SHEAR STRENGTH OF EXPANSIVE SOILS

Thesis

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in

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BY

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بسم الله الرحمن الرحيم

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 GENERAL

In arid and semi-arid regions, the deposite of expansive soil create an engineering problems for Urban expansion. In these regions the soil is mainly partially saturated, development of the land will accompanied by increase in water consumption and hence surface water will infiltrate down to the soil. This will cause a change in the characteristics of the expansive soil layers. For foundation design, as the water infiltrates the soil, the main concern is to know (a) the amount of heave for a specific type of foundation carrying a certain load, (b) the swelling pressure response on the foundation and (c) the soil shearing strength.

Numerous works have been done to study the heave and the swelling pressure of expansive soil due to wetting, (Chen 1975, Yong 1975, Rabba 1975, Mazen 1978, El-Rayes et. al. 1978, Abd-Elmaksoud 1982).

However, little attention has been paid to investigate the shearing strength behaviour of expansive soil as a function of wetting, (R.K Katti 1973, Olson 1974, Sridharan and Rao 1979, Darrag 1984, Aly-Fattah 1985).

1.2 Object of this research

The object of this study is to investigate the strength characteristics of an expansive soil for a moisture range starting from a state of air dried to full saturation. This investigation is limited to study the effect of the following variables : (a) initial density, (b) degree of swelling, (c) imposed normal stress and (d) stress path.

1.3 Organization of the thesis

This thesis is organized into five chapters as follows:

Chapter 1: deals with the definition of the problem and the object of this study.

Chapter 2: contains a literature review for the research dealing with the behaviour of expansive soil.

Chapter 3: deals with the experimental investigations covering type of soil and testing technique.

Chapter 4: contains the experimental results and discussion.

Chapter 5: this chapter summarizing the outcome of this research.

CHAPTER 2

REVIEW OF PREVIOUS WORK

2.1 General

This chapter contains a review of the available previous works on the behaviour of the expansive soils with reference to swelling characteristics and shear strength. Generally, the expansive soils are hard when dry, shrink and expand with decreasing and increasing the water content respectively.

The degree of expansion depends upon the type and amount of clay minerals and exchangeable ions. (Lamb 1969, Chen 1975, Yong 1975). The main groups of clay minerals are illite, kaolinite and montmorillonite. Existing montmorillonite in the soil creats most of expansive soil problems (Chen 1975).

Swelling may be characterised by the amount of heave or pressure response. Different methods and setups are used to determine the swelling pressure.

Swelling pressure has no unique definition; it may be defined as the normal pressure required to hold the soil at a constant volume when it is in contact with water, (Holtz & Gibs 1956, Uppal & Plait 1969) as shown in figures 2.1, 2.2 and 2.3. It may be also defined as the normal pressure required to produce certain percentage of volume change, (Jennings 1965, El Rayes

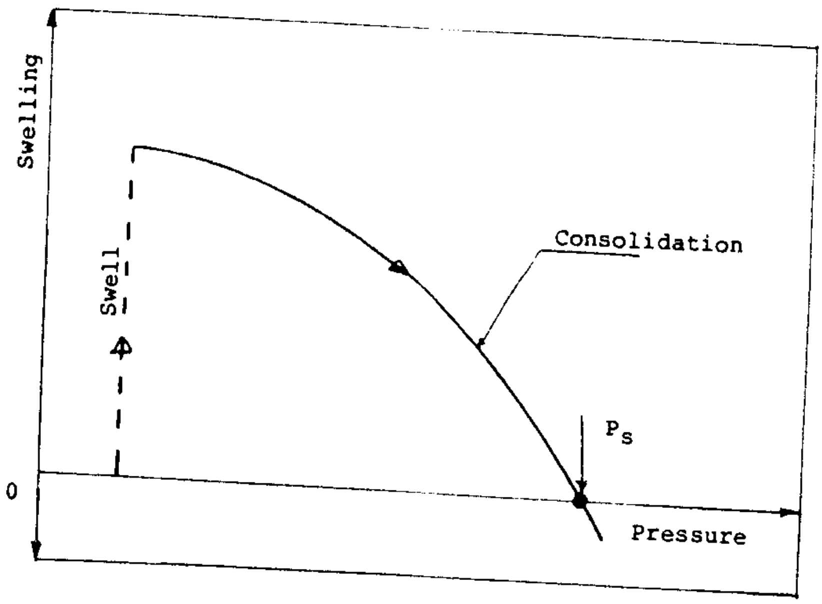

Fig: 2.1 Determination of swelling pressure according to preswell sample method (HOLTZ & GIBS 1956)

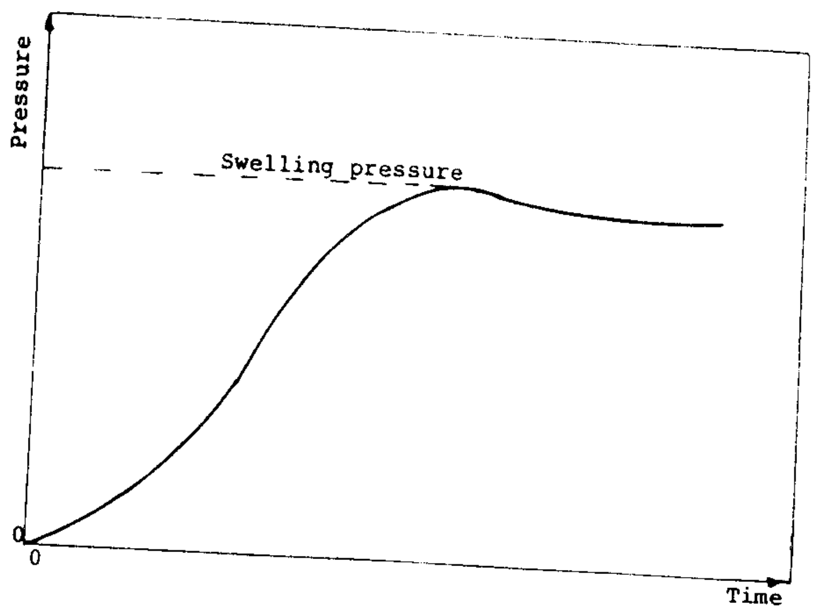

Fig: 2.2 Determination of swelling pressure according to constant volume method (HOLTZ & GIBS 1956)

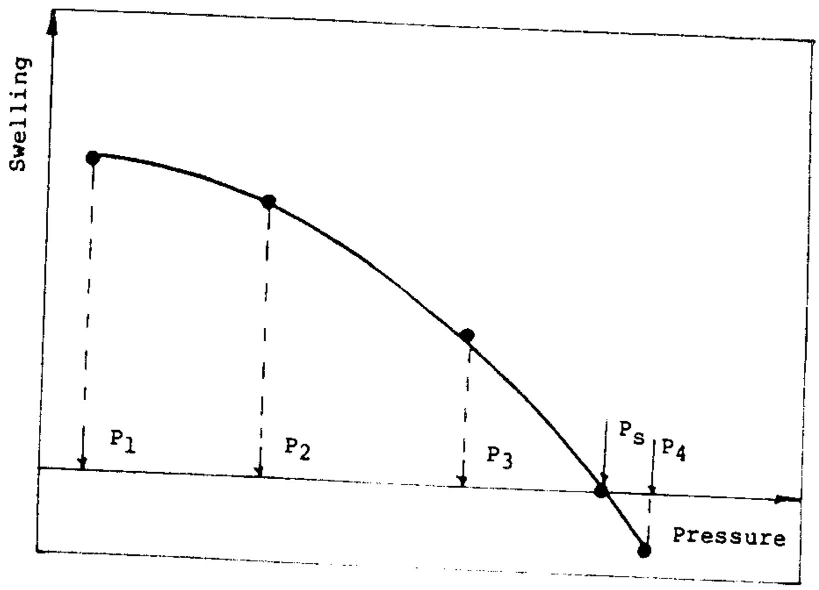

Fig: 2.3 Determination of swelling pressure by using pressure-swelling percent method (UPPAL and PLAIT 1969)

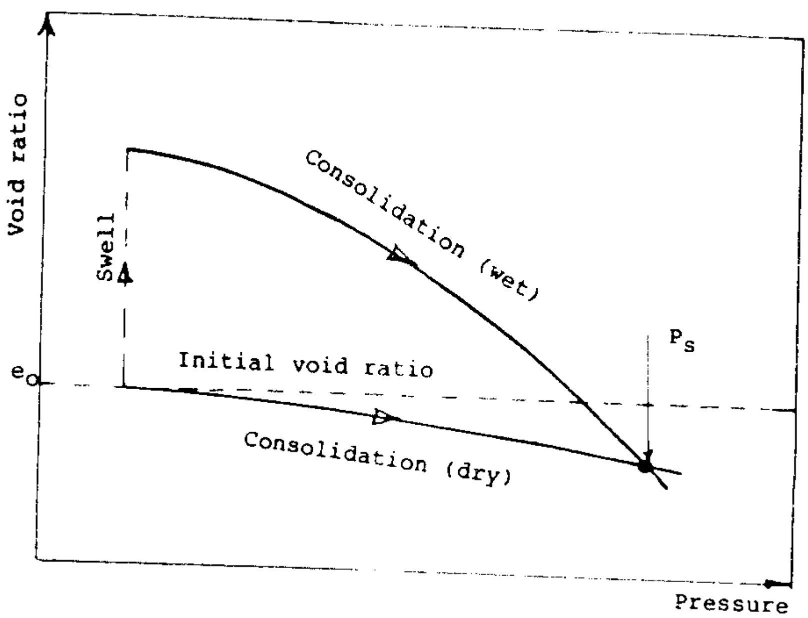

Fig: 2.4 Determination of swelling pressure using the double Oedometer (JENNINGS 1965) et. al. 1979), fig. 2.4.

Yong and Warkentin, (1975) state that the swelling pressure is equal to the osmotic pressure developed due to the differences in the concentrations of ions between clay particles surface and outside pore water.

Katti (1969) defined the swelling pressure as the pressure balanced by the external applied pressure and internal resisting forces.

2.2 Mechanism of swelling

The mechanism of swelling due to water absorption could be investigated in terms of kinematic of clay particles, and/or force of equilibrium between the particles. This could be studied in micro scale and macro scale. In the micro scale, the mechanism of swelling is considered in terms of; fabric, minerals and interparticle forces. In the macro scale; the stability of the system as a continuum and boundary conditions are investigated.

2.2.1 Clay minerals

Clay minerals are alumino-silicates, i.e. oxides of aluminium and silicon with smaller amounts of metal ions substituted within the crystal. The basic units of clay are i) silica sheet (tetrahedron unit) and ii) alumina sheat (octahedral unit). The silica tetrahedron unit consists of a silicon atom surrounded by four oxygens atoms. These oxygens are arranged at the corners of a tetrahedron with each of the three oxygens at the base of the tetrahedron shared by two silicons of adjacent units to form a sheet "Silica sheet".

The alumina of magnesium octahedral unit is an alumina of magnesium atom equidistant from six oxygens or hydroxyls. Each of the oxygen is shared by two aluminium ions, forming sheets of two layers of oxygen (or hydroxyl). These sheets are stacked into layers to form a clay particle, as shown in figures 2.5 and 2.6. The kaolinite crystal consists of repeating layers, each layer consisting of silica sheet and an alumina sheet sharing a layer of oxygen atoms between them. The layers are held together by hydrogen bonding which is strong bond, preventing hydration between layers and allowing many layers to build up.

The illite consists of a repeating layers of an alumina sheet between two silica sheets with oxygens. The layers are bonded together by potassium ions which are weaker than the hydrogen bonds in kaolinite, thus the water can enter between the sheets causing expansion in case of illite.

The montmorillonite which is highly active clay, consists of a repeating layers of an alumina sheet

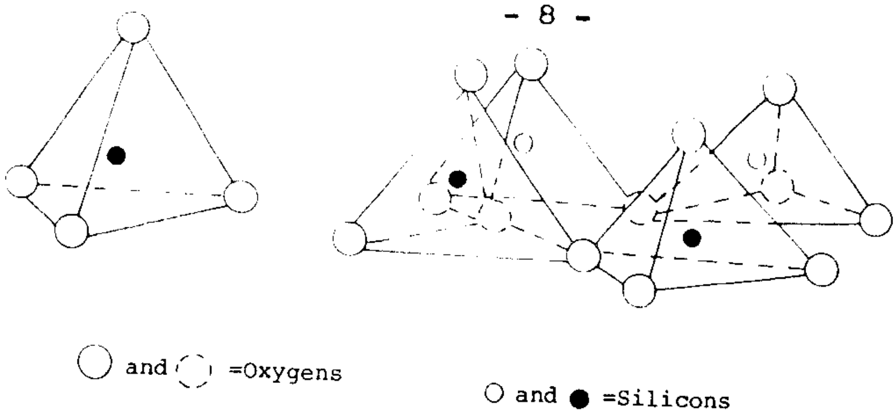

Fig: 2.5 Silica tetrahedron unit and silica tetrahedron arranged in hexagonal network (MITCHELL 1976)

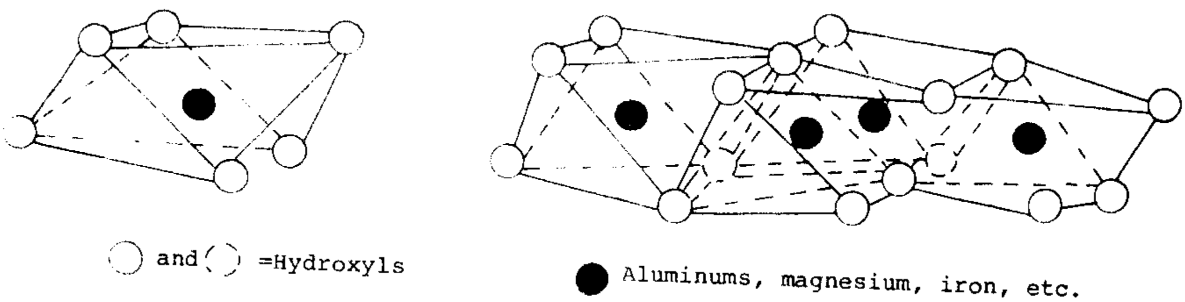

Fig: 2.6 Octahedral unit and sheet structure of octahedral units (MITCHELL 1976)

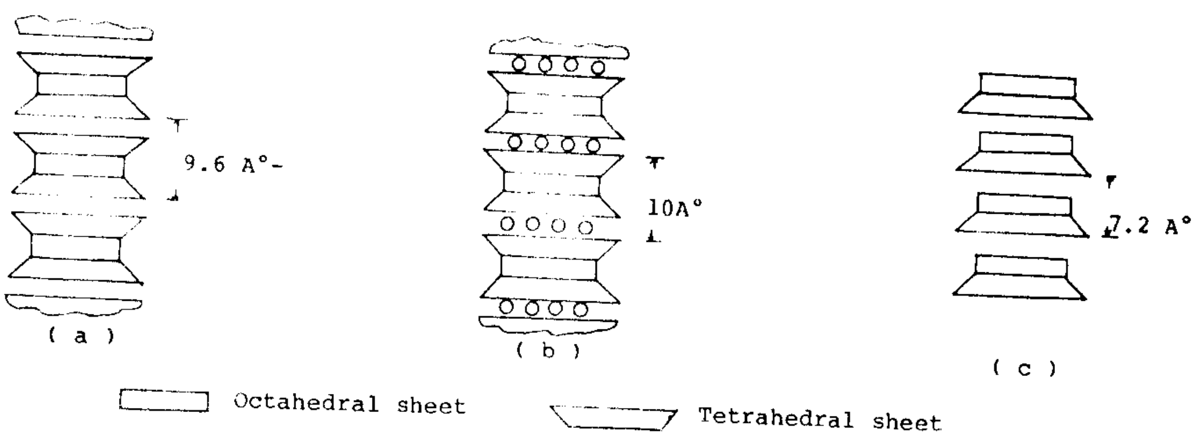

Fig: 2.7 Schematic diagrams of the structures of:
(a) Montmorillonite (b) Illite and (c) Kaolinite
(MITCHELL 1976)

between two silica sheets. The bonds between the layers are Van der Waals forces and exchangeable cations caused by attraction to balance charge deficiencies in the structure. These bonds are weak and easily separated by adsorption of water causing the lattic to expand. A schematic diagrams of the structures of montmorillonite, illite and kaolinite are shown in figures 2.5, 2.6 and 2.7.

Water molecules are adsorbed and oriented on the particles surfaces due to formation the hydrogen bonds between the water molecules and the oxygen atoms at the surface or between water molecules and surface hydroxyls. The attractive of water molecule continues until the free water formed.

2.2.2 Soil Fabric

Generally, for active clay minerals, there are two types of fabrics depending on the environment of sedimentation. The oriented and/or semi-oriented fabric which occur when clay sediment in fresh water where the repulsive forces are dominanting fig. 2.8. The flocculated structure resulted where sediment occur in marine environment and result in edge to face arrangment where the dominanent are attractive forces.

Since the swelling response in terms of forces or displacement are boundary measurements, the attraction