THE EFFECTIVENESS OF PALM OIL CLINKER (POC) AS SOIL STABILIZER

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ABSTRACT

Soft soils often cause difficulties in construction, operation with their low strength and low stiffness nature. However, the engineering properties of these soils can be enhanced by soil stabilization. This research was carried out to study the effectiveness of Palm Oil Clinker (POC) as soil stabilizer for soft soil around the area of Pekan, Pahang. Palm Oil Clinker (POC) was taken from Lepar Hilir Palm Oil Mill, Gambang, Pahang. The objectives of this research are to determine the effect of Palm Oil Clinker as soil stabilizer and to propose the optimum percentage of POC to increase the soil characteristics. The soil was classified as clay with very medium plasticity (CV), having liquid limit, plastic limit and plastic index of 33.5%, 7.3%, and 26.2% respectively, maximum dry density and optimum moisture content of 1.67g/cm^3 and 7.6% respectively. There are five laboratory test conducted for this research. Sieve Analysis Test conducted to determine the type of soil. The result from this test shows 74% is silt while remaining 26% is clay proved that this soil is silty clay. Falling Head Test determine the coefficient of permeability for each sample which is for soft soil only is 3.05 x 10^{-6} m/s then decreased to 1.08 x 10^{-6} m/s when POC and cement added. Atterberg Limit Test conducted to determine PL, LL, and PI. Platicity index for soft soil decreased about 52.4% when POC and cement added. From Standard Proctor Test was applied to determine the maximum dry density and the optimum moisture content of the soils. From this testing, the maximum dry unit weight was obtained for sample with 5% cement, sample with 5% to 25% POC and sample with combination 5% cement and 5% to 25% POC. Unconfined Compression Test shows the maximum load can resist by soil is 66 kPa but increased to 185 kPa when POC and cement added. For overall, addition of POC shows positive result in increasing soil characteristic and soft soil with combination of 5% cement and 25% of POC content shows the effective amount to be added in soft soil stabilization and the objective of this research was achieved.

ABSTRAK

Tanah lembut sering menyebabkan kesukaran dalam operasi pembinaan, dengan kekuatan yang rendah dan sifat kekakuan yang lemah. Walau bagaimanapun, sifat kejuruteraan tanah ini boleh dipertingkatkan dengan penstabilan tanah. Kajian telah dijalankan untuk mengkaji keberkesanan Klinker Minyak Sawit sebagai penstabil tanah lembut di sekitar kawasan Pekan, Pahang. Klinker Minyak Sawit diambil dari Kilang Minyak Sawit Lepar Hilir, Gambang, Pahang. Objektif kajian ini adalah untuk menentukan kesan Klinker Minyak Sawit sebagai penstabil tanah dan untuk mencadangkan peratusan optimum Klinker Minyak Sawit yang sesuai untuk meningkatkan sifat tanah. Terdapat lima ujian makmal dijalankan untuk penyelidikan ini. Tanah ini diklasifikasikan sebagai tanah liat berkelodak dengan sifat keplastikan yang sederhana iaitu 26.2. Nilai had cecair, had plastik dan indeks plastik masing-masing adalah 33.5%, 7.3% dan 26.2%. Ujian meter telap turus menurun menentukan pekali kebolehtelapan bagi setiap sampel tanah dimana pekali bagi tanah lembut adalah 3.05 x 10^{-6} m/s kemudian menurun kepada 1.08 x 10^{-6} m/s apabila Klinker Minyak Sawit dan simen ditambah. Ujian had Atterberg dijalankan untuk menentukan nilai PL, LL dan PI. Indeks keplastikan untuk tanah lembut menurun kira-kira 52.4% apabila klinker minyak sawit dan simen ditambah. Ujian Proctor Piawai telah digunakan bagi menentukan maksimum ketumpatan kering dan kandungan lembapan optimum tanah. Hasil ujian ini membolehkan maksimum ketumpatan kering diperoleh bagi sampel tanah dengan 5% simen, sampel dengan 5% hingga 25% Klinker Minyak Sawit dan sampel dengan gabungan 5% simen serta 5% hingga 25% Klinker Minyak Sawit. Ujian mampatan tak terkurung menunjukkan beban maksimum yang boleh ditahan oleh tanah lembut meningkat dari 66kPa kepada 185kPa apabila klinker minyak sawit dan simen dicampur. Keseluruhan ujian mendapati bahawa penambahan Klinker Minyak Sawit memberi hasil yang positif dalam peningkatan ciri-ciri tanah dan tanah lembut dengan gabungan 5% simen dan 25% Klinker Minyak Sawit menunjukkan jumlah yang berkesan untuk ditambah dalam penstabilan tanah dan objektif penyelidikan tercapai.

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LIST OF ABBREVIATIONS

POC	-	Palm Oil Clinker
OPC	-	Ordinary Portland Cement
LL	-	Liquid Limit
PL	-	Plastic Limit
SL	-	Shrinkage Limit
PI	-	Plastic Index
SS	-	Soft Soil
C	-	Cement
UCT	-	Unconfined Compression Test
ASTM	-	American Society for Testing and Materials
USCS	-	Unified Soil Classification System
No	-	Number

LIST OF SYMBOLS

g	-	Gram
cm	-	Centimeter
mm	-	Milimeter
%	-	Percent
σ	-	Normal Stress
q_u	-	Unconfined Compressive Strength
S_u	-	Shear stress
c	-	Cohesion
C	-	Celcius
F	-	Fahrenheit
k	-	Coefficient of Permeability
Gs	-	Specific Gravity

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CHAPTER 1

INTRODUCTION

1.1 Background of Research

The palm oil industry forms the economic backbone of Malaysia and continues to face new challenges in the face of globalization. However on the way to extract palm oil, the palm oil refineries also produce tones of waste products known as palm oil clinker (POC). POC produced in the boiler when the burning process of husk fiber and shell of palm oil. This burning process is the phase to generate the energy in order to generate the plant boiler in palm oil mill. POC is only known as industrial waste material and if no attempts made to recycle these materials, they were dumped completely. Since palm oil clinker are abundant and have small commercial value in Malaysia, attempts have been made to utilize these materials as stabilizer in soil.

Soil stabilization refers to the process of changing soil properties to improve their characteristics strength. There are two primary method of soil stabilization used today which is mechanical and additive. Example of mechanical is compaction of the soil while addition of cement, lime, bituminous or other agent is referred as additive method of soil stabilization. There are two basic types of additive used which is chemical additive and mechanical additive. Addition of POC in soil can be classified as mechanical additive where the soil is mechanically alter by adding a quantity of material that has the engineering characteristics to upgrade the load bearing capacity of the existing soil.

1.2 Problem Statement

Nowadays, many construction have face the problem of soil where the soil cannot reach the required specification such as bearing capacity of soft soil too weak to support superstructure above it. The existing soil at a construction site may not always be totally suitable for supporting structures such as buildings, bridges, highways, and dams. Due to that, the understanding and knowledge of engineering characteristics of soft soil are critical and should be understand by people related in this field. The selection of construction method on this formation is restricted by cost, duration of completion, and benefits. The type of soil focused on this study is soft soil.

Soft soil is chosen as a sample in this study because of their low shear strength and high compressibility. The strength properties of clays are complex and subject to changes over time through consolidation, swelling, weathering and creep. The high shrink-swell potential and low permeability characteristic are also among the undesirable engineering properties of soft soil for construction purposes. Sensitivity of clay soil is high, so any disturbance of soil will cause a decrease in its strength.

The continued growth and development of large urban area within Pekan, Pahang leading to a lack of suitable building sites. Developer are now investing in sites with challenging soil conditions that were viewed in years past as being difficult or costly for construction. So, they had to use the available land for their construction area and that is the beginning of existence numerous research of soil stabilizer.

1.3 Research Objectives

The objectives of this study are:

i) To determine the effect of Palm Oil Clinker (POC) as a soil stabilizer.

ii) To propose the optimum percentage of POC to increase the soil characteristics.

1.4 Scope of study

The term of soft soils had been used in this study to describe soils that have high moisture content, approaching that of the liquid limit and have a high sensitivity. Soil samples from flood area locations in Pekan, Pahang were collected and brought to the laboratory for classified and to be investigated for use in various laboratory test. The soil samples were chosen to represent plasticity index is less than about 25 and clay fraction (passing No. 200 sieve) are less than about 40 percent.

Ordinary Portland Cement (OPC) was used in this research. Portland cement had proven to be a very good method of base stabilization by decrease the liquid limit and increase the plasticity index and workability of soft soil.

POC categorized as waste by product and has appearance of a porous stone with gray in color. The clinkers forms are usually flaky and irregular with rough and spiky broken edges. The POC for this study was collected from a palm oil mill factory located at Lepar Hilir, Pahang. To ensure a better bonding with the clay, the clinker has been ground to powder form before combined together with soft soil.

In soil classification tests, there are two laboratory testing were carried out that are Particle size distribution test and Particle analyzer test. The main testing was carried out to compare the strength and characteristic of soft soil before and after treating with different concentration of cement and POC. The testing were Atterberg Limit, Standard Proctor test, Falling Head, and Unconfined Compression test. There were five different ratios (5%, 10%, 15%, 20%, and 25%) of POC content were mixed with the soft soil to make soil samples. Cement ratio is constant 5% to the weight of soil sample.

Atterberg Limit was conducted to determine the liquid limit, plastic limit and plastic index of the soils. Standard proctor test was applied to determine the maximum dry density and the optimum moisture content of the soils while Falling Head Test to determine the coefficient of permeability. Unconfined Compression Test was conducted to measure the unconfined compressive strength of soil.

1.5 Significant of study

This study is about improving soil characteristic by using palm oil clinker (POC) as stabilizer. The use of POC combining in soil can be form into useful material such is together to minimize wastes, maximize recycling, enhance environmental sustainability and offers technical, ecological and environmental advantages. For economic advantage, field recycling is a significant savings factor as this reduces to minimum stripping cuts, landfill, provision of aggregates and thus the cost of their transport. The absence of transport of aggregates and of cuts to the landfill contributes to preserving the road network in the vicinity of the building site.

Therefore the appropriate use of POC can help preserve the environment from undesirable effects, while at the same time contributes to cost reduction for the palm oil industry. In addition, these materials are characterized by great stiffness and excellent fatigue strength. This study also enable unsuitable soil to improve and used in construction. Therefore, developers no need to find for only suitable land to start their project but just stabilize the existing soil.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Malaysia for many decades has been known as the main manufacturers of palm oil. The waste that been produced in palm oil mill known as clinker (Omar, W. & Mohamed, R.N. 2001). As the aggregates were decreasing rapidly, inorganic material was explored as a suitable material as soil stabilizer (Kukko, H, 2000). Palm oil clinker can be found easily in our country as Malaysia is the largest manufacturer of palm oil products. Malaysia is holding the main production for world palm oil production as 51%, 62% for the world exports and 30% for the oils and fats exportation (Asean Sources.Com, 2004).

Combustions of shell and fiber from the palm oil create clinkers as waste material which will be thrown away from mill (Omar, W. & Mohamed, R.N. 2001). Usage of clinkers also will minimize the cost of the soil stabilization due to the rate of palm oil clinker is cheaper than the other chemical stabilizer (Neville A.M, 1995).

POC categorized as waste by product and has appearance of a porous stone with gray in color. The clinkers forms are usually flaky and irregular with rough and spiky broken edges. The POC for this study was collected from a palm oil mill factory located at Lepar Hilir, Pahang. To ensure a better bonding with the clay, the clinker has been ground to small particle form before combined together with soft clay and cement (Robani, R & Chan, C.M. 2009).

2.2 Soft Soil

Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical, and mineralogical characteristics (Birkeland, 1999). Soft soils can be considered as near-normally consolidated clays, clayey silts and peat. The special features of these materials are their high degree of compressibility. But in the same time soft soil has a high sensitivity and low strength compared to another types of soil and the most important problem related to building on soft soil is settlement which is relatively large and takes long time to complete.

Usually, due to sedimentary process on different environments, both physical and engineering properties such as void ratio, water content, grain size distribution, compressibility, permeability and strength are show a significant variation. Further, they exhibit high compressibility, reduced strength, low permeability and compactness, and consequently low quality for construction.

According to McCarthy (2007), clay soil has particle sizes less than about 0.005mm. Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks (usually silicate-bearing) by low concentrations of carbonic acid and other diluted solvents. Soft Clay has particle sizes less than about 0.002mm or easily breaks down to the size (Liu & Evett, 2005). Soft clay is the finest of all and even it can only be clearly monitored by using microscopic tools. Soft clay is part of fine grained soil, with soil grains finer than 0.075mm.

According to Unified Soil Classification System (USCS), clay soil is classifies as small particle soil that 50% pass sieve no. 200 Specification US (0.075mm). According to Brand & Brenner (1981), soft clay is defined as clay with shear strength less than 25kPa. The strength of clay is low by comparing with other type of soils. Aside from this, clay and silt soil are part of cohesive soil as their particles are closed together and tend to stick within its particles. When a soil that has 50% or more particles with sizes of 0.002mm or less, it is generally termed clay (Aysen, 2005).

Many areas in Malaysia have soft clay soil as major soil distribution percentage. This is happened from the fact that Malaysia has many parts of coastal areas and also rivers that located in many state in Peninsular Malaysia. Fine grained saturated soils are believed to be located at many near coastal and river area (Schaefer, 1997). The geotechnical properties of clays are shown in Table 2.1.

Table 2.1: Geotechnical properties of clays *(Source: http://umpir.ump.edu.my)*

Properties	**Kaolinite**	**Illite**
Specific Gravity, Gs	2.61	2.60
Liquid Limit, LL	50-62	95-120
Plastic Limit, PL	33	45-60
Plasticity Index, PI	20-29	32-67
Shrinkage Limit, SL	29	14-17
Activity, A	0.2	0.6
Compressibility Index, Cc	0.2	0.6-1.0
Friction angle drained, degree	20-30	20-25

2.3 Ordinary Portland Cement (OPC)

Portland cement, often referred to as OPC, from Ordinary Portland Cement is the most common type of cement in general use around the world because it is a basic ingredient of concrete, mortar, stucco and most non specialty grout. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate (which controls the set time) and up to 5% minor constituent which is Tricalcium Silicate, Dicalcium Silicate, Tricalcium Aluminate, Tetracalcium Aluminoferrite, and Gypsum with each percentage is 50, 25, 12, 8 and 3.5 respectively as shown in Table 2.2.

Table 2.2: Main constituents in an Ordinary Portland Cement *(Source: http://training.ce.washington)*

Chemical Name	**Chemical Formula**	**Shorthand Notation**	**Percent by Weight**
Tricalcium Silicate	$3CaO \times SiO_2$	C_3S	50
Dicalcium Silicate	$2CaO \times SiO_2$	C_2S	25
Tricalcium Aluminate	$3CaO \times Al_2O_3$	C_3A	12
Tetracalcium Aluminoferrite	$4CaO \times Al_2O_3 \times Fe_2O_3$	C_4AF	8
Gypsum	$CaSO_4 \times H_2O$	CSH_2	3.5

By referring Figure 2.1, there are six main stages of cement making process which are quarry, proportioning, blending and grinding, preheated tower, kiln, clinker cooler and finish grinding, bagging and shipping.

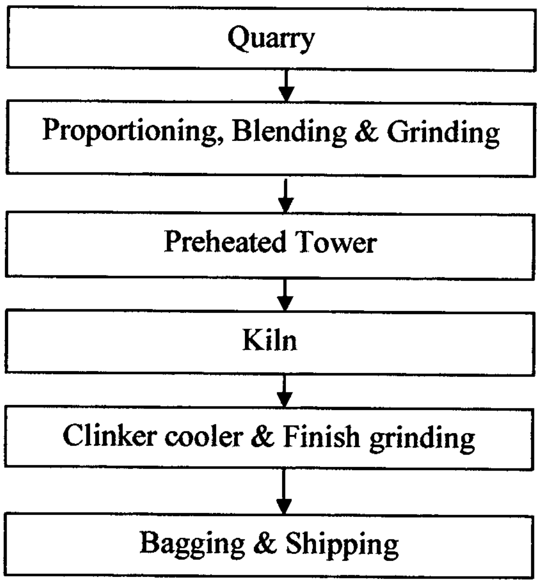

Figure 2.1: Flow Chart for the OPC making process *(Source: http://training.ce.washington*

Rock blasted from the quarry face is transported to the primary crusher, where chair sized rocks are broken into pieces the size of baseballs. A secondary crusher reduces them to the size of gravel. Some plants now crush materials in a single stage. The next stage is proportioning, blending & grinding. At this stage, the raw materials are now analyzed in the plant laboratory, blended in the proper proportion, and then ground even finer. Plants grind the raw materials with heavy, wheel type rollers that crush the materials into powder against a rotating table. After grinding, the material is now ready for the kiln or preheated, depending on plant type. Then it will be transferred to the preheated tower that supports a series of vertical cyclone chambers through which the raw materials pass on their way to the kiln. To save energy, modern cement plants preheat the materials before they enter the kiln. Rising more than 200feet, hot exit gases from the kiln heat the raw materials as they swirl through the cyclones.

From the preheated, the raw materials enter the kiln at the upper end. It slides and tumbles down the kiln through progressively hotter zones toward the flame. At the lower end of the kiln, fuels such as powdered coal and natural gas feed a flame that reaches 3400°F. This intense heat triggers chemical and physical changes. Expressed at its simplest, the series of chemical reactions converts the calcium and silicon oxides into calcium silicates, cement primary constituent. At the lower end of the kiln, the raw materials emerge as a new substance which is red hot particles called clinker.

At the fourth stage, the clinker tumbles onto a grate cooled by forced air. Once cooled the clinker is ready to be ground into the gray powder known as Portland cement. The clinker is ground in a ball mill. As the tube rotates, the steel balls tumble and crush the clinker into a super-fine powder. It can now be considered Portland cement. Finally the powder will be bagging and shipping. From the grinding mills, the cement is conveyed to silos where it awaits shipment.

Table 2.3: Type and uses of OPC *(Source: http://www.fhwa.dot.gov)*

Cement Type	Uses
I1	General purpose cement, when there are no extenuating conditions.
II2	Aids in providing moderate resistance to sulfate attack.
III	When high-early strength is required.
IV3	When a low heat of hydration is desired (in massive structures)
V4	When high sulfate resistance is required.
IA4	A type I cement containing an integral air-entraining agent.
IIA4	A type II cements containing an integral air-entraining agent.
IIIA4	A type III cements containing an integral air-entraining agent.

Table 2.3 shows eight type of OPC with the uses. Type I is a general purpose Portland cement suitable for all uses where the special properties of other types are not required. It is used where cement or concrete is not subject to specific exposures, such as sulfate attack from soil or water, or to an objectionable temperature rise due to heat generated by hydration. Its uses include pavements and sidewalks, reinforced concrete buildings, bridges, railway structures, tanks, reservoirs, culverts, sewers, water pipes and masonry units.

Type II Portland cement is used where precaution against moderate sulfate attack is important, as in drainage structures where sulfate concentrations in groundwater are higher than normal but not unusually severe. Type II cement will usually generate less heat at a slower rate than Type I. With this moderate heat of hydration (an optional requirement), Type II cement can be used in structures of considerable mass, such as large piers, heavy abutments, and heavy retaining walls. Its use will reduce temperature rise, an important quality when the concrete is placed in warm weather.

Type III is a high early strength Portland cement that provides high strengths at an early period, usually a week or less. It is used when forms are to be removed as soon as possible, or when the structure must be put into service quickly. In cold weather, its use permits a reduction in the controlled curing period. Although richer mixtures of Type I cement can be used to gain high early strength, Type III, high-early-strength Portland cement, may provide it more satisfactorily and more economically.

Specifications for three types of air-entraining Portland cement (Types IA, IIA, and IIIA) are given in ASTM C 150. They correspond in composition to ASTM Types I, II, and III, respectively, except that small quantities of air-entraining materials are interground with the clinker during manufacture to produce minute, well-distributed, and completely separated air bubbles. These cements produce concrete with improved resistance to freeze-thaw action.

Type IV is a low heat of hydration cement for use where the rate and amount of heat generated must be minimized. It develops strength at a slower rate than Type I cement. Type IV Portland cement is intended for use in massive concrete structures, such as large gravity dams, where the temperature rise resulting from heat generated during curing is a critical factor.

Type V is sulfate-resisting cement used only in concrete exposed to severe sulfate action principally where soils or groundwater have a high sulfate content. The following Table describes sulfate concentrations requiring the use of Type V Portland cement. Low Tricalcium Aluminate (C_3A) content, generally 5% or less, is required when high sulfate resistance is needed.