UTILIZATION OF DEMOLISHED TILE MATERIAL AND CEMENT TO STABILIZE MARINE CLAY

ERMYZA HILLARY

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I would like to dedicate this master research to all the precious persons in my life especially,

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ABSTRACT

The presence of marine clay soil in the fundamental establishment has been liable for the disappointment in a few geotechnical designs. Substance techniques for soil improvement are the typical practices to work on the strength of soils. Nonetheless, distributions on the key microstructural conduct of traditional materials stirred in with waste material added substance to treated marine clay soils and their effect on the designing conduct are restricted. Malaysia is rich with huge stores of rock stone, which is a kind of Demolished Tile Material (DTM), that leads to contamination because of the procedures and cycles utilized during manufacturing and the idea of the high alkalinity of this waste. However, this research aimed at determining the stabilisation mechanism and performance of marine clay soil treated by traditional stabiliser and waste material additive, specifically cement and DTM. The utilization of DTM helps to reduce the negative impacts on the environment through recycling. As for the macrostructural tests, the unconfined compressive test (UCS) and oedometer consolidation tests were implemented to evaluate the engineering properties of the treated soil. Microstructural studies from various spectroscopic and microscopic techniques, such as X-ray Diffractometry (XRD), Energy-Dispersive X-ray Spectrometry (EDX) and Scanning Electron Microscopy (SEM) had been conducted to explain the adjustment system. The research test results show the variety of cement and DTM rates at day 0 until 60 days of the curing period. The laboratory tests showed that the addition of 16% (as the optimum amount) of DTM additive increased the strength along the curing period. The compressibility of treated soils decreased with the increase in the curing period. The microstructural study revealed that the stabilisation process modified the porous network of marine clay soil. The consequences of the microstructural tests demonstrated the development of another mineral item in the blends, which was recognized as Calcium Aluminium Silicate Hydrate (CASH) for treated marine clay. In XRD test, a slight decrease in the intensity of kaolinite and montmorillonite peak for treated soils with C10% mixed with various percentages of DTM was identified. While, in EDX test the consumption of Ca, Al and Si was confirmed with the increase in the DTM in treated marine clay soils. In short, the chosen materials for marine clay treatment had effectively improved the strength of marine clay at an early period as expected and the use of the chosen waste material additive was considered as low carbon and harmless to the ecosystem for the geotechnical projects.

ABSTRAK

Kehadiran tanah liat marin dibawah asas telah menyebabkan kegagalan dalam beberapa reka bentuk geoteknik. Teknik menggunakan bahan tambah untuk penambahbaikan tanah adalah kaedah biasa yang mempengaruhi pada kekuatan tanah. Walau bagaimanapun, kajian mengenai ciri-ciri mikrostruktur utama bahan tradisional yang dicampurkan dengan bahan buangan sebagai bahan tambah, untuk merawat tanah liat marin dan kesan terhadap ciri-ciri mereka bentuk adalah terhad. Malaysia kaya dengan simpanan batu dalam kuantiti besar, termasuk Bahan Jubin Dihancurkan (DTM), yang menyumbang kepada pencemaran disebabkan prosedur dan kitaran bahan buangan selepas pembinaan dan idea tentang kealkalian tinggi sisa ini. Walau bagaimanapun, penyelidikan ini bertujuan untuk menentukan mekanisme penstabilan dan prestasi tanah liat marin yang dirawat oleh penstabil tradisional dan bahan buangan, khususnya simen dan DTM. Penggunaan DTM membantu mengurangkan kesan negatif terhadap alam sekitar melalui proses kitar semula. Bagi ujian makrostruktur, ujian mampatan tak terkurung (UCS) dan ujian pengukuhan telah dilaksanakan untuk menilai sifat kejuruteraan tanah yang dirawat. Kajian mikrostruktur daripada pelbagai teknik spektroskopi dan mikroskopik, seperti difraktometri sinar-x (XRD), tenaga serakan x-ray spektrometri (EDAX) dan pengimbas elektron mikroskop (SEM) telah dijalankan untuk menerangkan mekanisme penstabilan tersebut. Keputusan ujian kajian menunjukkan kesan penggunaan simen dan bahan buangan DTM mengikut peratus yang berbeza, sepanjang tempoh pengawetan iaitu dari hari 0 hingga 60 hari. Ujian makmal menunjukkan bahawa penambahan 16% (sebagai jumlah optimum) bahan tambah DTM, meningkatkan kekuatan sepanjang peningkatan tempoh pengawetan. Kebolehmampatan tanah yang dirawat berkurangan mengikut peningkatan tempoh pengawetan sampel. Kajian mikrostruktur memaparkan bahawa proses penstabilan mengubah suai permukaan tanah liat marin yang berliang. Hasil daripada keputusan ujian mikrostruktur menunjukkan kewujudan item mineral lain dalam campuran, yang dikenalpasti sebagai Kalsium Aluminium Silikat Hidrat (CASH), yang terbentuk di dalam tanah liat marin yang telah dirawat. Dalam ujian XRD, sedikit penurunan pada puncak intensiti mineral kaolinit dan montmorilonit untuk tanah yag telah dirawat dengan C10% bercampur dengan pelbagai peratusan DTM telah dikenalpasti. Manakala, bagi ujian EDAX, kewujudan Ca, Al dan Si telah disahkan meningkat, selaras dengan peningkatan DTM dalam tanah liat marin yang telah dirawat. Ringkasnya, bahan-bahan yang dipilih untuk merawat tanah liat marin, telah meningkatkan kekuatan tanah liat marin dengan berkesan, pada tempoh awal pengawetan seperti yang telah dijangkakan, dan penggunaan bahan tambah iaitu bahan buangan yang dipilih dianggap sebagai karbon rendah dan tidak berbahaya kepada ekosistem serta projek geoteknik.

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12T7D	-	DTM 12% Treated at 7 Days
Al	-	Aluminium
C	-	Carbon
C10%	-	Cement 10%
Ca	-	Calcium
CASH	-	Calcium Aluminium Silicate Hydrate
DTM	-	Demolished Tile Material
EDX	-	Energy Dispersive Electron Microscopy
Fe	-	Iron
GS	-	specific gravity
K	-	Potassium
LIR	-	Load Increment Ratio
LL	-	Liquid Limit
LVDT	-	Linear Variable Displacement Transducer
Mg	-	Magnesium
NASH	-	Sodium Aluminosilicate Hydrate
O	-	Oxygen
OPC	-	Ordinary Portland Cement
PL	-	Plastic Limit
S	-	Sulfur
SEM	-	Scanning Electron Microscopy
Si	-	Silicon
UCS	-	Unconfined compressive strength
USCS	-	Unified Soil Classification System

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the geotechnical field, fundamentally, the serious issue to be looked into is the development of the soil qualities, for example, marine clay soil which can affect the augmentation of any development to have an enormous settlement. The basic issue that regularly happens in the street or other development industries is settlement. This is because of the condition in the embankment base, which is influenced by the marine clay soil. Essentially, settlement might happen if the interstate is based on lands that are less steady and have a low bearing limit, especially marine clay soil. Therefore, before continuing with an interstate or any development that have arrangements with marine clay soil, this soil should first be settled, improved, and treated.

There are different techniques to take care of issues related with marine clay soil like blending the soil in with any ground materials, compaction, vibration, lightweight material, fly grouting, and others. One of the creative soil upgrades that have been utilized generally these days is waste material additives. As such, an additional procedure is likewise needed to deliver the best thought which can supplant existing waste for soil improvement strategies and simultaneously produce a superior new material in contrast with past research.

The soil improvement strategy can be divided into two that are traditional and non-traditional. Essentially, traditional additives are the adjustment strategies that have been previously talked about in past research from the essential things to the subtle mechanisms and performances. Traditional stabilisers include Ordinary Portland

Cement (OPC), lime, fly debris, and bituminous materials (Rashid et al., 2017). The other classification, which is non-traditional, is any uncommon additives that have been utilized in the industry. For the most part, Demolish Tile Material (DTM), granite tile debris, biopolymer, lignin, resin, enzyme, acid, and ion are incorporated as types of non-traditional additives (Tingle *et al*., 2007). Non-traditional additives are presented as fluid and powder structures by a few companies (Latifi et al., 2016).

Moreover, by referring to previous research, OPC used as a traditional additive was identified to be harmful to the environment. OPC material might harm the regular habitat by influencing the pH of the soil and simultaneously produce ozone depleting substances (Chen et al., 2019). In addition, OPC production contributes roughly 5% of carbon oxide (CO^2) all over the world. Until 2012, cement volumes are approximately 3.7 billion ton and forecasted to reach 4.4 billion ton by 2050. Average emissions are approximately 900 kg CO^2/ton OPC. The prices of OPC are also expected to increase year by year. For these reasons, utilization of demolished tile waste materials is seen to be a good measure in creating a new sustainable and environmentally friendly method for marine clay treatment.

Furthermore, OPC and also DTM alone are proven as effective additives used for soil improvement where OPC additives increase the permeability of the marine clay (Kamruzzaman, 2002), while DTM act as material that improves the mechanical and index properties. DTM has also been proven to be good for strength enhancement (Zainuddin et al., 2019a). However, the mixing of both materials has not been intensely researched. Therefore, this study will identify and explain clearly about the primary (formed by hydration reaction) and secondary (formed by pozzolanic reaction) reaction (Kamruzzaman, 2002), that occur between two different traditional and non-traditional additives that will be mixed together.

In a nutshell, as for an innovation in soil stabilisation, the main idea is to study the combination of more than one additive in a marine clay soil. Sometimes, there is a need of an alternative that are more environmentally friendly, sustainable, and economical by reduction of curing period. The study done for the combination of DTM and cement will clearly identify other mechanisms and performances of the marine clay soil. By focusing on the environmentally friendly and sustainable materials, DTM also proved the characteristics as mentioned by the researchers (Zainuddin et al., 2019a).

1.2 Problem Statement

Marine clay soil is known as problematic soil that is constantly identified with terrible showing when loaded (Al-Bared, Harahap et al., 2018). Moreover, the primary issues in the development industry these days is the designing properties of marine clay soil, which have high compressibility, low shear strength, both low and high-enlarging, settlement, and low bearing limit (Latifi et al., 2017). Previously, these issues were treated with traditional stabilisers that incorporates bituminous products, OPC, fly debris, and lime that have been strongly explored, and their fundamental stabilisation mechanisms have been acquired (Obuzor et al., 2012).

In recent years, an expanding number of waste material additives have been developed for soil stabilisation purposes. The waste material additives have been developed and promoted to address the issue for elective innovations which are harmless to the ecosystem, economical, and sustainable. Notwithstanding, the impacts of these additives are yet to be seen, particularly in stabilising mechanisms and their confidential chemical composition, which makes it difficult to assess the stabilising mechanisms and foresee their presentation (Latifi, 2014). The natural environmental properties such as pH value of the soil and greenhouse gas emissions will experience a negative impact from the cementing materials as a traditional chemical stabiliser (Chen *et al.*, 2019). Basically, the impact can only be seen a few years later, but the awareness among the community should be highlighted as an early prevention for a clean and safe environment in the future. It is important to consider the next generation and to appreciate nature for a better life.

The price of Ordinary Portland cement (OPC) are also expected to increase year by year. Besides, OPC is presently being discussed for its expenses as well as for its environmental impacts during manufacture (Antony & Nair, 2016). For these reasons, utilization of Demolished Tile Material (DTM) waste material as an additional and environmental friendly materials to reduce on utilization of OPC quantity, for marine clay soil treatment. DTM additionally would add to diminishing the CO_2 delivered during the production of OPC (Al-Bared, Harahap, et al., 2018).

Moreover, Malaysia is rich with enormous granite stones (a kind of DTM), that is cut as requested into several different interior and exterior tiles at the tile of the industrial facilities (Alavi Nezhad Khalil Abad *et al*., 2016). The yearly production of granite and marble stone wastes were assessed to be 78 million tons around the world (Zainuddin *et al*., 2019). The waste of DTM exceptionally contaminates because of the procedures and cycles utilized during manufacturing and the idea of the high alkalinity of this waste. This is in agreement with Hamza *et al*. (2011) that measured the amount of DTM waste in Egypt where the waste of DTM during production per m^3 is 39% and 53% for 300 mm × 20 mm × free length and 305 mm × 305 mm × 10 mm, respectively. Mishra *et al*. (2014) expressed that the amount of every day DTM in the tile cutting processing plants is 3000 metric tons. Singh *et al*. (2016) announced that the deficiency of DTM mass is around 30% during the manufacturing process of DTM. Besides that, the complete granite stone production is 45–55 million square meters each year and the waste during the cutting process in India is 15%. Sehgal and Malviya (2019) indicated that granite powder is generated in large quantities as a by-product of industrial waste. The amount of DTM waste during production is around 65% of the complete production as detailed by Singh *et al*. (2016). In addition, the construction and demolition (C&D) wastes comprised 25% of the strong waste generation in India. C and D incorporated tile and ceramic wastes that contributed an enormous extent as landfill prompted serious social and ecological issues (Antony & Nair, 2016). Additionally, roughly 7% to 30% of the absolute production of the ceramic tile plants end up as waste. Furthermore, a ton of environmental issues and air contamination might be caused by the presence of this fine ceramic tile contents in the climate (Al-Bared, Harahap et al., 2018). This adverse consequence can be diminished through recycling. The chance of recycling waste from the development industry is along these lines of expanding significance (Antony & Nair, 2016). Also, squashed tile and ceramic materials in Egypt gave more added qualities to these ecologically harmful wastes and subsequently encouraged their recycling endeavours (Sharkawi et al., 2018).

In a nutshell, reduction in cementing material industries might help to reduce the negative impacts toward the environment with the addition of DTM as a filler. The investigation on utilization of DTM in certain amounts after mixing with OPC would definitely help the reduction of OPC materials used. The ideas of using DTM mixed with OPC is because in previous papar stated that, by using DTM alone the binder effects were not enough. Besides, UCS is reduced when the marine clay soil is treated with the DTM alone (Zainuddin et al., 2019b). All of these processes will be proven and conducted by implementing macrostructural and microstructural behaviours of treated marine clay soil. Macrostructural and microstructural testing include several tests that involved Unconfined Compression Strength (UCS), consolidation test, X-ray Diffraction (XRD), Scanning Emission Microscopy (SEM) and Energy Dispersive X-Ray Spectrometry (EDX) analysis. The mineral and effect of DTM and OPC, for both untreated and treated marine clay soil will be identified at the end of this study.

1.3 Objectives

This research aims to identify the improvement in performance and mechanism of marine clay soil treated with OPC mixed with DTM. Thus, the objectives of this research are as the following:

i. To determine the progression in the macrostructure of treated marine clay soil with different percentages of DTM combined as one with a constant amount of OPC that have been fixed at various curing periods;
ii. To determine progression in the microstructural behaviour of treated marine clay soil; and
iii. To evaluate correlation between macrostructural and microstructural changes of treated marine clay soil on engineering properties.

1.4 Scope of Work

This research focuses on the solution of problems that occurs on marine clay soil. Generally, there are several ways to treat marine clay soil but, in this research, will discuss more on traditional mixed with waste material for marine clay soil improvement. To be more specific, OPC mixed with DTM are materials that will be selected for this research. This is because DTM was identified as one of the problematic waste production materials from the construction industry.

Furthermore, this research will focus on several selected tests for both macrostructural and microstructural changes. As for the macrostructural study, it comprises the unconfined compression test and consolidation test, while the micro-structural study involved X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectrometer (EDX).

The tests were ready and cured as explained in the British Standard (BS 1924: Part 2: 1990). The percentages of the DTM utilized in the mixture of soil samples were 4%, 8%, 12%, 16%, and 20% restored at 0, 7-, 14-, 28-, and 60-day curing periods, whereas for the cement, it is 10% consistently for each sample. As there are great amounts of samples and significant expenses for the microstructure tests, the test was restricted to the sample that showed the highest degree of stabilisation. The 10% of cement stabiliser and 16% of DTM additives were picked as the optimum value through the investigation of the outcomes from UCS testing.

1.5 Significance of Study

The mechanism of the treatment of marine clay soils with OPC mixed with DTM had been set up. The significance of the study are as follows:

i. Understanding the component of the treatment process through the outcomes of the macrostructural (UCS and Consolidation Test) and microstructural studies (XRD, SEM and EDX);

ii. Another finding from the physical changes from the macrostructural test new mineralogy from the microstructural test results of treated marine clay soils can be utilized for additional studies;

iii. The performance of treated marine clay soil could be utilized to allow the practice of engineers to utilize traditional stabilisers mixed with waste material, the DTM additive, to treat marine clay soils, especially in sub-grade application construction. The strength reached a minimum value of subgrade design strength for low volume road (0.8MPa) after marine clay was treated with DTM mixed up with cement (Arshad et al., 2018).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter present the current knowledge from past researchers, especially the fundamental of waste material, Demolished Tile Material (DTM) and cement that used for marine clay soil improvement. DTM was chosen due to the environmentally friendly consideration. The topic is discussed about the evidence of what is currently known about the research topic. Besides, this chapter provides clarification about parameters, including the bearing capacity of the soil, engineering properties, shear strength, chemical combination, compressibility and others.

2.2 Background of Marine Clay Soil

Marine Clay soil is also known as soft soil or very soft soil. In many construction industries, among the highest consideration is given to determine and consider the type of soil. These days, the augmentation of failure in any development because of the soil factor has been known around the world. Marine clay soil is among the ambiguous soils that need to be given more attention due to the shrink-swell characteristic that is frequently encountered in civil engineering projects. Basically, there are several behaviours of marine clay soil that caused major failure in any civil engineering project, such as sensitivity to environmental conditions, low bearing limit, high compressibility, and poor shear strength. Marine clay soil is broadly found in surficial regions; nonetheless, it is known to be muddled and difficult to manage, particularly as a foundation for different overhead structures in any civil engineering project. Therefore, in order to improve the marine clay soil performances, addition of a stronger material for better execution under different loads are applied. Moreover, the difference between marine clay and other soil are obviously seen from their appearance, but something that is unseen but important to be identified is the amount of mineralogy of each type of soil. As for marine clay soil, there are many amount minerals that can be found such as the amount of kaolinite, bentonite and others, especially after the additional with an additive.

2.2.1 Marine clay Minerals

Marine clay soil includes wide-ranging mineralogical compositions that might contain various amounts and kinds of marine clay minerals like kaolinite, illite, and montmorillonite just as non-clay minerals like quartz, and additional natural matter. Most marine clay minerals are structurally and chemically analogous to other phyllosilicates which allow for more substitution of their cations. There are complicated aluminium silicates made out of one of two essential units: silica tetrahedron and alumina octahedron. Every tetrahedron unit comprises four oxygen particles encompassing a silicon iota. A combination of tetrahedral silica gives sheet silica. An octahedral unit comprises six hydroxyls encompassing an aluminium particle while a combination of the octahedral aluminium hydroxyl units gives an octahedral (gibbsite) sheet. The tetrahedral and octahedral sheets are the major primary units of these minerals. It ought to be noticed that when a silica sheet is stacked over an octahedral sheet, these oxygen particles replace the hydroxyls to fulfil their valence bonds (Figure 2.1).

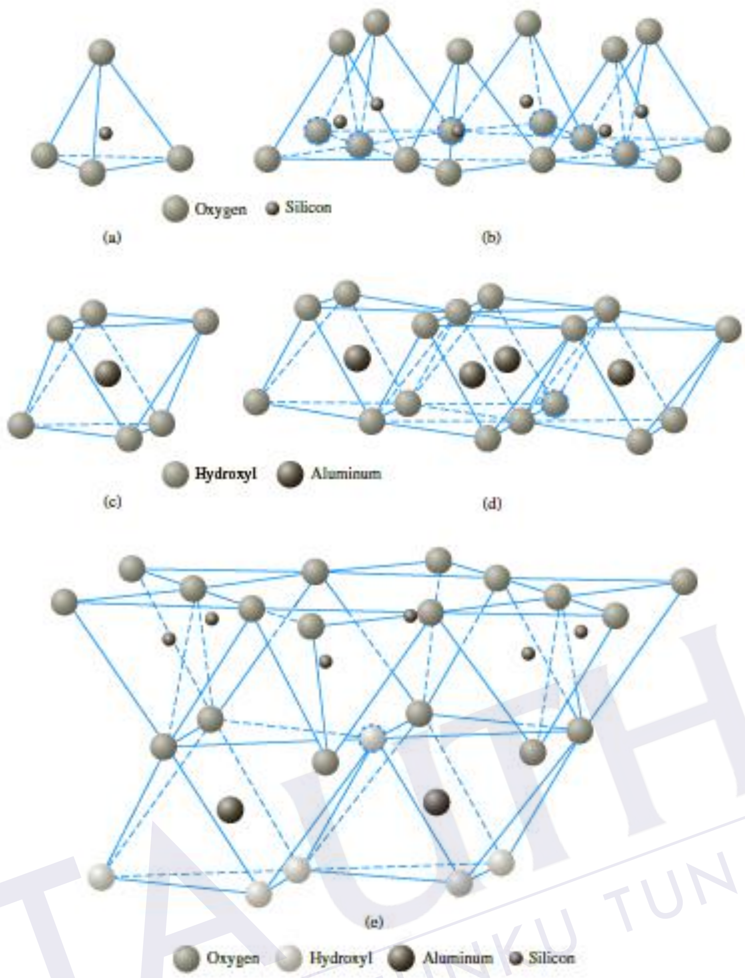

Figure 2.1: Basic unit arrangements of silicon and aluminium (a) Silica tetrahedron; (b) silica sheet; (c) alumina octahedron; (d) octahedral (gibbsite) sheet; (e) elemental silica-gibbsite sheet (Das, 2013).

2.2.1.1 Kaolinite

There are various types of mineralogy of marine clay. Different sources of marine clay soil have different percentages of each type of mineral. Kaolinite is a common mineral that can be found in marine clay soil. This mineral represents a low-swelling clay. The contents of kaolinite include silica and alumina plates. In addition, kaolin clay is very stable and contributed to the very strong connection between the plates. Figure 2.2 shows a diagram of the structures of kaolinite.

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