STABILIZATION OF CLAYEY SOIL USING POLYETHYLENE AND POLYPROPYLENE

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ABSTRACT

A number of studies have been conducted recently to investigate the influence of randomly oriented fibers on the geotechnical behavior of grained soils. However, very few studies have been carried out on fiber-reinforced clayey soils. Therefore, this experimental work has been performed to investigate the influence of randomly oriented fiber and systematically oriented inclusion on the geotechnical behavior of clayey soils. This research evaluates the use of waste fiber materials such as polyethylene and polypropylene fiber for the modification of clayey soils. This investigation focuses on the shear strength of the reinforced soils with randomly and systematically included waste fiber materials. The unreinforced soil were subjected to specific gravity test, hydrometer test, Atterberg limits and proctor compaction and unconfined compression test to determine the geotechnical properties. The results for the basic properties of clayey soil are as following, optimum moisture content: 32.5%, maximum dry density: 13.43 kN/m^3, specific gravity: 2.51, liquid limit: 74.67%, plastic limit: 45.98% and plasticity index: 28.69%. However, for the reinforced soil were subjected to unconfined compression test only in order to differentiate the shear strength with unreinforced soil. These waste fibers improve the strength properties of clayey soils. The UCS value enhanced with increasing percentage of polypropylene fiber and reached at optimum content on 10% reinforcement where it showed the highest improvement of 730 kN/m^2 from 650 kN/m^2 and depleted when reach 20% reinforcement. For polyethylene fiber, the reinforced soil showed the highest UCS on 20% reinforcement by 733 kN/m^2. The polyethylene and polypropylene fibers can be successfully used as reinforcement materials for the modification of clayey soils.

ABSTRAK

Beberapa kajian telah dijalankan untuk menyiasat pengaruh gentian terhala secara rawak ke atas tingkah laku yang geoteknik tanah secara terperinci. Namun, hanya beberapa kajian telah dijalankan ke atas tanah liat bertetulang gentian. Oleh itu, kajian eksperimen ini telah dijalankan untuk menyiasat pengaruh serat berorientasi secara rawak. Kajian ini menilai penggunaan bahan serat sisa seperti polietilena dan serat polipropilina untuk pengubahsuaian tanah liat. Penyelidikan ini memberi tumpuan kepada kekuatan ricih tanah yang bertetulang secara rawak dan tersusun. Tanah tanpa tetulang tertakluk kepada ujian spesifik graviti, ujian hidrometer, had Atterberg dan proktor pemadatan dan ujian mampatan untuk menentukan sifat-sifat geoteknikal tanah. Hasil ujikaji bagi sifat asas tanah liat adalah seperti berikut, kandungan kelembapan optimum: 32.5%, ketumpatan kering maksimum: 13,43 kN / m3, graviti spesifik: 2.51, had cecair: 74,67%, had plastik: 45,98% dan indeks keplastikan: 28,69 %.Walau bagaimanapun, nilai kekuatan bagi tanah bertetulang adalah tertakluk kepada ujian mampatan sahaja untuk membezakan kekuatan ricih dengan tanpa tetulang gentian. Bahan-bahan gentian tersebut dapat memperbaiki sifat kekuatan tanah liat. Nilai UCS meningkat dengan peningkatan peratus serat polipropilina dan mencapai kandungan optimum pada pengukuhan 10% di mana ia menunjukkan peningkatan tertinggi iaitu 730 kN/m^2 dari 650 kN/m^2 dan tidak berubah apabila mencapai 20% pengukuhan. Untuk serat polietilina, tanah bertetulang menunjukkan UCS tertinggi adalah pada penghukuhan sebanyak 20% iaitu 733 kN/m^2. Serat polietilena dan serat polipropilina mampu digunakan sebagai bahan tetulang untuk pengubahsuaian tanah liat.

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Tf	Shear Stress
c	Cohesion
σ	Normal Stress On The Failure Plane
φ	Angle Of Internal Friction
σ'	Effective Stress
u	Pore Water Pressure
ρ	Density
ε	Strain

LIST OF ABBREVIATIONS

MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PL	Plastic Limit
LL	Liquid Limit
PI	Plastic Index

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Soil can be branched into four primitive types: gravel, sand, clay and silt. Soil generally has low tensile and shear strength and it characteristics highly depend on the environment conditions. Hence, it requires certain reinforcement to enhance the fundamental properties for construction purpose of the soil. Generally there are diversified materials can be used for soil reinforcement and these are diversified material that can be used for soil reinforcement and these materials are divided into three main types: natural, fabricated and by –products. Therefore, soil improvement is interpreted as a technique to improve the engineering properties of soil by cooperating certain materials with some desired properties which does not consist of or contain least in the soil to evolve the parameters such as shear strength, hydraulic conductivity, compressibility and density.

Soil reinforcement is divided into two categories: systematically reinforced soils and randomly reinforce soils (Akbulut et al., 2007). Systematically reinforced soil can be obtained by organizing continuous reinforcement inclusions within a soil mass in a defined pattern in the form of sheet, strip or bar. In comparison with randomly reinforced soil the discrete fibers are randomly mixed with soil.

Various reinforcement methods feasible for stabilizing soil such as mixing with additives, rewetting, soil replacement, compaction control, moisture control, surcharge loading and thermal method. However, the routines might bring the hindrances from claiming expensive and ineffective. Therefore, new methods are still continuously explored way to enhance strength properties and to decrease the swell behaviors of soil.

Nevertheless, scientific environment research and real field executive of geotechnical engineering utilization had increased attention towards randomly distributed fiber soil composites also known as short fiber soil composite weather in the form of natural or synthetic. The past investigations demonstrate that strength properties of fiber-reinforced soils consisting of randomly distributed fibers are a function of fiber content and fiber-surface friction along with the soil and fiber strength characteristics.

The concept and principle of soil reinforcement was originated in ancient times. During the Mesopotamians and Romans separately identified the way to enhance the capability of pathways to carry traffic. They discovered that stabilizing agents such as pulverized limestone or calcium can be added into weak soil. This mixture will improve the quality of pathways.

About 5000 years ago, ancient civilization found the concept of natural fiber reinforcement such as straw and hay to reinforce mud blocks in order to create reinforced building blocks. In addition, the presence of plant roots can be considered as randomly oriented fiber inclusions in the soil. This natural reinforcement helps to improve the strength of the soils and stability of natural slopes. Several of historic ancient monuments that applied this concept are the Great Wall of China where they used branches of trees as tensile elements and Ziggurats of Babylon, woven marts of read were used. (Hejazi et al., 2011)

In the modern era of soil stabilization, the concept and principle of soil reinforcement was developed by Sir Henri Vidal at 1966, a French engineer who termed it as Terre Armee (reinforced earth). He demonstrated that the introduction of reinforcement elements in a soil mass increases the shear resistance of the medium. More or less 4000 structures have been built in more than 37 countries after the invention of Vidal. One of the examples, traditional brand of “Texsol” introduced polyester filaments before staple fibers that are used in retaining walls and for slope protection. Likewise, synthetic staple fibers have been utilized within soil since the late 1980's when initial studies using polymeric fibers were conducted. (Hejaze et al, 2011)

1.2 PROBLEM STATEMENT

Natural disasters happen all over the world including Malaysia itself and they can be utterly devastating for people's live and the environments in which they live. Malaysia recently was surprised by several natural disasters involving geotechnical problems. Firstly, tunnel landslide at Jalan Imbi, Kuala Lumpur. This disaster happened on July 2014 at 10.38 am at Jalan Imbi, cross Puduraya near Penjara Pudu and again occurred at 12.20 pm. Secondly, slope failure at Mahameru Highway near National Forestry Department for twice on 8 May 2013 at about 6.05 pm and 7 January 2014 at about 5.30 pm. Additionally, the worst case scenario that had happened in Malaysia's geotechnical arena was the slope failure at Bukit Antarabangsa, Ampang, Selangor. The slope failure occurred on 6 December 2008 and caused fatality rate and deprivation of property whereas exceeding numbers of 20 houses were destroyed. This incident happened due to down poured for a few hours causing and increasing soil saturation and plasticity properties.

Meanwhile, solid waste generation in Malaysia is estimated about 26 million tons in 2007. The composition of municipal solid waste is 30% from the total solid waste generated (Larsen, 2007). Statistics show nearly 50% of the municipal solid waste generated in Malaysia institutional, industry and construction (Saeed, 2009)..

Table 1.1 shows the municipal solid waste generation in urban centers of Peninsular Malaysia according to the source and type of solid wastes.

Table 1.1: Municipal Solid Waste Generation in Urban Centers Of Peninsular Malaysia

Source of municipal solid waste	Type of solid waste
Residential	Food waste, food container and packer, can, bottles, papers and newspaper, clothes, garden, e-wastes furniture wastes
Commercial Centre (office lot, small shop, restaurant)	Vary type of papers and boxes, food waste, food container and packer, can, bottles
Institutional (school, university, college, hospital)	Office waste, food waste, garden waste, furniture waste
Industry (factory)	Office waste, cafeteria waste, processing waste
City Centre (drainage and road)	Vary type of garden waste, construction waste, public waste

Table 1.2 shows the physical composition of municipal solid wastes with their basic classifications and examples.

Table 1.2: Physical Composition of Municipal Solid Waste

Physical composition	Basic classification	Examples
Organic	Food waste	Vegetables, meats
	Garden waste	Dried leaves, twigs, cut grasses
	Textile and rubber	Clothes, leather products
	Paper and Box	Newspaper, vary type of paper and box products
Inorganic	Plastic	1. Polyethylene terephthalate 2. High-density polyethylene 3. Polyvinyl chloride 4. Low –density polyethylene 5. Polypropylene 6. Polystyrene 7. Multilayer Plastic *based on coding plastic system by Plastic Industry Association Incorporation
	Glass	Vary type of glass products used in home, laboratory and etc
	Metal	Ferrous products, zinc, chromium, and vary type of metal products

Due to the increase number of waste production day by day and slope failure happened repeatedly, these two major problems will be able to associate with each other to be one efficient solution. Table 1.3 shows the percentage of solid waste composition in Malaysia since 1975 until 2005

Table 1.3: Percentage of Solid Waste Composition In Malaysia Since 1975 Until 2005

Physical Composition	Type of Solid Waste	1975	1980	1985	1990	1995	2000	2005
Organic	Food/garden	63.7%	54.4%	48.3%	48.4%	45.7%	43.2%	44.8%
	Paper	7.0%	8.0%	23.6%	8.9%	9.0%	23.7%	16.0%
	Plastics	2.5%	0.4%	9.4%	3.0%	3.9%	11.2%	15.0%
	Glass	2.5%	0.4%	4.0%	3.0%	3.9%	3.2%	3.0%
	Metal	6.4%	2.2%	5.9%	4.6%	5.1%	4.2%	3.3%
	Others	17.9%	34.6%	8.8%	32.1%	32.4%	14.5%	17.9%

In this study, the waste products such as plastic materials (polyethylene fibers) and glass material managed to be recycled and modified as a synthetic reinforcement for soils. The usage of these compounds is reasonable, cost effective and constantly available.

1.3 OBJECTIVE

1. To determine basic properties of clayey soil before reinforcement

2. To determine shear strength of clayey soil after reinforced with polypropylene and polyethylene in random orientation

3. To compare shear strength of clayey soil after reinforced with polypropylene and polyethylene in random orientation

1.4 SCOPE OF STUDY

Pahang is known for its logistic area for marine action and development industry. By topographical perspective, marine territories were accepted to comprise as a type of clayey soil. Any advancement of industry in this marine territory ought to be influenced by the nature of the earth soil. A suitable clayey soil is necessary to conduct the study. The soil samples were taken at Kampung Tanjung Medang, Pekan, Pahang with coordinate There are several tests will be conducted before and after the reinforcement of soil using polyethylene waste. Before reinforcement; specific gravity of soil, atterberg limits, proctor compaction test and unconfined compression test. After reinforcement; unconfined compression test.

1.5 RESEARCH SIGNIFICANCE

As mentioned before, waste production rates, plastic waste particularly have increased considerably. There are other factors that fortify an opportunity for recycled mixed plastic composites. Firstly, the continuing population explosions directly proportional to the growing demand for building materials. Secondly, the increased price of construction materials. Unfortunately, greater amount of plastics have been used in packaging, land/soil conservation, automotive, healthcare application, housing and etc. in our daily life.

In order to reduce the waste volume and scale down environmental issue, recycling is the best way to manage the waste production rather than incineration. Thus, plastic waste recycling has been a focus of many researchers in the past few decades. In addition, the advance cost and the lessening space of landfills causes considerations of alternative options for the waste disposal. However, most of the recycled plastic cannot be used for the same purpose for the reasons of health and environmental protection. One of the deliberations to meet this is to transform these plastic wastes into items applicable for development, construction and housing. The usage of this compound with the aid of glass wastes is reasonable, cost effective and constantly available.

CHAPTER 2

LITERARUTE REVIEW

2.1 SOFT CLAYEY SOIL

2.1.1 Definition and Behavior in General

2.1.1.1 Geotechnical Characteristics

Soft clays are fine grained soils that are highly plastic with moderate to high clay fraction. Soft clays are typified by low shear strength (usually less than 25 kPa) and high compressibility. The following are their conventional characteristics; Generally fined grained i.e. over 50% of soil passing through 75N IS sieve, high plastic limit (PL) and liquid limit (LL) values, high natural water content (higher than liquid limit), low material permeability, high compressibility on high compressible organic content and low shear strength (varies with depth). Classifications of soil are based on the values of undrained strength. There are two types of classification which are undrained strength less than 12 kPa for very soft soil and undrained strength less than 25 kPa for soft soil.

2.1.1.2 Shear Strength Characterictics

Shear strength of soil is defined as internal resistance per unit area in order the soil can resist failure and sliding occurrence on plane (Das, 2014).

Mohr (1990) proposed a theory where failure in material is not only caused by maximum normal stress or shear stress alone but also the critical combination of normal stress and shear stress. The relationship of normal stress and shear stress of failure plane is a circled line and expressed

$$Tf = c + \sigma \quad 2.1$$

Coulomb (1976) indicated that most of soil mechanic problems, the shear stress on the failure plane are approximated as linear function of the normal stress (Das, 2014). The function can be expressed as

$$Tf = c + \sigma \tan \varphi \quad 2.2$$

where;

Tf = shear stress

c= cohesion

φ= angle of internal friction

σ = normal stress on the failure plane

The undrained shear strength of normally consolidated clays increased almost linearly with depth. Skempton proposed an expression on the ration of undrained shear strength to the effective overburden pressure when it is related to plasticity index. This relationship is relevant to soft marine clay alongside to the coastline where primary consolidation has just completed.

For saturated soil, the total normal stress at a point is the one of the effective stress and pore water pressure. The equation is known as Mohr-Coulomb failure criterion

$$\sigma = \sigma' + u \qquad 2.3$$

For Mohr-Coulomb failure expressed in terms of effective stress, the expression is

$$Tf = c' + \sigma' \tan \varphi \qquad 2.4$$

The stiffness of the soil is affected by the poor condition of the soil and this caused the soil become weak in strength. Furthermore, strength of soil is the most crucial factor in soil properties. Without decent design and proper analysis of soil, building any structures may cause hazardous implication. (A.Razzak, 2013)

2.1.1.3 Typical Characteristics of Clay Soil

Soft clay has low shear strength. For undrained shear strength, the range is between 10 to 20 kPa and may vary from as low as 5 kPa. The natural moisture content is usually very high and closed to the liquid limit LL. There are certain time it may exceed the liquid limit and turn to be in liquid state. One of the main causes that could lead to high settlement is high compressibility properties of soft clay. This is due to soft clay particles itself, the particles are very fine. In addition, the clay soil will be too cohesive with the presence of water.

Soft clay can be considered as impermeable Soft clay contains very high percentage of clay fraction. The coefficient of permeability of is very low and is about less than 10^-7 cm/sec. The excess pore pressure dissipation in soft clay is relatively slow. This condition caused the behavior to be time depended.

Water is the primary substance that caused soil to be unstable specifically the ability of soft clay soil to trap great amount of water within its particles. The high moisture content in soft clay due to low permeability caused water difficult to penetrate through the particles.

Furthermore, residual strength of soft cay may vary from 20% to 60% of the peak strength which is very low. Strength of soft clay may be reduced if it disturbed.

The shear strength of soil can be affected by creep. Cassagrande and Wilson (1949) reported that if the shearing rate was decreased by 10, 000 times, the undrained shear strength of soft clay can be reduced by 15% to 30%. (A.Razzak, 2013)

2.2 SOIL STABILIZATION

2.2.1 Definition and Types of Stabilization

Soil stabilization goes for enhancing soil quality and increasing imperviousness to softening by water through bonding the soil particles together, water sealing the particles or mixture of the two. There are many different alternatives that technology provides to the geotechnical world. The simplest solutions are composition and drainage (soil become stronger when water drains out of the wet soil). Another alternatives can be used is through developing gradation of particle size and adding binders to the soft soil for a better improvement. Various mechanisms can be attained for soil improvisation. These methods are divided into two main categories (Makusa, 1993) namely mechanical stabilization and chemical stabilization. For mechanical stabilization, soil stabilization can be attained via physical process by adjusting the physical nature of the soil particles in a way of either induced vibration, compaction or by consolidation alternative physical properties; barrier and nailing. For chemical stabilization, soil stabilization can primarily rely upon chemical reaction between stabilizer (cementitious element) and soil minerals (pozzolanic element) to accomplish expected result.

2.2.2 Advantages of Soil Stabilization

Firstly it improves engineering properties of soil. Soils treated with stabilizer are much stronger compare to non-stabilized soils because the reaction between soil and stabilizer enhance the strength properties of soil. Hence, several productive application can be applied in this context; thickness of foundation can be reduced, concrete or blacktop can layered directly onto the soil, usage of sub base, concrete and bituminous material can be saved.

Moreover, it is time and cost saving. Stabilized soils minimize the time of site preparation because the site does not require tradition 'dig and dump method' which take numerous amount of time. It also allows wet ground to be dried and straightened in time. Hence, this process enable faster construction period. As mentioned before, in comparison to 'dig and dump method', lesser amount of money will be used since stabilized soil does not require vehicle movement, landfill tax and aggregate purchasing like the 'dig and dump' method.

Next, savings in disposal of poor materials and construction waste. By a simple treatment process, importation of new materials are not required, thus generation of construction waste can be reduced. For that reason, the need of landfill site for dumping is not necessary.

Lastly, it is eco and environmental friendly. Negative impact on the environment from haul truck carrying massive loads can be reduced. Furthermore, stabilized soil can give positive impact to the site surrounding where there are no destruction and deterioration of roads during and after the construction project. Therefore, this may lead to reducing global warming phenomenon.

2.3 STABILIZING AGENTS

2.3.1 Chemical Additives

2.3.1.1 Cement

Cement stabilization of soil is an action where pulverized soil is mixed with cement and the mixture is compacted to form a durable material. This material is also known as soil-cement, cement-stabilized based or cement treated-aggregate base. Invention of soil stabilization technology started since 1960's where cement is one of the earliest binding agents. Cement is considered as primary stabilizing agent or hydraulic bonder since it can be applied by itself for stabilizing action. (Sherwood,1993; EuroSoilStab,2002). There different types of cement available in the market for example, rapid hardening cement, high alumina cement, pozzolanic cement, sulphates resisting cement and etc. The selection of cement is based on the type of soil and desired final strength. All types of soil combination can be stabilized with cement such as gravelly and sandy to fine-grained silts and clays. Mainly, the more granular materials are used due to few amount of cement required and also they are pulverized and readily mixed.

Certain amounts of cement were used during compaction process. The cement filled the void spaces between soil particles thus reducing the void ratio. Hydration process is a process where reaction of cement takes place. Cement hydration consists of complex set of unknown chemical reactions (MacLaren and White, 2003). The hydration response is low progressing from the surface of the cement grains and the core of the grains may stay unhydrated (Sherwood, 1993). The process started when water is added to the compaction and the reaction caused the cement to be hardened. The structure of soil will not altered during the hardening (setting) of cement and it will enclose soils like glue (EuroSoilStab, 2002). Hence, unit weight of soil, shear strength and bearing capacity increased. In addition, the permeability of soil also decreased. Factors affecting cement stabilization are type of soil, water-cement ratio, curing