Engineering Properties of Stabilized Tropical Peat Soils

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ABSTRACT

Peaty soils are not suitable as foundation soils as they are weak and highly compressible. This paper describes a study on peat soil stabilisation to improve its physical and engineering properties. It investigates the effect of additives (binder amount 5%, 10% and 15% (85%cement, 15% bentonite) and range of sand 5% to 25% on the index properties as well as, pH, compaction, California Bearing Ratio and unconfined compressive strength of tropical peat soils. The amount of additives added to the peat soil sample was investigated in terms of the percentage of the dry soil mass. The results showed that of the additive admixtures altered the engineering properties of tropical peat soils. The soil liquid limit was found to decrease with increase of the additive content. The pH was found to increase with increase binder. The maximum dry density was found to increase while the optimum moisture content was found to decrease with the increase of the additive content. The California Bearing Ratio of the soil was found to increase significantly with increase in the additives.

KEYWORDS: Chemical stabilization, cement, bentonite, sand, peat soil

INTRODUCTION

Peat soil is a representative material of soft soils and classified as highly organic. In general, peat is mainly composed of fibrous organic matters, i.e. partly decomposed plants such as leaves and stems. Peat has largely organic residues of plants, incompletely decomposed through lack of oxygen. Therefore, it has been said that peat shows unique geotechnical properties in comparison with those of inorganic soils such as clay and sandy soils which are made up of only soil particles.

Peat is found in all part of the world except in deserts and the arctic regions. The most extensive areas are located in the northern hemisphere. It is estimated that there are about 1 billion acres of peat land in the world or about 4.5% of total land areas. In United State; peat is found in 42 states with a total area of 50 million hectares, Canada has 110 million hectares and former USSR 150 million hectares. In Japan peat is widely distributed throughout Hokkaido, which is the northern of island Japan, with an area of approximately 200 thousand hectares. The total area of tropical peat swamp forest or tropical peat land in the world amounts to about 30 million hectares.

Chemical admixtures or chemical stabilization always involves treatment of the soil with some kind of chemical compound, which when added to the soil, would result a chemical reaction. The chemical reaction modifies or enhances the physical and engineering aspects of a soil, such as, volume stability and strength (Van Impe, 1989). In the case of sediment soils, addition of inorganic chemical stabilisers like cement and lime has a twofold effect on the soil which is acceleration and promotion of chemical bonding. The chemical bounding depends upon the type of stabiliser employed. Strength of silt and clay can be improved up to 30 folds (Ahnberg et.al., 1995, Janz and Johansson, 2002).

Peat has certain characteristic that sets it apart from mineral soils and it also requires special consideration. These special characteristics include:

- High natural moisture content (up to 800%).
- High compressibility including significant secondary and tertiary compression.
- Low shear strength (typically 5-20 kPa).
- High degree spatial variability.
- Potential for further decomposition as a result of changing environment conditions

Peat, on the other hand, may well appear to be completely organic, contain recognisable plant remains, low density and be black to dark brown in colour. The degree of decomposition or humification in peat is usually assessed based on the Von Post scale. Von Post (1922) proposed a classification system which is based on a number of factors such as degree of humification, botanical composition water content, content of fine and coarse fibres and woody remnants.

DESCRIPTION OF MATERIALS

Soil

Peat soil usually contains organic material with normal depth of 0.5metre. Peat is known for its high organic content which could exceed 75 percent. The organic contents classified as peat are basically of plant whose rate of accumulation is faster than the rate of decay. The content of peat soil differs in terms of locations due to factors such as temperature and degree of humification. Decomposition or humification involves the loss of organic matter either in gas or in solution, the disappearance of physical structure and change in chemical state (Huat, 2004).Table 1 presents the properties of peat soils.

Table 1: Properties of In-situ peat soil (A. Alwi, 2008)

Properties	value
Bulk density (γ_b)	1.059 Mg/ m^3
Dry density (γ_d)	0.112 Mg/ m^3
Moisture content (*w*)	700-850%
Void ratio (*e*)	10.99
Fiber content	84.99%
Degree of saturation (*S*)	100
Specific gravity (G_s)	1.343
Classification /Von Post	H4
Linear Shrinkage	5.58%
Liquid limit	173.75%
Plastic limit	115.8%
Plasticity Index	57.95%
pH	4.6
Scanning Electron Microscopy	
Loss on Ignition	98.46 %

Cement

A Portland cement particle is a heterogeneous substance, containing minute tri- calcium silicate (C_3S) dicalicum (C_2S), tricalcium (C_3A), and solid solution described as tetra calcium alumino-ferrite (C_4A) (Lea,1956). When the pore water of the soil encounters with cement, hydration of the cement occurs rapidly and the major hydration (primary cementitous) produces hydrated calcium silicates(C_2SH_x ,C_4AH_X), and hydrated lime $Ca(OH)_2$ (Bergado et. al, 1996).

Bentonite

Bentonite is an absorbent aluminum phyllosilicate which in general terms are impure clay consisting mostly of montmorillonite. Two types exist: swelling bentonite which is also called sodium bentonite and non-swelling bentonite or calcium. It is formed from weathering of volcanic ash, most often in the presence of water. Bentonite expands when wet – sodium bentonite can absorb several hundred percent of its dry weight in water. It is commonly used in drilling fluids, to make slurry walls, and to form impermeable barriers (i.e., plug old wells, as a liner at the base of landfills to prevent migration of leeches eating into the soil).

Sand

Sand plays a vital role in enhancing the bond in cementation reactions of soil mixing. It is found that grain size distribution provides a satisfactory skeleton, and the voids are filled with fine-sand, giving a compact and high load-bearing capacity. The type of sand used in the laboratory was from Kuala Selangor, Selangor in Malaysia.

SAMPLE PREPARATION AND TESTING PROCEDURE

(*a*) Atterberg limits tests

The Atterberg limits were determined in accordance with the British Standard methods –BS 1377: part 2. The peat soil was sieved through 424µm. Material retained on the sieve was rejected for this test. The soils were then dried for 24 hours, where moisture content reduced between 150% and 200% prior to the test. The tests were carried out on the soils with different proportions of binder and sand.

(*b*) pH tests

According BS 1377-1990, thirty grams of soil was placed in a 100ml beaker where 75 ml of distilled water was added, and stirred for a few minutes before left standing overnight. The samples were stirred immediately before testing. The pH value of the suspension was measured by electronically digital using a glass electrode. The first sample preparation was to dry out in room temperature. Then, it was sieved through, followed by 200µm test sieve. Then an adequate portion of soil was taken and placed in a beaker. Subsequently water was added to the beaker and stirred for a few minutes.

(*c*) Compaction tests

Modified proctor test, according BS 1377-1990: part 4 was applied to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. In the modified proctor test, the soil was compacted in a CBR mould .during the laboratory test, the mould was attached to a base plate. The soil was mixed with additives and water and subsequently compacted in three equal layers using an electric hammer that delivers 62 blows to each layer. The hammer energy was 4.5 Kg.

(*d*) California Bearing Ratio test

In this study the CBR specimens were compacted at the optimum moisture content determined from modified proctor tests according to BS 1377:part 4 :1990.The CBR mould which was used had a nominal internal diameter of 150 ± 0.5 mm. And about 125 mm high, hydraulic jack was used for compaction, equivalent energy was determined from the compaction test using the statistic method. The soil placed in the mould was divided equally into three layers and the surface was leveled using a compression device until it was one – third of the mould. After 3 days immersion in the water and other specimen for unsoaked was used immediately after compaction.

(*e*) Unconfined compressive strength test

The unconfined compressive strength is defined as the load per unit area at which an unconfined prismatic or cylindrical specimen of soil will be compressed in a simple compression test. The primary purpose of the test is to determine the unconfined compressive strength, which is then to calculate the unconsolidated undrained shear strength of the soil under unconfined conditions. The test was conducted in accordance to BS 1377:1990. Generally, the specimen shall be prepared in a height equal to about twice the diameter by extruding the soil sample from CBR mould. From each of the CBR specimens, a core was extruded in a cylindrical shape (50mm diameter and 100mm height).

TEST RESULTS AND DISCUSSION

Effect on consistency limits

The effect of different content binder and sand stabilised soils on the liquid limit (LL), plastic limit (PL) and plastic index (PI) are shown in Figures 1, 2 and 3

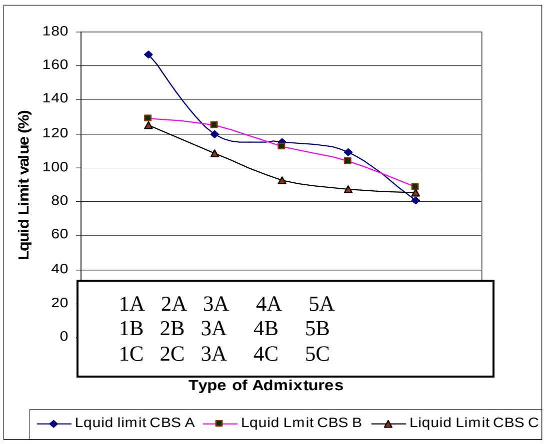

Figure 1: Variation of liquid limit

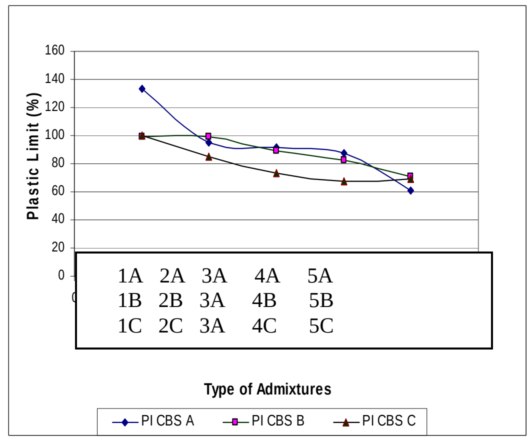

Figure 2: Variation of plastic limit

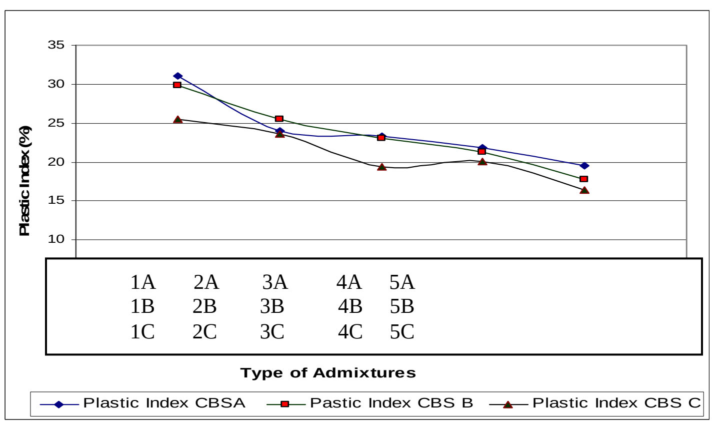

Figure 3: Variation of plastic index

Note: CBS 1A: (5% binder +5% sand +90%peat), CBS 2A (5%bnder+10% sand+85%peat)
CBS 3A: (5%binder+15%sand+80%peat), CBS4A (5%binder+20%sand+75% peat)
CBS 5A: (5%binder+25%sand+70%peat).
CBS 1B :(10%binder+5%sand +85% peat), CBS 2B (10%binder+10%sand+80%peat)
CBS 3B: (10%binder+15%sand+75%peat), CBS 4B (10%binder+20%sand +70%peat)
CBS 5B :(10%binder+25%sand +65%peat).
CBS 1C :(15%binder+5% sand +80%peat), CBS 2C (15%binder+10%sand+75%peat)
CBS 3C :(15%binder+15%sand+70%peat), CBS 4C (15%binder+20%sand+65%peat)
CBS5C :(15%binder+ 25% sand+ 60%peat)

From these figures, it can be observed that increase in the amount of binder and sand reduced the plasticity of soils.

Effect on pH values

The pH variation increased with increase in the binder and sand.

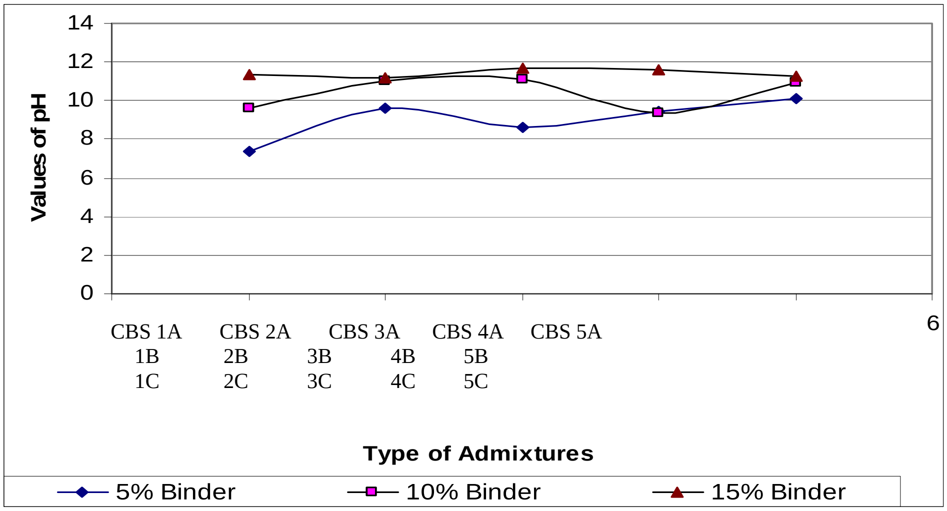

Figure 4: Variation of pH of peat soil with additives

As shown in Figure 4 the pH value increased when there was an increase in the binder cement and bentonite of each admixture. This is because the hydration of cement led to a rise in pH value. In cement stabilization, a primary reaction and secondary reaction will be distinguished during the stabilization. It was observed that the materials changed from acidic to alkaline.

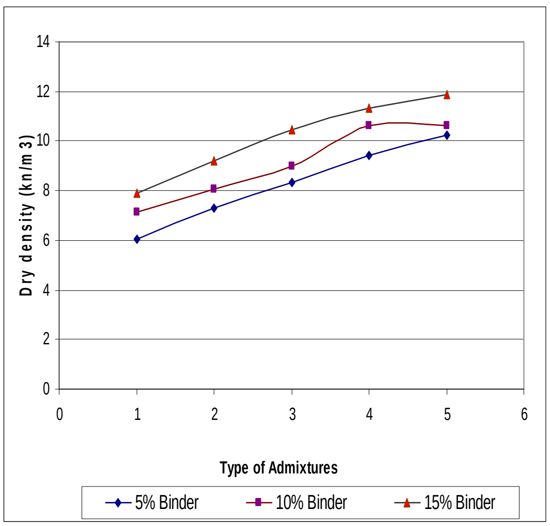

Figure 5: Variation of MDD

Effect on compaction

Figures 5 and 6 show the effect of addition of additives to peat soil on the compaction characteristics of soils tested. The figures indicate that adding binder and sand increased maximum dry density and decreased optimum moisture content.

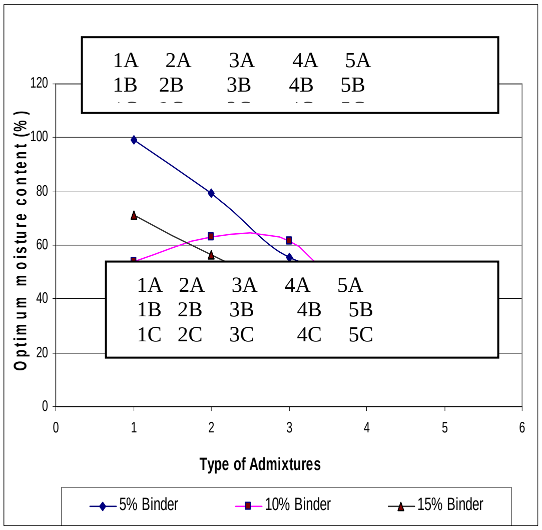

Figure 6: Variation of OMC

Effect on California Bearing Ratio

The laboratory determination of CBR of a compacted specimen was obtained by measuring the forces required to cause a cylindrical plunger of specified size to penetrate the specimen at specified rate. From Figures 7 and 8 it is apparent that the CBR values increased with increased addition of binder and sand. Moreover, the results show that the CBR increased with increase in the curing period.

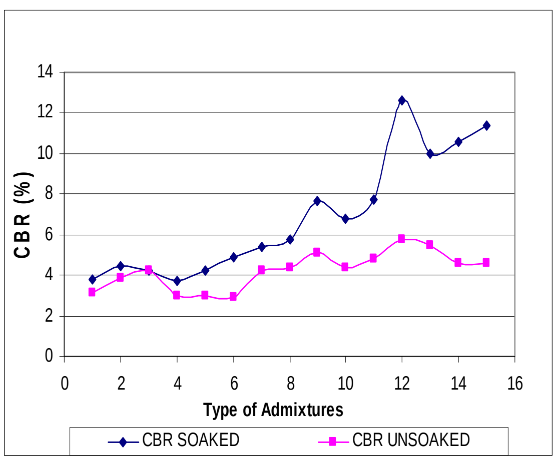

Figure 7: Effect of content additives on the CBR

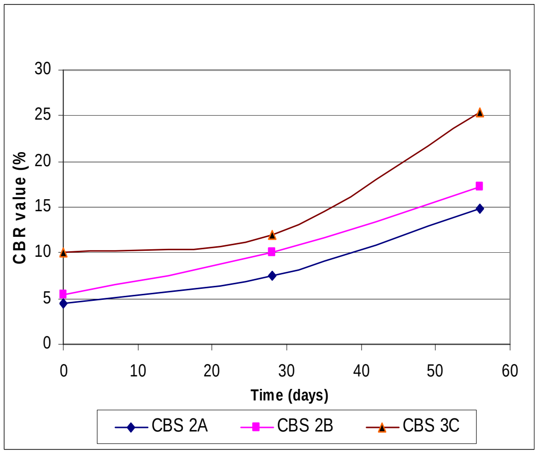

Figure 8: Effect of curing on the CBR

Effect on Unconfined Compressive Strength

The addition of additives on the unconfined compressive strength of peat soil samples was namely to examine the effect of additives content and curing period, Figures 9 and 10 clearly indicate the plot of unconfined compressive strength with binder content. However, the results also show the influence of curing period on the unconfined compressive strength of the soil samples. Similarly higher strength was obtained from samples that had been cured for 14 days compared with 7 days cured samples. Bargado, (1996) found that pozzolanic reaction can continue for months or even years after mixing, resulting in the increase in strength of cement stabilised with increase curing time.

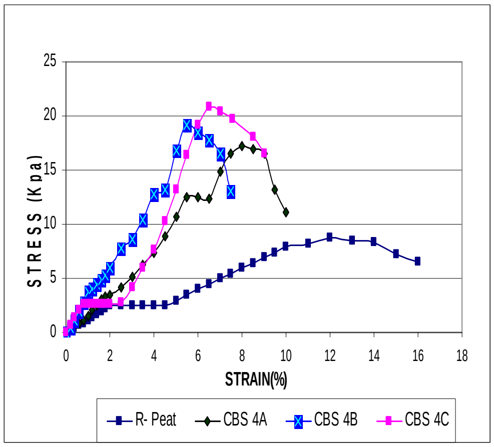

Figure 9: Effect of additives on UCS of peat soil (7Ds)

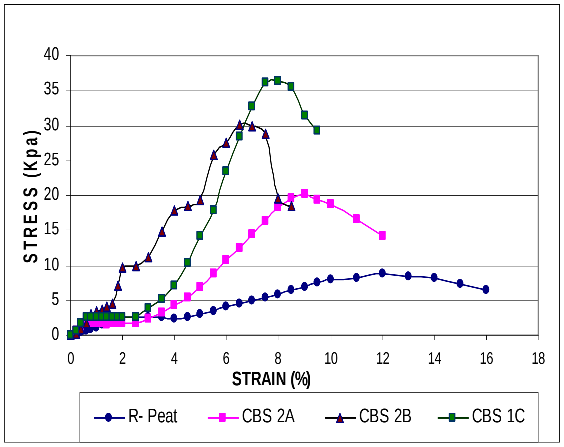

Figure 10: Effect of additives on UCS of peat soil (14Ds)

CONCLUSIONS

The following conclusions can be drawn on the basis of test results obtained from binder-sand stabilized peat soils.

- Cement and sand reduced the plasticity of peat soil.
- The materials changed from acidic to alkaline with the addition of additives.
- The MDD of stabilized peat soil increased with an increase in cement and sand. Moreover the addition of binder and sand, the OMC decreased.
- The increase in CBR value corresponded to increase of the additives content and curing period.
- The unconfined compressive strength of stabilized soils increased with addition of cement.

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