COMPRESSIBILITY AND SHEAR STRENGTH BEHAVIOUR OF PEAT SOIL IN SARAWAK

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Dedicated to my beloved family, friends and myself

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ABSTRACT

Peat soil are well known for their high water holding ability that make them highly compressible, low in shear resistance and low stability. In Sarawak, peat soil covers 13 % of total land area. Therefore, the objective of this study is to investigate the compressibility and shear strength behaviour of peat soil in Sarawak. In order to study the consolidation behaviour, two types of original peat soil samples was tested which are remolded and compacted samples. For remolded samples the approximate moisture content used is about 217 %. Besides, the compacted samples are compacted to approximate dry density of 0.433 Mg/m^3 moisture content of 139 %. The shear strength behaviour of peat soil are performed by testing three samples of original peat soil with different moisture content. The one-dimensional consolidation test and the direct shear test by using small shear box was used in this study. From the experiments performed, it was found that the coefficient of consolidation, C_v value is in the range of 0.133 –0.423 cm^2/min for remolded sample and 0.189-0.598 cm^2/min for compacted sample. Besides, the cohesion, c′ value are in the range of 7.8-17.7 kPa and angle of internal friction φ′ in the range of 24 °- 37 °.

ABSTRAK

Tanah gambut sangat di kenali kerana kebolehannya menampung kapasiti air yang besar yang membuatkan ia mempunyai tahap kebolehmampatan yang tinggi, kekuatan daya ricih yang rendah dan tahap kestabilan yang rendah.Di Sarawak, tanah gambut meliputi 13 % daripada jumlah keseluruhan kawasan tanah. Tujuan kajian ini adalah untuk mengkaji sifat-sifat kebolehmampatan dan sifat-sifat kekuatan ricih tanah gambut di Sarawak.Untuk mengkaji sifat-sifat pemendapan, dua jenis sampel tanah gambut asli akan di uji iaitu sampel yang di adun semula dan sample yang di padatkan. Untuk sample yang di adun semula kandungan lembapan yang di gunakan ialah lebih kurang 217%. Di samping itu, untuk sample yang dipadatkan telah dipadatkan sehingga ketumpatan kering mencapai 0.433 Mg/m^3 dan kandunagan lembapan 133%. Sementara itu, untuk mengkaji sifat-sifat kekuatan ricih untuk tanah gambut pula, tiga sampel tanah gambut asli dengan kandungan lembapan yang berbeza akan di uji. Alat yang akan digunakan untuk ujian pengukuhan ialah Oedometer dan untuk ujian ricih langsung pula kotak ricih kecil akan digunakan di dalam kajian ini. Daripada eksperimen yang di jalankan , di dapati nilai parameter pemalar kemendapan, C_v adalah dalam lingkungan 0.133 –0.423 cm^2/min untuk sampel yang di adun semula dan 0.189-0.598 cm^2/min untuk sampel yang telah dipadatkan. Sementara itu, nilai kepaduan, c' adalah dalam lingkungan 7.8-17.7 kPa dan sudut geseran dalaman φ' pula di dalam linkungan 24 ^{o}- 37 ^{o}.

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1 INTRODUCTION AND SCOPE OF STUDY

1.1 General

Peat is an organic complex soil, well known for its high compressibility and low stability. Peat forms naturally by the incomplete decomposition of plant and animal constituents under anaerobic conditions at low temperatures (Paikowsky et al., 2003). These problematic soils are known for their high compressibility and low shear strength. Access to these superficial deposits are usually very difficult as the water table will be at, near or above the ground surface. Undoubtedly, these are the consequences of the tendency to either avoid construction and buildings on these soils, or when this is not possible, to simply remove, replace or displace them, that in some instances may lead to possibly uneconomical design and construction alternative (Al Raziqi et al., 2003).

A review of soil science literature from different dates may be confusing as the terminology for these soils with an organic content has undergone changes over time especially in the term peat being substituted by organic soils. It is important to understand the meaning of peat and its replacement.

(a) Pre-1982

(i) The term peat was used for soils with an organic content prior to this date.

(ii) An exclusive definition of peat was used in Sarawak with a lower threshold requirement of more than 35% organic matter content in respect of an organic matter content of 65% as was normally used (Tie and Kueh, 1979).

(b) Post-1982

(i) Presently, since 1982, soils with an organic matter content are referred to as organic soil (with qualifications embodied in the Soil Classification of Sarawak). (Tie, 1991).

(ii) The definition of organic soil materials "covers materials which have been called peats and mucks" (Tie, 1991) previously. The above statement is interpreted to mean that the "peat" categorization is no longer used in the organic soils classification in Sarawak.

The revised nomenclature and classification of soils with an organic content are thus devoid of the term peat and it does not even exist as a sub category of any soil type (quoted by Singh and Bujang, 2003).

1.2 Background and Previous Research

In determining the identification test, the most important properties with regard to the compressibility and shear strength behaviour of peat soil are the moisture content, degree of decomposition, specific gravity, organic content, Atterberg limit and optimum moisture content. Moreover, these properties will be determined where possible for the peat tested.

One-dimensional may be defined as consolidation with zero lateral net strain or deformation. Traditionally forecast of this type of consolidation have been based on Terzaghi's famous equation using the results from the standard oedometer laboratory apparatus. However, Terzaghi's equation assumes that consolidation is wholly due to diffusion and does not allow for the important change in pore pressure caused by change of stress (quoted by Hanrahan, 1994).

Peat soils are characterized by their high compressibility and long-term settlement including primary, secondary, and tertiary compression. Because the one-dimensional compression behaviour of peat is so different from that of clays, important postulates pertaining to the consolidation of clays, such as the unique EOP void ratio and the constant C_α / C_c concepts, are found not to be applicable to the peat compression (Edil et al,. 1994).

Edil et al., (1994) stated that the magnitude of void ratio rate is exponentially related to the magnitude of the vertical effective stress increase. The stress coefficient of creep is not constant but increases with increasing void ratio. Evidence suggests that peat fabric has a strong influence on creep rate.

Peat is mainly composed of the fibrous organic matters, which consist partly of decomposed plants and shows the porous fibric with a very high compressibility. Thereby, by a considerable amount of volume change, which will occur in the processes of consolidation and drained shear, the remarkable unevenness will be generally observed on the boundary of the specimen. Thus, there is a strong suspicion that the inaccuracy cannot be avoided in regard to the method of correction for the cross-sectional used for the computation of the test data (Yamaguchi, 1994).

The peaty soil loses its undrained strength when it is subjected to undrained cyclic loading. Even if the drainage is allowed due to dissipation of excess pore pressures generated by undrained cyclic loading, undrained strength does not exceed the undrained strength before the cyclic loading (Yasuhara, 1994). The maximum shear strength of peat is reached after large strains (15 to 20 %). In the triaxial test the test equipment itself can limit the strain. Przytanski suggested that the maximum shear strength can be found by extrapolation of the test results, using the hyperbolic formulation proposed by Kondner (quoted by Termaat, 1994).

Peat soil can be categorized into two types, based on its organic contents in order to analyse its strength characteristics (Landva et al, 1986). The first category, name as Category A represents the peat, which contains low organic matter and it, has been decomposed completely. Peat in this category, in general, has low permeability, but still very compressible. Its strength is also low in the normally consolidated state. Analysis for this category, may follow as that performed for organic soil.

Peat with high organic content which hasn't been decomposed completely, named as Category B. The fibre content of this type influences the shear strength. It has very compressible and high permeable. In this case, the undrained condition almost doesn't exist. The triaxial CD has shown that at large strain, 30% to 40% strain, strength failure has not been reached yet. Because of this, Landva and Rochelli(1983) stated that strength parameters obtained from triaxial shear test are not suitable to be taken as the design criteria. They suggest to use ring shear test to obtain the strength parameters for design, even though the main important criteria is the excessive settlement which will occur before full mobilization of soil strength. Rowe and Mylleville (1996) suggest to use simple shear test to obtain the failure envelope and deformation parameters for both categories A and B which can be used as input in finite element analysis (quoted by Djajaputra and Shouman, 2003).

1.3 Scope of Present Study

The objective of this project is to study the physical properties of peat soil in Sarawak by using soil classification properties and to investigate and analyse the compression and shear strength behaviour based on experimental study.

Peat soil is chosen because it can easily be found in Sarawak. Thus, it is important to understand the characteristics and behaviour of this soil. Since it covers approximately 1.7 million ha or 13 % of the total land area (12.4 million ha) of Sarawak and peat soils have generally been recognized as a problematic soil (Melling and Hatano, 2003).

In chapter two, a presentation of literature review is made in order to review some of the application and geotechnical properties of peat soil. From this section, a comparison between present study and recent study is made and in orderly manner.

The characteristics and the one-dimensional compression and shear strength behaviour of peat soil in Sarawak will be determined from the experimental investigation that will be discussed in chapter 3.

Chapter four presented the results and discussion of experimental investigation that have been conducted. The comparison between present data and recent study is outlined to enable the analysis and discussion of data collected. Finally, chapter five consists an outlined of the conclusions drawn in the project and recommendations for further development of the present work for future research.

2 LITERATURE REVIEW

2.1 General

Before construction works of any structures can be carried out, studies about the behaviour of soil at the location of proposed construction site must be prepared first. The behaviour of the soil and rock at the location of any project has a major influence on the success, economy, and safety of the work (Mitchell,1993).

Sarawak, a state in Malaysia has a land area of 12.4 million hectares. It has approximately 1.7 million ha of peat swamp covering almost 13% of the total land area (Melling and Hatano, 2003). Peat is a material consisting of organic residues formed through the decomposition of plant and animal constituents under aerobic and anaerobic conditions associated with low temperatures and geological effects such as glacial ice. Common names for accumulation of organic soils include bog, fen, moor, muck, and muskeg (Paikowsky et al., 2003).

The soil maps of Sarawak currently in circulation are the 1 : 500 000 maps dated 1968; and 1 : 100 000 and 1 : 50 000 maps dated 1972. the various estimates for organic soil area coverage is given in Table 2.1.

2.2 Engineering Application

2.2.1 Peat as an Energy Source

Peat has been used as form of energy for at least 2000 years. It was useful as an alternative to firewood for cooking and heating in temperate and boreal regions of Europe, in particular Ireland, England, the Netherlands, Germany, Sweden, Poland, Finland and the USSR. The increasing use of gas and oil as cooking and heating fuels during the 20^{th} century resulted in a diminishing use of peat for such domestic purposes. The high demand for electricity, however, locally stimulated the development of large electricity power plants fuelled by peat. Peat appeared especially competitive in the 60-200 MW power plants which necessitated the reclamation of vast areas of peat for large scale peat extraction, particularly in Ireland, Finland and the USSR. Specialized technology was developed for these reclamation efforts. Recently, peat has been used for electricity generation in small units in the range of 20-1000 KW.

As well as these energy uses, peat is mixed with mineral soil in horticulture to increase the moisture holding capacity of sands, to increase the water infiltration rate of clayey soils, and to acidify soils for specific pot plants. Industrial uses include the extraction of valuable hydro-carbons (Table 2.2), and in the building industry it can be used as an insulator because of its poor heat conducting properties. Such uses are however relatively minor in relation to the large-scale extraction for energy purposes on which this chapter concentrates (Andriesse, 1988,WWW).

2.2.2 Peat Filters

A peat filter pretreats septic tank effluent by filtering it through a two-foot-thick layer of sphagnum peat before sending it to the soil treatment system. Peat is partially decomposed organic material with a high water-holding capacity, large surface area, and chemical properties that make it very effective in treating wastewater. Unsterilized peat is also home to a number of different microorganism, including bacteria, fungi, and tiny plants. All of these characteristics make peat a reactive and effective filter.

In research conducted in Minnesota, peat filters removed high concentrations of nutrients (nitrogen and phosphorus) and produced a high quality effluent with less than 30 mg/liter BOD (Biological Oxygen Demand, a measure of organic material), less than 25 mg/liter TSS (Total Suspended Solids), and less than 1000 cfu/100 ml fecal coliform bacteria, an indicator of pathogens and viruses

Wastewater flows from the home into a septic tank where the large solids settle out and the liquid flows into a pump tank. An effluent screen or filter is often installed to restrict smaller solids and grease from flowing out of the septic tank. The liquid effluent is then pumped to the peat filter, where it is pretreated and delivered to the soil treatment system for final treatment. (Gustafson et al., 2001).

2.2.3 Peat As Source Of Ammonia

A decision was made in the late 1970s to use raw Finnish peat as a raw material for manufacturing ammonia in Oulu. The process consists of the refinement of the peat into a synthesis gas, which can also be used as a raw material for other chemical products.

The hydrogen contained in peat can be utilized by converting it to a synthetic gas by a fluidized bed gasification method.

2.3 Classification of Peat Soil

Peat in strict definition usually refers to the accumulation of a purely one hundred percent organic material and the distinction between soil and vegetative accumulation is not clear, by Andriesse, 1992 (quoted by Mohamed et al ., 2002). Peat commonly occur as extremely soft, wet, unconsolidated superficial deposits normally as an integral part of wetland systems (Al-Raziqi et al ., 2003). The term peat is described as a naturally occurring highly organic substance derived primarily from plant materials (Singht et al ., 1997). Soil organic matter originates from plant/animal remains and is often observed in various stages of decomposition with an end product known as humus (Edil , 2003).

Generally, peat soil can be described as soil that formed by the dead wetland materials that cannot decay in a normal way because of the presence of high water table. When the organic matter decomposes, it turns into a sort of glue called humus, which is strong enough to bind several smaller particles together, making them into larger multi-particles, which can alter the behavior of the soil (Paikowsky et al., 2003).

According to Singh and Bujang (2003) the fibre content of peat described by the U.S Department of Agriculture (USDA), which has three-point scale classification of peat, based on fibre content resulting from decomposition and humidification. This classification is given in Table 2.3. Molenkamp (1994) has referred to the organic fibre content as the fabric of organic soils. A fibre is defined as > 0.15 mm in diameter. Molenkamp (1994) stated that the appreciation of the constituent matter of organic soil and its attributes like orientation aid in the constitutive modeling of this soil type for a basic understanding of mechanical behaviour.

Review of literature indicates that peat and organic soils are very variable in their properties, both from one deposit to another and from point to point in the same deposit. Such variations are associated with the origin of these soils, the type of plant which they are derived, the mineral content of the deposit and the amount of decay or humification that had occurred. All these features are reflected in the mechanical behaviour with which the geotechnical engineer is concerned , (Tressidder ,1966 ; quoted by Al-Raziqi et al ., 2003).

In Sarawak, the individual peat bodies range from a few to 100 000 hectares and they generally have a dome-shaped surface. The peat is generally classified as the ombrogenous peat (rainfed) and therefore poor in nutrients (oligotrophic). According to Yogeswaran (1995), the ombrogenous peat comprises mainly of disaggregated tree trunks, branches, and leaves, roots and fruits. Due to coastal and alluvial geomorphology they are often elongated and irregular, rather than having the ideal round bog shape. Most of the coastal peat swamps are elevated well above adjacent river courses, varying from about 4 metres near the coast to more than 9 metres inland. Steep gradients are found at the periphery while the central peat plain is almost flat. Surface slopes vary between 1 and 2m/km at the sides of the domes near the adjacent channel sides,