A STUDY ON UNCONFINED OF A CHEMICALLY STABILIZED SOIL WITH CEMENT AND TIMBER INDUTRIAL ASH (TIA)

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A Study on Unconfined Strength of a Chemically Stabilized Soil with Cement and Timber Industrial Ash (TIA)

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Abstract

Chemical soil stabilization is an extensive method that has been used for improving the properties of soft soil. A variety of stabilizers have been used for stabilizing soft soils. Portland cement, lime, Pulverized Fuel Ash (PFA), and Ground Granulated Blast Furnace Slag (GGBS) have been widely accepted for stabilizing soft soils. Such pozzolanic materials have been found to improve the physiochemical and engineering behavior of treated soils. However, there are several obstacles to the commercial utilization of the ashes despite the favorable laboratory findings on the performance of it. One of it is the high cost of importing the fly ashes as PFA and GGBS are not common in Malaysia. The purpose of this study is to experiment with another recently identified pozzolanic material in Malaysia, which is known as Timber Industrial Ash (TIA). TIA was derived mainly from the controlled burning of rubber wood bark from timber industries in Malaysia, which is available easily over the country. Hence, the main objective of this study is to assess utilization of TIA and cement in combination for improving the strength of soft soils. The combination of TIA and cement are referred as blended cement in this study. Soil samples utilized in this study are disturbed samples taken from The Research Centre for Soft Soils (RECESS) with 1.8m ± 0.1m in depth under the ground surface. The samples were compacted manually in steel mould to form unit weight of $14.5 kN/m^3 \pm 0.1 kN/m^3$. Ten percents of blended cement were utilized (by dry unit weight of soil) with the range of TIA replacement percentages are 10%, 13% and 15% respectively. The samples were soaked in water for simulating the worst condition. The laboratory results showed that the replacement of TIA in blended cement had improved its strength.

Key words: Soil Stabilization, Timber Industrial Ash (TIA), Blended cement.

1.0 Introduction

Soil, a gift of nature, is both a complex and variable material. Because of its variable characteristics, soil at any particular place may be unsuited, wholly or partially to the requirements of the users. In such conditions there are three choices: (a) to use the soil in its present non-ideal state accepting all the limitations that it imposes, (b) remove the site material replacing with a superior one, and (c) modify the soil in ways that can make the soil more suitable for the intended use (Abdul Awal et al.,1998).

As clayey Silt, they tend to have lower shear strengths and to lose shear strength further upon wetting or other physical disturbances. They can be plastic and compressible, and they expand when wetted and shrink when dried (Liu, 2003). It is impossible to build any construction directly or it will cause structure failure. Thus, this situation can be improved by modifying the soils with chemical stabilization.

Chemical stabilization is a general method in which one or more chemical compounds are mixed into the soil to improve its engineering properties (Eriktius et al., 2001). The art of utilizing the full pozzolanic potential of fly ash in soil stabilization had been reported by researchers (see, eg. Phani Kumar & Sharma (2004); Patil & Kolhe (2006)).

However, most pozzolanic materials require some form of mechanical processing especially sieving and grinding to produce the desired results as the pozzolanic reactivity of the ash depends very much on its fineness.

The purpose of this study was to experiment with another pozzolanic material in Malaysia. A suitable blend of TIA that required minimum processing was used for the study. The TIA (Timber Industrial Ash) was derived from the controlled burning of rubber wood bark and remnants from wood based industries in Malaysia. The advanced combustion technology currently available in Malaysia produced TIA of consistent quality (Lee & et. al., 1999).

In the mean time, open burning and ash proliferation had also become a main hazard to the environment. Ash proliferation resulting from the steady increase in the number of timber industries and co-generation plants has caused disposal problems where there is no proper method of waste treatment or disposal. Landfills have been used until the depletion of suitable dumping site (Lee, 1999).

The chemical and physical test results indicated that TIA complied with the requirements of Class F fly ash according to ASTM C618-89 (Lee & et. al., 1999). The relevant oxides and physical properties are shown in Appendix 1.

As TIA is categorized as non self-cementing fly ash, it is believed that by itself, has little effect on soil stabilization. Hence, in this study the TIA was blended together with cement which was known as blended cement in this study as the additive for soil stabilization. Based on ASTM D5239-98, the advantage of adding fly ash to fine-grained soils, along with cement, is for its pozzolanic properties and improved soil texture.

This paper aims to report, discuss and make comparison on gained strength of soil stabilized by TIA along with cement. Disturbed samples were collected from The Research Centre for Soft Soils (RECESS), KUiTTHO by using motorized auger with the range 1.8m ± 0.1m in depth under the ground surface.

2.0 Literature Review

In concrete research, it has shown that the initial findings about the use of TIA in combination with Portland cement are positive. The utilization of Timber Industrial Ash (TIA) in cement bricks was found to reduce density and enhance strength development at early age (Lee et al., 1999).

The purpose of the combination of soil-TIA-cement all together mixed for new method of stabilization is to identify the reaction and the suitability. Based on previous literature review, pozzolanic reaction is believed to increase the strength of the soil.

3.0 Experimental Setup

The aim of the study was to determine the suitability use of TIA along with cement to improve the strength of the soils. All the laboratory tests were performed in accordance with standard procedures as listed in BS 1924-1:Part 1:1990, BS 1924-2:Part 2: 1990, and ASTM Standard on Soil Stabilization with Admixtures and Soil-Cement Laboratory Handbook. TIA of 10%, 13% and 15% were blended, respectively, in cement to form blended cement which is as Blended cement A (with 10% of TIA), Blended cement B (with 13% of TIA), and Blended cement C (with 15% of TIA).

The soil samples were retrieved by utilizing motorized auger from a depth of approximately 1.8m ± 0.1m under the ground surface to avoid backfilled soil as the land originally was palm oil estate. It was a grey clayey Silt with small quantities of organic matter. The disturbed samples were remolded in the laboratory for the preparation of test specimens. All the samples were compacted manually in the steel mould to unit weight of $14.5kN/m^3 \pm 0.1\ kN/m^3$ as the repeatability measure for the test. A comparison between water contents taken on site at the time of sampling and prior to remolding in the laboratory was carefully taken out to make sure the constant of moisture content for all the remolded samples. Additional water was added for some samples to compensate the loss of water due to the hot weather.

The specimens were prepared by mixing blended cement of various percentage of TIA, respectively, with soil. The mixture was then transferred to a steel mould of 100mm x 200mm in diameter, in 4 layers each of which was tamped with a miniature compaction tool. The specimen was removed from the mould after 24hrs and soaked in water at a room temperature of 20°c, for various periods of 7, 14 and 28 days.

3.1 Physical Analysis

Physical analysis consisted of five common tests which were particle size analysis, Atterberg limit, specific gravity, moisture content and electrometric pH test. The tests were the most basic and simplest of laboratory test to determine the physical properties of the soil that used in the study.

3.2 Unconfined Compression test

The unconfined compression test is the easiest and simplest test for determining the shear strength of cohesive soil. Indeed, perhaps due to its simplicity and acceptable results for clay, it has found wide use throughout the world. It is applicable to undisturbed as well as disturbed cohesive soils. Obviously, it is not applicable to cohesion less soils since such a specimen would fall apart as it is laterally unsupported.

4.0 Results and Analysis

4.1 Properties of Original Soil

According to the Unified Classification System (USCS) the soil was categorized as clayey Silt (MH) with 83.51% silt and 16.49% clay for the soil distribution. Silt consumes the greater soil portion than clay which exists in small quantity. From the grain size distribution graph in Figure 1, the effective size, D_{10} is 0.002, uniformity coefficient, C_u is 4.9 and the coefficient of curvature, C_c is 1.08.

Based on cone penetration (mm) versus moisture content (%) graph in Figure 2, the Liquid Limit (LL) has been determined. Based on the plot, LL is found to be 57.1%. The Plastic Limit (PL) for this studied soil is 34.19%, with it Plasticity Index (PI) is reported as 22.91%. Through the specific gravity test, the specific gravity, G_s, is determined as 2.48. The pH for the studied soil is found to be 3.17, which is quite acid in nature.

4.2 Unconfined Compressive strength

Based on Unconfined Compression (UC) test, the strength of the soil has been increased by adding the blended cement when compared to the original soil. The results of the unconfined compression test were summarized in Table 2. Stress versus strain curves were plotted for the specimens based on the types of additive added. For specimen A & B, the highest strength gained is 36.99 kPa and 26.81kPa, respectively, for the soaking period of 7 days (as shown in Figure 4 and Figure 5). Whilst for Specimen C, the highest strength gained is 28.02kPa for the soaking period of 28 days, which is shown in Figure 6.

5.0 Discussion

5.1 Properties of Original Soil

Table 1 shows the physical properties of the original soil. Based on the Unified Classification System, the soil is categorized as inorganic silts of high compressibility based on its plot under the Line A of Plasticity index versus Liquid Limit. Hence, the workability as a construction material for MH category soil is poor.

Table 1: Properties of original soil

Properties	Values
Liquid limit, LL (%)	57.1
Plastic limit, PL (%)	34.19
Plasticity index, PI (%)	22.91
Moisture Content (%)	82.28
pH	3.17
Unit weight (kN/m^3)	14.5
Color	Light gray
Specific gravity, G_s	2.48
Grain size distribution	
Silt (%)	83.51
Clay (%)	16.49
Soil Categorized	MH

The specific gravity for the studied soil is found to be 2.48. Silts normally have higher specific gravity than sands (Truitt, 1983). However, organic bits are certainly present in this case and influence the value of the specific gravity. The higher organic content in the soil, the specific gravity will decrease. Percentages of the different mineral constituents present also influence the decreasing of the value.

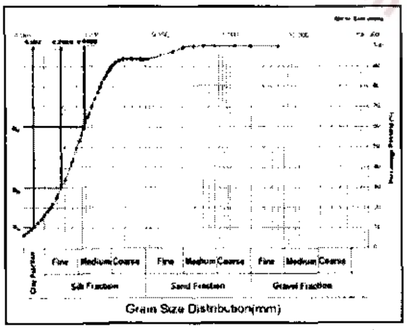

Figure 1: Grain size distribution

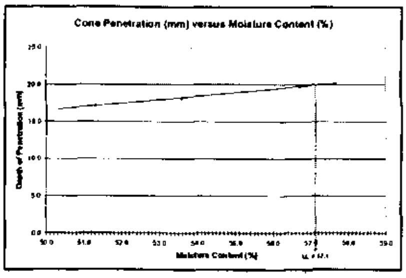

Figure 2: Determination of Liquid limit from graph cone penetration (mm) versus moisture content (%)

5.2 Unconfined compressive strength

Table 2 summarized the strength properties of soil based on additive content and curing period. The tests were carried out using hand operated machine to produce a compressive strain rate of about 10% per minute (approximately 8 mm per minute compressive deformation of the sample). The type of failure for the original soil was plastic failure and showed in Appendix 2. With the plastic failure there is no clear reduction of load at failure. The highest strength of the original soil was 7.64 kPa. The increasing value for the original soil is slow and constant.

Table 2: Unconfined compressive strength of treated soil

Additive Content \ Curing Period	7 Days	14 Days	28 Days
10% TIA + 90% cement (Specimen A)	36.99 kPa	31.51 kPa	28.28 kPa
13% TIA + 87% cement (Specimen B)	26.81 kPa	18.94 kPa	20.61 kPa
15% TIA + 85% cement (Specimen C)	19.77 kPa	26.94 kPa	28.02 kPa

According to BS 1924 Part 2 1990, cement and lime have a marked effect on the plasticity properties of materials containing clay minerals. This is brought about by two separate mechanisms. Firstly, there is an immediate effect as a result of cation exchange at the surface of the clay particle and, secondly, there reaction between the cement or lime and the clay minerals. The cation exchange reactions have the most influence on the plasticity properties whilst the pozzolanic reaction is largely responsible for the increase in strength which occurs over a period of time. Figure 4, 5 and 6 shows the plot of stress-strain response curve for specimen A, B and C, respectively. The types of failure for the specimens were brittle failure. The brittle type failure produces a distinct maximum compressive load clearly defining failure (Appendix 3).

The 10% replacement TIA gives the highest strength with 36.99 kPa on 7 days. But the strength decreased respectively with the increased period of soaking (as shown in Figure 4). Same pattern of test results obtained for 13% replacement TIA, as the highest strength reported on 7 days as 26.81 kPa and the strength decreased with the soaking period.

Hence, it can be deduced that the amount of pozzolanic material is not enough for strengthen the specimen as the soaking water had disintegrated the specimens.

Whilst for the 15% TIA replacement (as shown in Figure 6), the test results showed that the strength increased respectively with the soaking period. It was shown that the replacement of the 15% TIA reacted well with soil and significantly increased strength of soil regardless the destruction caused by the soaking. Hence, it is clear that the 15% TIA replacement in blended cement had successfully strengthen the soil and prevented it from disintegrated by the water.

According to Lee et al., (1999), the optimum cement replacement level by TIA to produce blended cement bricks was found to be around 10% under a pilot plant environment. Hence, the studied shown the similar result with the past studied. Based on the plot of Figure 7, 8 and 9, it showed that the highest strength gained by 10% TIA replacement, even though the specimens were successively disintegrated with respect to soaking period.

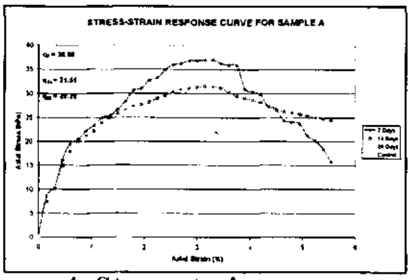

Figure 4: Stress-strain response curve for specimen A

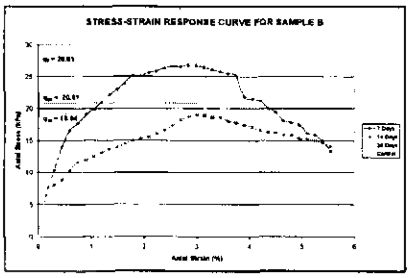

Figure 5: Stress-strain response curve for specimen B

6.0 Conclusion

Based on the results of laboratory tests, the following conclusions are drawn.

a) The replacement of TIA in cement stabilization is practical to apply for improving the strength of soil at RECESS, KUiTTHO.
b) The highest strength is found to be with the 10% replacement of TIA in cement.
c) However, the 15% replacement of TIA in cement showed increasing strength of specimen with respect to soaking period. Hence, it can be concluded that higher amount of TIA is needed to make the stabilized soil to have more resistant on soaking.

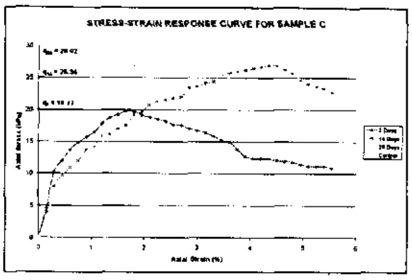

Figure 6: Stress-strain response curve for specimen C

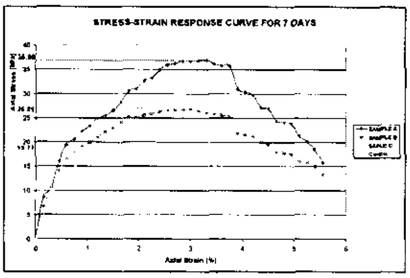

Figure 7: Stress-strain response curve for 7 days soaking

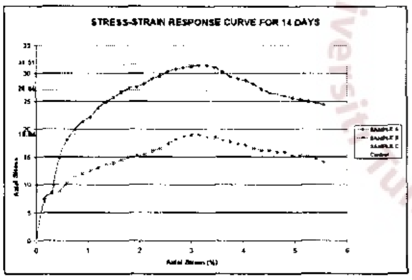

Figure 8: Stress-strain response curve for 14 days soaking

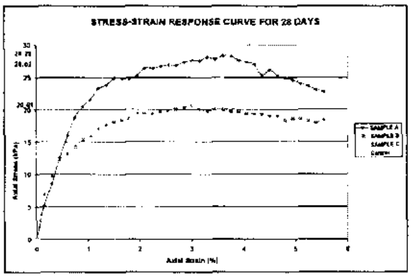

Figure 9: Stress-strain response curve for 28 days soaking

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Appendixes:

Appendix 1: Chemical composition and physical properties of OPC and TIA

Chemical composition (% w/w)	OPC	TIA
Aluminium Oxide, Al_2O_3	7.16	2.80
Calcium Oxide, CaO	60.00	0.10
Iron Oxide, Fe_2O_3	3.98	1.53
Magnesium Oxide, MgO	2.01	2.00
Potassium Oxide, K_2O	0.55	0.53
Silica Oxide, SiO_2	18.58	67.70
Sodium Oxide, Na_2O	0.33	0.60
Sulphur Trioxide, SO_3	1.90	1.59
Titanium Oxide, TiO_2	<0.001	<0.001
Physical Properties	**OPC**	**TIA**
Loss in Ignition	3.55	0.45
Fineness (m^2/kg)	275	330
Specific Gravity	3.15	2.39

Appendix 2: Plastic failure of original soil

Appendix 3: Brittle failure of specimen treated with blended cement