PHYSICAL AND CHEMICAL PROPERTIES OF ARTIFICIAL SOIL WITH HUMIFIED AND NON-HUMIFIED ORGANIC MATTERS

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To my beloved parents and siblings

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ABSTRACT

Considerable research has been carried out on organic soils which consist of various components of organic matter but the effect of particular organic matter is less reported. This may cause some of the contributing factors of each organic matter are not well understood because each type of organic matter have its own characteristic and the effect on the properties of soils is different. Hence, understanding the physico-chemical characteristic of organic soils is the fundamental needs for researcher and important to identify suitable method for further experiment. Artificial soil was used in this study to control the inconsistency of test results which may be obtained due to complexity of characteristics of natural organic soils. The main objective of this study to determine the effect of humified and non-humified organic matter of the soil samples on the physico-chemical and mineralogy, as well as the shear strength. Two types of artificial soils were utilized, namely kaolin mixed with compost (KC) and kaolin mixed with LM Bio Humus Juice (KH). Physical and chemical properties such as Atterberg limit, moisture content, specific gravity and acidity level were determined to establish the basic characteristics of soil. Mineralogy and molecular characteristic of samples were determined based on the X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR). Strength of artificial soil was evaluated using unconfined compressive strength test (UCS). Based on the results obtained, compost had changed with decomposition in which it had degraded from fibric peat to hemic peat after a period of 6 months. Decomposition process also affected the physical and chemical properties of artificial soil. Specific gravity of artificial soil KC had reduced with the increment of decomposition period. Humified organic content of compost was found to be increased with decomposition period which shown that the fibres were decomposed. Fiber content had significantly decreased with decomposition period as well as its losses on Ignition (LOI). The strength of soil specimens KC were increased with decomposition period in which the humified matter were increased from 38% to 41% within the test period. The effect of humified matter on strength was tested utilizing artificial soil KH. The plasticity index of artificial soil KH decreased with increment of LM Bio Humus Juice which can be associated with flocculation of soil aggregate. Unconfined compressive strength of artificial soil KH had increased with higher content of LM Bio Humus Juice. The results obtained throughout this study will be beneficial for the understanding on the basic characteristic of organic soil as reference for further experiment in order to identify the strength and improvement method in real construction environment.

ABSTRAK

Kebanyakan penyelidikan telah dijalankan pada tanah organik yang terdiri daripada pelbagai komponen bahan organik tetapi kesan bahan organik tertentu kurang dilaporkan. Perkara ini akan menyebabkan beberapa sumbangan kepada setiap bahan organik tidak difahami dengan baik kerana setiap jenis bahan organik mempunyai ciri-ciri tersendiri dan kesan terhadap tanah yang berbeza. Oleh itu, memahami ciri fiziko-kimia tanah organik adalah keperluan asas bagi penyelidik untuk mengenal pasti kaedah yang sesuai untuk percubaan selanjutnya. Tanah buatan telah digunakan dalam kajian ini untuk mengawal ketidakselarasan keputusan ujian yang mungkin dapat disebabkan kerumitan ciri-ciri tanah organik semula jadi. Objektif utama kajian ini untuk menentukan kesan bahan humified dan bukan humified organik daripada sampel tanah di fiziko-kimia dan mineralogi, serta kekuatan ricih. Terdapat dua jenis tanah buatan telah digunakan, iaitu kaolin dicampur dengan kompos (KC) dan kaolin dicampur dengan Jus LM Bio Humus (KH). Sifat-sifat fizikal dan kimia seperti had cecair, kandungan kelembapan, berat jenis dan tahap keasidan ditentukan untuk menwujudkan ciri-ciri asas tanah. Mineralogi dan ciri-ciri molekul sample ditentukan berdasarkan X-Ray pendarfluor (XRF), X-Ray Diffraction (XRD) dan Fourier Transform Infrared Spektroskopi (FTIR). Kekuatan tanah tiruan telah dinilai menggunakan tak terkurung ujian kekuatan mampatan (UCS). Berdasarkan keputusan yang diperolehi, jenis-jenis bahan organik dalam kompos telah berubah dengan penguraian di mana kompos digunakan dalam tanah KC telah bertukar dari gambut fibric ke gambut hemic selepas 6 bulan. Process penguraian turut memberi kesan kepada sifat-sifat fizikal dan kimia tanah buatan. Graviti tentu tanah buatan KC mengurang dengan peningkatan tempoh penguraian. Kandungan bahan humified telah didapati meningkat dengan tempoh penguraian yang menunjukkan bahawa gentian telah mereput. Kandungan serat telah menurun dengan ketara dengan tempoh penguraian dan juga kerugian pada pencucuhan (LOI). Kekuatan tanah buatan KC telah meningkat dengan tempoh penguraian dimana bahan humified meningkat daripada 38% kepada 41% dalam tempoh ujian. Kesan daripada bahan humified telah diuji menggunakan tanah buatan KH. Indeks keplastikan tanah buatan menurun apabila kandungan Jus LM Bio Humus bertambah dimana boleh dikaitan dengan pemberbukuan agregat tanah. Kekuatan mampatan tak terkurung tanah buatan KH telah meningkat dengan kandungan Jus LM Bio Humus yang lebih tinggi. Kekuatan tanah buatan telah meningkat dengan kenaikan kandungan Jus LM Bio Humus. Keputusan yang diperolehi sepanjang kajian ini akan memberi manfaat kepada pemahaman mengenai ciri-ciri asas tanah organik sebagai rujukan untuk mengenalpasti kekuatan dan penambahbaikan dalam persekitaran sebenar pembinaan.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Soil is the base and primary material used in construction work. Before any construction work starts, the properties of foundation soil for a project must be identified to ensure it can sustain the building and prevent it from collapsing. There are many types of soil with their unique characteristic in this earth. One of these types is organic soil, which is normally removed or requires special treatment by contractors before any construction can be done on it. Organic soil is normally found in low-lying areas where the water table is near or above the ground surface. Growth of aquatic plants is due to presence of high water tables and when these aquatic plants decompose, they form organic soil. Thus, organic soil is usually found in coastal areas and in glaciated regions (Das, 2013).

In geotechnical engineering, soil with more that 20% organic content is classified as organic soils (IKRAM, 1995; Huat, 2004). Organic soils are known as soils with low strength and high compressibility, which cause settlement and foundation failure. This is because presence of organic matter that will influences the properties of soils (Bot and Benites, 2005).

Soil organic matter (SOM) is one of the major components in organic soils. It can be categorized into living and non-living organisms. Non-living fraction is made up of plant and animals a residue which undergoes the degradation and decomposition process (Manley, Feller & Swift, 2007). Decomposition is a naturally occurring process and also a biological process that physical breakdown and transformation of biochemical of complex molecules into simpler organic and inorganic molecules (Juma, 1998).

Dead material can be divided into two group which are degraded material and humus (completely decomposed material). Degraded material is also known as materials in which the plant substance is still visible. Humus is composed of non-humified and humified substances. Humified and non-humified organic matter will influence the properties of soil. The humified and non-humified organic matter is found to increase the water holding capacity of soils causing the strength of soil to decrease and the settlement problems to occur (Murphy, 2014). According to Ling *et al.* (2013), pH value of soil might be influenced by the type of organic matter and humification level.

The use of artificial organic soil, especially the mixed of kaolin with humic acid, are widely used nowadays by previous researcher (Pakir *et al.*, 2013, Yunus *et al.*, 2011, Xu *et al.*, 2008 and Li *et al.*, 2012). The purpose of using artificial organic soils was to focus on identifying the effect of specific types of organic matter on the properties of soils. Onitsuka *et al.* (2002) found that humic acid was one of the main organic matter that affect the strength of soils.

1.2 Problem Statement

Organic soils have not received the required attention in civil engineering, whereas they have always been categorized by civil engineers as unsuitable soil material or “problematic soils”. This is due to the presence of organic matter in soils that is associated with high compressibility, high water content, low permeability and low shear strength. These characteristics have caused organic soils to become unsuitable for engineering construction purpose. Natural organic soils are made up of different kind of organic matter. With each type having its own characteristics and effect on the property of soils. Huat, Maail & Mohamed, (2005) and Yunus, Wanatowski & Stace (2011) had stated that a high concentration of organic matter will destabilise the soil. The effect of organic matter, especially organic acid, on the strength development of organic soils are not fully understood yet. Hence, further studies are required to quantify the effect of humified and non-humified organic matter on the physical, chemical and engineering properties of soils.

Previous studies by Xu *et al*. (2008), Yunus *et al*. (2011) and Pakir *et al*. (2013) had focused on identifying the effect of organic content on the physical and chemical characteristic of artificial organic soil in terms of quantity. However, due to different decomposition and humification levels of organic soil, the properties of organic soils are not only affected by the amount of organic matter, but also by the types of organic matter. Hence, it is important to determine the behaviour of organic soil behaviour when the organic matter changes with decomposition. This study looked into the type of organic matter as well as its physical, chemical and mineralogical characteristic and its effect on the strength.

1.3 Objectives

The objectives of this study are shown as below:

1. To identify the physical, chemical and soil mineralogy properties of humified and non-humified organic matter.

2. To determine the effect of humified and non-humified organic matter on soil samples in regards to the physical and chemical properties, as well as shear strength.

1.4 Scope of Study

This study had focused on experimental work to investigate the physical, chemical properties and microstructure of humified and non-humified organic matter.

Artificial organic soils were mixed and utilized in this study for the purpose of minimize the inconsistency of test results that could be affected by the geochemical variability of natural organic soils. For artificial soil (KC1), 70% of kaolin was mixed with 30% of compost (humified and non-humified organic matter). Compost was created when decomposition occurred on coir fiber mixed with microbials after a one month period of decomposition. The total decomposition period for compost was 6 months. Hence, overall, 6 samples were created. Whereas, artificial soil type 2 (KH15) was obtained by using a constant amount of kaolin (inorganic matter) at 85%, mixed with LM Bio Humus Juice, (humified organic matter) at 15%. The LM Bio Humus Juice was diluted into different concentrations by adding 7.5%, 10% and 11.25% of distilled water.

The created compost was tested by using the Von post test and its fiber content was identified for each month. Physical and chemical property tests were carried out to determine characteristics of soils. In order to determine the physical and chemical properties of artificial organic soils, the experimental test used were Atteberg limit, specific gravity, moisture content, pH determination and Loss on Ignition (LOI), In additional, the mineralogy characteristic and chemical composition were determined by X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR). The strength properties of soil samples were evaluate by applying the unconfined compressive strength test (UCS).

Artificial soil KC were remoulded by compaction using self-weight and the unconfined compressive strength test was carried out using a triaxial test frame, in accordance to BS 1377 - 7: 1990. The soil samples were cured for 7 days under room temperature. Besides that, soil KH were remoulded with dimension of 50mm in diameter and 100mm in height and prepared using axial compression in accordance to BS EN 13286-53: 2004. Soil specimens were cured for 7 or 28 days under room temperature and 50°C.

1.5 Significance of Study

The significant effect of typical organic matter on the characteristics and strength of soils is not yet fully understood even though numerous studies have been done on it. One of the main challenges is to clarify the types and quantity of the organic matter contained in the soil since it changes according to the decomposition or humification from time to time. Therefore, by controlling the variables in artificial soil, the effect of particular organic matter on soil properties and strength behavior can be easily determined. The results obtained throughout this study would be beneficial for understanding basic characteristics of organic soil as references for further studies to identify the strength and improvement method in real construction environment.

1.6 Thesis Outline

This thesis aims to investigate the effect of humified and non-humified organic matter on physical, chemical, mineralogical and strength properties of artificial soils. A brief summary of each chapter is explained in this section with each chapter focusing on a different subject matter, as follows.

Chapter 1 describes the introduction of the research, the problem statement, objective of study, significance of study and the scope of study. There is a brief overview of the humified and non-humified organic matter as well as problem or issues pertaining to organic soil.

Chapter 2 contains the review of the literature from past studies related to organic soil, decomposition of organic matters, soil's physical and chemical characteristics, effect of organic matter on soils, effect of decomposition on soils and strength behavior of organic soils.

Chapter 3 focuses on the material characterization and selection, detailing which artificial soils were mixed as well as describing all the experimental testing procedures.

Chapter 4 analyses and presents the test results based on experimental test conducted. All the index properties, chemical test, soil mineralogy, chemical composition and strength properties are discussed in detail. The material properties reported in this topic portray the characteristics and behavior of artificial soils.

Lastly, Chapter 5 outlines the conclusion of the research and a summary of the present study as well as detailed recommendation for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of the research related to the current study. A review of the literatures and previous studies are important to enhance the basic knowledge of organic soil before proceeding further in to the process of this study. Most of the information and knowledge related to this study were obtained from sources such as journals, books, thesis, internet and conference papers.

There is a brief review on organic soil in section 2.2. Soil is made up of organic and inorganic matter. Soil organic matter can be divided into humified and non-humified, as a result of the decomposition or humification process. There are few types of classification systems focused in this chapter. Section 2.3 highlights the methods of testing commonly used or recommended in previous studies for determining physical and chemical properties of organic soil, which has its own pros and cons. Understanding each testing requirement is important to ensure that the results obtained are applicable. Section 2.4 is an overview of the factors that affect the physical, chemical and microstructure characteristic of artificial soils. The physical and chemical properties can be reviewed through the data obtained by previous researchers. The last part of this chapter summarized the research work of various researchers and highlighted the gap in the subject matter.

2.2 Organic soil

Soil with more than 20% of organic matter can be classified as organic soil (Zulkifley *et al.*, 2013). The soil can be classified as organic soil when it contains a mixture of mineral grains and organic matter of mainly vegetable origin in varying stages of decomposition (Whitlow, 2001).

Organic soils are predominantly plants remains, usually dark brown, dark grey, black or blue-black in colour. It is normally has a distinctive smell and low bulk density (Head, 2009). Presence of organic matter gives the soils a smooth texture when touched. In Malaysia, there are over 3 million hectares of land covered by peat or organic soil (Huat, 2014). However, organic soils has high compressibility, high moisture content and low shear strength, which usually been defined as "unsuitable soil material" for construction purposes.

2.2.1 Classification of organic soil

Myslinka (2003) stated that classification system of organic soils for engineering geology can be classified into 3 classes, namely genetic classification, non-genetic classification and descriptive-genetic classification.

- Genetic classification system: classifies organic soils based on the environment in which it is found.
- Non-genetic classification system: classifies organic soils based on the organic matter contained in it (different in every country).
- Descriptive-genetic classification system: based on the threshold values of the organic content as well as the origin of the soil.

In France, soils are categorized as organic soil when it contains more than 10% organic matter (Perrin, 1974). It is sub-divided into highly organic, medium organic soil and poorly organic soils as shown in Table 2.1. The classification systems in the Netherland are shown in Table 2.2. In Germany norm DIN 18190 (10.88) had concluded that soil could be classified as organic soil when the sandy soil contains more than 3% of organic matter and sandy-silty fine sand contains more than 5% of organic matter.

Table 2.1 Non-genetic classification of organic soil in France (Myslinka, 2003)

Classification	Requirement
Highly organic soils	>30% of organic matter
Medium organic soils	10% - 30% of organic matter
Poorly organic soils	3 – 10% of organic matter

Table 2.2 Non-genetic classification of organic soil in the Netherlands (Myslinka, 2003)

Material	Classification	Requirement
Peat	Poorly clayey	30-55% of clay fraction
	Strongly clayey	55-70% of clay fraction
	Poorly sandy	22.5-35% of organic matter 30-55% of clay fraction 0-8% of sand fraction
	Strongly sandy	15-22.5% of organic matter >8% of sand fraction
Humic Soil	Poorly humic	0-2.2% of organic matter
	Strongly humic	2.2-15% of organic matter

According to Polish norm PN-86/B-0248, a non-rocky organic soil is divided into humic soils, warps, gyttja and peats. Table 2.3 shows the soils classification based on ash content which mentioned by Wolski (1996). Another classification system by Borys (1996) had stated that organic soils is classified based on the soil types, degree of decomposition, calcium carbonate content, ash content, humidity and angle of internal friction.

Table 2.3 Descriptive-genetic classification by ash content (Wolski, 1996)

Classification	Ash content
Low ash peats	0-25%
Medium ash peaty soils	25-50%
High ash muds	50-80%
Organic silts and clays	80-98%
Gyttja and lake marl	Organic-calcareous soils, distinguished as a separate group, irrespective of ash content.

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