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NATURAL CLAY S … DISTILLED WATER

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ABSTRACT

Nowadays waste is increasing day by day as a result of human activity and its disposal becomes a major problem. Waste disposal by landfill is the most popular method, which is currently in practice. Landfills are often lined with clayey liner material to prevent migration of contaminants into the environment. For cheaper alternatives, natural soils are used as liner materials. In the case of landfills constructed near coastal areas, intrusion of seawater might affect the stability of the liner system. This study presents the effect of sodium chloride (NaCl) solution and distilled water towards the compressibility behavior of natural soil (KB soil) from saturated slurried condition. The pressure-void ratio and pressure-water content relationships were then established using double-oedometer tests. Furthermore, the effect of NaCl and distilled water on the physical properties of KB soil was also determined. The liquid limit and plastic limit were slightly higher than the values obtained using distilled water. On the other hand, the double-oedometer test results showed that the pressure-void ratio relationship for distilled water was higher than that of NaCl. Similar trend was also observed in the pressure-water content relationship. Test results indicated that cation concentration contained within the seawater affects the plasticity and compressibility characteristics of KB soil.

ABSTRAK

Pada masa kini sisa semakin meningkat hari demi hari akibat aktiviti manusia dan pelupusan yang menjadi masalah utama. Pelupusan sisa oleh tapak pelupusan adalah kaedah yang paling popular, yang kini dalam amalan. Tapak pelupusan sering dipenuhi dengan bahan pelapik bertanah liat untuk mencegah penghijrahan bahan cemar ke alam sekitar. Untuk alternatif yang lebih murah, tanah semula jadi yang digunakan sebagai bahan pelapik. Dalam kes tapak pelupusan yang dibina berhampiran kawasan pantai, pencerobohan air laut mungkin menjejaskan kestabilan sistem pelapik. Kajian ini membentangkan kesan larutan natrium klorida (NaCl) dan air suling ke atas kelakuan kebolehmampatan tanah semulajadi (tanah KB) daripada keadaan buburan tepu. Nisbah tekanan tidak sah dan hubungan kandungan tekanan air kemudiannya ditubuhkan menggunakan ujian dua oedometer. Tambahan pula, kesan NaCl dan air suling pada sifat-sifat fizikal tanah KB juga telah ditentukan. Had cecair dan had plastik adalah lebih tinggi sedikit daripada nilai-nilai yang diperolehi dengan menggunakan air suling. Sebaliknya, keputusan ujian dua oedometer menunjukkan hubungan tekanan nisbah lompang untuk air suling adalah lebih tinggi daripada NaCl. Arah aliran yang sama juga diperhatikan dalam hubungan tekanan kandungan air. Keputusan ujian menunjukkan bahawa kepekatan kation yang terkandung dalam air laut yang memberi kesan kepada ciri-ciri keplastikan dan kebolehmampatan tanah KB.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

NaCl	-	Sodium Chloride
Na^+	-	Sodium
Cl^-	-	Chloride
KB	-	Kuantan Bricks
Fig	-	Figure
Sg	-	Sungai
UMP	-	Universiti Malaysia Pahang
BS	-	British Standard
ASTM	-	American Society for Testing and Materials

LIST OF SYMBOLS

%	-	Percentage
kg	-	Kilogram
mm	-	Millimeter
μm	-	Micrometer
K	-	Permeability
cm/s	-	Centimeter per second
kg/cm^2	-	Kilogram per centimeter square
N	-	Newton
ºC	-	Degree of Celsius
kPa	-	Kilopascal
m/s	-	Meter per second
<	-	Less than
Å	-	Angstrom

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of study

As populations grow and technologies advance, the type and quantity of waste produced keeps on growing. The world's total solid waste generation was about 12.7 billion tonnes in 2000 and this is predicted to rise to about 19.0 billion tonnes in 2025 (Yoshizawa et al. 2004). In the case of Malaysia, it is estimated that 17,000 tonnes of solid waste is generated every day and this will increase to more than 30,000 tonnes per day by 2020 consequent upon the increasing population and per capita waste generation (MHLG, 2003). Fauziah and Agamuthu (2006) estimated that the generation rate of solid waste may be increased by 3% per year due to the increase in population and the economic development in the country. As a result, waste disposal became a huge environmental problem. Solution for waste disposal that being used today is landfilling and landfilling is the only waste disposal method that can deal with all kinds of materials in the solid waste stream and it is also the simplest and cheapest way of disposing solid waste (Choong, 2001).

Landfill is designed with liner systems to protect groundwater quality from the disposed wastes. The liner systems consist of low-permeable materials (viz. compacted clay, geo-membrane, geo-synthetic clay liner) and must contain the disposed wastes effectively (Sharma & Reddy, 2004). The essential function of the bottom line is to provide stability and to support the total waste mass as well as to prevent from the pollution of ground water with the landfill leachate (Holzlöhner et al., 1995; Eggloffstein et al., 2000). Leachate consists of water and water-soluble compounds in the refuse that accumulate as water moves through the landfill. This water may be from rainfall or from the waste itself. Leachate may migrate from the landfill and contaminate soil and ground water, thus presenting a risk to human and environmental health.

Liners consist of various components made of natural synthetic materials. These consist of low permeability materials such as natural clays, soil-admixed materials, synthetic materials such as high density polyethylene and geo-synthetic clay liners and drainage materials. Drainage materials could be naturally obtained sands and gravels or synthetic materials such as geo-textiles, geo-nets and geo-composites (Sharma & Reddy, 2004). Alternatively, clays can be used as cost-effective bottom liners. Clay liners at the bottom of landfill body play a very important part in the whole multi barrier system for retaining pollutants. Porosity of clay particle is 40 - 70% and K value of clay is less than 10-7 cm/s and so the rate of advection transport through clay is very low and it is cheap. Clay has the property of swelling, plasticity, cohesion and adhesion. Some clay soils have the ability to act as membrane that restricts the passage of charged solutes (Saha, 2006).

In some areas, landfills are constructed near coastal area. In Malaysia, for examples are The Pulau Burung Landfill, Pulau Pinang, The Padang Siding Landfill, Perlis, The Taiping Landfill, Perak and The Kelantan Sanitary Landfill. Figure 1.1 shows the location of Pulau Burung Landfill on map.

Fig. 1.1: Location of Pulau Burung Landfill on map

These landfills are prone to salt water intrusion, particularly during high tide. In other case, landfill liners are exposed to various types of chemical, biological, and physical processes and are affected by the leachate. The leachate includes a lot of components such as water and different types of salts (Shariatmadari, Salami & Fard, 2011). These salts and water could affect the long-term performance of these liners. The effects of saline waters on the engineering behavior of soils need to be determined since the salinity of pore fluid of fine grained soils near coastal areas increases continuously. Such increase is due mainly to lowering the groundwater level below mean sea level in coastal areas, resulting in seawater migration towards land (Aksoy et al., 2008)

As such that, NaCl solution is used in substitute of seawater due to the fact that, seawater contained majority of Na+ and Cl- ions (Petrov & Rowe, 1997).

1.2 Problem statement

There are amount of Malaysia's landfill constructed and located near coastal area. The behavior of clay liner when exposed to seawater is not known. Therefore, it is important to study the clay behavior when they interact with seawater for the evaluation and design requirement for liners near the sea area. The compressibility behavior of natural clay soil by using salt solution which is sodium chloride and distilled water are determined. Sodium chloride is used as a seawater substitution because the major ions contained in seawater are Na^+ and Cl^-.

1.3 Objectives of study

Objectives of this study are:

1. To determine the effect of NaCl solution and Distilled Water on the physical properties of natural clay soil.

2. To determine the compressibility behavior of the natural clay soil by using NaCl solution and Distilled Water.

1.4 Scope of study

The scope of study is to determine the compressibility behavior of natural soil containing kaolinite clay mineral under different solution which are Sodium Chloride (NaCl) and Distilled Water. The soil sample is taken at Kuantan Brick Sdn.Bhd located at Felda Sg. Panching, Kuantan, Pahang which is the company manufactures and supplies clay and cement bricks. Only experimental investigation is considered and the sample is tested in Soil & Geotechnical laboratory, UMP. The compressibility behavior was specified from the oedometer test.

1.5 Significant of study

This study will present data and information for researchers and engineers to measure the effect of NaCl solution and distilled water on the compressibility behavior of clayey soils and design requirement for landfill liners near coastal area.

1.6 Thesis overview

In Chapter 2: Literature Review, the explanation and the information of Behavior of Fine-grained Soil: Factors & Mechanism, Soil-water Interaction, Soil Mineralogy, Clay Mineralogy, Kaolinite and Oedometer Test are presented together with the review of reported studies and related books of various investigator and writer.

In Chapter 3: Material Properties and Methodology, the methodology of the whole study are presented and well explained in terms of the determination of physical and mineralogical properties of soil used and the determination of compressibility of soil used using double-oedometer test.

In Chapter 4: Results and Analysis, the laboratory data obtained is analyzed and the results are presented through table and graphical method.

In Chapter 5: Conclusion, the results are concluded and checked whether the objectives of this study well achieved or not.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a brief explanation and information of Behavior of Fine-Grained Soil: Factors & Mechanism, Soil-water interaction, Soil Mineralogy, Clay Mineralogy, Kaolinite and Oedometer Test are presented along with the review of reported studies and related books of various investigator and writer. Moreover, the reviews of earlier investigations about the use of clay as landfill liner are also presented at the end of chapter.

2.2 Behavior of Fine-grained Soil: Factors & Mechanism

The various factors influencing the index and engineering properties of fine-grained soil are:

1. Type and amount of clay
2. Pore fluid characteristics (e.g. ion concentration, valency, dielectric constant)
3. Soil structure

2.2.1 Type and Amount of Clay

The volume-change behavior of fine-grained soils is essentially a function of the predominant type of clay-mineral present in the soil system. It is well recognized that soils rich in smectite group of clays undergo a large volume change. While soils with fixed lattice such as kaolinite, muscovite and illite clays undergo relatively less compressibility (Mitchell 1993)

2.2.2 Type of Exchangeable Cation

Increase in ionic vacancy for a given concentration decreases the double-layer distance and here by aggregation of particles occur. Bolt (1956) found that for sodium montmorillonite the void ratio change for a pressure range of 0.1 to 1.0 kg/cm^2 was 1.5 times higher than calcium montmorillonite. Similar observations were made by Shainberg (1971) and Mesri and Olson (1971). In general, as the valency increases, the permeability increases whereas compressibility, swell ability and plasticity characteristics decreases.

2.2.3 Pore Fluid

In the case of soils containing the smectite group of clays, an increase in the pore electrolyte concentration, decreases the plasticity, swelling and compressibility characteristic of the soils. Mesri and Olson (1971) noted that in the case of sodium montmorillonite, increasing the electrolyte (Sodium Chloride) concentration from $5x10^9$ to $1x10^{11}$ N, the void ratio decreased from 11.18 to 5.4 for an effective consolidation pressure of 0.05 kg/cm^2, while in the case of calcium montmorillonite, an increase in the electrolyte (calcium chloride) concentration from $1x10^3$ to 1.0 N resulted in the void ratio decreasing form 2.18 to 1.84 only, at the same pressure of 0.05 kg/cm^2.

2.2.4 Dielectric Constant

Increase in the dielectric constant, increase the plasticity, swelling, compressibility and decreases the shear strength characteristic of montrmorillonite soils, while there will be reverse effect on kaolinite soils. Mesri and Olson (1971) have presented data on consolidation curves for montrmorillonite with different organic fluids with varying dielectric constants and have shown that the void ratio decreases with the decrease in dielectric constant.

2.2.5 Soil Structure

Net attraction of soil system results in flocculated particles and net repulsion results in dispersed structure. Inter-particle forces (attractive and repulsive) have been observed to have a profound influence on a wide range of soil engineering properties, which include: consistency, consolidation and shear strength characteristic of clay soils (Quirk, 1964; Yong and Warkentin 1966; and Mitchell. 1993). In addition to inter-particle attractive and repulsive forces, the fabric also plays an important role. The term fabric refers to the arrangement of particles, particle groups and pore spaces in a soil. The particle associates in clay suspension can be described as follows (Van Olphen. 1963, Yong and Warkentin, 1966. and Mitchell 1976):

1. **Dispersed**: No face to face association of clay particles. Possibility of this arrangement arises, in the presence of high inter-particle repulsion and particles will have parallel orientation with respect to each other.

2. **Aggregated**: Face to face association of clay particles as a result of net reduction of inter- particles repulsion and hence aggregation of particles.

3. **Flocculated**: This involves edge to edge or edge to face association of clay particles. Attraction exists between the oppositely charged ends of the particles.

4. **Oriented**: Oriented fabric arises primarily from consolidation effects and particles will be arranged parallel to each other which are normally, perpendicular to the direction of the application of load.

For a given electrolytic concentration, temperature and dielectric constant soils with flocculated structure, generally results in high shear strength, high permeability, low compressibility and low swell ability However, reversal in the behavior will take place for dispersed structure. Apart from the above factors, water content, voids ratio, temperature, aging, organic content/ any cementing material and pH, also influence the behavior of fine- grained soil. The above factors have direct relation with the behavior of soil in terms of compressibility, swell ability and shear strength and permeability.

2.3 Soil-water interaction

Water is strongly attracted to soil mineral surfaces; particularly to clays. Dried clays adsorb water from the atmosphere even at low relative humidity, many soils swell when given access to water, and temperatures above 100°C are needed to remove all the water from a soil. In fact not always evident just what is meant by a dry soil (Lambe, 1949). Several possible mechanisms for water adsorption have been proposed (Low, 1961). They are shown schematically in Fig.2.3.

1. Hydrogen Bonding

Surface of soil minerals are composed of a layer of either oxygen or hydroxyl, so hydrogen bonds can form easily with oxygen attracting the positive corners and hydroxyl attracting the negative corners of water molecules (Fig.2.3*a*). Early concepts of the structure of adsorbed water suggested an ice-like character because of the similarity between the hexagonal symmetry of the oxygen and hydroxyls in clay surfaces and the structure of ice; however, subsequent studies have shown that the structure cannot be that of ice (Mitchell and Soga, 2005)

2. Hydration of Exchangeable Cations

Mitchell and Soga (2005) said that because cations are attracted to negatively charged clay surfaces, so is their water of hydration (Fig 2.3*b*)

3. Attraction by Osmosis

Cations concentration increases as negatively charged clay surfaces are approached (Fig.2.3*c*). This increased concentration means that water molecules tend to diffuse toward the surface in an attempt to equalize concentrations (Mitchell and Soga, 2005).

4. Charged Surface-Dipole Attraction

Mitchell and Soga (2005) stated that clay particles can be viewed as negative condenser plates. Water dipoles then orient with their positive poles directed toward the negative surfaces with the degree of orientation decreasing with increasing distance from the surface. However, at the mid-plane between parallel plates there would be adjacent to each other. Ingles (1968) suggested that because of the high hydration number and energy of aluminum in the clay structure, water is so strongly attracted to the surfaces that it interposes itself between the surfaces and the counter ions with the counter ions removed as far as possible from the surface, that is, to the mid-plane between opposing parallel sheets.