ) as determined from UU test ranged between 160.76- 191.34kPa and 10º-12º for saturated sample respectively. Unconfined compression strength (qu) ranged from 245-332 kPa)

Key Words: Konso, Index Properties, Shear strength, geo-chemical

1. INTRODUCTION

Formation processes of tropical residual soils are very different compared to formation of sedimentary soils. These soils are formed in situ by deep chemical weathering of rocks, usually in a tropical climate. The degree of weathering and extent to which original structure of the rock mass is destroyed varies with depth from the ground surface. Some components are removed as a result, usually leaving a clay-based deposit. This factor causes the behavior and properties of both soils to be different. Besides, behavior and properties of tropical residual soil also vary by location based on geological formation, surrounding environment and climate: the main factors in their formation processes. Because of these differences, testing and sampling procedures in the determination of their properties and strength of tropical residual soils cannot be directly adopted from the conventional method of testing and sampling for sediments type soils, without some modifications. Preparation and handling of samples for tropical residual soil sometimes need special care and methods as conventional methods normally used on sedimentary soils may not be applicable. Residual soils that are frequently encountered in tropical regions require special procedures to obtain reliable and consistent test results. (Bujang B.K.Huat, 2004)

A Civil Engineering structures by far depends on the accurate estimation of index and engineering properties of the soil which are the basis for giving their intended purpose for a design period of the structures. Unless a detailed investigation is made on the index and engineering properties of the soil under consideration, geotechnical failures may encounter which are inevitable and their remedial measures are expensive and sometimes difficult. Konso town is among the newly evolving towns in Ethiopia, whereby needing the expansion of civil engineering structures (public and commercial buildings, residences and condominiums), and infrastructures (like road, drainage structures etc.). Thus, this research is developed to determine the index and engineering properties of soils in Konso town and to find out the similarity and differences with other similar soils in other parts of Ethiopia in terms of index and engineering properties of the soils. There is no previously done research around Konso town to classify the soil type, to determine the index and engineering properties of the soils. This work gives a better understanding about the behavior of the soil with respect to shear strength and settlement characteristics of the soils in Konso town. It can also be used as a start point for decision makers and geotechnical designers, for the current and future expansion of civil engineering structures.

The Konso area characterized by Sub-Tropical dry and hot climate with general temperature increase towards South West .The average annual temperature is about 25 ℃ .The plateau areas in the north and east are relatively moist, cool and receive more rain fall than the southern and western lowland parts, which are hot and dry. In general the area is characterized by two rain seasons that range from March to May and September to mid of November. The March to May rainy season is the main rainy season and mostly accompanied by East – West blowing heavy wind. The average annual value reaches up to 1000mm.

2. LITERATURE REVIEW

A distinctive feature of laterite and lateritic soils is the higher proportion of Sesquioxide of Iron and/or Aluminum relative to the other chemical components. The amount of Alumina or Iron Oxides is an important factor in differentiating Aluminous and Ferruginous varieties. The base (alkalis and alkaline earths) is almost absent in lateritic horizons, except in some Ferruginous crusts developed in alluvium and some concretionary horizons in Ferruginous tropical soils. Other lateritic constituents are Manganese, Titanium, Chromium and Vanadium Oxides.

Chemical analyses do not usually reveal the origin, nature or even the composition of laterites or lateritic soils. The mineralogical composition is considered to be more important in explaining the physical properties of laterite and lateritic soil. The mineralogical constituents can be divided in to major elements, which are essential to laterization, and minor elements, which do not affect the laterization process. The major constituents are Oxides and Hydroxides of Aluminum and Iron, with clay minerals and, to a lesser extent, Manganese, Titanium and Silica. The minor constituents are residual remnants or elastic material (Blight G.E. and Leong C.E., 2012)

It is revealed that tropical soils are different from temperate zone soils in terms of genesis and structure. Their structures as compared to dispersed temperate zone soils have necessitated modifications to the mechanical or grading tests; the conventional pretreatment methods have considerable effect on the index properties of tropical soils. Therefore, special consideration is required (Blight G.E. and Leong C.E., 2012)

(Dante Fratta, 2007)Two test specimens should be prepared for moisture content determinations. One specimen should be oven dried at 105 ºC until successive weighing's show no further loss of mass.The moisture content should then be calculated in normal way. The second sample should be air dried (if feasible); or oven dried at a temperature of not more than 50 ºC and a maximum relative humidity (RH) of 30% until successive weighing's show that no further loss of mass.The two moisture content results should then be compared; a significant difference (4-6% of moisture content obtained by oven drying at 105 ºC) indicates that structural water is present.

The soils to be used in this test should be in its natural moisture content. Pre- test drying of the soil should be avoided as this tends to reduce the measured specific gravity. In residual soils the specific gravity may be unusually high or unusually low depending on mineralogy (Blight G.E. and Leong C.E., 2012)

The free swell test is performed by slowly pouring 10cm3 of dry soil which has passed the No. 40 (0.425mm) sieve in to 100 cm3 graduated cylinder filled with distilled water. After 24 hours, final volume of the suspension being read. Hence, free swell is given as

$$\text{Free swell (FS)} = (V_f - V_o)/V_O \times 100$$

Where V_f =Final Volume of the soil

V_o =Initial volume of the soil

The degree of expansivity and possible damage to lightly loaded structures may be qualitatively assessed from Table 2.1 In areas where the soils have high or very high FS values, conventional shallow foundations may not be adequate.

Table 1.1: Degree of expansiveness and Free swell (FS)(Bujang B.K. Huat, 2013):

Degree of expansiveness	Free swell (FS)
Low	< 20
Moderate	20-35
High	35-50
Very high	>50

The particle size distribution of residual soils is affected by

i. **Effect of drying** The most widely reported effect of drying is reduce the percentage that is reported as the clay fraction (finer than 2µm).It is accordingly recommended that drying of the soil prior to testing be avoided. Oven dried lateritic soils were found to give the least amount clay fraction, as compared to air dried or as received (natural moisture content) samples (Blight G.E. and Leong C.E., 2012).
ii. **Chemical pretreatment** if it is considered necessary to eliminate Carbonates or Sesquioxides, then pretreatment with hydrochloric acid is recommended
iii. **Sedimentation** is essential to achieved complete dispersion of fine particles prior to Carrying out a sedimentation test. The sample should be immersed in a solution of dispersant such as dilute alkaline Sodium Hexametaphosphate and therefore washed through the standard nest of sieves (Blight G.E. and Leong C.E., 2012).

(Lyon, 1971) found that wet sieving increases the silt and clay fraction from 7 to 20 % as compared to dry sieving .It has been found that Sodium Hexametaphosphate generally gives better dispersion.

Atterberg Limits are arbitrary boundaries through which a soil passes from liquid, to Plastic, semi solid and solid states. These boundaries are defined by moisture contents. They are used to determine the consistency of fine-grained soils.

Because the formation of lateritic soils involves differential weathering as well as movement and deposition of dissolved materials, the variation of plasticity characteristics with depth cannot be predicted even in two similar profiles on different topographical sites. Some of the atterberg limits in some tropical residual soils are shown in table 2.2

Table 2.2: Atterberg limits of some tropical residual soils (Wesley L. , 1988)

Parent material	LL(%)	PL (%)	Location	Source
Basalt	92-105	48-59	Malaysia	West &Dumbleton (1970)
Basalt	46-52	15-19	Malaysia	West &Dumbleton (1970)
Basalt	45-49		Hawaii	Lohnes rt al(1983)
Granite	42-107	20-21	Malaysia	West &Dumbleton (1970)
Granite	79	44	Malaysia	Ting et al.(1982)

The influence of the pretreatments and testing procedures on the plasticity characteristics have been widely studied and discussed. The variations in test result due to pretreatments and testing procedures have made the interpretation of test results very difficult.

(Lyon, 1971)States that mixing the soils with water during testing procedure causes the breaking up of the fine particles and also deflocculating. (Lyon, 1971)Founded the limits change with drying and with manipulation. Also states 'when liquid limit tests carried out the aggregations of clay particles were broken down by the manipulation, this led to difficulties in consistent values for liquid limit. Laterites formed under continuously wet regions are likely to be characterized by high natural water contents; high liquid limits are observed to result in irreversible changes upon drying. Upon drying the plasticity decreases and grain size increases such that much of clay sized particles agglomerates to the size of silt.

On the other hand, lateritic soils formed under seasons of distinct wet and dry seasons are likely to be characterized by low natural moisture content, low plasticity, and presence of concretions and cemented horizons. Laboratory tests run from natural water content or from the air-dried state lead to essentially the same result.

According to (Blight G.E. and Leong C.E., 2012), the effect of drying prior to testing is attributed to.

- ✓ Increased cementation due to oxidation of the iron and aluminum Sesqueoxides, or
- ✓ Dehydration of Allophane, or both.

The Unconfined Compression Test procedure similar to the UU test procedure, except that no confining pressure is applied to the specimen (i.e. $\sigma 3$ is equal to zero).The test is commonly performed in a simple loading frame by applying an axial load to the soil specimen (D.G. Fredlund and H.Rahardjo, 1993) . Unconfined Compression Test was done according to ASTM D 2166. This test method covered the determination of the unconfined compressive strength of cohesive soil in remolded condition, using strain-controlled application of the axial load. The sample was prepared with length to diameter ratio of 2. The load that would produce an axial strain of 1% per minute was applied at the specimen and the load and deformation dial readings were recorded at every 10 to 50 divisions on deformation the dial. The loading was applied until the load (load dial) decreases on the specimen significantly.

General relationship of Consistency and Unconfined Compression Strength (UCS) of clay is shown in Table 2.3

Table 2.3: Relationship between consistency and UCS

Consistency	Unconfined Compressive Strength q_u (kN/m2)
Very soft	0-25
Soft	25-50
Medium	50-100
Stiff	100-200
Very stiff	200-400
Hard	>400

Consolidation 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

The earliest and the most widely used method to determine the pre-consolidation pressure was the one proposed by

Casagrande (1936). The method involves locating the point of maximum curvature on the laboratory e-log p curve. From this point, a tangent is drawn to the curve and a horizontal line is also constructed. The angle between these two lines is then bisected. The abscissa of the point of intersection of this bisector with the upward extension of the inclined straight part corresponds to the pre-consolidation pressure. The relative amount of pre-consolidation is usually reported as the over-consolidation ratio

3. MATERIALS and METHODOLOGY

Accurate values of Index and Engineering properties of the soil samples of the study areas are very much helpful data for construction of any structures. To achieve thatinformation was collected from the city administration which included like town plans to assess the expansion potential of the town and the current distribution of the dwellings and buildings in the town. There were four provinces (namely Doketu, Darra, Duraite and Mechelo). A field visit of the town was conducted to identify suitable locations for pit excavations based on the future expansion plan of the town and the representativeness of the test pit in each province.

Laboratory tests were performed to determine the index and engineering properties of the soil. The tests were conducted according to ASTM standards. Standard procedures for performing laboratory tests were followed. Laboratory tests were conducted in the Soil Mechanics laboratory of Arba Minch University and geochemical analysis tests were conducted in Mafecon Engineering& construction PLC.

Different pre-treatment methods have been applied to a number of samples tested in the laboratory leading to different moisture contents. Samples tested for the four moisture pre-treatment methods were prepared in the following manner

As Received (AR) - at natural moisture content.
Soaked (S) - immersed in water for 24 hours.
Air dried (AD) - dried to constant weight under normal temperature.
Oven dried (OD) - dried in an oven for 24 hours at 105ºc

In this study soil specimens were collected in different places from Konso-town. The area of the town is judiciously inspected based on visual variation of soil, after prudent inspection, Eight sampling areas were selected at an intervals of around 1.5 to 1.7 km at different parts of the town, which could represent the whole area of the town. Pits were excavated manually. Disturbed and undisturbed soil samples were collected at 1.5m, 3m and 5m depths from Pits No 1 to 4 and at 2m and 5m depths from Pits No 5 to 8. The soil samples were collected from the following sites: Doketu (TP1 and TP2), Darra (TP3 and TP4), Duraite (TP5 and TP6) and Mechelo (TP7 and TP8).

The soil samples taken from test pits were shifted to Laboratory for further investigation. Different tests were conducted for different cases such **as received**, **air dried** and **oven dried** cases for comparison.

The grain-size distribution of mixed soils was determined by combined sieve and hydrometer analyses. Hydrometer analysis was conducted with Sodiumhexameta phosphate dispersing agent for the soil samples passed on NO 200 sieve size. (0.075mm) and the soils were classified by using USCS and AASHTO classification systems.

Atterberg's Limit tests were conducted for air-dried and oven dried samples (AD and OD as per the ASTM D4318-00). The air-dried samples were prepared by spreading the Specimen in the air for about 5 days at the temperature about 26℃. However, the OD samples were prepared by putting the samples in an oven at a temperature of 105℃.The wet preparation is also applied for the as received (AR) samples. The portions of the samples passing the No. 40(0.425mm) sieve were used for the preparation of the sample in order to investigate the effect of temperature on the Atterberg Limits.

For UU Triaxial compression test the specimens were prepared as diameter of 38mm and height of 76mm. The dry soil was mixed with natural moisture content and compacted in three layers until the field density is obtained. Three test samples were prepared at each test pits and the test was conducted by applying initial confined pressure and deviatoric load till the soil specimen failed. Similarly the other two samples were tested by increment of the confined pressure followed by diviatoric stress till the soil failed then Mohr circle was developed for shear strength parameter determination.

For consolidation tests, it is used to determine the magnitude and rate of consolidation of soil when it is restrained laterally and drained axially while subjected to incrementally applied controlled-stress loading. Undisturbed soil samples were taken by ring sampler and cut the sides of the sample to be approximately the same as the outside diameter of the ring. A soil sample diameter of 63mm and 20mm height were used for determination of CC and Cr. The loading pressures were applied as 25kPa, 50kPa, 100kPa, 200kPa, 400kPa, 800kPa and 1600kPa and unloading readings were noted at 1600kPa, 400kPa, 100kPa and 25kPa pressures. The dial gauge readings were recorded for 24 hours.

4. RESULTS AND DISCUSSIONS

4.1 Natural Moisture Content

The difference in moisture content obtained between the two drying temperatures was less than around 4% for both textured laterite soils. This indicates that laterite soils do not

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contain a considerable amount of „water of hydration" or „structural water" which leads to irreversible changes on drying. It is concluded that for general purposes the moisture content tests for the soils can be conducted using the conventional oven drying (105ºC) method. As a result, ASTM D: 2216–98, standard test method for laboratory determination of moisture content is considered acceptable for determining the natural moisture content of laterites. It was suggested to use three or more duplicate samples of AR soil with weighted average to obtain the most accurate results. The values of the moisture content variations were compared and summarized in Table 4-1

Test Pit	Sampling depth (m)	Natural Moisture content		Difference (%)
		105°C	50°C ,RH=30%	
TP1	1.5	29.69	27.29	2.4
	3	31.94	29.02	2.92
	5	33.05	30.84	2.21
TP2	1.5	32.79	29.97	2.82
	3	38.96	38.96	2.81
	5	43.37	40.37	2.93
TP3	1.5	15.5	14.9	0.58
	3	18.2	17.1	1.1
	5	20.3	19	1.31
TP4	1.5	34	32.6	1.37
	3	34.8	31.2	3.62
	5	37.9	34.9	2.01
TP5	2	29.73	27.44	2.29
	5	30.15	28.25	1.9
TP6	2	27.49	26.68	0.8
	5	28.22	25.33	2.89
TP7	2	26.2	24.94	1.26
	5	26.6	22.4	4.2
TP8	2	29.75	28.13	1.62
	5	32.17	31.06	1.11

4.2 Free Swell

Free swell test results for both air and oven dried samples are summarized in Table 4-2. From the test result it can than seen that the free swell of the soil under investigation ranged from 13% to 43%. Those soils having a free swell less than 50% are considered as low in degree of expansion. Hence all soil samples under investigation are non-expansive soils

Table 4-2Free swell test results at different Conditions

Test Pit	Depth in (m)	Test condition	Free Swell (%)
TP1	1.5	Air dried	30
		Oven dried	25
	3	Air dried	35
		Oven dried	30
	5	Air dried	41
		Oven dried	38
TP2	1.5	Air dried	40
		Oven dried	38
	3	Air dried	41
		Oven dried	36
	5	Air dried	42
		Oven dried	40
TP3	1.5	Air dried	18
		Oven dried	12
	3	Air dried	19
		Oven dried	15
	5	Air dried	20
		Oven dried	13
TP4	1.5	Air dried	30
		Oven dried	25
	3	Air dried	33
		Oven dried	26
	5	Air dried	38

		Oven dried	30
TP5	2	Air dried	33
		Oven dried	25
	5	Air dried	36
		Oven dried	28
TP6	2	Air dried	22
		Oven dried	20
	5	Air dried	23
		Oven dried	22
TP7	2	Air dried	30
		Oven dried	28
	5	Air dried	32
		Oven dried	28
TP8	2	Air dried	30
		Oven dried	24
	5	Air dried	31
		Oven dried	26

4.3 Specific Gravity

The specific gravity of laterite soil was found to be increased in specific gravity with depth. This is interpreted as due to a high concentration of iron oxide. There is a clear trend of higher specific gravity for the AR (no pre-drying) samples. The specific gravity was in the range between 2.61 to 2.86 for different pretreatment conditions (Table 4-3).Whereas Specific gravity in TP2 and TP3 it is low this can be the type of minerals the soil constitute like Gypsum

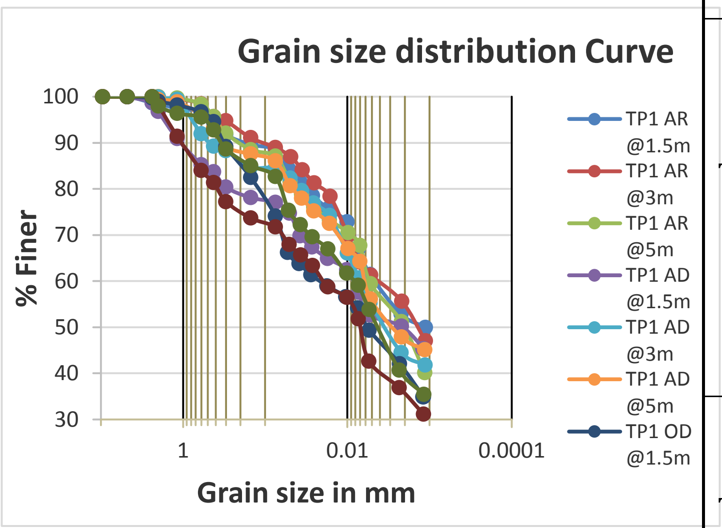
Table 4-3 Values of specific gravity at different Conditions

Designation	Sample depth (m)	Test condition	Specific Gravity
TP1	1.5	Oven dried	2..61
		Air dried	2.62
		As received	2.63
	3	Oven dried	2.65
		Air dried	2.68
		As received	2.66
	5	Oven dried	2.67
		Air dried	2.7
		As received	2.7
TP2	1.5	Oven dried	2.48
		Air dried	2.5
		As received	2.51
	3	Oven dried	2.52
		Air dried	2.6
		As received	2.61
	5	Oven dried	2.5
		Air dried	2.51
		As received	2.59
TP3	1.5	Oven dried	2.4
		Air dried	2.42
		As received	2.44
	3	Oven dried	2.41
		Air dried	2.42
		As received	2.45
	5	Oven dried	2.45
		Air dried	2.45
		As received	2.46
TP4	1.5	Oven dried	2.7
		Air dried	2.72
		As received	2.74
	3	Oven dried	2.72
		Air dried	2.76
		As received	2.77
	5	Oven dried	2.73
		As received	2.79
TP5	2	Air dried	2.71
		As received	2.73
	5	Oven dried	2.71
		As received	2.74
TP6	2	Oven dried	2.71
		As received	2.75
	5	Oven dried	2.74
		As received	2.78
TP7	2	Oven dried	2.66
		As received	2.72
	5	Oven dried	2.68
		As received	2.74
TP8	2	Oven dried	2.75
		As received	2.82
	5	Oven dried	2.76
		As received	2.86

4.4 Grain size Analysis

The grain size analysis distribution curves for soil samples under investigation at different testing conditions are shown in Fig 4-1

Oven dried (OD), air dried (AD) and as received (AR) sample preparations were carried out to investigate the effect of pretreatment on grain size distribution of the soil samples under investigation. From the curves observed that the three methods of pretreatment produce a change in cumulative percentage passing between OD, AD and AR for sample all pits the difference between OD and AR sample clay fraction greater than 7%, moreover oven drying temperature also effect the fraction of clay when oven drying temperature decrease from 105º C to 50º C the clay fraction increase. The results obtained from the grain size analyses indicated that the dominant proportion of soil particle in the research area was clay. The percentage of soil passed through sieve No. 200 (0.75mm) was ranging from 71.7% to 94.8, which indicated that the soil in the study area was fine grained soil.



4.5 Consistency Limits

Atterberg Limit values for konso city soil and it is shown on Table 4.4 shows that the PI values do not vary significantly as received property could not be reversed on soaking or unsoaking. More over this shows that the clay fraction is not getting enough moisture when taken from oven and mixed with water to determine the Atterberg values. The AR samples gave liquid limits somewhat greater than those of the AD samples, which in turn gave values greater than those of the OD samples. The difference between the AR and OD samples is typically around 5%.

Table 4-4: Atterberg Limit values at different testing conditions

Test pits	Depth (m)	Test condition	Liquid Limit (%)	Plastic Limit (%)	Plasticity index
TP1	1.5	As received	62.2	39.64	22.56
		Air dried	58.9	35.63	23.27
		Oven dried	57.2	36.44	20.76
		Unsoaked	49.9	28.65	21.25
	3	As received	59.9	37.06	22.74
		Air dried	56.2	34.18	22.02
		Oven dried	53	34.83	18.17
		Unsoaked	51.6	31.5	20.1
	5	As received	53.7	33.58	20.12
		Air dried	51	32	19
		Oven dried	48.9	29.1	19.8
		Unsoaked	47.8	28.7	19.1
TP2	1.5	As received	62.8	37.35	25.45
		Air dried	57	34.86	22.14
		Unsoaked	56.2	35.79	20.41
	3	As received	56	33.71	22.29
		Air dried	54.2	35.01	19.19
		Unsoaked	53.6	34.77	18.83
	5	As received	55	35.77	19.23
		Air dried	53.2	34.67	18.53
		Unsoaked	53.2	32.8	20.4
TP3	1.5	As received	54.6	34.37	20.37
		Air dried	47.7	28.14	19.56
		Unsoaked	45.8	26.55	19.25
	5	As received	48.8	29.15	19.25
		Air dried	46.4	27.27	19.13
		Unsoaked	43.2	24.1	19.3
TP4	1.5	As received	64.2	38.9	25.3
		Air dried	62.5	37.29	25.21
		Oven dried	59.7	38.15	21.55
		Unsoaked	59.4	38.04	21.36
	3	As received	59.4	35.65	23.75
		Air dried	56.2	33.81	22.39
		Oven dried	51.8	33.75	18.05
		Unsoaked	51.5	33.24	18.26
TP5	2	As received	58.4	37.25	21.15
		Oven dried	55.3	36.23	19.07
		Unsoaked	52.5	32	21.5

	5	As received	57.8	36.02	21.78
		Oven dried	52.2	32.5	19.7
		Unsoaked	52.2	40.16	20.7
TP6	2	As received	61.1	40.03	21.07
		Oven dried	54.4	35.08	19.32
		Unsoaked	52.7	33.04	19.66
	5	As received	56.5	36.73	19.77
		Oven dried	50.6	31.5	19.1
		Unsoaked	46	26.5	19.5
TP7	2	As received	58.7	38.21	20.49
		Air dried	54.4	34.9	19.5
		Oven dried	53.7	34.88	18.82
		Unsoaked	49.9	30.78	19.12
	5	As received	56.7	36.84	19.86
		Air dried	56.6	38.37	18.23
		Oven dried	51	31.97	19.03
		Unsoaked	48.9	29.5	19.4
TP8	2	As received	58	36.95	21.05
		Air dried	54.8	36.34	18.46
		Oven dried	54.4	36.21	18.19
		Unsoaked	53.2	34.24	18.96
	5	As received	59.1	38.65	20.45
		Air dried	55.2	35.82	19.38
		Oven dried	54.1	34.37	19.73
		Unsoaked	50.5	32.27	18.27

4.7 Unconfined Compression Strength

Based on the results obtained from Stress-Strain curves the values of unconfined compressive strength varies from 245 to 332 kN/m2.The results are shown in table 4-6.

Table 4-6: UCS test results

Test Pit	Depth (m)	Dry density g/cm3	NMC (%)	qu (kPa)	Su (kPa)
TP1	3	1.71	30	245	122.5
TP1	5	1.77	33	282	141
TP4	5	1.79	38	250	125
TP7	2	1.75	25.4	332	166
TP7	5	1.76	26	326	163
TP8	2	1.65	31	294	147
TP8	5	1.66	32.3	315	157.5

4.8 Geochemical Tests

Geochemical tests were carried out at Mafecon engineering and construction plc in Addis Ababa to obtain the percentage oxide composition of silicon oxide, aluminum oxide, iron oxide and magnesium oxide the soil samples were analyzed using Wagtech photometer 7000. The degree of laterization of the soil samples can be evaluated based on silica – sesquioxides. The sesquioxide, designated as R2O3, is the combination of aluminum oxide (Al2O3) and Iron oxide (Fe2O3). The chemical formula SiO2 designates the silica. Accordingly unlaterized soils have $\frac{SiO2}{R2O3}$ ratio greater than 2. For lateritic soils $\frac{SiO2}{R2O3}$ ratio lie between 1.33 and 2 and for true laterites the ratio is less than 1.33. Lateritic soil has not under gone a considerable degree of laterization as compared to true laterite.

The results of analysis are shown in the table 4-7 and it shows that the lowest molecular silica: sesquioxide ratio gave the soil is lateritic soils.

Table 4-7: Average geo-chemical oxide composition for Konso town lateritic soil with depth

Test pit	Depth (m)	SiO2	Al2O3	Fe2O3	MgO	$\frac{Sio_2}{R_2o_3}$
TP1	1.5	48.6	24.2	22.7	0.221	1.04
	3	48.8	23.9	22.67	0.213	1.05
	5	49.2	23.8	22.65	0.211	1.06
TP4	1.5	52.12	26.6	23.4	0.89	1.04
	3	52.31	26.58	23.37	0.86	1.05
	5	52.51	26.56	23.36	0.85	1.05
TP5	2	25.57	27.86	32.45	0.23	0.42
	5	32.68	28.88	17.81	0.22	0.67
TP7	2	40.38	22.9	18.05	0.44	0.98
	5	38.24	25.01	17.03	0.37	0.91
TP8	2	32.88	23.91	24.61	0.20	0.68
	5	33.97	23.81	24.52	0.21	0.70

4.9 Consolidation test

Table 4-8a: Consolidation test results

Location	Depth (m)	Unit Weights (KN/m3	C_c	C_r	Po
Deketuo (TP1)	5	17.17	0.283	0.033	85.85
Darra (TP4)	5	17.59	0.370	0.044	87.95
Duraite (TP6)	5	18.72	0.340	0.040	93.6
Mechelo (TP7)	5	17.28	0.312	0.037	86.4
Mechelo (TP8)	5	16.25	0.273	0.032	81.25

Table 4-8b: Consolidation test results

Location	Depth (m)	Unit Weights (KN/m3	Cv 10^{-6} mm^2/min	a_v m2/ KN	K 10^{-6} cm/sec
Deketuo (TP1)	5	17.17	0.646	0.322	1.734
Darra (TP4)	5	17.59	0.79	0.184	2.394
Duraite (TP6)	5	18.72	0.646	0.355	1.743
Mechelo (TP7)	5	17.28	0.667	0.328	1.79
Mechelo (TP8)	5	16.25	0.678	0.329	1.81

5. Conclusions

Based on the investigations made on the soils of Konso Town, the following conclusions are drawn.

- ✓ The use of the wet sieving method is preferred with the soil soaked until the coating material is fully softened. The modification of the grading curves using modified mass proportion is not considered important if the wet sieving method is used.
- ✓ It is considered appropriate that laterite soil samples for Atterberg limit testing should be broken down by soaking in water and not by drying and grinding as is conventional practice for temperate zone soils
- ✓ The Konso town area soils indicate sensitive to test procedures which are affected during testing manipulation. Hence desegregation results in the test value different from the in-situ condition. Accordingly, the minimum mixing time, usually of 5minutes and fresh soil has to be used for each point on the Atterberg Limit.
- ✓ Laterite soils of Konso area are characterized by high concentration of Iron Oxide, Aluminum Oxide (Sesqueoxide) and Kaolinite minerals.
- ✓ The soil samples subjected to test fall below A-line under MH (inorganic silt with medium strength).
- ✓ The liquid limit and plastic limit values varies from 43.2 to 64.2% and 24.1 to 40.16% respectively
- ✓ Specific gravity test results for this case study indicated 2.61 up to 2.82 which are higher values than the usual ranges due to high amount of iron oxide.
- ✓ Soils variation in percentage of particle sizes in the different test procedures is not significant.
- ✓ Geochemical tests indicate that the soils of Konso area had Silica to Sesqueoxide ratio, below 1.33, that indicated the soil is laterites having high concentration of Iron Oxide and Aluminum Oxide / Sesqueoxide /.
- ✓ The Values of friction angle vary from 10 to 12º and cohesion vary from 160 to 191.34kN/m^2.
- ✓ The values of unconfined compressive strength range from 245 to 332 kN/ m^2, which was in the ranges of very stiff consistency.
- ✓ From one-dimensional consolidation test, the Compression Index Cc ranged from 0.273-0.37 and coefficient of Permeability ranged from1.81x10^{-6} to 2.39x10^{-6} cm/sec. which indicates that the soil in the area is relatively impervious.

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