UNIVERSITY OF GAZIANTEP
GRADUATE SCHOOL OF
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AN INVESTIGATION OF SWELLING BEHAVIOR OF RESIDUAL CLAY IN GAZIANTEP KARATAS REGION

A MASTER PROJECT
IN
CIVIL ENGINEERING

BY
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An Investigation of Swelling Behavior of Residual Clay in Gaziantep Karataş Region

M. Sc. Thesis
in
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Supervisor
Assoc. Prof. Dr. Hanifi ÇANAKÇI

by

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ABSTRACT

AN INVESTIGATION OF SWELLING BEHAVIOR OF RESIDUAL CLAY IN GAZIANTEP KARATAS REGION

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M.Sc. in Civil Eng.
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In civil engineering, using all kinds of natural materials in constructions, such as industrial buildings, railways, roads etc. is an important and economical issue. From this point of view, one of the main problems is the uses of clayey materials, which are known as being very sensitive to water content variations. It has been shown that such materials e.g. clay can be the source of short-term and long-term disorders in road or railway structure, thus generating non negligible maintenance costs. The swelling of clays in constructions, mentioned above, is one of the phenomena related to these disorders. Soil swelling deformations are mainly depended on the following parameters. The nature of soils (clay fractions, mineralogy etc), dry density, water content, and amount of water intake.

This proposed study focuses on effect of a aforementioned parameters on swelling behavior of Gaziantep residual soils in Karatas region. For this study two samples were taken. These regions are Karatas and Gaziantep University Campus. Campus sample was taken to compare the results with Karatas samples. Free swell and swell pressure of soil will be determined in the laboratory using standard test procedures.

Keywords: clay, swell, swell pressure, water content

ÖZET

GAZİANTEP KARATAŞ BÖLGESİNDEKİ RESİDUAL KİLLERİNİN ŞİŞME DAVRANIŞLARININ İNCELENMESİ

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İnşaat mühendisliğinde, yapılarda tüm doğal malzeme çeşitlerinin yapılarda kullanılması örneğin, endüstriye binalar, demiryollarıi karayolları v.s.önemli ve ekonomik sorunlardır.. Bu noktadan bakıldığında, temel problemlerden biri su muhtevası varyasyonlarında çok hassas olarak bilinen killi malzemelerin kullanımıdır. Bu da gösterir ki, karayolları ve demiryollarında kısa ve uzun süreli düzensizliklerin kaynağı olabilen şişen malzemelerin örneğin kil, gözardı edilemeyen bakım maliyetleri doğurur. Yapılarda bu malzemelerin şişmesi,bu düzensizliklere bağlı fenomenlerden biridir. Zemin şişme deformasyonları temel olarak aşağıdaki parametrelere bağlıdır, zeminin cinsi, kuru yoğunluk, su muhtevası ve içindeki su miktarı.

Bu çalışma, Gaziantep Karataş bölgesindeki residual killerinin şişme davranışlarının önceden bahsedilen prametlerin etkileri üzerine yapılmıştır. Bu çalışma için iki numune alınmıştır. Bu bölgeler Karataş ve Gaziantep Üniversitesi Kampüsüdür. Kampüs numunesi Karataş Numunesi ile karşılaştırılmak için alınmıştır. Zeminin serbest şişme ve şişme basıncı standart test prosedürleri kullanılarak labaratuarlada belirlenecektir.

Anahtar kelimeler; kil, şişme, şişme basıncı, su muhtevası

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Finally, I would like to thank all those whom give support during my master thesis.

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LIST OF SYMBOLS

LL	liquid limit
PL	plastic limit
PI	plasticity index
W_{opt}	optimum water content
γ_{max}	maximum unit weight
γ_{dry}	dry unit weight
D	diameter of ring (odometer apparatus)
h	height of ring (odometer apparatus)
A	area of ring (odometer apparatus)
W_{dry}	dry weight
W_{water}	water weight
$P_{swelling}$	swell pressure
S_f	free swell

CHAPTER 1

INTRODUCTION

1.1 General

Soils that exhibit volume change from variations in soil moisture are referred to expansive or clayey soils. In case of a structure rested on expansive soil (which are present in many parts of the world) though are expected to have volumetric changes in presence of water, because of its presence, this volume increase (swell) is prevented and as a consequence, leads to swelling pressure. This swelling pressure has serious consequence in the form of crack and distress on the structures founded on expansive soils. Lightweight structures are severely affected due to high swelling pressure exerted by these soils.

For an engineered construction activity on expansive on expansive soils, the first step is to assess the degree of expansiveness and the likely swelling pressure on the structure. Swelling pressure is defined in many ways and is dependent on the testing procedure. To assess the degree of swell, many procedures, both simple and elaborate including laboratory methods of determining swell pressure have been developed by geotechnical researchers and engineers.

The understanding, modeling and prediction of interaction of clays with water and other environmental fluids is an important issue in the field of geotechnical engineering. The swelling response of montmorillonite clay and corresponding development of swelling pressure when swelling is restrained is a result of fairly complex clay-water interactions between particles and within the particles itself. A lot of civil engineers are working hard for solutions of swelling problems. Swelling soils are dangerous for construction areas. It causes soil flood, hazards to buildings etc. Construction industry has used tire particles in recent years especially to improve the concrete and soil properties.

Changes in the moisture content of clay soils are generally accompanied by volume changes. On moisture uptake there is generally a volume increase and moisture loss is accompanied by shrinkage Gillott, (1968). Expansion of soils is generally observed in unsaturated clays which are of certain mineralogical structures (eg. Smectites). Such soil shave a high capacity of water absorption thus they absorb water meanwhile their volume increase. Expansive soils are generally abundant in the arid or semi-arid regions where the rate of evaporation is much higher than rate of precipitation. In Turkey, climatic conditions of Central Anatolia and Southeastern Anatolia regions may favor the formation of such soils . There are many definitions of expansive soils. Expansive soil is a term generally applied to any soil that has a potential for shrinking and swelling under changing moisture conditions Nalbantoğlu and Güçbilmez, (2002). An expansive soil will shrink when water (or moisture) content is reduced and will swell when the water content increases.

As mentioned earlier, expansive soils swell when given access to water and shrink when they dry out. The moisture may come from rain, flooding, leaking water from sewer lines or from reduction in surface evapotranspiration when an area is covered by a building or pavement. Soils containing the clay mineral montmorillonite (a smectite) generally exhibit high swelling properties Wayne,(1984), Komine and Ogata, (1996). There are many correlations that are useful for identifying potentially expansive soils. It is also possible to identify them visually.

Visual indications may be Wayne, (1984).

1- Wide and deep shrinkage cracks occurring during dry periods,
2- Soil is rock-hard when dry, but very stiff and sticky when wet,
3- Damages on the surrounding structures due to expansion of soil.

The swelling and shrinkage phenomenon depends on several factors, including type and amount of clay minerals and cations, moisture content, dry density, soil structure, and loading conditions Al- Rawas, (2002).

Expansive soils cause more damage to structures, particularly light buildings and pavements, than any other natural hazard, including earthquakes and floods in USA.

Expansive soils are a worldwide problem that poses several challenges for civil engineers. They are considered a potential natural hazard, which can cause extensive damage to structures if not adequately treated Al-Rawas, (2002). The movement of swelling may exert enough pressure to crack sideways, driveways, basement floors, pipelines and even foundations. Thus, it is very important that studies be done in order to limit the hazards caused by expansive soils.

Gaziantep is the one of the biggest industrial city in Turkey and industry improves from day to day. Construction on this residual soil causes some disorders such as settlement for better understanding of swelling behavior of Gaziantep residual clays. This will be used to prevent source of short-term and long-term disorders on structure. This way non negligible maintenance costs can be reduced or minimized.

In this thesis, two different type of soil were used. One of them was taken from Karatas which is the new placement part of Gaziantep, the other type of soil was taken from Gaziantep University Campus. For each type of soil five set of tests were carried out to determine the free swell and swell pressure. And then according to the test results some additives such as lignin and waste plastic were added. The effects of additives on free swell and swell pressure were observed.

1.2 Aim and Objectives

This thesis is seeking to investigate the swelling behavior of Gaziantep residual clay. The result of this thesis, we hope to find some solutions to reduce or minimize the disorders about constructions.

The purpose of this thesis is to investigate the swelling behavior of Gaziantep residual clays and improve it by using some additives.

Objective of this study can be described as,

- To determine the free swell and swell pressure
- Adding some additives to reduce the swelling potential of clay

1.3 Organization of the Thesis

The thesis is divided into six chapters, which are arranged as follows.

General information about clay, properties and classification, formation, clay structure, clayey soils etc., was given in chapter 2.

Chapter 3 describes mechanism of swelling and factors affecting swelling on clayey or expansive soil.

In chapter 4, how to measure swelling properties was determined. And odometer that is used to determine swelling and its apparatus was explained.

The test results of free swell and swell pressure of the samples taken from Karatas and Gaziantep University Campus are presented and effects of additives also presented.

In the last chapter, the conclusions drawn from this research work and the recommendations for the future study are given.

CHAPTER 2

CLAY

Clay is common name for a number of fine-grained earthy materials. It become plastic when it was wetted. Chemically, clays are hydrous aluminum silicates, ordinarily containing impurities, e.g., potassium, sodium, calcium, magnesium, or iron, in small amounts.

2.1. Prosperities and Classification

Properties of the clays include plasticity, shrinkage under firing and under air drying, fineness of grain, color after firing, hardness, cohesion, and capacity of the surface to take decoration. On the basis of such qualities clays are variously divided into classes or groups; products are generally made from mixtures of clays and other substances. The purest clays are the china clays and kaolins. “Ball clay” is a name for a group of plastic, refractory (high-temperature) clays used with other clays to improve their plasticity and to increase their strength. Bentonites are clays composed of very fine particles derived usually from volcanic ash. They are composed chiefly of the hydrous magnesium-calcium-aluminum silicate called montmorillonite.

Individual clay particles are always smaller than 0.004 mm. Clays often form colloidal suspensions when immersed in water, but the clay particles flocculate (clump) and settle quickly in saline water. Clays are easily molded into a form that they retain when dry and they become hard and lose their plasticity when subjected to heat.

2.2. Formation

Clays are divided into two classes: residual clay, found in the place of origin, and transported clay, also known as sedimentary clay, removed from the place of origin by an agent of erosion and deposited in a new and possibly distant position. Residual clays are most commonly formed by surface weathering, which gives rise to clay in three ways by the chemical decomposition of rocks, such as granite, containing silica and alumina; by the solution of rocks, such as limestone, containing clayey impurities, which, being insoluble, are deposited as clay; and by the disintegration chemical decomposition of feldspar.

Clay consists of a sheet of interconnected silicates combined with a second sheet like grouping of metallic atoms, oxygen, and hydroxyl, forming a two-layer mineral such as kaolinite. Sometimes the latter sheet like structure is found sandwiched between two silica sheets, forming a three-layer mineral such as vermiculite. In the lithification process, compacted clay layers can be transformed into shale. Under the intense heat and pressure that may develop in the layers, the sale can be metamorphosed into slate.

2.3. Clayey Soil

A clayey soil is though distinguished by the color which it bears, namely black, white, yellow and red, differs from all other soils, being tough, wet, and cold, and consequently requiring a good deal of labor from the husbandman before it can be sufficiently pulverized, or placed in a state for bearing artificial crops of corn or grass. Clay land is known by the following qualities, or properties.

It holds water like a cup, and once wetted does not soon dry. In like manner, when thoroughly dry, it is not soon wetted; if we except the varieties which have a thin surface, and are the worst of all to manage. In a dry summer, clay cracks and shows a surface full of small chinks, or openings. If ploughed in a wet state, it sticks to the plough like mortar, and in a dry summer, the plough turns it up in great clods, scarcely to be broken or separated by the heaviest roller.

2.4. Clay Structure

Clay minerals are hydrous aluminium phyllosilicates, sometimes with variable amounts of iron, magnesium, alkali metals, alkaline earths and other cations. Clays have structures similar to the micas and therefore form flat hexagonal sheets. Clay minerals are common weathering products (including weathering of feldspar) and low temperature hydrothermal alteration products. Clay minerals are very common in fine grained sedimentary rocks such as shale, mudstone and siltstone and in fine grained metamorphic slate and phyllite.

Hydrated alumino-silicate weathered from feldspars.

- (Si_2O_5) layer of SiO_4^{2-} tetrahedrons joined at corners
- $AlO(OH)_2$ layer of octahedral arrangement of O and OH around the Al
- Layers connected by O^{2-} ions which are shared by the layers
- Substitutions of Mg^{2+} for Al^{3+} in the AlO(OH) layer gives the layer an overall negative charge.
- Charges balanced by cations that insert between layers: Ca^{2+}, K^+, Na^+

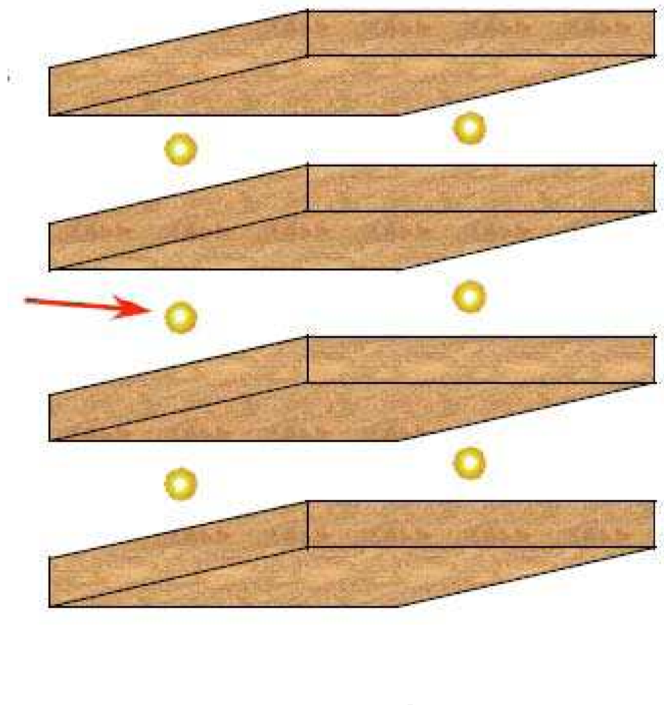

Figure 2.1. Clay Structure

It is well known that at least two definitions of clay exist. The geotechnical definition depicts as *clay* those particles that have an effective diameter smaller than 0.002 mm. Mineralogists on the other hand define clay as particles formed by polimeric chains of some 3 specific mineral, while no size restrictions are given. As a consequence, not all the soil particles with a diameter < 0.002 mm are mineralogically clays, nor clay minerals have to be smaller that 0.002 mm Musso,(2000).

The basic units of which the clays are made are Silica (SiO_2) tetrahedral sheets and Aluminum (Al) or Magnesium (Mg) Oxides octahedral sheets. Sheets can combine in different ways, so as to form layers of different minerals. In most clay mineral structures, the silica tetrahedra are interconnected in a sheet structure. Three of the four oxygens in each tetrahedron are shared to form a hexagonal net as shown in figure 2.1. The bases of the tetrahedra are all in the same plane, and the tips all point in the same direction. The structure can repeat indefinitely and has the composition $(Si_4O_{10})^{4-}$ Mitchell, (1993).

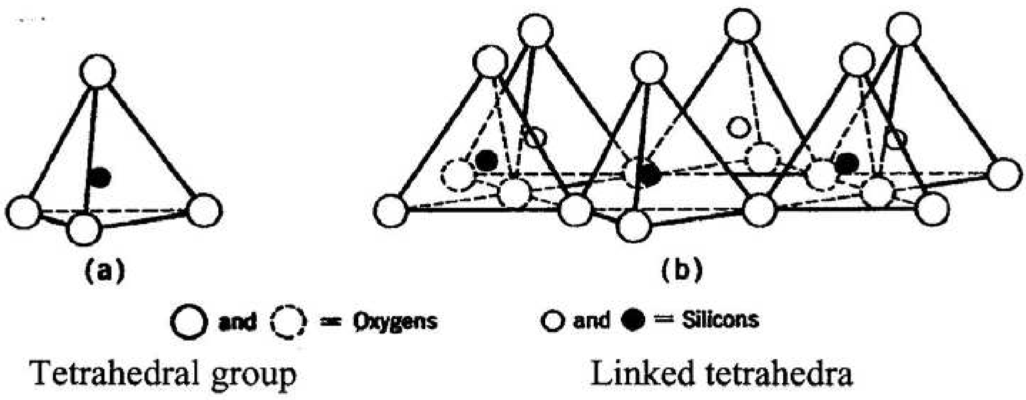

Figure 2.2 Silica Tetrahedron and Layer (after Grim, 1953)

In a sharp notation, useful for schematic representation of mineral layers, the silica sheet is identified as Figure 2.3

Figure 2.3 Scheme for the Silica sheet (after Craig, 1992)

The octahedral sheet is composed of magnesium or aluminum coordinated octahedrally with oxygens and hydroxyls. The coordination of Aluminum or Magnesium atoms with oxygens or hydroxils gives rise to structural units with an octahedral shape. Octahedrons, as for tetrahedrons, have the capacity to join in sheets. Depending on the charge of the main cation (Al^{3+}, Mg^{2+}) the distinction between dioctahedrals and trioctahedrals structures is made Mitchell, (1993).

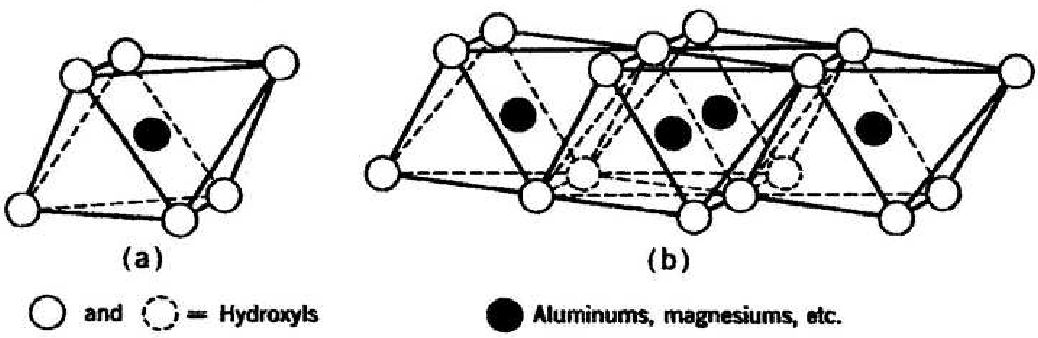

Figure 2.4 Octahedron and Octahedral Sheet (after Grim, 1953)

Those cations have to balance the negative electrical charge of the octahedral arrangement of oxygens and hydroxyls, equal to two electrons per unit. Therefore while the Magnesium ion needs to be present in every unit, the Aluminum ion will be required just in two cells over three. The mineralogical name for the Aluminum sheet is Gibbsite, the one for Magnesium is Brucite. Schematic representations are shown in figure 2.4.

Figure 2.5 Schemes for Gibbsite and Brucite .

The various clay minerals are formed by the stacking combinations of basic sheet structures with different forms of bonding between the combined sheet.

The main clay minerals are;

1. Kaolinite
2. Illite
3. Montmorillonite

2.5. Kaolinite

Kaolinite is a clay mineral with the chemical composition Al2Si2O5(OH)4. It is a layered silicate mineral, with one tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina octahedra. Rocks that are rich in kaolinite are known as china clay or kaolin.

Kaolinite consists of a structure based on a single sheet of silica tetrahedrons combined with a single sheet of alumina octahedrons as shown in figure 2.5. The combined silica-alumina sheets are held together fairly tightly by hydrogen bonding, thus a kaolinite particle may consist of over one hundred stacks.

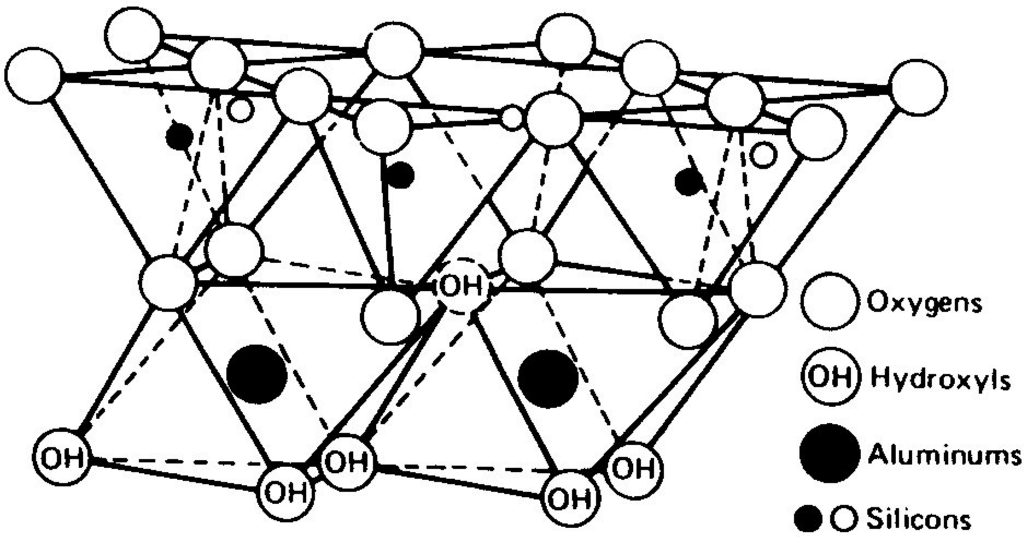

Figure 2.6 Diagrammatic Sketch of the Structure of Kaolinite.

2.6.Illite

Illite is a non-expanding, clay-sized, micaceous mineral. Illite is a phyllosilicate or layered alumino-silicate. Its structure is constituted by the repetition of Tetrahedron – Octahedron – Tetrahedron (TOT) layer. The interlayer space is mainly occupied by poorly hydrated potassium cations responsible for the absence of swelling. Structurally illite is quite similar to muscovite or sericite with slightly more silicon, magnesium, iron, and water and slightly less tetrahedral aluminum and interlayer potassium. The chemical formula is given as $(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$, but there is considerable ion substitution. It occurs as aggregates of small monoclinic grey to white crystals. Due to the small size, positive identification usually requires x-ray diffraction analysis. Illite occurs as an alteration product of muscovite and feldspar in weathering and hydrothermal environments. It is common in sediments, soils, and argillaceous sedimentary rocks as well as in some low grade metamorphic rocks. Glauconite in sediments can be differentiated by x-ray. (Figure 3.1)

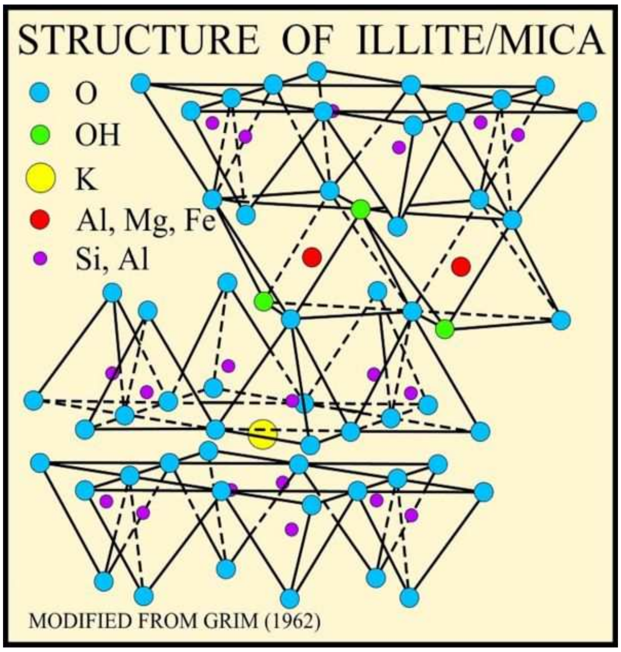

Figure 2.7 Structure of illite

Illite has a basic structure consisting of a sheet of alumina octahedrons between and combined with two sheets of silica tetrahedrons as shown in figure 2.6. The combined sheets are linked together by fairly weak bonding due to (non-exchangeable) potassium ions held between them.

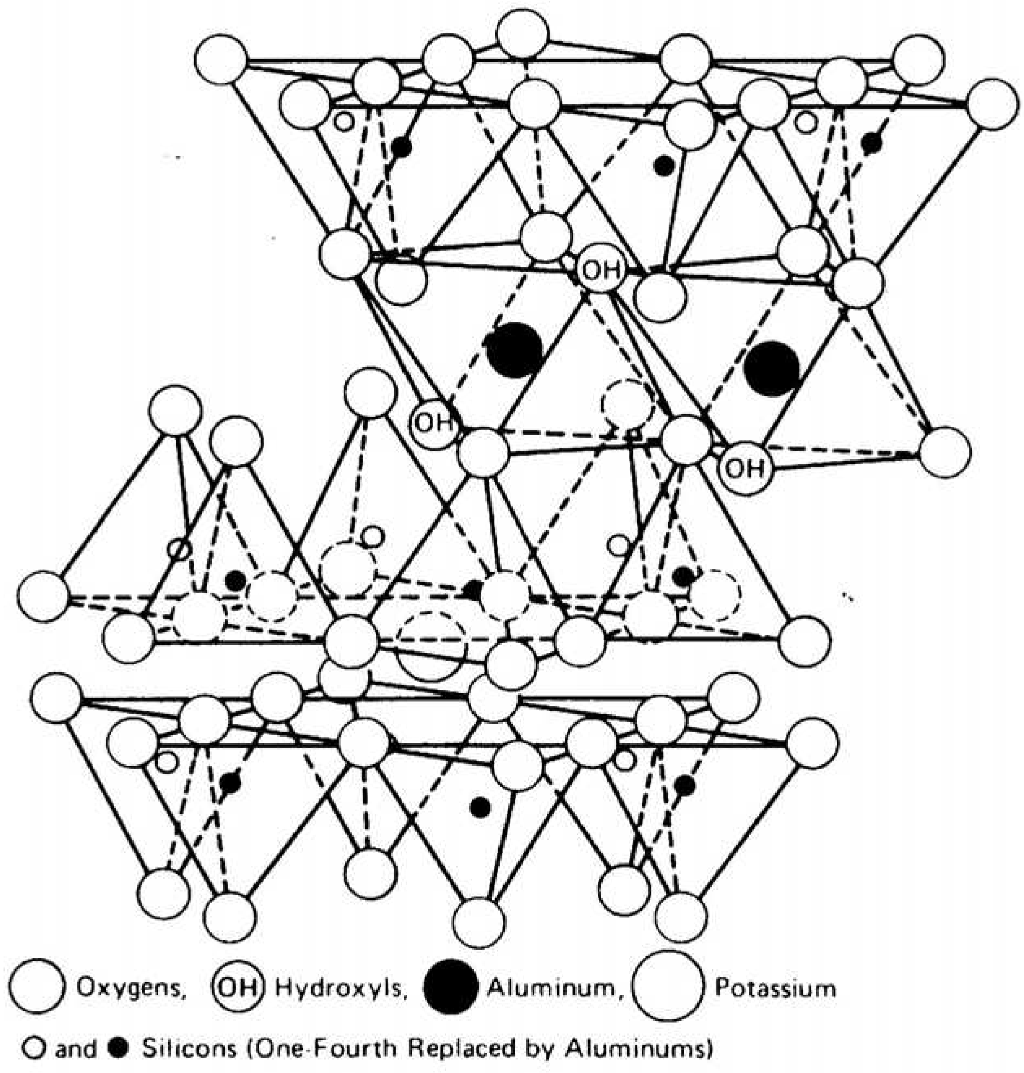

Figure 2.8 Structure of illite

2.7.Montmorillonite

Montmorillonite is a very soft phyllosilicate mineral that typically forms in microscopic crystals, forming a clay. It is named after Montmorillon in France. Montmorillonite, a member of the smectite family, is a 2:1 clay, meaning that it has 2 tetrahedral sheets sandwiching a central octahedral sheet. The particles are plate-shaped with an average diameter of approximately 1 micrometre.

It is the main constituent of the volcanic ash weathering product, bentonite.

Montmorillonite's water content is variable and it increases greatly in volume when it absorbs water. Chemically it is hydrated sodium calcium aluminum magnesium silicate hydroxide $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$. Potassium, iron, and other cations are common substitutes, the exact ratio of cations varies with source. It often occurs intermixed with chlorite, muscovite, illite, cookeite and kaolinite. (Figure 3.2)

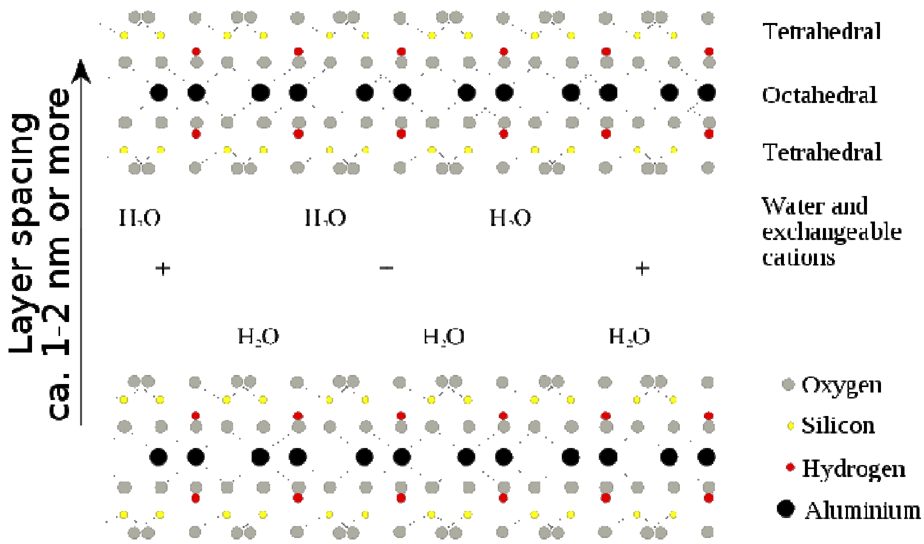

Figure 2.9 Structure of montmorillonite

Montmorillonite has the same basic structure as illite as shown in figure 2.7. In the octahedral sheet there is partial substitution of aluminum by magnesium. The space between the combined sheets is occupied by water molecules and (exchangeable) cations other than potassium. There is a very weak bond between the combined sheets due to these ions. Considerable swelling of montmorillonite can ocur due to additional water being absorbed between the combined sheets.

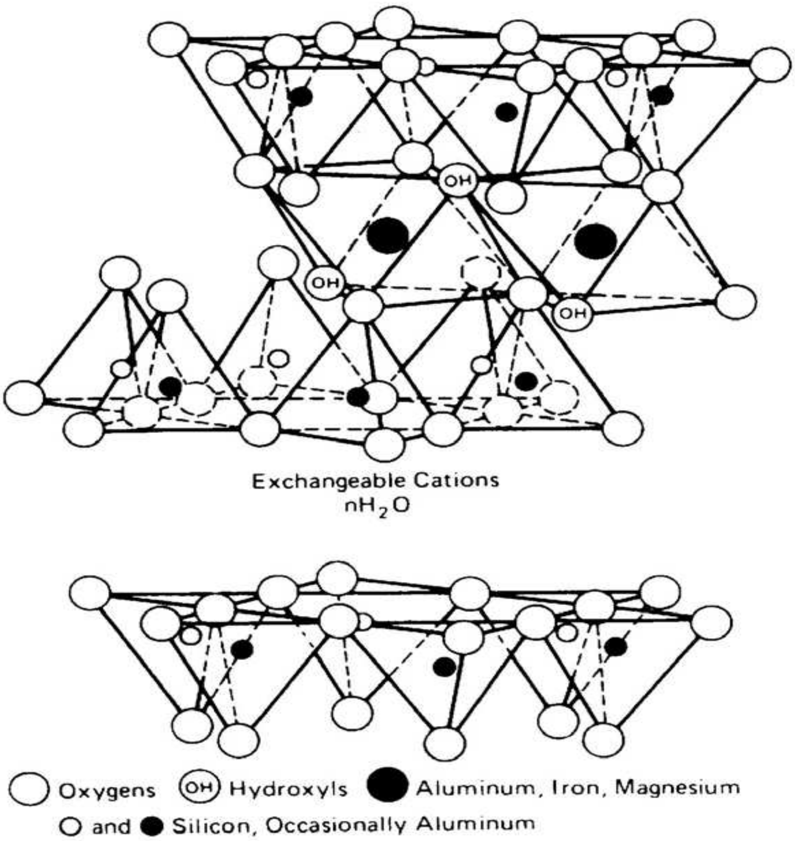

Figure 2.10 Structure of Montmorillonite

Schemes for the basic clay minerals are shown on figure 1.8

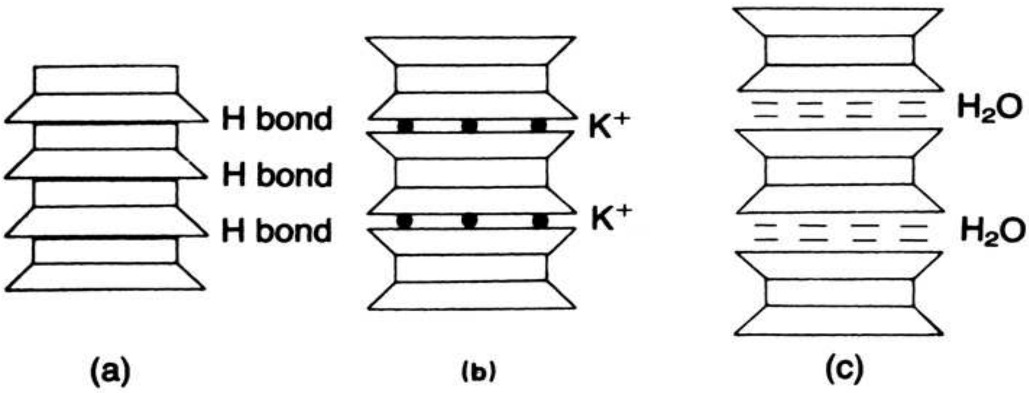

Figure 2.11 Schemes for a) Kaolinite b) Illite c) Montmorillonite

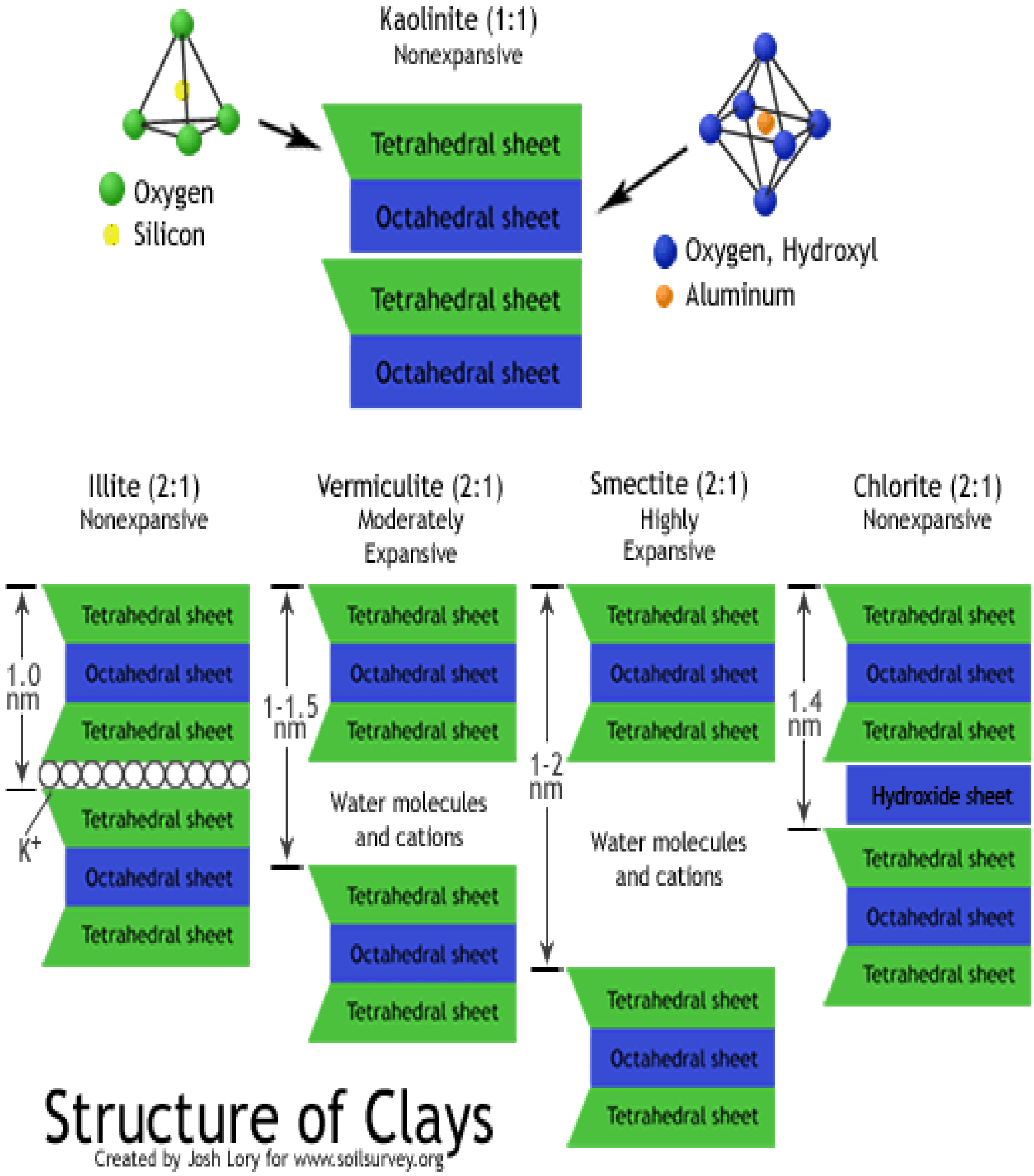

Figure 2.12 Structure of Clays

CHAPTER 3

MECHANISM OF SWELLING

3.1 General

There are two basic mechanisms involved in swelling phenomena:

1. Interparticle or intercrystalline swelling, shown diagrammatically, which is effective for all kinds of clay minerals. In a nearly dry clay deposit relict water holds the particles together under tension from capillary forces. On wetting, the capillary tensions are relaxed and the clay expands. The effect is the same whether the clay has the form of particles as shown in the upper part of the figure or of crystals as shown in the middle part. The short dashes in the figure which link the layers of the clay crystals imply that the layers are strongly bonded by molecular forces.

2. Intracrystalline swelling is chiefly a characteristic of the montmorillonite group of minerals. The layers that make up the individual single crystals of montmorillonite are weakly bonded, mainly by water in combination with exchangeable cations. On wetting, water enters not only between the single crystals, but also between the individual layers that make up the crystals .

In montmorillonites the interlayer cations become hydrated, and the large hydration energy involved is able to overcome the attractive forces between the unit layers. Since in the prototype minerals interlayer cations are absent, there is no cation hydration energy available to separate the layers. Cernica, (1995)

There can be two reasons of intracrystalline swelling: Clay particles are generally platelets having negative charges on their surfaces and positively charged edges. Cations in the soil water attach to the surfaces of the platelets and the negative charges on the surfaces of clay particles. The unbalanced electrostatic charges on clay-particle surfaces draw water molecules into the area between silicate sheets and force the sheets apart.

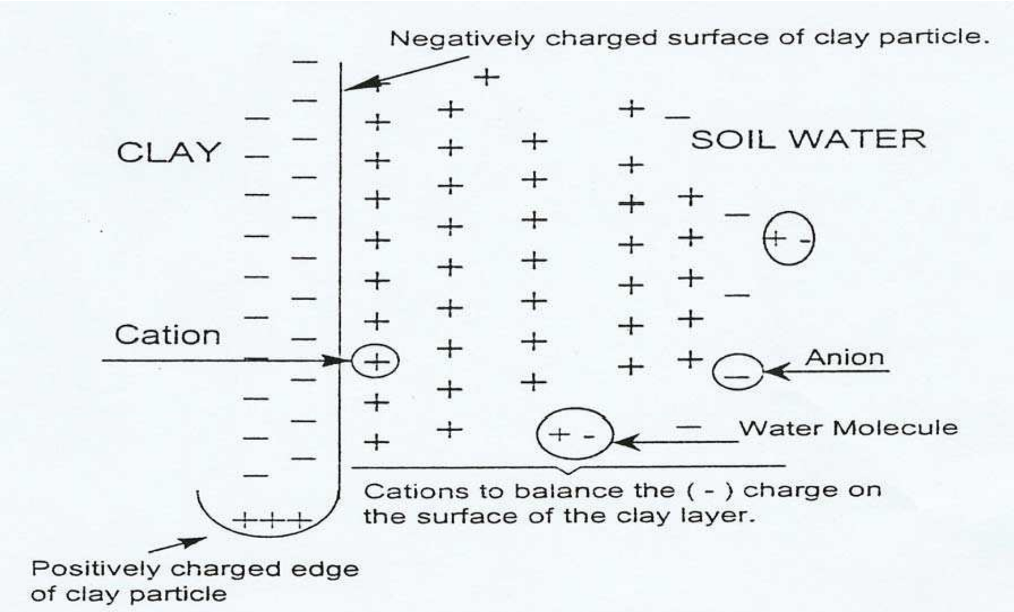

Figure 3.1 Force sheet

The other factor is provided by cations attracted to the clay surfaces. Due to the attraction of negatively charged clay surfaces for the cations, the concentration of cations between the clay-particle surfaces is higher than the concentration of cations in the pore fluid. This creates an osmotic potential difference between the pore fluid and clay-mineral surfaces. In the actual case cations should migrate from the intracrystalline spacing (higher potential) to the intracrystalline spacing (lower potential) to equalize the cation concentration. But due to the attraction of clay surfaces, cations cannot move and water moves into the area between clay-mineral surfaces. Due to this condition a repulsive force is exerted on the clay-mineral surfaces and the volume of clay soil increases.

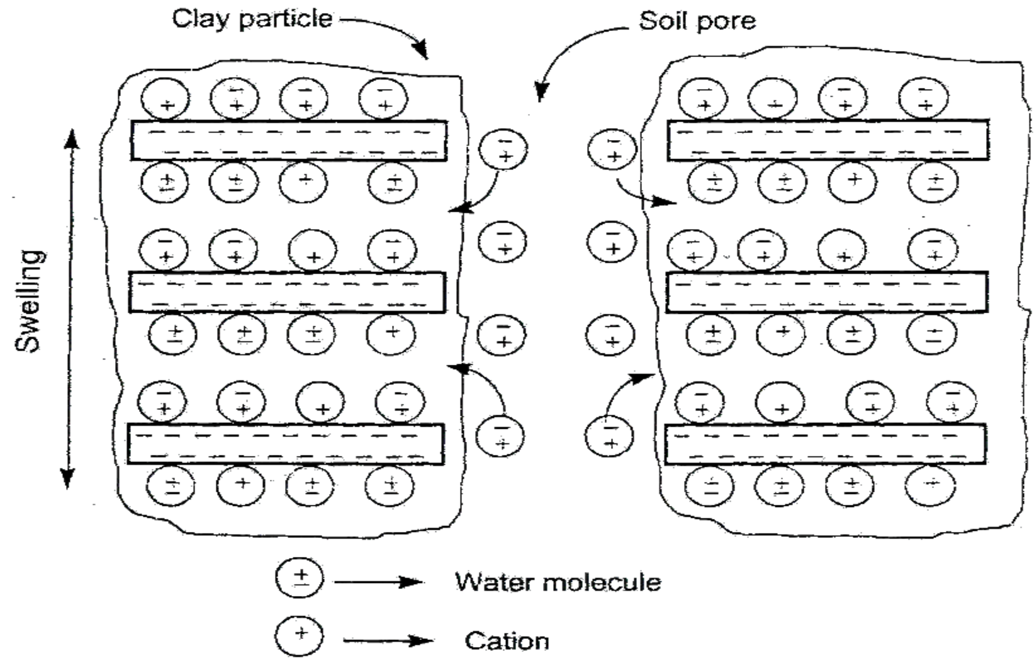

Figure 3.2 Effect of cations to swelling

3.2 Factors Affecting Swelling of Soils

Nelson and Miller (1992) had made some research on expansive soils. According to these results factors affecting swelling soil were determined in three main groups. These are soil characteristics (Table 3.1), environmental factors (Table 3.2), and the state of stress (Table 3.3)

Table 3.1 Soil Properties Influencing Swelling Potential of Soils

FACTOR	DESCRIPTION
Clay Content and Mineralogy	Clay minerals which typically cause soil volume changes are montmorillonites, vermiculates, and some mixed layer clay minerals. Swelling potential increases with the increasing amount of such clay minerals.
Soil Water Chemistry	Swelling is repressed by increased cation concentration and increased cation valance. For example, Mg^{+2} cations in the soil water would result in less swelling than Na^{+} cations.
Soil Structure and Fabric	Flocculated clays tend to be more expansive than dispersed clays. Cemented particles reduce swell.
Initial Dry Density	Higher densities indicate closer particle spacings which mean greater repulsive forces between particles and larger swelling potential.
Initial Water Content	As the initial water content increases, the initial degree of saturation will also increase and the affinity of soil to absorb water will decrease, so the amount of swelling will decrease.
Fine Grained Fraction	As the amount of fine particles increase, the amount of swelling will increase due to the larger surface area.
Plasticity Index	In general, soils that exhibit plastic behavior over wide ranges of moisture content and that have high liquid limits have greater potential for swelling. Plasticity index is an indicator of swelling potential.

Table 3.2 Environmental Conditions Influencing the Swelling Potential of Soils

FACTOR	DESCRIPTION
Climate	Amount and variation of precipitation and evapotranspiration greatly influence the moisture availability and depth of seasonal moisture fluctuation. Greatest seasonal heave occurs in semiarid climates that have short wet periods.
Groundwater	Shallow water tables provide a source of moisture and fluctuating water tables contribute to moisture content of soils.
Drainage	Poor surface drainage leads to moisture accumulations or ponding.
Vegetation	Vegetation (trees, shrubs, grasses, etc.) deplete moisture from the soil through transpiration, and cause the soil to be differentially wetted in areas of varying vegetation.
Permeability	Soils with higher permeabilities, particularly due to fissures and cracks in the field soil mass, allow faster migration of water and promote faster rates of swell.
Temperature	Increasing temperatures cause moisture to diffuse to cooler areas beneath pavements and buildings.

Table 3.3 Stress Conditions Influencing the Swelling Potential of Soils

FACTOR	DESCRIPTION
Stress History	An overconsolidated soil is more expansive than the same soil at the same void ratio, but normally consolidated.
Loading	Magnitude of surcharge load determines the amount of volume change that will occur for a given moisture content and density. An externally applied load acts to balance interparticle repulsive forces and reduces swell.
Soil Profile	The thickness and location of potentially expansive layers in the profile considerably influence potential movement.

3.3 Types of Expansive Soil Movement

3.3.1. Lateral Movement

Expansive soil movement can affect all types of civil engineering projects. For many retaining and basement walls, especially if the clay backfill is compacted below optimum moisture content, seepage of water into the clay backfill causes horizontal swelling pressure well in excess of at-rest values. measured the swell pressure of a compacted clay for zero lateral strain to be 420 Kpa . Besides the swelling pressure induced by the expansive soil, there can also be groundwater or perched water pressure on the retaining or basement wall because of the poor drainage of clayey soils. Because of these detrimental effects of clay backfill, a common recommendation is to use only free-draining granular material as retaining or basement wall backfill.

3.3.2. Vertical Movement

If a structure having a large area, such as a pavement or foundation, is constructed on top of a desiccated clay, there are usually two main types of expansive soil movement:

1.Cyclic heave and shrinkage. The first type of expansive soil movement is cyclic heave and shrinkage which commonly affects the perimeter of the foundation, by uplifting the edge of the structure or shrinking away from it.

Clays are characterized by their moisture sensitivity. They will expand when given access to water and shrink when they are dried out. A soil classified as having a "very high" expansion potential will swell or shrink much more than a soil classified as "very low" expansion potential. For example, the perimeter of a pavement or slab-on-grade foundation will have during the rainy season and the settle during the drought if the clay dries out. This causes cycle of up and down movement, causing cracking and damage to the structure. Field measurements of this up and down cyclic movement have been recorded.

The amount of cyclic heave and shrinkage depends on the change in moisture content of the clays below the perimeter of the structure. The moisture change in turn depends on the severity of the drought and rainy season, the influence of drainage and irrigation, and the presence of live tree roots, which can extract moisture and cause clays to shrink. The cyclic heave and shrinkage around the perimeter of a structure is generally described as a seasonal or short-term condition.

2. Progressive swelling beneath the center of the structure (center lift). Two ways that moisture can accumulate underneath structures are by thermal osmosis and capillary action. It has been stated that water at a high temperature than its surrounding will migrate in the soil toward the cooler area to equalize the thermal energy of the two areas Chen, (1988: Nelson and Miller, (1992). This process has

been termed “thermal osmosis” Sowers, 1979; Day, (1996).Especially during the summer months, the temperature under the center of a structure tends to be much cooler then at the exterior ground surface.

Because of capillary action, moisture can move upward through soil, where it will evaporate at the ground surface. But when a structure is constructed, it acts as a ground surface barrier, reducing or preventing the evaporation of moisture. It is the effect of thermal osmosis and the evaporation barrier due to the structure that causes moisture to accumulate underneath the center of the structure. A moisture increase will result in swelling of expansive soils. The progressive heave of the center of the structure is generally described as long-term condition, because the maximum value may not be reached until many years after construction.

CHAPTER 4

MEASUREMENT SWELLING PROPERTIES OF CLAY

Generally, the easiest way of measurement of swelling properties of clays are the Odometer Test Methods. Three different methods are described in ASTM Standards with designation number D 4546-90, namely, Standard Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils. It is essential that the terminology in these methods is clearly understood.

Swell: The increase in elevation or dilation of soil column following absorption of water.

Percent Swell: 100dH/H, where dH is the increase or decrease of vertical height of soil column, and H is the original height of soil column.

Primary Swell: The short term swell that ends at the point of intersection of the tangent of reverse curvature to the curve of a dimensional change vs. logarithm of time plot with the tangent to the straight-line portion representing long-term of, or secondary swell

Secondary Swell: starts at the intersection point of the tangents and ends at the point of completion of the total swell. It is also defined as long-term swell (Figure1.10). As it can be seen on Figure 1.10, there is a slight difference in the amount between the primary and the total swell. In most cases this difference is negligible. Thus, in this study, the term “Swell” refers to “Total Swell” for which the vertical height of the specimen no longer increases with time.

4.1. Odometer Apparatus

A self-contained consolidometer (oedometer) used to conduct swell expansion tests on soil specimens. Set includes: stainless steel base/acrylic ring device with adjustable, dial indicator standard and bracket, a compaction specimen ring, top and bottom porous stones and a 60 psf stainless steel loading weight.

Figure 4.1 Odometer apparatus

The Test Methods in ASTM D4546-90 require that a soil specimen be restrained laterally and loaded axially (vertically) in a consolidometer (oedometer) with access to free water. These methods are summarized as follows.

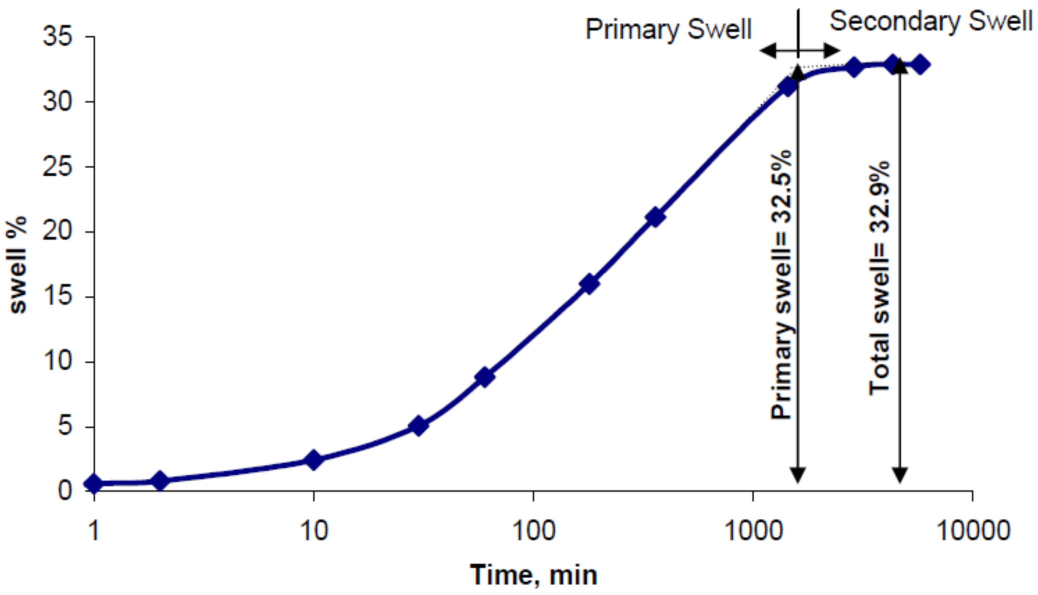

Figure 4.2. Swell versus log time relationship

4.2. ASTM D4546 Test methods

4.2.1. Method A

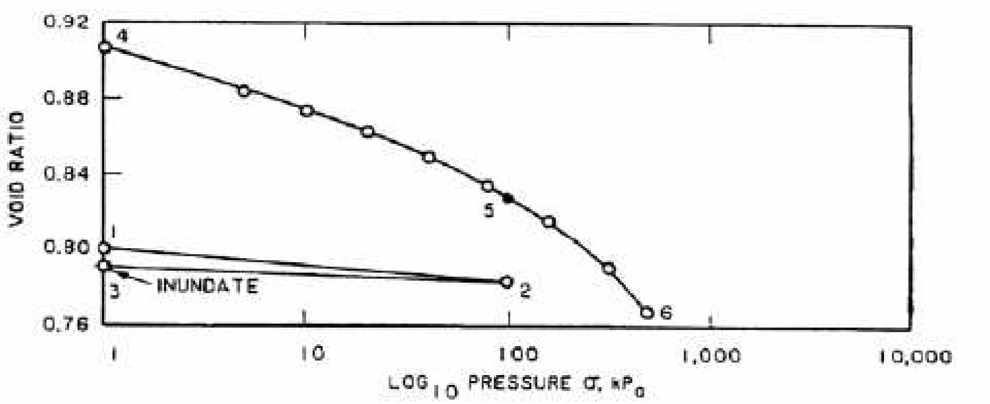

Figure 4.3 An Example Void Ratio-Log Pressure Curve for Method A.
(ASTM D 4546-90, 1993)

The specimen is inundated and allowed to swell vertically at the seating pressure (pressure of at least 1 kPa applied by the weight of the top porous stone and load plate) until the primary swell is complete (Figure 4.2.1.). The specimen is loaded vertically after primary swell has occurred until its initial void ratio/height is obtained (Figure 4.2.1.) This method measures (a) the free swell, (b) percent heave for vertical confining pressures up to the swell pressure, and (c) the swell pressure.

4.3 Sample Preparation and Testing Procedure

4.3.1 Sample Preparation

In this experimental study, two different type of expansive or clayey soil taken from two different region of Gaziantep, which are Karatas and Gaziantep University Campus. Firstly these samples were sieved from 425 micron sieve by adding water. Then liquid limit (LL), plastic limit (PL), and plasticity index (PI) of sieved samples were determined. According to these results optimum water content of samples was found. After that, some water add on samples. Amount of water is related to the ring volume which is a part of a oedometer. Then samples were mixed to be made them homogenous.

4.3.2 Testing Procedure

“Free Swell Method” was used to determine the amount of swell. The samples were prepared as outlined and compacted directly into consolidation ring to obtain a bulk density of 1.80 g/cm3. . This value of bulk density with 10%, moisture content gave a dry density of 1.70 g/cm3. The soil samples were placed directly into the consolidation ring, no guide rings were used. In the preliminary studies, the samples were compacted in the guide rings satisfying the specified dry density and later transferred into the consolidation rings. But it was observed that during this transference, the specimens were terribly disturbed. Sometimes cracks were formed on the surfaces of the specimens or some pieces were dropped out from the top and bottom of the specimen. Consequently, in order to avoid further spoilage of specimen it was decided that the samples had to be compacted directly into the consolidation rings.

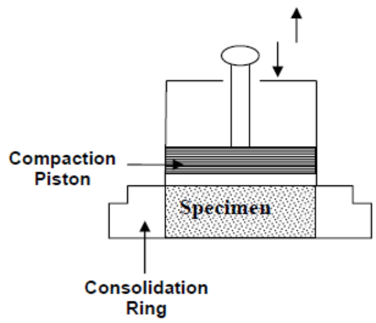

Figure 4.4 Compaction of Specimen into the Consolidation Ring

4.3.2.1. Free Swell Method

The specimen was prepared as explained in section 3.4. The consolidation ring containing the specimen was placed in the oedometer after placing filter papers on the top and bottom of the specimen not to clog the porous stones. An air-dry porous stone was placed on top of the specimen. After the oedometer was mounted on the loading device, the dial gauge measuring the vertical deflection was set to zero (Figure 6.1.1). The specimen was inundated by applying water to the upper surface of the sample directly, and to the lower surface through standpipes. As soon as the specimen was inundated, swelling began. The specimen was allowed to swell freely. Dial gauge readings showing the vertical swell of the specimen were recorded until the swell stopped. These data were used to calculate the time-swell relations and final swell of each sample upon inundation. After the sample stopped swelling, the final water content was determined in accordance with ASTM Test Method with designation number D2435 – 90.

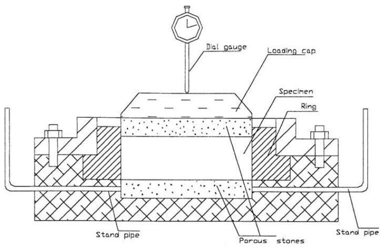

Figure 4.5 Free Swell Apparatus (Oedometer)

Free swell percent was calculated from the following formula:

Free Swell (%) = 100 ΔH/H (Eq. 1)

Where Δ H= Change in initial height (H) of the specimen
H= Initial height of the specimen
The procedure of the tests was as follows; at first the specimens was compacted in the consolidation ring and then the ring was placed into the oedometer after placing dry filter papers on top and bottom of the sample. The consolidation ring was assembled in the oedometer and air-dry porous stone was placed on top of the sample (there had already been one at the bottom of the oedometer.) After the oedometer was mounted on the loading device, the deflection dial was adjusted to zero reading. The sample was inundated by providing water through standpipes and pouring water directly from the top of the oedometer. Swelling of the sample started at the moment the sample was started to be inundated. The tests were finished when there was no change on the dial gauge.

Free swell tests were performed as described above on samples with an initial water content of 10% and having a dry density value of 1.70 g/cm^3 under a small surcharge of about 1.94 kPa. All mixtures which were sieved through No.30 sieve were prepared and compacted in humidity room in order to maintain its initial water content constant.

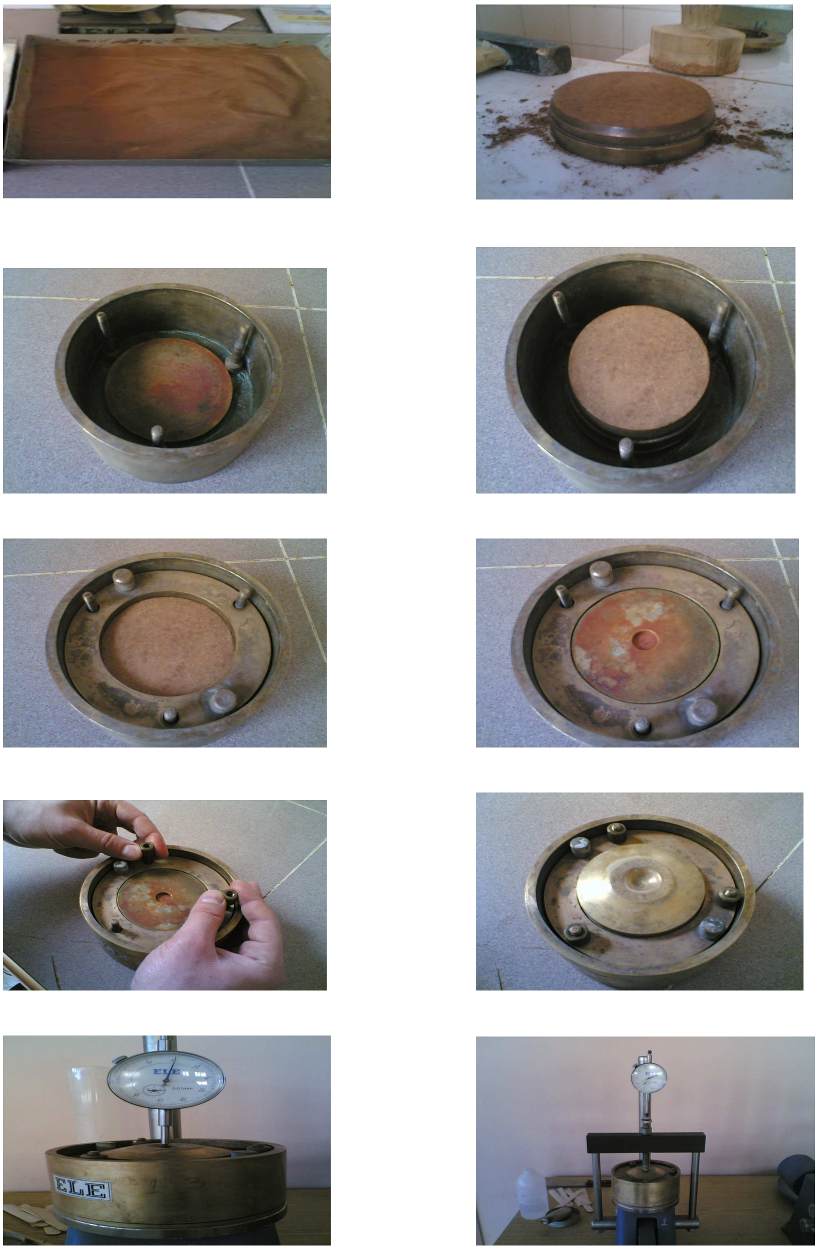

Figure 4.6 Preparation and placing the sample to ring respectively

CHAPTER 5

TEST RESULTS AND DISCUSSION

5.1 General

In this thesis study, two different type of clayey soils that were taken from Karatas and Gaziantep University Campus were used. For each sample three set of tests were carried out. These tests are;

- Samples having optimum water content
- Samples having % 10 dry of optimum water content
- Samples having % 10 wet of optimum water content

At the results of these tests, free swell and swell pressure of some samples were determined. In addition to this, an additive called “lignin” was used to reduce the free swell of residual clays. The lignin was used only for Karatas region sample and effect of this additive on free swell potential was observed.

So many studies were reported in the literature about the free swell and swell pressure of clayey soils. Based on these studies researchers recommended differed cllas,f,cat,on systems. Vijarvergiyav and Ghazzaly ,(1973) developed a chart to determine the percent swell of clay based on natural water content and liquid limit (figure 5.1). Abdyljauvad and Al-Sulaimani (1993) developed a chart to determine the qualification description of clay as low, medium, high, very high and extreme high based on plasticity index and liquid limit (Figure 5.2). O’neili and Poormoayed (1980) developed a table to classify the clay as low, medium and high according to the liquid limit, plasticity index and swell potential (Figure 5.3)

At the end of the tests, the results were compared with this chart and tables, then Gaziantep residual clays were classified.

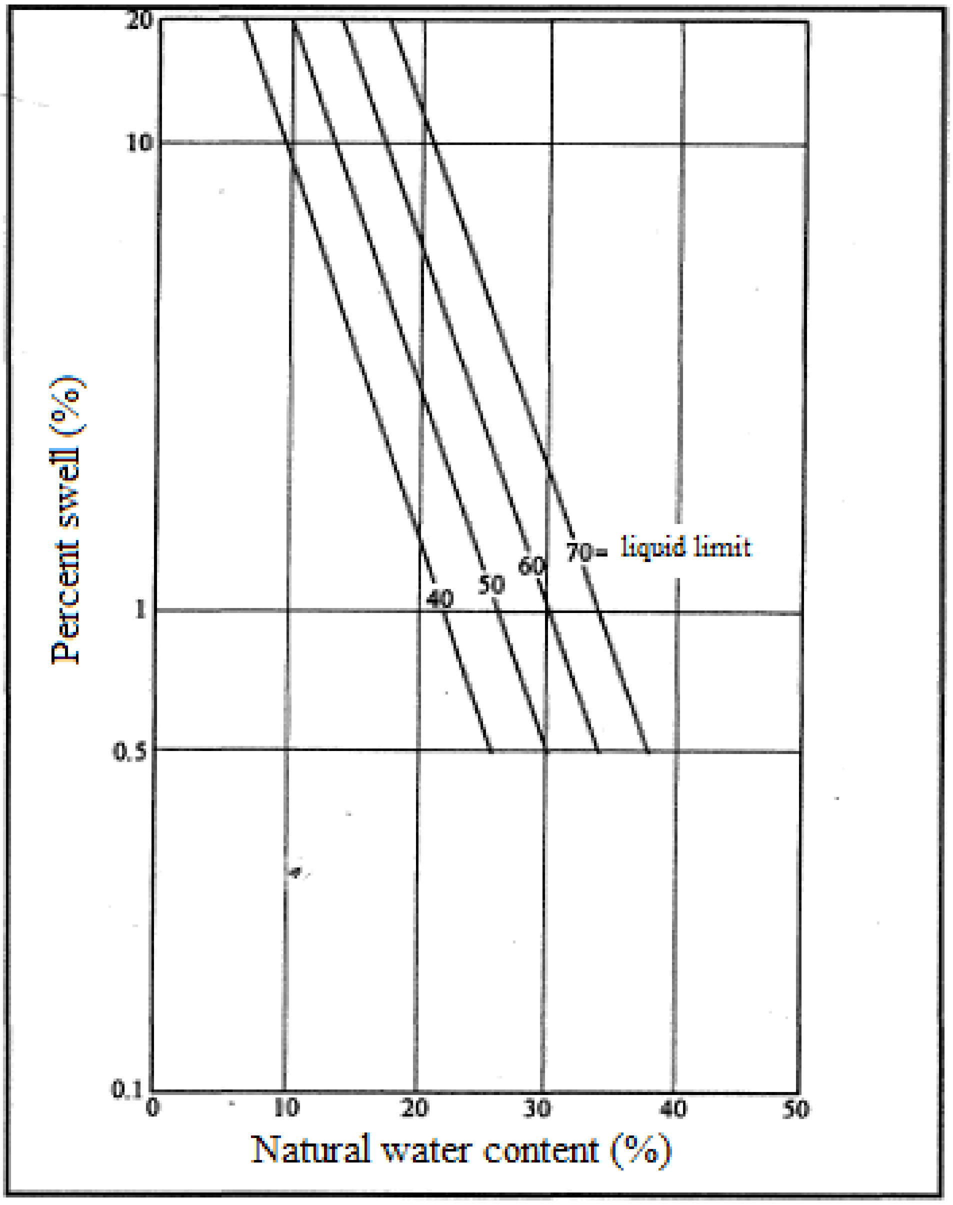

Figure 5.1 Free swell, liquid limit and water content correlation table (Vijarvergiyav and Ghazzaly, 1973)

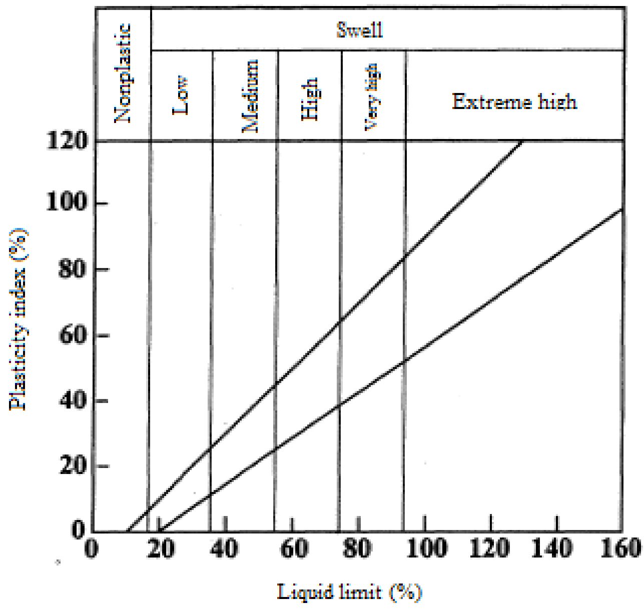

Figure 5.2 Abak used to determine the swell pressure Abdyljauvad and Al-Sulaimani (1993)

Table 5.1 Classifications of soils.

Liquid limit	Plasticity index	Swell potential	Swell potential classification
<50	<25	<0.5	Low
50-60	25-35	0.5-1.5	Medium
>60	>35	>1.5	High

5.2 Data Calculation

5.2.1 Karatas Clay

Karatas region was formed generally basalt. Basalt is a common extrusive volcanic rock. It is usually grey to black and fine-grained due to rapid cooling of lava at the surface of a planet. It may be porphyritic containing larger crystals in a fine matrix, or vesicular, or frothy scoria. Unweathered basalt is black or grey.

In order to determine swelling properties of Karataş residual soil sampale was taken from a vacant parcel (Figure 5.4).

Figure 5.3 Karatas region where the sample taken

The samples were brought to Geotechnical laboratory and Attarberg limit tests were performed on it. Results obtained from the test are given below. Using these test results optimum water content and maximum dry density of the sample soil were determined from empirical equations suggested in the literature. Optimum water content and maximum dry density values were given below.

Swelling properties of the sample soil is determine at its there different water content. These are optimum water content, 10% dry side of optimum, and 10% wet side of optimum. Using phase diagram necessary mass of soil and water were calculated and results are given below.

$LL = 0{,}674$

$PL = 0{,}41$

$PI = 0{,}26$

At Optimum Water Content

$W_{opt} = 6{,}77 + 0{,}43LL - 0{,}21PI$

$W_{opt} = 6{,}77 + 0{,}43 * 67{,}4 - 0{,}21 * 26$

$W_{opt} = 30{,}29 \sim 30\ \%$

$\gamma_{max} = 20{,}48 - 0{,}13LL + 0{,}05PI$

$\gamma_{max} = 13{,}02 \sim 14kN/m^3$

$\gamma_{dry} = \frac{\gamma}{1+Wc} \Rightarrow 14 = \frac{\gamma}{1+0{,}30}$

$\gamma = 18{,}20\ kN/m^3$

$\gamma = 1{,}86\ g/cm^3$

$D = 75\ mm$

$h = 20\ mm$

$RING\ VOLUME = \frac{\pi}{4} * D^2 * \mathrm{h} = 88{,}36\ \mathrm{cm}^3$

$Wet\ Total\ Material = 88{,}36 * 1{,}86 = 164{,}35\ \mathrm{g}$

$W_{dry} = \frac{\mathrm{Wwet}}{1+\mathrm{Wc}} = \frac{164{,}35}{1+0{,}30} = 126{,}42\ g$

$W_{water} = 164{,}35 - 126{,}42 = 37{,}93\ g$

$W_{dry} = 164{,}42\ g$

$W_{water} = 37{,}93\ g$

At 10% Dry Side of Optimum Water Content

$W_{opt} = 0{,}27 \rightarrow 27\ \%$

$\gamma_{dry} = \frac{\gamma}{1+Wc} \Rightarrow 14 = \frac{\gamma}{1+0{,}27}$

$\gamma = 17{,}78\ kN/m^3$

$\gamma = 1{,}81\ g/cm^3$

$RING\ VOLUME = 88{,}36\ \text{cm}^3$

$Wet\ Total\ Material = 88{,}36 * 1{,}81 = 160{,}15\ \text{g}$

$W_{dry} = \frac{\text{Wwet}}{1+\text{Wc}} = \frac{160{,}15}{1+0{,}27} = 126{,}1\ g$

$W_{water} = 160{,}15 - 126{,}1 = 34{,}05\ g$

$W_{dry} = 126{,}1\ g$

$W_{water} = 34{,}05\ g$

At 10% Wet Side of Optimum Water Content

$W_c = 0{,}33 \rightarrow 33\ \%$

$\gamma_{dry} = \frac{\gamma}{1+Wc} \Rightarrow 17 = \frac{\gamma}{1+0{,}33}$

$\gamma = 18{,}82\ kN/m^3$

$\gamma = 1{,}9\ g/cm^3$

$RING\ VOLUME = 88{,}36\ \text{cm}^3$

$Wet\ Total\ Material = 88{,}36 * 1{,}9 = 167{,}9\ \text{g}$

$W_{dry} = \frac{\text{Wwet}}{1+\text{Wc}} = \frac{167{,}9}{1+0{,}33} = 126{,}25\ g$

$W_{water} = 167{,}9 - 126{,}25 = 41{,}65\ g$

$W_{dry} = 126{,}25\ g$

$W_{water} = 41{,}65\ g$

5.2.2 Gaziantep University Campus Clay

Main rock formation in capus are is composed of limestone that is called Gaziantep formation. Limestone is a sedimentary rock composed largely of the mineral calcite (calcium carbonate: $CaCO_3$). Like most other sedimentary rocks, limestones are composed of grains; however, most grains in limestone grains are skeletal fragments of marine organisms such as coral or foraminifera. Other carbonate grains comprising limestones are ooids, peloids, intraclasts, and extraclasts. Some limestones do not consist of grains at all and are formed completely by the chemical precipitation of calcite or aragonite. i.e. travertine.

In order to determine swelling properties of Campus clay soil sampale was taken from a vacant parcel (Figure 5.5).

Figure 5.4 Gaziantep University Campus region where sample taken

The samples were brought to Geotechnical laboratory and Attarberg limit tests were performed on it. Results obtained from the test are given below. Using these test results optimum water content and maximum dry density of the sample soil were determined from empirical equations suggested in the literature. Optimum water content and maximum dry density values were given below.

Swelling properties of the sample soil is determine at its there different water content. These are optimum water content, 10% dry side of optimum, and 10% wet side of optimum. Using phase diagram necessary mass of soil and water were calculated and results are given below.

$LL = 0{,}313$

$PL = 0{,}21$

$PI = 0{,}10$

At Optimum Water Content

$W_{opt} = 6{,}77 + 0{,}43LL - 0{,}21PI$

$W_{opt} = 6{,}77 + 0{,}43 * 31{,}3 - 0{,}21 * 10$

$W_{opt} = 18{,}1 \sim 18\ \%$

$\gamma_{max} = 20{,}48 - 0{,}13LL + 0{,}05PI$

$\gamma_{max} = 16{,}91 \sim 17\ \%$

$\gamma_{dry} = \frac{\gamma}{1+Wc} \Rightarrow 17 = \frac{\gamma}{1+0{,}181}$

$\gamma = 20\ kN/m^3$

$\gamma = 2{,}05\ g/cm^3$

$D = 75\ mm$

$h = 20\ mm$

$RING\ VOLUME = \frac{\pi}{4} * D^2 * \mathrm{h} = 88{,}36\ \mathrm{cm}^3$

$Wet\ Total\ Material = 88{,}36 * 2{,}05 = 181{,}14$ g

$W_{dry} = \frac{Wwet}{1+Wc} = \frac{181{,}14}{1+0{,}181} = 153{,}4\ g$

$W_{water} = 181{,}14 - 153{,}4 = 28\ g$

$W_{dry} = 153{,}4\ g$

$W_{water} = 28\ g$

At 10% Dry Side of Optimum Water Content

$W_c = 0{,}16 \rightarrow 16\ \%$

$\gamma_{dry} = \frac{\gamma}{1+Wc} \Rightarrow 17 = \frac{\gamma}{1+0{,}16}$

$\gamma = 19{,}72\ kN/m^3$

$\gamma = 2{,}01\ g/cm^3$

$RING\ VOLUME = 88{,}36\ cm^3$

$Wet\ Total\ Material = 88{,}36 * 2{,}01 = 177{,}60$ g

$W_{dry} = \frac{Wwet}{1+Wc} = \frac{177{,}60}{1+0{,}16} = 153{,}11\ g$

$W_{water} = 177{,}60 - 153{,}11 = 24{,}5\ g$

$W_{dry} = 153{,}1\ g$

$W_{water} = 24{,}5\ g$

At 10% Wet Side of Optimum Water Content

$W_c = 0{,}20 \rightarrow 20\ \%$

$\gamma_{dry} = \frac{\gamma}{1+Wc} \Rightarrow 17 = \frac{\gamma}{1+0{,}20}$

$\gamma = 20{,}4\ kN/m^3$

$\gamma = 2{,}08\ g/cm^3$

$RING\ VOLUME = 88{,}36\ \mathrm{cm}^3$

$Wet\ Total\ Material = 88{,}36 * 2{,}08 = 183{,}75\ \mathrm{g}$

$W_{dry} = \frac{\mathrm{Wwet}}{1+\mathrm{Wc}} = \frac{183{,}75}{1+0{,}20} = 153{,}1\ g$

$W_{water} = 183{,}75 - 153{,}1 = 30{,}6\ g$

$W_{dry} = 153{,}1\ g$

$W_{water} = 30{,}6\ g$

$P_{swelling} = \frac{0{,}240}{44{,}178} = 0{,}0054\ \mathrm{kg/cm^2}$

$P_s = 0{,}0054\ \mathrm{kg/cm^2}$

$P_s = 0{,}54\ \mathrm{kN/mm^2}$

5.3 Test Results

5.3.1 Karatas Test Results

Table 5.2 Time versus swell for optimum water content

time(min)	1.reading(mm)	2.reading(mm)	mean reading
0,1	1	1	1
0,12	1	1	1
0,5	1	1	1
1	2	2	2
2	3	3	3
4	5	4	5
8	7	9	8
15	9	14	12
30	13	21	17
60	19	30	25
120	29	40	35
240	39	51	45
480	48	60	54
1440	69	72	71
2880	75	77	76
4320	77	79	78

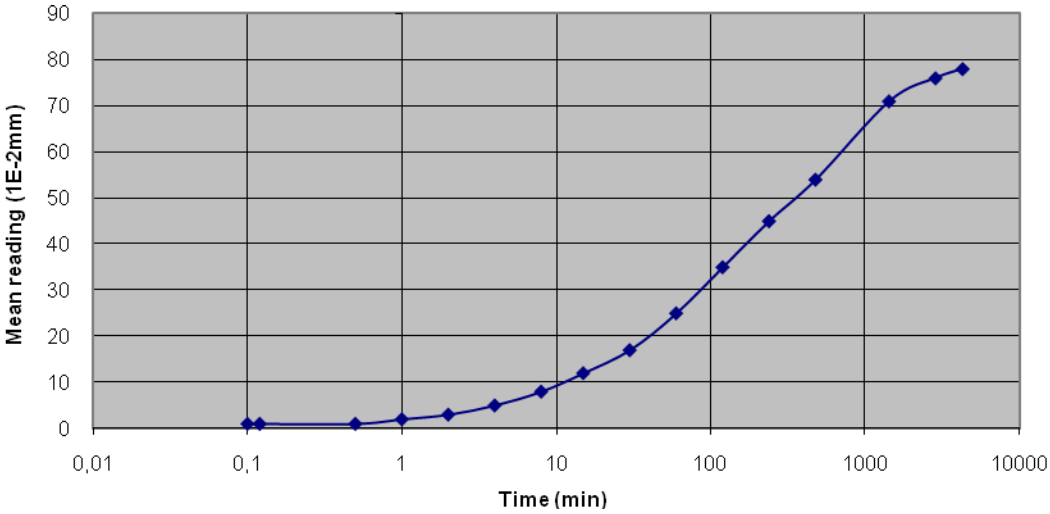

Figure 5.5 Swell versus log time relationship at optimum water content

%Swell (Sf **)=** (Δh/H)*100 (Eq. 1)

Sf = 0.78/20 = 0.039 Sf = 3.9 %

Swell Pressure at Optimum Water Content

test 1;

A (area of ring) = 44.178 cm^2

Load = 1.4128 kg

$P_{swelling}$ = 1.4128 / 44.178 = 0.032 kg / cm^2

$P_{swelling}$ = 3.2 kN / m^2

test 2;

Load = 1.100 kg

$P_{swelling}$ = 2,4 kN / m^2

Average:

2.8 kN/ m^2

Table 5.3 Time versus swell for %10 dry side of optimum water content

time(min)	1.reading(mm)	2.reading(mm)	mean reading
0,1	2	2	2
0,12	3	3	3
0,5	5	3	4
1	11	10	11
2	17	16	17
4	27	27	27
8	38	36	37
15	50	48	49
30	69	67	68
60	96	98	97
120	123	141	132
240	151	180	167
480	174	219	197
1440	190	243	216
2880	195	250	222
4320	225	255	240

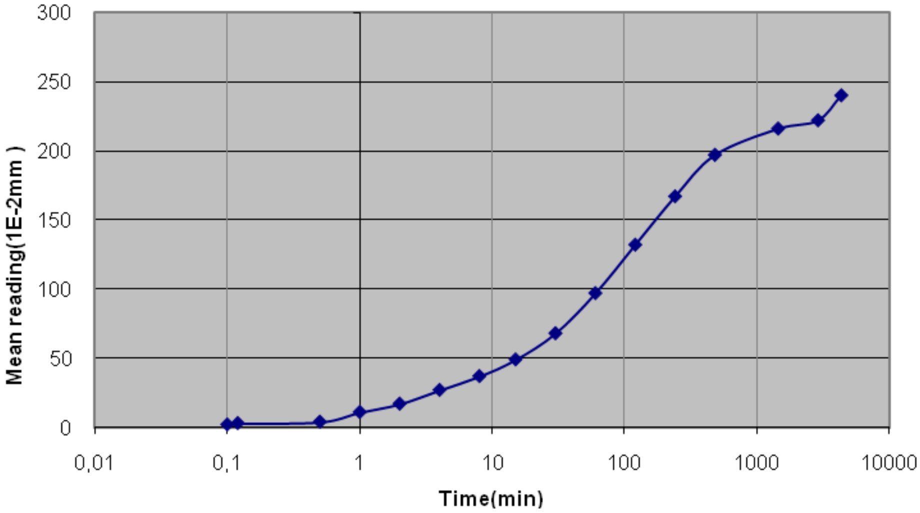

Figure 5.6 Swell versus log time relationship at 10 % dry side of optimum water content

%Swell (Sf **)=** (Δh/H)*100 (Eq. 1)

Sf = 2.40/20 = 0.12 Sf = 12 %

Swell Pressure of % 10 Dry of Optimum Water Content

A (area of ring) = 44.178 cm^2

Load = 6.5 kg

$P_{swelling}$ = 6.5 / 44.178 = 0.147 kg / cm^2

$P_{swelling}$ = 14,7 kg / mm^2

Table 5.4 Time versus swell for % 10 wet side of optimum water content

time(min)	**1.reading(mm)**	**2.reading(mm)**	**mean reading**
0,1	1	2	2
0,12	1	2	2
0,5	2	3	3
1	4	3	4
2	6	5	6
4	8	7	8
8	12	11	12
15	18	16	17
30	27	22	25
60	39	32	36
120	55	45	50
240	77	62	70
480	97	85	91
1440	122	107	115
2880	134	120	127
4320	138	127	133

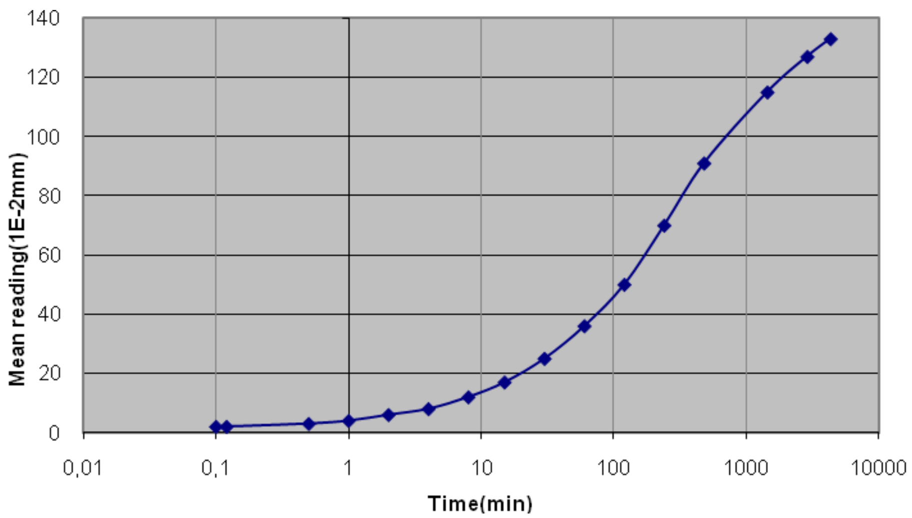

Figure 5.7 Swell versus log time relationship at 10 % wet side of optimum water content

%Swell (Sf **)=** (Δh/H)*100 (Eq. 1)

Sf = 1.33/20 = 0..666 Sf = 6.65 %

Swell Pressure % 10 Wet of Optimum Water Content

A (area of ring) = 44.178 cm^2

Load = 0.75 kg

$P_{swelling}$ = 6.5 / 44.178 = 0.0169 kg / cm^2

$P_{swelling}$ = 1,69 kg / mm^2

At optimum water content, 10 % dry side of optimum water content and 10 % wet side of optimum water content, free swell found as follows,

- For optimum water content, Sf = 3.9 %
- For 10 % dry, Sf = 12 %
- For 10 % wet, 6.65 %

Respectively these results compared with charts and tables given in literature following conclusions can be found;

According to the Abdyljauvad and Al-Sulaimani 1993, Karatas residual soils in all water content conditions (optimum, dry and wet)can be classified as high swell potential clay. According to the O'neili and Poormoayed, 1980,classification Karatas residual soil (optimum, dry and wet) has a high swell potential in all water content.

5.3.2 Gaziantep University Campus Clay Test Results

Table 5.5 Time versus swell for optimum water content

time(min)	1.reading(mm)	2.reading(mm)	mean reading
0,1	1	1	1
0,12	1	1	1
0,5	1	1	1
1	1	1	1
2	1	2	2
4	1	2	2
8	1	3	2
15	1	3	2
30	2	4	3
60	2	5	4
120	3	7	5
240	4	9	7
480	6	11	9
1440	21	16	19
2880	23	17	20
4320	23	18	20

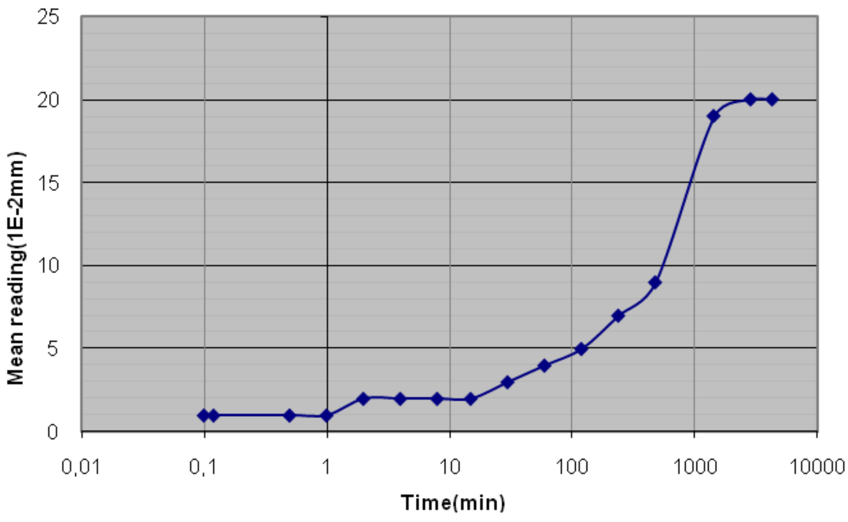

Figure 5.8 Swell versus log time relationship at optimum water content

%Swell (Sf **)=** $(\Delta h/H)*100$ (Eq. 1)

Sf = 0.02/20 = 0.01 Sf = 1 %

Swell Pressure of Optimum Water Content

Optimum test 1;

A (area of ring) = 44.178 cm^2

Load = 0.05298 kg

$P_{swelling}$ = 0.05298 / 44.178 = 0.012 kg / cm^2

$P_{swelling}$ = 1,2 kg / mm^2

Optimum test 2;

Load = 0.240 kg

$P_{swelling}$ = 0,54 kg / mm^2

Table 5.6 Time versus swell for %10 dry side of optimum water content

time(min)	1.reading(mm)	2.reading(mm)	mean reading
0,1	1	1	1
0,12	1	1	1
0,5	1	1	1
1	1	2	2
2	2	4	3
4	3	6	5
8	6	9	8
15	10	12	11
30	16	17	17
60	21	22	22
120	25	27	26
240	31	31	31
480	34	35	35
1440	39	41	40
2880	42	41	42
4320	45	42	43

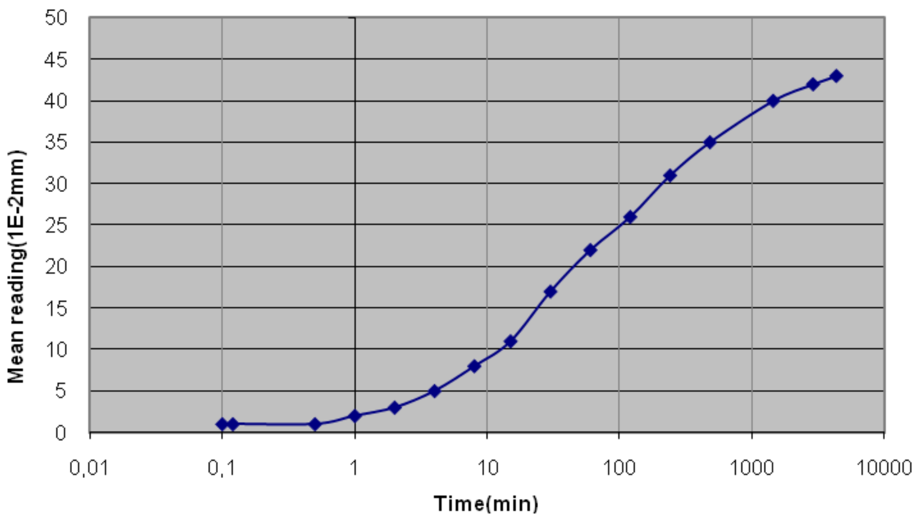

Figure 5.9 Swell versus log time relationship at 10 % dry side of optimum water content

%Swell (Sf **)=** (Δh/H)*100 (Eq. 1)

Sf = 0.43/20 = 0.0215 Sf = 2.15 %

Swell Pressure of % 10 Dry of Optimum Water Content

A (area of ring) = 44.178 cm^2

Load = 1.5 kg

$P_{swelling}$ = 1.5 / 44.178 = 0.0339 kg / cm^2

$P_{swelling}$ = 3,39 kg / mm^2

Table 5.7 Time versus swell for % 10 wet side of optimum water content

time(min)	1.reading(mm)	2.reading(mm)	mean reading
0,1	1	1	1
0,12	1	2	2
0,5	2	2	2
1	3	3	3
2	4	5	5
4	5	8	7
8	6	11	9
15	8	16	12
30	14	22	18
60	27	27	27
120	27	32	30
240	35	37	36
480	45	43	44
1440	58	55	57
2880	69	67	68
4320	72	69	71

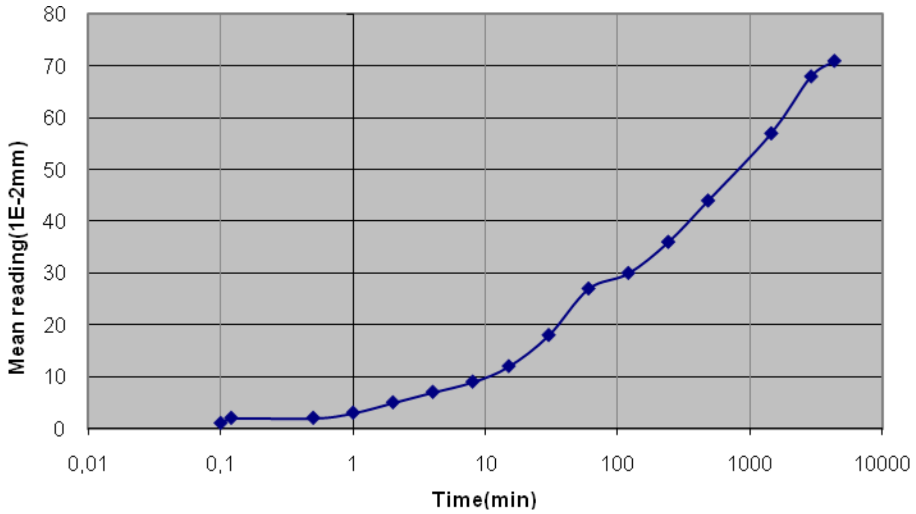

Figure 5.10 Swell versus log time relationship at 10 % wet side of optimum water content

%Swell (Sf **)=** (Δh/H)*100 (Eq. 1)

Sf = 0.71/20 = 0.0355 Sf =3.55 %

Swell Pressure of % 10 Wet of Optimum Water Content

A (area of ring) = 44.178 cm^2

Load = 0.75 kg

$P_{swelling}$ = 6.5 / 44.178 = 0.0169 kg / cm^2

$P_{swelling}$ = 1,69 kg / mm^2

At optimum water content, 10 % dry side of optimum water content and 10 % wet side of optimum water content, free swell found as follows,

- For optimum water content, Sf = 1 %
- For 10 % dry, Sf = 2.15 %
- For 10 % wet, 3.55 %

Respectively these results compared with charts and tables given in literature following conclusions can be found;

According to the Abdyljauvad and Al-Sulaimani 1993, Gaziantep University Capmus residual soils in all water content conditions (optimum, dry and wet)can be classified as low swell potential clay. According to the O'neili and Poormoayed, 1980,classification Gaziantep University Campus residual soil (optimum, dry and wet) has a low swell potential in all water content.

5.3.3 Test Results of Adding Lignin on Karatas Sample

5.3.3.1 Lignin

Lignin or **lignen** is a complex chemical compound most commonly derived from wood, and an integral part of the secondary cell walls of plants and some algae. The term was introduced in 1819 by de Candolle and is derived from the Latin word lignum, meaning wood. It is one of the most abundant organic polymers on Earth, exceeded only by cellulose, employing 30% of non-fossil organic carbon http://en.wikipedia.org/wiki/Lignin - cite_note-boerjan-3 and constituting from a quarter to a third of the dry mass of wood. As a biopolymer, lignin is unusual because of its heterogeneity and lack of a defined primary structure. Its most commonly noted function is the support through strengthening of wood (xylem cells) in trees.

Biological function

Lignin fills the spaces in the cell wall between cellulose, hemicellulose, and pectin components, especially in tracheids, sclereids and xylem. It is covalently linked to hemicellulose and thereby crosslinks different plant polysaccharides, conferring mechanical strength to the cell wall and by extension the plant as a whole. It is particularly abundant in compression wood but scarce in tension wood.

Lignin plays a crucial part in conducting water in plant stems. The polysaccharide components of plant cell walls are highly hydrophilic and thus permeable to water, whereas lignin is more hydrophobic. The crosslinking of polysaccharides by lignin is an obstacle for water absorption to the cell wall. Thus, lignin makes it possible for the plant's vascular tissue to conduct water efficiently. Lignin is present in all vascular plants, but not in bryophytes, supporting the idea that the original function of lignin was restricted to water transport. However, it is present in red algae, which seems to suggest that the common ancestor of plants and red algae also synthesised lignin. This wouldsuggest that its original function was structural; it plays this role in the red alga Calliarthron, where it supports joints between calcified segments.

Economic significance

Highly lignified wood is durable and therefore a good raw material for many applications. It is also an excellent fuel, since lignin yields more energy when burned than cellulose. Mechanical or high yield pulp used to make newsprint contains most of the lignin originally present in the wood. This lignin is responsible for newsprint yellowing with age. Lignin must be removed from the pulp before high quality bleached paper can be manufactured from it In sulfite pulping, lignin is removed from wood pulp as sulfonates. These lignosulfonates have several uses:

- Dispersants in high performance cement applications, water treatment formulations and textile dyes
- Additives in specialty oil field applications and agricultural chemicals

- Raw materials for several chemicals, such as vanillin, ethanol, sugar and humic acid

- Environmentally sustainable dust suppression agent for roads

More recently, lignin extracted from shrubby willow has been successfully used to produce expanded polyurethane foam.

In 1998, a German company, Tecnaro, developed a process for turning lignin into a substance, called Arboform, which behaves identically to plastic for injection molding. Therefore, it can be used in place of plastic for several applications. When the item is discarded, it can be burned just like wood

Structure

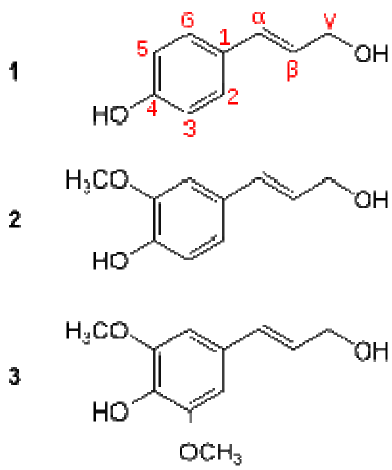

Figure 5.11 The three common monolignols: paracoumaryl alcohol (1), coniferyl alcohol (2)

5.3.3.2 Effect of Lignin on Swell Behavior

At the result of the tests, Karatas residual clay has high swell potential. Four set of tests performed by adding lignin (3%, 6%, 9%, 12%) to reduce swell potential of clay. These test were performed 10 % dry side of optimum water content. Because it was seen that, the highest swell potential was observed at result of 10 % dry test. Effect of lignin on swell behavior was shown below with tables and figures.

Table.5.8 3 % Lignin added Sample

time(min)	mean reading
0,1	3
0,12	4
0,5	5
1	9
2	13
4	20
8	30
15	41
30	59
60	85
120	106
240	128
480	145
1440	152
2880	155
4320	157

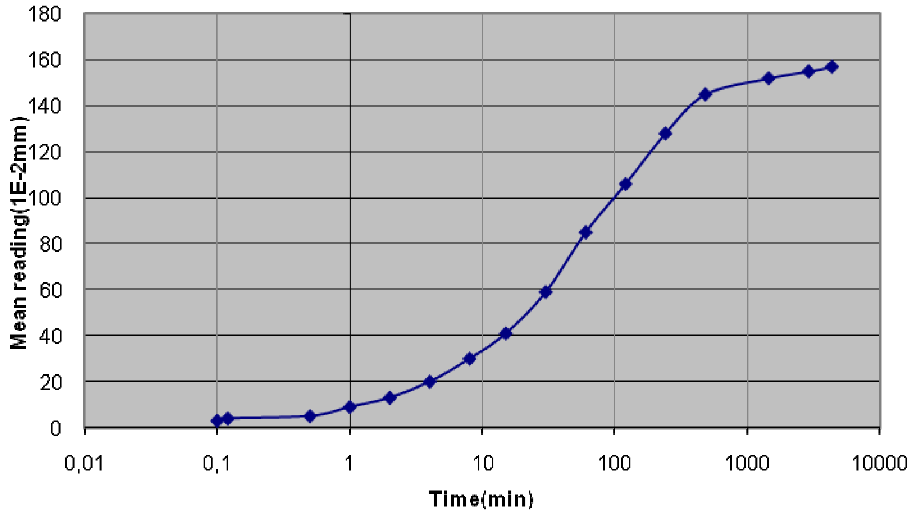

Figure 5.12 Swell versus log time relationship at 10 % dry side of optimum water content (adding 3% lignin)

%Swell

Maximum swell 1.45

Sf = 7 %

Table.5.9 6 % Lignin added Sample

time(min)	mean reading
0,1	1
0,12	2
0,5	3
1	5
2	7
4	13
8	20
15	28
30	38
60	52
120	65
240	85
480	99
1440	122
2880	128
4320	130

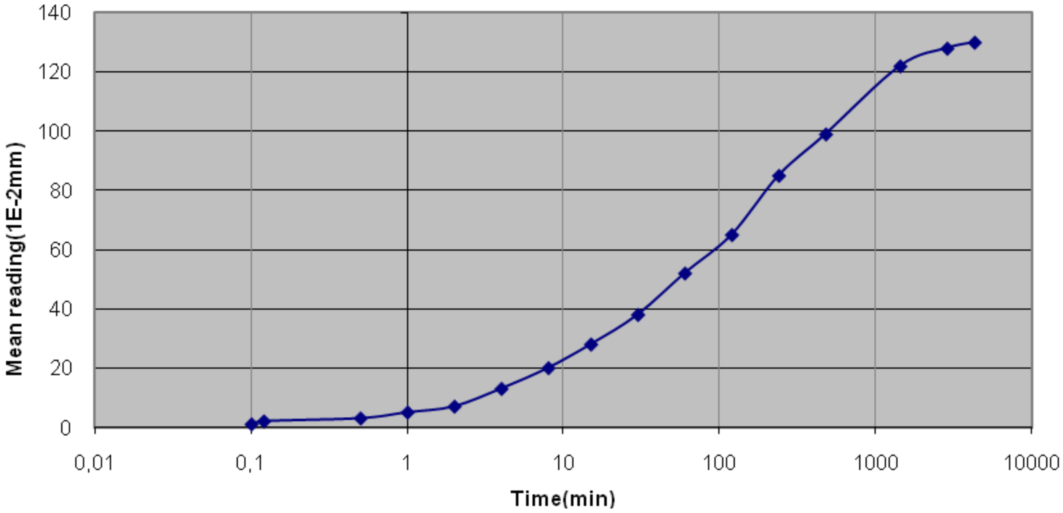

Figure 5.13 Swell versus log time relationship at 10 % dry side of optimum water content (adding 6% lignin)

%Swell

Maximum swell 1.22

Sf = 6 %

Table.5.10 9 % Lignin added Sample

time(min)	mean reading
0,1	2
0,12	3
0,5	5
1	7
2	9
4	12
8	19
15	28
30	48
60	64
120	80
240	95
480	100
1440	103
2880	105
4320	107

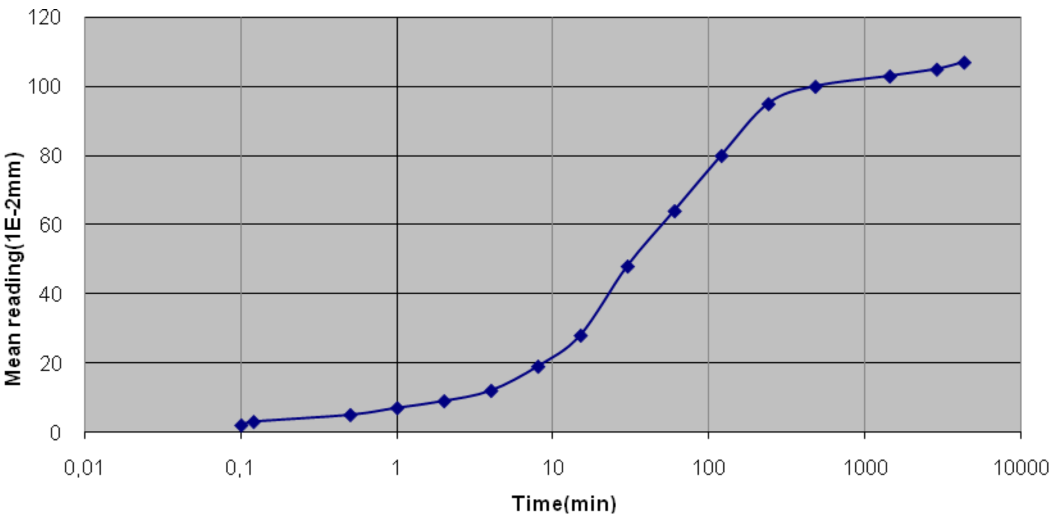

Figure 5.14 Swell versus log time relationship at 10 % dry side of optimum water content (adding 9% lignin)

%Swell

Maximum swell 1

Sf = 5 %

Table.5.11 12 % Lignin added Sample

time(min)	mean reading
0,1	1
0,12	2
0,5	3
1	3
2	4
4	5
8	7
15	10
30	15
60	19
120	25
240	32
480	43
1440	71
2880	76
4320	78

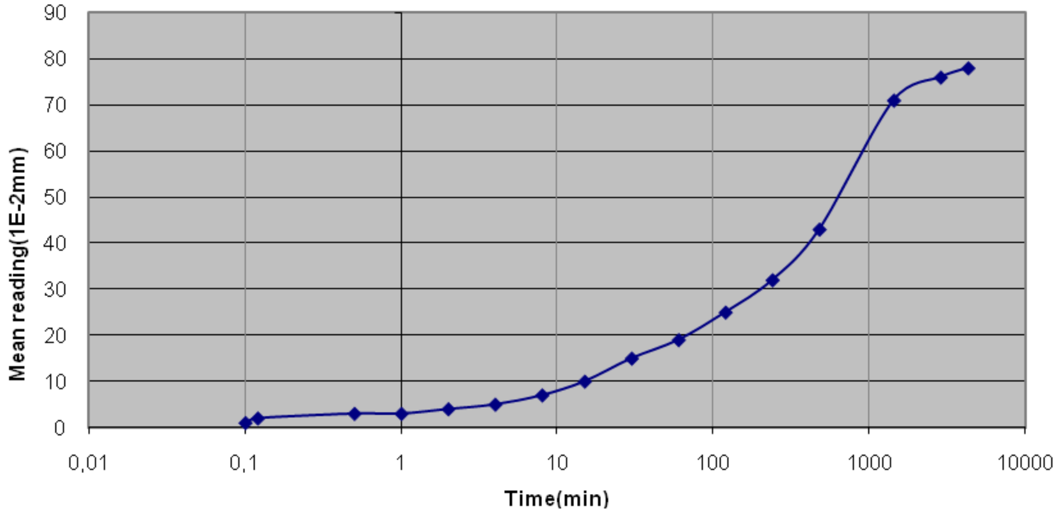

Figure 5.15 Swell versus log time relationship at 10 % dry side of optimum water content (adding 12 % lignin)

%Swell

Maximum swell 0.71

Sf = 4 %

Table.5.12 Effect of Adding Lignin on Sample

Additive (%)	**Swell (%)**
3	7
6	6
9	5
12	4

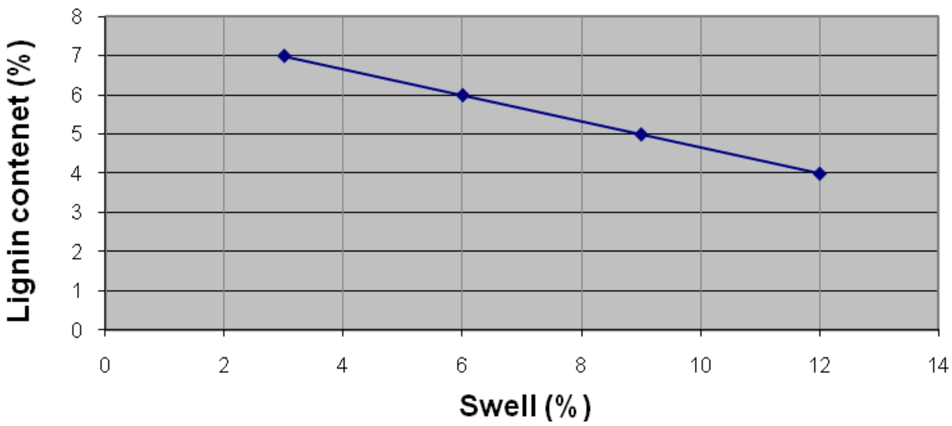

Figure 5.16 Lignin content versus swell relationship at 10 % dry side of optimum water content

The effects Lignin on the volume change of an expansive soil sample of .Karatas, is shown in the figure 5.14. As can be seen from the figure, as the amount of the Lignin increases swell potential decreases linearly.

CHAPTER 6

CONCLUSION

In this thesis, we have studied on two different Gaziantep residual clays, which were taken from Karatas and Gaziantep University Campus, to determine free swell and swell pressure. A few set of test were carried out by using odometer according to the standard of ASTM D4546. Then, lignin was added to Karatas residual soil to reduce the swell potential. At the result of this test effects of lignin on swell behavior were observed.

Following conclusions are drawn from this study;

- Swelling potential of two Karataş and Campus residual soil are completely different. Because origin of the Karataş clay and Campus clay are different.
- Free swell values of Karataş clay showed different results at different water content. These are 3.9 % at optimum water content, 12 % at 10 % dry side of optimum, and 6.65 %. at 10 % wet side of optimum water content. According to these percent swell values Karatas clay is classified as high swell potential clayey soil.
- Campus clay also effected from initial water content of the sample. Free swell values of clay are 1.0 % at optimum water content, 2.15 % at 10 % dry side of optimum, and 3.55 %. at 10 % wet side of optimum water content. According to these percent swell values Campus clay is classified as low swell potential clayey soil.
- Lignin that is added to clay to reduce swell potential of clay work well and reduced swell potential of Karatas clay in a significant amount. At 3% lignin inclusion, free swell value of Karataş clay reduced from 12% to 7%, and at 12% inclusion of lignin, free swell value reduced from 12% to %4. Therefore, it may be used as swell controlling additive.

- Light structures, that will be constructed at Karatas region, should not been constructed before ground was improved to prevent swell of soil.

RECOMMENDATIONS AND FUTURE WORKS

From this study, it was found that Karataş clay has great potential of geotechnical problem regarding swell potential. Before constructing any light weight structure such as pavement and single story building precaution has to be taken to prevent swelling problem of clay under these structures. If fill need to be done on any structure it should be compacted at wet side of optimum water content to reduce swell potential. Lignin was used to control swell potential of clay. It has good potential for reducing swelling of clay. This study was done in laboratory condition therefore its application in the field has to investigate.

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