JIMMA UNIVERSITY

INSTITUTE OF THECNOLOGY

SCHOOL OF CIVIL AND ENVIROMINTAL ENGINERING

PROJECT TITLE:

LITERATURE REVIEW OF EXPANSIVE SOILS (CASE STEDY IN JIMMA TOWN)

MASTER OF ENGINEERING IN CIVIL ENGINERING (GEOTHECNIC)

BY: MITIKU AYELE

JIMMA, ETHIOPIA

MAY, 2016

LITERATURE REVIEW OF EXPANSIVE SOILS (CASE STEDY IN JIMMA TOWN)

By: Mitiku Ayele

A Project Paper to be submitted to Jimma University in the Partial Fulfillment of The Requirements of Master of Engineering in Civil Engineering (Geotechnical).

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May, 2016

ABSTRUCT

One of the most important and the most controversial engineering properties of soil is its shear strength or ability to resist sliding along internal surfaces within a mass. The stability of a cut, the slope of an earth dam, the foundations of structures, the natural slopes of hillsides and other structures Built on soil depend upon the shearing resistance offered by the soil along the probable surfaces of slippage. There is hardly a problem in the field of engineering which does not involve the shear properties of the soil in some manner or the other.

The laboratory studies have shown that most expansive soils are highly expansive, possesses lower shear strength at peak values and most of all their consolidation behavior is hard to predict with the common triaxial apparatus. It has been established that these characteristics are mainly in friction angle in the CU tests.

Influenced by the volume change during saturation stage (type and amount of clay minerals present) and physical state of the soil.

One of the most important and the most controversial engineering properties of soil is its shear strength or ability to resist sliding along internal surfaces within a mass. The stability of a cut, the slope of an earth dam, the foundations of structures, the natural slopes of hillsides and other structures Built on soil depend upon the shearing resistance offered by the soil along the probable surfaces of slippage. There is hardly a problem in the field of engineering which does not involve the shear properties of the soil in some manner or the other.

Acknowledgement

First of all I would like to express my heartfelt thanks to Almighty God for granting me this big and decisive opportunity in my life and his endless mercy and support in my progress.

I would like to express my gratitude to my adviser Mr.Tadesse for reviewing and providing valuable suggestions to my project study.

I wish to express my appreciation and thanks to all my families specially my mother, friends and my lovely Fiancée Yetenayte ahmede.

Finally, my deep appreciation and thanks goes to Ethiopian Roads Authority for giving me such big chance and help in providing me with the necessary materials and literatures.

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Symbols and abbreviations

Symbol	Description	Unit
C	Cohesion	KPa.
CU	Consolidated Undrained Test	_
CD	Consolidated Drained Test	_
DIR	Direct Shear Test	_
DFS	Differential Free Swell	percent
GPS	Geographical Positioning System	_
LL	Liquid Limit	%
M.D.D.	Maximum Dry Density	gm/cc
O.M.C.	Optimum Moisture Content	%
PL	Plastic Limit	%
PI	Plastic Index	%
SL	Shrinkage Limit	%
STP	Standard Test Pit	_
TP	Test Pit	__
σ1	Major Principal Stress	KPa
σ3	Minor Principal Stress	KPa
Δσ1, Δσ3	Change in Principal Stresses	KPa
φ	Angle of Internal Friction	Degree
U.S.C.S.	Unified Soil Classification System -	_

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CHAPTRE ONE

1 INTRODUCTION

The safety of any geotechnical works is closely related to the shear strength of the soil. The shear strength is the internal frictional resistance and Cohesion of soils to shearing forces. Shear strength is required to make estimates of the load bearing capacity of soils, the stability of geotechnical structures and in analyzing the stress strain characteristics of soils.

Swelling or expansive soils occur very widely throughout the world-both in temperate and tropical climates; and problems associated with these soils have been reported in Africa, Australia, Europe, India, Israel, South America, Soviet Union, the United States as well as some regions in Canada [6, 33]. In the United States alone, expensive clays have been estimated to produce at least two billion dollars of damage annually [6, 33]. In many areas of the tropics especially Africa and India, tropical expansive soils often known as black cotton soils are the major problematic soils. These soils show very strong swelling and shrinkage characteristics under changing moisture conditions.

1.2 Engineering problems with expansive black clays

1.2.1 Expansive soils in general

The engineering problems associated with tropical expansive soils are similar to those caused by other expansive soils.

Drainage, broken drains, transpiration (drying effect) and so on. A potentially expansive soil is not necessarily dangerous unless it has access to pressures leading to considerable tilting and ultimately failure of the structures water, and the resulting volume change depends on the initial water content of the soil and the quantity of water imbibed. Moisture variation in the soil may result from seasonal climatic changes, changed surface condition and extraneous influences. The seasonal climatic changes involve changes in precipitation, evaporation, temperature etc.

Effects of changed surface condition are brought about when an impermeable membrane such a building or pavement is placed on soil surface and thus causing changes in moisture regime of the soil. The extraneous influences are the supply of moisture due to poor.

The swelling characteristics of soils result in heaving, distortion, cracking and breaking up of pavements, buildings, channels, buried conduits and reservoir linings. Retaining walls with expansive soil backfills may be subjected to very high earth pressures leading to considerable tilting and ultimately failure of the structures.

1.2.2 Experience in Ethiopia

1.2.2.1 Buildings

Buildings Research work made by Afewerk Sisay [18] in Addis Ababa, shows most building constructed on expensive soils with cracks from heave from the underlying soil has foundations made from masonry with tie beams. Found on swelling soils often show movements, which appear to be opposite to the dish shaped distortion resulting from consolidation settlement. Since the building acts as an impermeable membrane, there will be a tendency of moisture accumulating underneath the building resulting in maximum heave at the center. For the same vertical deformation at the center of the buildings, hogging (heaving) develops very serious crack patterns compared to sagging (settlement).

1.2.2.2. Roads

Pavement movements due to swelling and / or shrinkage of sub grade soil can cause very extensive cracking and distortion which may finally lead to total failure of the entire structure. The overburden weight of the pavement is small- usually about 10 KN/m^2 thus the pavement is easily lifted and distorted by swelling subsoil. The distortion creates humps and bumps and when tolerable limits are exceeded cracks develop. Through these cracks moisture migrates to the sub grade which when loaded, soaked and undrained excessive deformations occur which lead to failure of the pavement. Cracks can result from both sub grade shrinkage and sub grade swelling.

Sub grade shrinkage, which is produced under continuous drying condition, makes the soil warp and induce tension to the pavement. Swelling on the other hand causes compression in the pavement which itself is not detrimental but the resulting differential heave causes severe cracking of the pavement in the form of longitudinal Cracks.

In Ethiopian, bituminous pavements on expansive soils have failed prematurely. The Addis Ababa – Jimma stretch for example, was partially destroyed a few years after construction. Some areas in the country are similarly affected due to extensive occurrence of expansive soils. [22]

1.2.2.3 Railways

The reduction of untrained shear strength of the sub grade due to swelling is the main cause of excessive settlements and misalignment of railway tracks crossing soils. During the dry season, large and deep cracks occur in the sub grades, which are then filled with water during the rainy season.

1.3 Objectives and scope of the study

Examples shown in Section 1.3 illustrate that expansive soils are hazardous construction materials, which in this country, may produce annual damage in the order of tens of millions of Birr. Previous works have been reported in the field of soil engineering on expansive clays in Ethiopian that aim at identifying and classifying these soils using standard laboratory methods.

The major objective of this investigation is to examine the fundamental shear characteristics of expansive soils using different drainage conditions, factors influencing the shear strength of expansive soils, and the relations of shear strength to index properties by taking few soil samples from three different places in Jimma Town .

The study mainly involves Direct Shear test to evaluate the shear strength of expansive soils both on undisturbed and compacted samples. This work is compared with similar investigation carried out on expansive soils of Tanzania.

The following steps were followed in the course of the study

- Literature review, data collection and identification of possible research sites were made,
- Samples were dug from tests pits and taken for different identification lab tests,
- Triaxial shear tests were conducted on proven expansive soils,
- Lab results as well as additional collected data were analyzed,
- Finally, this research paper was compiled.

CHAPTER TWO

LITERATURE REVIEW

2.1 NATURE AND OCCURRENCE OF EXPANSIVE CLAY SOILS

Tropical expansive soils are often called black cotton soils. The latter name is believed to have originated in India where locations of these soils are favorable for growing cotton. Other local terms are used to describe these soils in many areas such as " regur" soils in India, "margalitic" soils in Indonesia and "black turfs" in Africa. With the new soil taxonomy system these soils are referred to as "vertisols". Some investigators in India have defined black cotton soils as "soils derived from the weathering of trap rock (basalt) in particular, which are black, heavy and climatologically suited to the growth of cotton" [40].

2.2 Origin

Expansive soils occur both as residual and alluvial deposits. Parent rocks for the residual clays are usually basic and the most common is basalt. In some areas these soils have been formed from other rock types, which have been formed from other rock types such as shales, gneisses and some calcareous rocks.

Climate and topography play a very significant role in the formation of tropical soils. Expansive soils are common in areas of moderate rainfall and poor drainage. Under these conditions, and in an alkaline environment where there is adequate supply of magnesium, silica and alumina, montmorillonite, which is the principal clay mineral, is formed. These soils are rich in alkaline earths. Horizons of calcium sometimes develop or lime concretions may be found scattered through the profile.

Table 2.1 Chemical Mineralogical Properties Expansive Soils [40].

Location	Samples No.	Parents Materials	Clay Mineralogy	Cation Exchange Capacity in	Exchangeable Cations	PH	Organic Content
Chad Basin	CB-1	Alluvium		34.90	mostly Ca; with Mg; minor K and Na	8.4	<1.0%
Chad Basin	CB-2	Alluvium		32.83	mostly Ca; with Mg; minor K and Na	6.3	<1.0%
Chad Basin	CB-3	Alluvium	kaolinite, illite, montmorillonite				
Chad Basin	CB-4	Alluvium	quartz, kaolinite montmorillonite			6.3	
Nigeria	NBC-1	Calcereous Rocks	montmorillonite kaolinite,	44.08	mostly Ca; with Mg; minor K and Na		<1.0%
Ethiopia	ETH-1	Basalt	montmorillonite, kaolinite	64.90	mostly Ca; with Mg; minor K and Na	7.2	<1.0%
Kenya	KEN-6	Basalt	montmorillonite, kaolinite			8.8	
Kenya	KEN-9	Basalt		45.02	mostly Ca; with Mg; minor K and Na	7.2	
Zambia	ZAM-1	Alluvium		32.16	mostly Ca; with Mg; minor K and Na		1.0-1.5%
Zambia	ZAM-2	Basalt		33.34	mostly Ca; with Mg; minor K and Na	6.4	<1.0%
Uganda	U-12	Basalt		56.74	mostly Ca; with Mg; minor K and Na	7.4	1.0%
Tanzania	TAN-X-1	Alluvium		30.07	mostly Ca; minor Mg, K and Na	9.2	<1.0%
Tanzania	TAN-3A	Alluvium					
Morocco	MOR-2	Alluvium from basalt	montmorillonite chlorite, kaolinite				
Morocco	MOR-3	Alluvium from	montmorillonite chlorite, kaolinite				
Sudan	SU-1	Alluvium from basalt	montmorillonite, kaolinite, illite, quartz, calcite			8.9	
Sudan	SU-2	Alluvium from basalt	montmorillonite illite, kaolinite calcite				
Sudan	SU-3	Alluvium from basalt	montmorillonite kaolinite, illite quartz, calcite				

2.3 Chemical and Mineralogical Characteristics

The chemical composition of expansive soils differs considerably from that of the reddish tropically weathered soils.

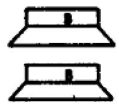
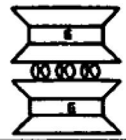
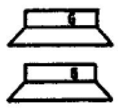
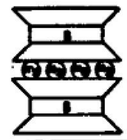
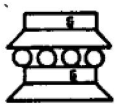
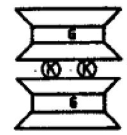
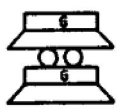
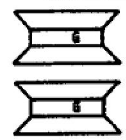
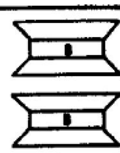
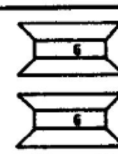
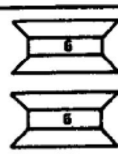
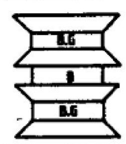
The silican content is always high and the iron content relatively low. The silica- sesquioxide ratios are above 2.50, considerably higher than the reddish soils [40]. Explanations suggest that the black colour may be due to the presence of iron and titanium, which exist, in small quantities.

Table 2.1 indicates that the mineralogical composition of expansive soils are basically similar, montmorillonite being the predominate clay mineral. Kaolinite, and sometimes halloysite and illite occasionally occur but in small quantities. In most cases only alluvial soils contain illite and only soils over volcanic rocks contain halloysite.

The most common clay minerals found in tropical soils are grouped as Kaolinite, illite, and montmorillonite. They are essentially hydrous aluminum silicates. Since clays minerals are products of chemical weathering of rocks, both climate, which determines weathering, and the parent rock, influence the type of minerals found.

Montmorillonite is also formed when chemical alterations take place within poorly drained soils in an alkaline environment and in the presence of magnesium ions. Kaolinite is a non- expansive clay mineral with low activity and is found in soils that have undergone considerable weathering in warm moist climates such as lateritic soils. Illite has properties intermediate between Kaolinite and Montmorillonite. It occurs widely in sedimentary rocks in temperate and arid regions. The mineral names and structure diagrams of the various clay minerals are shown in Table 2.2.

Table 2.2 Structure diagram and properties of the various clay minerals [34].

MINERAL	STRUCTURE SYMBOL	MINERAL	STRUCTURE SYMBOL
SERPENTINE		MUSCOVITE	
KAOLINITE		VERMICULITE	
HALLOYSITE ($4H_2O$)		ILLITE	
HALLOYSITE ($2H_2O$)		MONTMORILLONITE	
TALC		NONTRONITE	
PYROPHYLLITE		CHLORITE	

2.4 Ethiopia

Expansive soil is known to be widely spread in Ethiopia. Although the extent and range of distribution of this problematic soil has not been studied thoroughly; the southern, south-east and south-west part of the city of Addis Ababa areas, where most of the recent construction are being carried out and central part of Ethiopia following the major truck roads like Addis-Ambo, Addis-Wolliso, Addis-Debre Birhan, Addis-Gohatsion, Addis-Modjo are covered by expansive soils. Also areas like Mekele and Gambella are covered by expansive soil. The distributions are shown in Figure. 2.1.

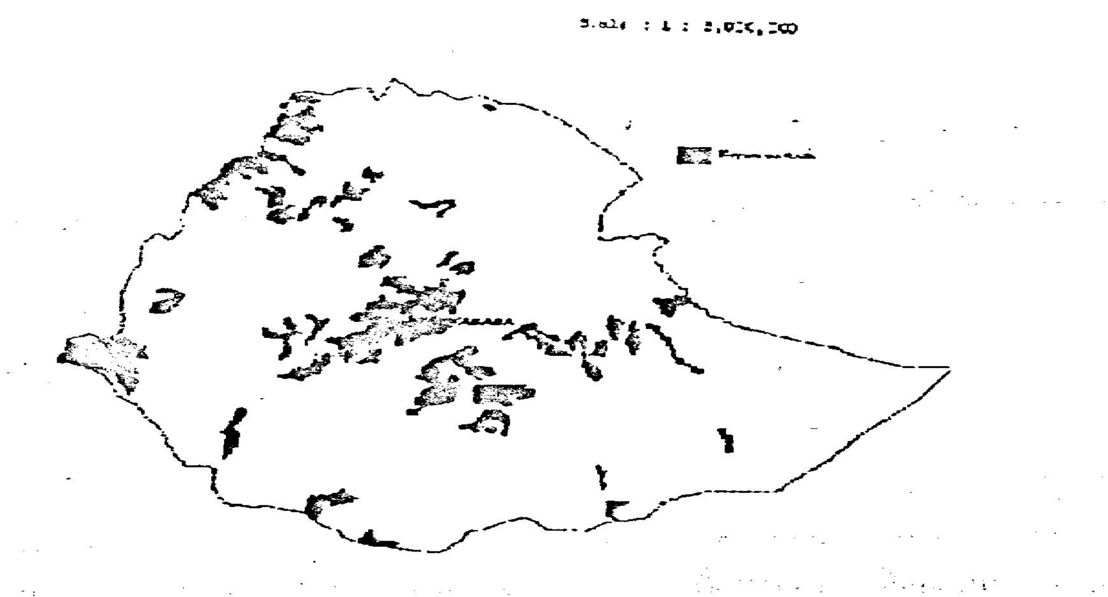


Figure 2.1 Distribution of Expansive soil in Ethiopia [22]

2.5 JIMMA TOWN

Jimma town is located at about 350km from Addis Ababa, and it is bordered on the south by the Southern Nations, Nationalities and Peoples Region (SNNPR), the Northwest by Illubabor Zone, on the North by East Wellega, and on the Northeast by West Shewa Zone of the Oromia Regional State. It covers a total area of 18,412.54 square kilometers; and lies within 7^0 45′ N Latitude and 35^0 30′ E-37^0 30′ E Longitude. The altitude of the area ranges from 1300m to 2100m. The mean annual rainfall of the area is between 1800 mm to 2300 mm with maximum rainfall between months of June and September. The annual mean temperature of the area is between 15^0C and 22^0C. Based on figures from the CSA in 2005, the zone has an estimated total population of 2,773,730, of whom 1,382,460 are men and 1,391,270 are women; 340,666 or 12.3% of its population are urban dwellers (CSA, 2005).

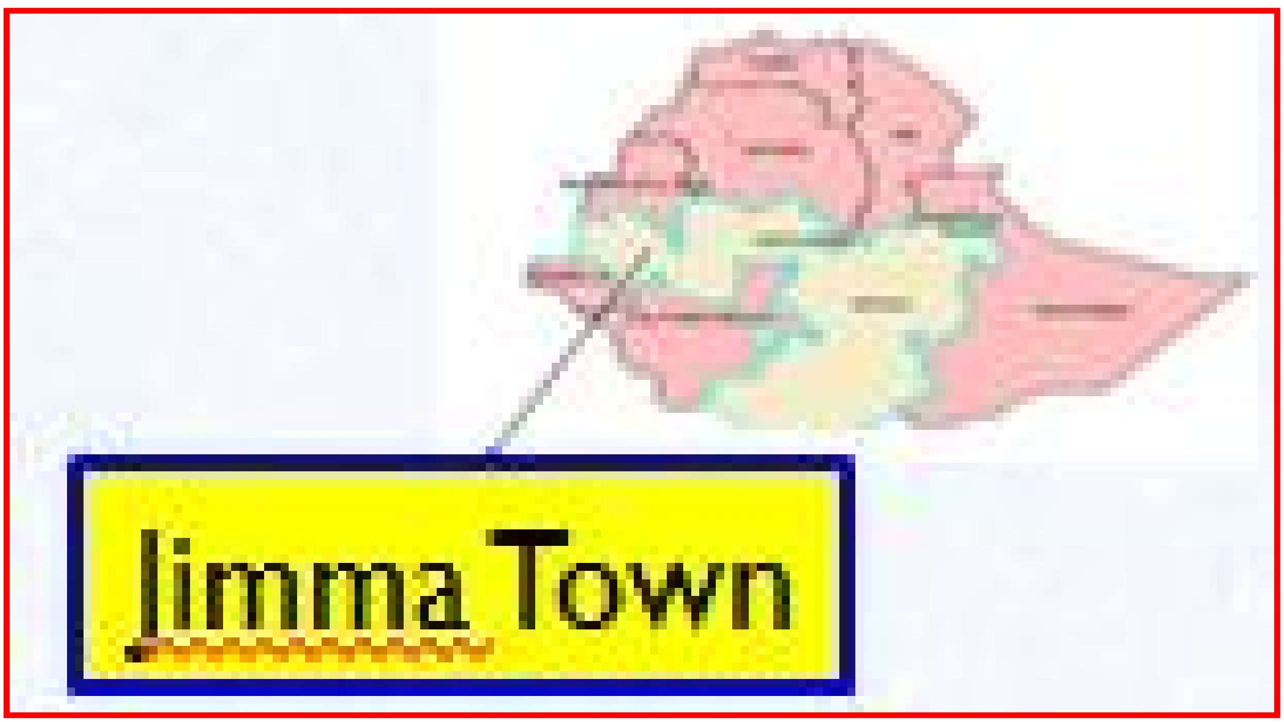


Fig. 2.2 Location of Jimma Town

2.6 STRENGTH CHARACTERISTICS OF EXPANSIVE SOILS

The stability of a soil mass is its resistance to deformation under stress application. The resistance to deformation is largely due to shearing resistance.

The shear resistance of a soil is due to:-

(i) Interlocking of particles,
(ii) Cohesion between the soil particles,
(iii) Frictional resistance between the particles

According to Mohr's theory, a soil mass will fail when the function of the normal stress acting on that plane, is greater than the shear resistance of the soils

i.e. $S = F(\sigma_n)$ (3.1)

The shearing strength of a soil is represented by the following Coulomb's equation

$S = C + \sigma_n \tan \varphi$ (3.2)

Where

S = shear stress at failure

C = cohesion

i.e. the resisitance of soil particles to displacement due to intermolecular attraction and surface tension of the held water.

σ_n = Normal stress,

φ = Angle of internal friction.

The angle of internal friction depends upon dry density, particle size distribution, shape of particles, surface texture, and water content. Cohesion depends upon size of clayey particles, types of clay minerals, valence bond between particles, water content, and proportion of the clay .

The following tests could be conducted to find the strength of soils:

(i) Shear tests,
(ii) Bearing tests,
(iii) Penetration tests.

In this research, triaxial and direct shear tests are used to investigate the shear strength characteristics of expansive soils.

There are different criteria of 'failure', from which the shear strength of a soil is determined. And these are: - (1) Maximum Deviator Stress

(2) Maximim Pricipal Stress Ratio

(3) Limiting Strain

(1) Maximum Deviator Stress

The maximum or peak deviator stress criterion is associated with 'failure' in the testing of soil samples. It is the condition of maximum principal stress difference. If the vertical and horizontal total pricipal stresses are denoted by σ_1 and σ_3 respectively, the peak deviator stress is writtenas $(\sigma_1 - \sigma_3)_f$, and the corresponding strain is denoted as ε_f.

(2) Maximum Principal Stress Ratio

If the principal effective stresses σ'_1, σ'_3 are calculated for each set of readings taken during undrained test, values of principal ratio σ'_1 / σ'_3 can be calculated and plotted against strain.

The maximum valuey scla of the ratio occurs at about the same strain as thepeak deviator stress I n many undrained test on normally consolidated.

(3) Limiting Strain

This criterion is not often used except in multistatge drained triaxial tests. However, for soils in which a very large deformation is needed to mobilise the maximum shear resistance, a limiting strain condition might be more appropriate.

Three types of laboratory tests are commonly available to determine shear characteristics of soils. These tests are the direct shear test, the triaxial compression test and the unconfined compression test. The material characteristics that can be determined from these tests are the strength parameters (angle of internal friction, and cohesion) and in some triaxial tests properties related to volume change such as modulus of elasticity and poisson's ratio are determined. These parameters are used for analysis and design in conventional civil engineering problems relating to slope statbility, bearing capacity and any other situations where shear strength controls.

It should be noted that laboratory strength tests is meaningful only if the laboratory conditions of loading, drainage etc adequately represents the actual field conditions and also the soil sample being tested is representatative of the insitu soil. Out of the three types of tests mentioned above, the triaxial compression test is more versatile and simulates the insitu conditions better, therefore, are used in this study.

2.7 Shear strength parameters

Angle of internal friction (φ'): represents the frictional resistance between the soil particles, Which is directly proportional to the normal stress? Cohesion (C'): holds the particles of the Soil together into a soil mass and is independent of the normal stresses.

According to Bowles (1978), one of the most important engineering properties of soil is its shear strength; ability to resist sliding along internal surfaces with in a mass. Different types of structures such as slope of an earth dam, the natural slopes of hillsides, the foundations of structures, the stability of a cut and other structures built on soil etc. depend on shearing resistance of the soil. Differen research work has been done on the shear strength parameters of tropical soil (Tilahun, 2004; Sailie, 1984). Factors like parent materials, degree of weathering, and pre-test preparation have been found to have significant effect on the value of shear strength parameters. There exists little information on the shear strength characteristics of expansive clays of Africa. The factors that significantly affect the strength and their effects are difficult to account in most shear laboratory test. On the research conducted by Sailie (1984), the consistency tests and the results on its index properties of expansive soil the amount of clay fractions having a mean value of 40% with the aaverage amount of finess is about 75%.

Table 2.3 Representative value of cohesion according to Arora (2004)

Cohesion,C′ (KN/m2)	Soil
< 12	Very soft clay
12-25	Soft to medium clay
50-100	Stiff clay
100-200	Very stiff clay
> 200	Hard

2.8 The Triaxial Compression Test

As its name implies, triaxial tests on cylindrical specimen subjects the soil specimen to theoretically three compressive stresses at right angles to each other whereby the intermediate and minor stresses are the same. One of the three stresses is increased until the sample fails in shear. Its great advantage is that the plane of shear failure is not predetermined as in the direct shear box test.

The soil sample is cylindrical with a height equal to twice its diameter. The specimen is subjected to an all-round stress by water pressure and fails under an increasing axial stress. The test sample is first covered with a thin rubber membrane to prevent it from being affected by the water, which is contained in a cell

The cell pressure can be measured directly from a manometer or a gauge, and an adaptation also enables the pore water pressure inside the sample to be recorded. The additional axial stress is obtained by an axial load applied through a proving ring in a similar manner to the horizontal shear force used in the shear box.

The intermediate principal stress, σ_2, and the minor principal stress, σ_3, are equal and are the radial stresses caused by the cell pressure. The major pricipal stress, σ_1, consists of two parts: the cell water pressure acting on the ends of the sample and the additional axial stress from the proving ring.

From this, one can see that the triaxial test can be considered as happening in two statges, the first being the application of the cell water pressure (i.e. σ_3), whilst the second is the application of a deviator stress (i.e. σ_1 - σ_3).

Sets of at least three samples are tested. The deviator stress is plotted against vertical strain and the point of failure of each sample is obtained. The Mohr circles for each sample are then drawn and the best common tangent to the circles is taken as the strength envelope.

Generally the application of the all-round pressure and of the deviator stress forms two separate stages of the test; tests are therefore classified according to the conditions of drainage obtained during each stage:

(i) **Undianed tests**: No drainage, and hence no dissipation of pore pressure, is permitted during the application of the all-round stress. No driange is allowed during the application of the deviator stress.

(ii) **Consolidated-undrained tests**: Drainge is permitted during the application of the all-round stress, so that the sample is fully consolidated under this pressure. No drainage is allowed during the application of the deviator stress.

(iii) **Drained tests**: Drainage is permitted throughout the test, so that full consolidation occurs under the all-round stress and no excess pore pressure is set up during the application of the deviator stress.

2.9 The Pore Pressure Coefficients A and B

In problems concerning the undrained shear strength of soils, it has been found convenient to express the pore pressure change *Au,* which occurs under changes in the principal stresses Ao1 and Ao_3, by the following equation:

$$Au = B[Aa_3 + A\{Aa_1\text{-}Aa_3)] \quad (3.1)$$

Where A and B are "pore-pressure coefficients" These coefficients are measured experimentally in the undrained triaxial test, and the values of $Aa_{\}}$ and Aa_3 are, in general, chosen to represent the changes in principal stress occurring in the practical problem under consideration. [19]

$$AM = [ACT3 + A(ACT_1\text{-}ACT_3)] \quad (3.2)$$

For any given soil, the coefficient *A* varies with the stresses and strains. Its values may be quoted at failure (maximum deviator stress), at maximum effective principal stress ratio, or at any other required point. At failure, the values of A for various clay soils, with positive total stress increments, may be summarized approximately Skempton and Bishop covered carefully, in the paper they wrote to the Journal "*Geotechnique*", the derivation of equation (3.1) and its application and hence reference can be made there.

REVIEW OF SHEAR STRENGTH TESTS ON EXPANSIVE SOILS

Considerable research work has been done on the shear strength properties of tropical soils such as lateritic materials, and factors like parent materials, degree of weathering and pretest preparations have been found to have significant influence.

Very little information is available on the shear strength characteristics of African expansive clays. This is mainly due to the fact that many investigators have concentrated most of their efforts towards finding solutions to the swelling behaviour associated with these clays. Nevertheless, the strength behaviour of expansive clays need not be overlooked, since such factors as swelling and fissures influence the strength significantly and their effects are difficult to account for in most laboratory shear tests.

On paper by E.L. Salie and F. Bucher have presented their findings in the laboratory under the title “Shear Strength Properties of Tropical Black Clays.”[16]. They used consolidated undrained triaxial shear test on undisturbed samples. The outcomes of the research only are presented here. For detail procedures of the tests, and discussion, the specific paper can be referred to.

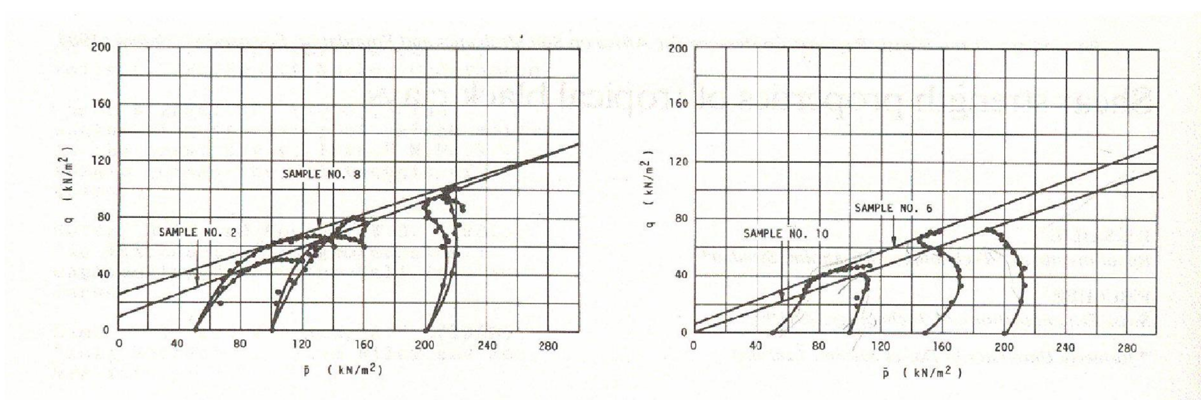


Figure 4.1 Effective stress paths for samples no. 2 and 10 [16]no. 6 and 8 Figure 4.2 Effective stress path for sample

On another paper, by both above-mentioned authors under the title “Swelling behavior of tropical black clays”, they took samples of expansive clays and did some consistency tests Plasticity Chart (by According to their tests results 40 %. All on index properties, they found that the average amount of fines is about 75 % with the clay fraction having mean value of liquid limits and plasticity indices are above 50 % and 25 % respectively. (i.e. highly plastic clays). They tried to use the correlations between swelling properties and index properties by using the Modified .

Dakshanamurthy and Raman, D&R, 1975), Expansive Chart (by V.D. Merwe, 1975) and Expansiveness Chart (Seed et al, 1962). In order to supplement the predicted results, Different Free Swell (DFS) tests was performed. According to their outcome they came up with a conclusion that the qualitative estimation of swelling potential based on the above mentioned criteria show a close agreement. The D&R method and the classification chart after V.D. Merwe compare very well.

In this research, accordingly, the methods by D&R and Seed are adopted. They also came up with a conclusion that the soil type, the dry density, the water content and the surcharge pressure influenced the rate and magnitude of swelling,. In lue of this conclusion, the author thinks those above mentioned parameters have influence on the shear strength of expansive soil. If correlations are to be made to determine the shear strength, those parameters have to be taken into account.One last scientific paper by Ventura Escarrio is covered here which is written under the title “Determination of the Geotechnical Characteristics of Expansive Soils“.

The expansive sample were taken from Madrid, Spain, whereby the samples which had been subjected to air drying, independently of the sieve used, (No. 40, 100, 200), the influence of the curing time after mixing, which varied between 12 hrs and 7 days, was small in the bentonite and in the grey clay. On the contrary a great increase in plasticity limits unless otherwise more scientific outcome shows these procedure are not appropriate in determining those limits. was observed in the specimens, which after air-drying were passed through sieve nos. 100 and 200 instead of No. 40. In fact, in the case of grey clay the liquid limit changed, from approximately 64 for sieve no. 40, to 76 for sieve nos. 100 and 200. The plasticity index for this clay changed from 39 to approximately 47.

CHAPTER THREE

SAMPLES INVESTIGATED IN THE PRESENT RESEARCH

3.1 General

Index tests are extensively used for identification and classification of soils without having to resort to the expensive and detail required with the engineering properties tests. These simple tests provide information about the engineering properties of soils and are called index tests. The most widely used are the particle size distribution and the soil consistency tests. Moisture and density relationships are also commonly used as index properties both in evaluating foundations and to control compaction, even though their determination is required in connection with other test results.

Index properties play a very significant role in identifying potential expansiveness of soils. This is based on the assumption that volume changes of soils depend upon the type and amount of clay minerals present and on the physical state of the soil for any given environment. The type and amount of clay minerals are manifested in the plasticity characteristics of soils while the density and the corresponding water content may be assumed to represent the physical state of the soils.

On the basis of these results, the gradation limits of the expansive soils in terms of mean and standard deviation may be defined within the following ranges of size fractions:

3.2 Classifications of the Expansive Soil Samples

The relationship between liquid limit and plasticity index (plasticity chart) plays a very significant role in classifying fine-grained engineering soils. On the basis of Casagrande's plasticity chart most of the expansive soils are classified as CH – inorganic clays of high plasticity and CV inorganic clays with very high plasticity. (see Figure 5.1) except for two samples, which fall just below the "A", line.

Two Indian researchers [5] modified the Casagrande's plasticity chart in an attempt to predict the potential expansiveness of soils by dividing the liquid limit into different ordinate.

3.2.1 Physical Characteristics

For the purpose of this investigation, the physical characteristics include the moisture and density conditions in the compacted states. The samples were compacted in the laboratory using the standard proctor method and the moisture density relationships determined. As seen on Table 5.1

In the Table 5.1 can generally be said to be following a similartrend.standard AASHO maximum density varies from 1.32 gm/ cc to 1.602 gm/cc.

Previous studies on compaction of soils have shown that grading characteristics and plasticity of fines influence compaction characteristics of natural soils considerably. Also most optimum moisture contents have been found to be either near or above the plastic limits. The results of the present investigation shown.

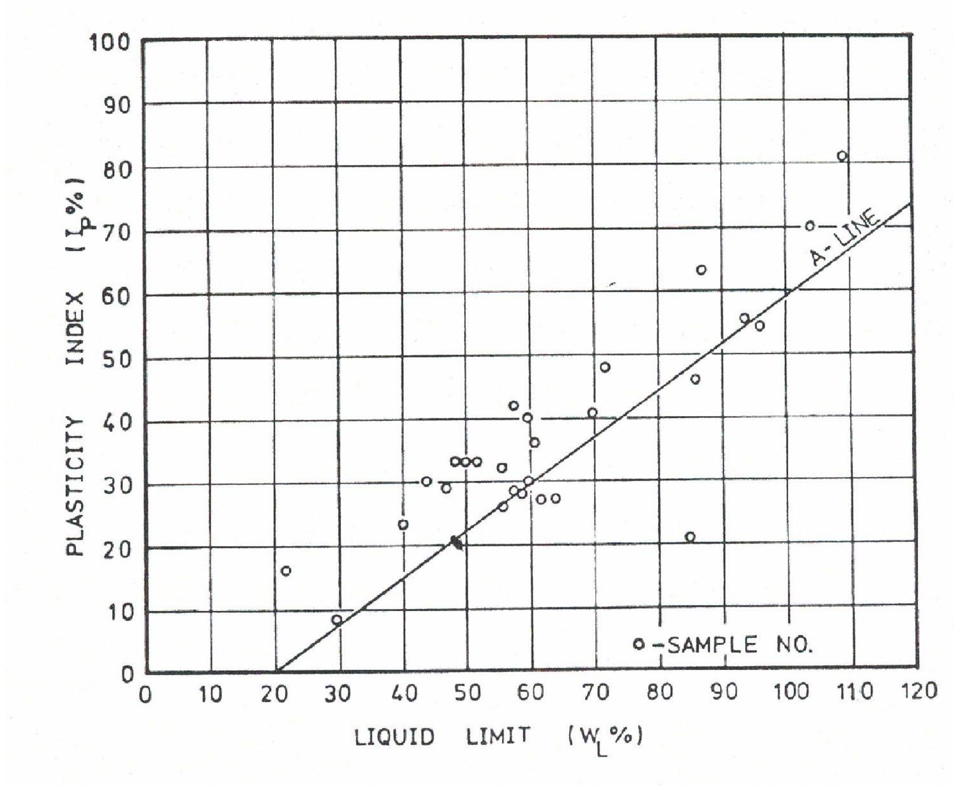


Figure 5.3 Plasticity Chart for some African Expansive Soils. [40]

3.2.2 Preliminary Investigations before Shear Strength Test

of an expansive soil foundation and also to evaluate the stability of dam, road and railway embankments built with these soils. Considerable research work has been done on the shear strength properties of tropical soil such as lateritic materials and, factors like parent material, degree of weathering and pretest preparations have been found to have significant influence. Unfortunately, very little information is available on shear strength characteristics of expansive soils, and, this is mainly due to the fact that many investigators have concentrated most of their efforts towards finding solutions to the swelling behavior associated with these clays. Nevertheless, the strength characteristics of expansive soils need not be overlooked since, such factors as swelling and fissures, for example, influence the strength significantly and their effects are difficult to account for in most laboratory shear tests. Furthermore, a thorough knowledge of shear strength is required to estimate the bearing capacity.

3.2.3 Triaxial shear test

A detailed study of shear strength characteristics of expansive soils is being carried out in the laboratory using triaxial shear apparatus. In his study the shear strength characteristics of expansive soil is investigated using Unconsolidated Undrained test. [2]. In continuation to his work emphasis is given to Consolidated Undrained (CU) tests with pore pressure measurement and Consolidated Drained (CD) tests in this research. For verification, more samples were sheared for Unconsolidated Undrained (UU) tests and compared with when samples are saturated and partially saturated. Both compacted and undisturbed samples were used but to minimize uncertainties from protruded inexpansive soils, mostly selected and samples compacted to standard proctor are used. For each tests, the stress-strain behaviour including the influence of pore pressure with the shear strength parameters are evaluated and discussed.

3.2.4 Undisturbed and Compacted Samples

Sample preparation

All undisturbed samples were recovered as either block or tube samples. The samples were trimmed by means of a wire saw and a frame. The specimens have diameter and height approximately equal to 3.60 cm and 7.80 cm respectively. Extreme care was taken when trimming the samples since most expansive soils are fissured. The lowest natural water content was above 20 percent. Below this water content, the soil is extremely hard and highly fissured making it impossible to obtain anything tests. For each test,close to a “ reasonable” sample for triaxial testing.

3.2.5 Test Procedure

Manually operated ELE triaxial equipment was used both in the laboratory of Ministry of Water Resources and Building Design Enterprise. Detailed description of the equipment can be obtained from the appropriate manual. Details of the testing technique have been described elsewhere. [30]

Different confining pressures were samples.used for different tests according to the pressure the soil is going to be exposed. If the soil is intended for dam embankments, higher confining pressure of 200 KPa, 400 KPa, and 600 KPa are used respectively. Otherwise, by determining the overburden pressure, pressures of 100, 200 and 300 KPa are used for undisturbed.

CHAPTER FOUR

EXPANSIVE SOILS FROM AND ALONG MAJOR TRUCK ROADS

4.1 Introduction

Expansive soils are abundantly and predominantly found on the western part of strength.the assessment of Pavement Failures Founded on Expansive Sub-grades.[22] To carry out their investigations, they chose major truck roads whereby proven failures were reported due to these expansive soils. In addition, due to accessibility for sampling, destination being Addis Ababa, these major roads (listed below) were chosen. In continuation of their work, samples previously collected, carefully tabulated and stored in the Addis Ababa University was made use in this research work to see their shear Strength.

To facilitate comparison of results, shear strength were determined on compacted soils to their optimum moisture content and maximum dry density using standard proctor compaction procedure.

SOME POINTS TO NOTE ON TRIAXIAL TESTING PROCEDURES

After making tests using triaxial apparatus, the author realized that triaxial testing for all ranges of soil types needs experience and care. Care has to be taken at every step during setting up and performing shear test to ensure reliable output. Any wrong result is hard to trace the cause of error if precautions are not taken on time. Hence, it is worthwhile to dot down some of the problems encountered during the research work with their solution For every test making sure the drain pipes are void of air is very important. Any air in the pipes could clog the smooth passage of water or can even give wrong pore pressure readings,

1) Also for every test the drain stones should be boiled. Any entrapped air and dust can seal the drain stones,
2) Uniform saturation of the sample is important. Uneven saturation can force failure at the weaker and more saturated part. Side drains seems to fasten the saturation stage as well as distributing the back water,

3) Saturation in fat clays, especially in expansive soils is difficult. Step saturation can sometimes solve the problem,
4) Trimming samples in the upright position is important. Any diagonally seated sample has cumulative effect on adversely affecting the shear mode,
5) Rate of shearing speed should be carefully controlled for pore pressure to dissipate evenly in CD test,
6) Careful dismantling and assembling of apparatus
7) parts during erection of samples is important in order not to damage the soil sample,
8) In the manual apparatus, due attention and continuous observation is needed when adjusting the level of mercury when measuring the pore pressure,
9) In automatic reading apparatus, the manufacturer did not build to read the pore pressure during saturation. The development stages of pore pressure till saturation is not known.
10) Preparation of proper tabulated format is necessary. As testing progress, it is easy to lose track of the test procedures for each sample,

CONCLUSION AND RECOMMENDATION

Conclusion

From the present investigation, it is observed that the engineering behavior of expansive soils studied compares very well with that of similar soils from other parts of Africa.

1) An ideal classification system for tropical expansive soils. Using the ordinary plasticity chart (after Casagrande), most expansive soils fall into the CH group i.e. inorganic clays of high plasticity. This chart is therefore inadequate for classifying expansive soils since it does not distinguish between various types of these clays. The modified plasticity chart, shown in Figure 4.1, on the other hand, has more division along the liquid limit ordinate and thus provides .
2) The Sample taken from Three Site All the analyzed soil samples had free swell index of
3) more than 50%, thus it can be concluded that all the samples had very high expansive potential.

Recommendation

1) It has been established that the engineering behavior of expansive soils is mainly influenced by the plasticity states, which may respectively be assumed to be represented by the index of plasticity and the dry density. Efforts should be made to establish a meaningful soils correlation between the shear strength, index of plasticity and dry density with stress history of expansive.
2. It is recommended that more triaxial tests be done using the principles of partial saturation with direct negative pore water pressure measurement.
3. More research on groundwater effects, interaction between moisture migration, climate and swelling potential of the soils is required.

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