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Bearing Capacity of Stabilised Tropical Peat by Deep Mixing Method

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Abstract: Soft tropical peat has unique characteristics and poses serious problem in construction industry due to its low bearing capacity. Construction work over this problematic soil is not possible in its natural state. The paper represents the findings of a study into stabilisation of peat in Klang, Selengor, Dharul Ehsan, Malaysia using various types of binder by deep mixing method and its effect on bearing capacity. The study comprised a field model study and soil columns have been constructed by hand mixing method using cement, bentonite, mining sand and calcium chloride. Hand operated cone penetrometer has been used to observe the bearing capacity of stabilised column after 14 days curing time. Microstructure of soil column has also been observed by performing SEM and EDX test. From the study it was found that bearing capacity peat can be improved considerably by stabilised column using binder.

Key words: Binder, soil column, hand mixing, cement, bentonite, $CaCl_2$

INTRODUCTION

Peat soil exhibits very low bearing capacity and this soil is not suitable for constructing embankment, highway, building or any other load bearing engineering structure. Peat in its natural state consists of water and decomposing plant fragments with virtualy no measurable bearing strength (Munro 2004). Peat is considered as soft soil because this soil has high settlement value and even under moderately applied load. These soils are found in many countries throughout the world. In the US, peat is found in 42 states, with a total area of 30 milion hectares. Canada and Russia are the two countries with a large area of peat, 170 and 150 milion hectares respectively (Hartlen, J. and J. Wolski, 1996). Tropical peat are located in Asia, South Africa and Latin America is covering more or less 30 milion hectors of land 66% of which are in south-east Asia. In Malaysia more than 3 milion hectors (8% of total land) of land are peat land.

There is a tendency in construction industry to avoid this type of problematic soil since improvement of peat soil is very expensive and time consuming. Nevertheless, necessity of utilisation of this type of problematic soil is increasing day by day due to high demand of land. Hence, a proper ground improvement work is essential before starting construction works over peat soil. A number of construction options that can be applied to improve peat and organic soils these are excavation-displacement or replacement; ground improvement and reinforcement to enhance soil strength and stiffness, such as by stage construction and preloading, stone columns, piles, thermal precompression, and preload piers; or by reducing driving forces by light-weight fil (Edil 2003). However these methods are not suitable as stabilisation by these methods is more expensive and takes long period of time.

Ground improvement work by deep mixing method by using binder is becoming more popular in construction industries. Deep soil stabilisation technique is often an economicaly attractive alternative to removal of deep peat or use as deep foundation. The essential feature of deep soil stabilisation is that columns of stabilised material are formed by mixing the soil in place with a 'binder' and the interaction of the binder with the soft soil leads to a material which has better engineering properties than the original soil (Hebib and Farrel, 2003). In this method soil-cement columns are constructed by using various types of mixing equipments and various types of binder. There are two methods of deep stabilisation namely: dry deep mixing and wet deep mixing. In dry deep mixing binder is applied in dry form and in wet deep mixing binder is injected in wet slurry form. Due to high water content in tropical peat dry mixing method is very much suitable for stabilisation.

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A number of laboratory research works have been conducted to improve peat soil by deep mixing method using various types of binder such as cement, sand, fly ash, bentonite, blast ground granulated furnace slag etc. Sing 2008 and Alwi 2007 conducted laboratory studies and revealed that strength of tropical peat soil can be improved considerably by using cement, wel graded siliceous sand, bentonite and calcium chloride as binder. Our present study is a continuation of these studies by field investigation to observe the improvement of bearing capacity of stabilised peat using mix designs of aforesaid study. Hence objectives of this study are as folows:

1. To investigate physical properties of tropical peat soil colected from Klang, Selengor, Dharul Ehsan, Malaysia.
2. To determine bearing capacity of tropical peat soil in its natural state by performing Mackintosh probe test.
3. To observe the formation of soil-cement column by deep mixing method using cement, sand, bentonite and calcium chloride in different proportions by visual inspection.
4. To measure the bearing capacity of stabilised column by conducting hand operated cone penetrometer test.

MATERIALS AND METHODS

Soil Characterisation and Site Preparation:

Test site was selected in Klang area under the province of Selengor Dharul Ehsan which is situated 35 km North West of Malaysian capital Kuala Lumpur. Test site was prepared for field experiment by cleaning tree, grass and roots. Trial peats were excavated to observe the ground water table and to colect both disturbed and undisturbed sample to conduct laboratory experiments. Soil samples were colected from different layers to observe the depth of peat by visual inspection. Water content, organic content, fibre content, ash content, specific gravity, initial void ratio and pH test were conducted folowing BS 1377:1990 standard to determine the physical properties of peat.

Materials Used for Soil Stabilisation:

Materials was used in this experiment were high setting and ordinary Portland cement, wel graded mining siliceous sand, bentonite and calcium chloride and al these materials are colected localy. Malaysian local made Mascrete brand cement is used as high setting cement which is produced by Lafarge. OPC cement is most widely used as concrete production which is manufactured from limestone or chalked (Calcium Carbonate), clay and gypsum. High setting cement contains pulverised fuel ash (PFA) in which is very much useful for pozzolanic reaction. Mining sand from Kuala Selengor was used in this study in a specified grain size to give uniformity of standard material in the mix design. Fine sand with maximum diameter of 1.18 mm was used to increase solid matrix to the peat. Bentonite which is used as a bonding material is a clay genertaed from alternation of volcanic ash consisting of aluminium phylosilicate which in general terms are impure clay consisting mostly of montmorilonite. Calcium chloride ($CaCl_2$) was used in this study as additive which increases early strength.

Equipments for Field Experimentation Mackintosh Probe Test:

Mackintosh probe test is most widely used in situ test to measure the soil bearing capacity of different layers in terms of N value. This test is very useful to find out the bearing capacity of soil upto 18 meter. One set of Mackintosh Probe equipment was used to investigate the bearing capacity of the untreated peat soil. Mackintosh

Probe equipment (Plate 1 a) consists of a series of 15 mm diameter steel rods. The length of each rod is 1.20 m. A 25 mm diameter and 60 degree cone screwed onto the lower rod driven into ground by a 4.5 kg hammer faling freely through a height of 300 mm onto an anvil. The number of blows require for every 300 mm penetration is recorded.

Hand Operated Cone Penetrometer:

The cone penetration test has been recognized as one of the most widely used in situ tests. The cone penetration test consists of advancing a cylindrical rod with a conical tip into the soil and measuring the forces required to push this rod. A proving ring hand operated cone penetrometer (Plate 1b) has been used in this experiment which consists of a T handle, penetration rod, proving ring of 1 kN capacity with dial indicator, and a removable cone point. The penetrometer is pressed into the soil manualy and relates the force required to drive the probe a certain distance through a soil in order to determine the relative density, stiffness, strength or bearing capacity. Unit cone tip (q_c) resistance is obtained from this test by folowing equation:

$$q_c = \frac{\text{Required force to penetrate the cone}}{\text{Base area of the cone}} \tag{1}$$

Bustamante and Gianeseli 1982 proposed an equation to determine the bearing capacity (q_t) from the cone tip resistance. The equation is as folows:

$$(q_t) = K_b \ q_c \tag{2}$$

where *kb* is an empirical bearing capacity factor that varies from 0.15 to 0.60 depending on the soil type and pile instalation procedure (table 1)

Table 1: Bearing capacity factor *(k_b)*

Soil Type	Bored Piles	Driven Piles
Clay-Silt	0.375	0.60
Sand-Gravel	0.15	0.375
Chalk	0.20	0.40

The proving hand operated cone penetrometer has been calibrated for peat soil by comparing with laboratory vane shear test data. It was found that the bearing capacity factor for peat soil is 0.10. We have used the value for our experiment.

a)

Plate 1: a) Mackintosh probe b) Hand operated cone penetrometer (Hashim et. al. 2008)

Construction of Soil Cement Column:

Four numbers of 200 mm diameter soil columns were constructed upto 1m depth of peat soil by hand mixing method. In this method a 200 mm diameter and 1 m height borehole has been made by a driling auger. Binder was mixed with peat soil in a mixing tray and placed into the hole and tamped in different layers. Dosage rate of binder was 300 $kg.m^{-3}$ of bulk volume of peat. Two different mix designs were used in this experiment. In first mix design high strength cement was used 100% of volume of binder, wel graded sand was used 25% of total volume of soil and calcium chloride was used in 4% of volume of binder. In second mix design ordinary Portland cement and bentonite were used in a ratio of 85:15 for the total volume binder and wel graded sand for 25% of total volume peat. Table 2 shows the detail of soil column.

Table 2: Detail of soil columns

Column no	dosage rate (kg.m-3)	binder	curing period (days)
1	300	high setting cement + sand + $CaCl_2$	14
2	300	high setting cement + sand + $CaCl_2$	14
3	300	Ordinary Portland cement + bentonite + sand	14
4	300	Ordinary Portland cement + bentonite + sand	14

RESULT AND DISCUSSION

Close examination of each trial pit indicated that the ground water table was below 0.3 meter from the ground surface. This showed that the peat had a very high water holding capacity. Visual observation on the peat soil indicated that the soil was dark brown in colour. When the soil was extruded on squeezing (pas sing between fingers), it was observed that the soil was somewhat pasty with muddy water squeezed out, and the plant structure was not easily identified. Based on the visual observation, the soil can be classified as fibrous peat mixed with vegetal fibre, wooden chips inside and roots appear top layer. According to Von Post classification system based on its degree of humification the peat can be classified as H4. Table 3 show index properties of the soils are as folows:

Table 3: Index properties of Klang peat (Hashim and Islam 2008)

Index Properties	Range	Average value
Natural moisture content (%)	414-674	555.000
Organic content (%)	88.61-99.06	96.450
Fibre content (%)	90.25-90.49	90.390
Ash content (%)	0.94-11.39	3.550
Specific gravity	0.95-1.34	1.240
pH		3.51
pH of ground water		4.07
Classification/ von post		H_4

Mackintosh Probe Test Result:

From the result of Mackintosh Probe test it was found that N value varies from 0 to 2 in peat and layer upto 4 m. Then N value gradualy increases upto 10 m depth and reaches at 40 after 10 m. This means bearing capacity of peat soil is very low. Figure 3 shows the mackintosh probe result for three different points.

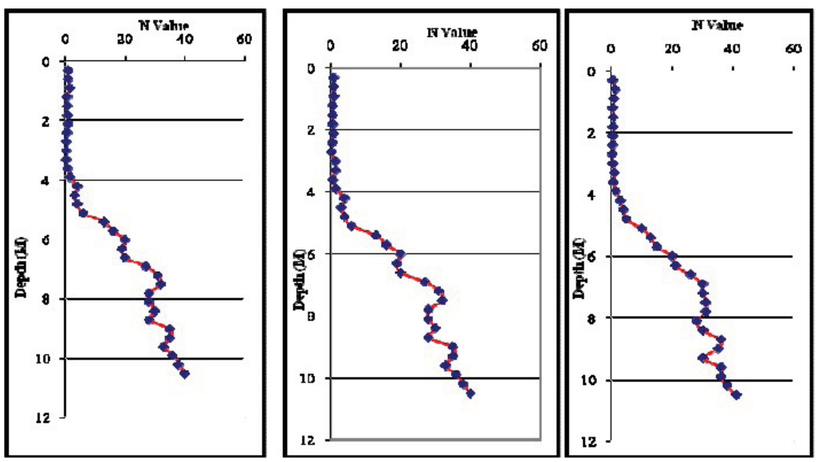

Fig. 1: Result of Mackintosh probe test (Hashim and Islam 2008)

Effect on Undrained Shear Strength after Stabilisation:

From the cone penetrometer test it was observed that the bearing capacity of stabilised column has reached at 151 kpa for the column stabilised by the mix design with high setting cement, $CaCl_2$ and sand. Binding agent of ordinary Portland cement, bentonite and sand had also a considerable effect on bearing which was 86 kpa. According to EuroSoilStab, 2002 design guide maximum achievable bearing capacity of stabilised column in situ condition by deep mixing method is 150 kpa. Our first result is equivalent with to EuroSoilStab, 2002 design guide.

SEM and EDX Test Result for Stabilised Peat:

The effect of stabilisation on peat soil column's structure has been observed by Scanning Electron Micrograph (SEM) and Energy Dispersive X-Ray (EDX) test as Fig 3 and 4. These figures explain that the new structure's soil has been appeared in stabilised soil column. Void spaces have considerably reduced after stabilisation with cement, sand and calcium chloride.

In natural peat carbonate and Kaolinite (C Ka) is peak which is 30.377%. But in stabilised peat reduced and reached at 9.90 %. It means that pozzolanic reaction is taking place form a cementious maeterials and reduction of organic materials.

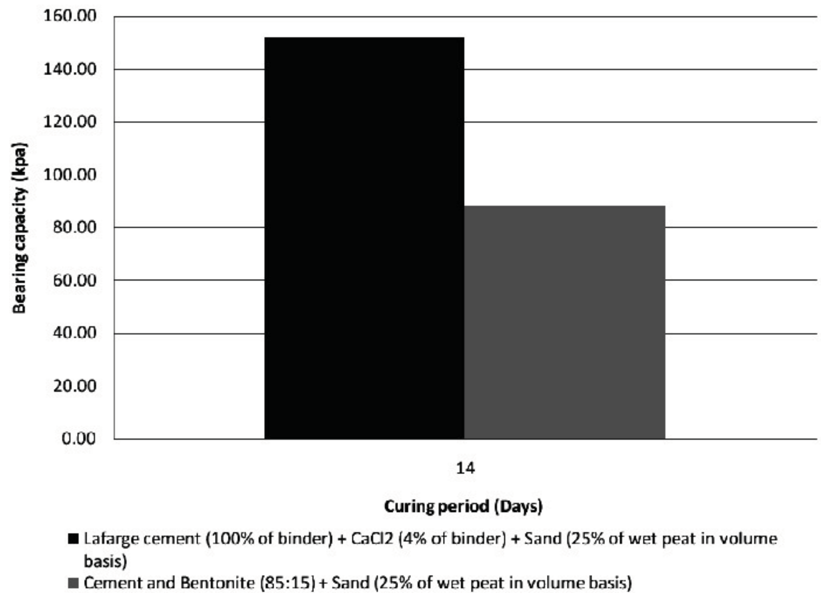

Fig. 2: Bearing capacity of stabilised column after 14 days curing time

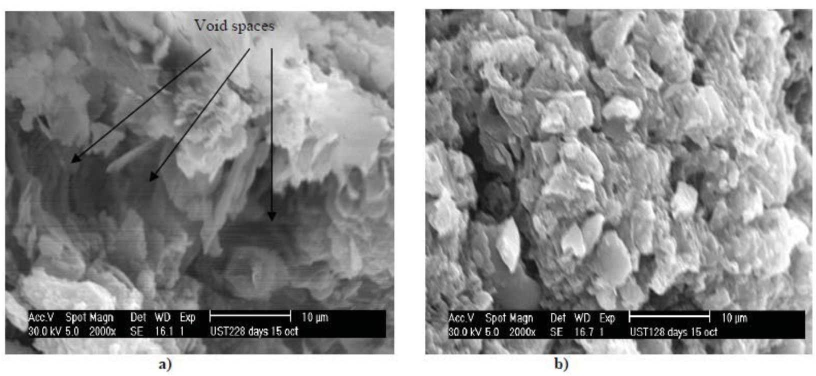

Fig. 3: Microstructure of a) natural peat and b) stabilised peat

Conclusion:

The folowing are the main conclusions from the experiments described in this paper:

Tropical peat soil has unique characteristics with its high water, organic and fibre content. This soil is very soft in its natural state and high compressible and very low shearing strength value. Associated with roots, leaf, bogs peat soil causes serious problem in construction industries because the area of peatland is not frequently accessible without ground improvement work.

1. Bearing capacity of peat soil is very negligible construction over this soft soil is quite impossible for its high settlement value. This soil does able to sustain even moderate load for that reason it can be categorised as extreme soft soil. Ground improvement work is mandatory to improve its bearing capacity before undertaking any construction works.
2. Peat soil can be stabilised by soil column which is very much effective in construction industries and comparing to the other method of soil stabilisation this method is more economical and soil can be stabilised very short period of time. From our experiment, it was observed that bearing capacity of peat soil increased considerably after stabilisation by deep mixing method. In addition high setting cement, sand and calcium chloride as binder has given better result compare with ordinary Portland cement, sand and bentonite.

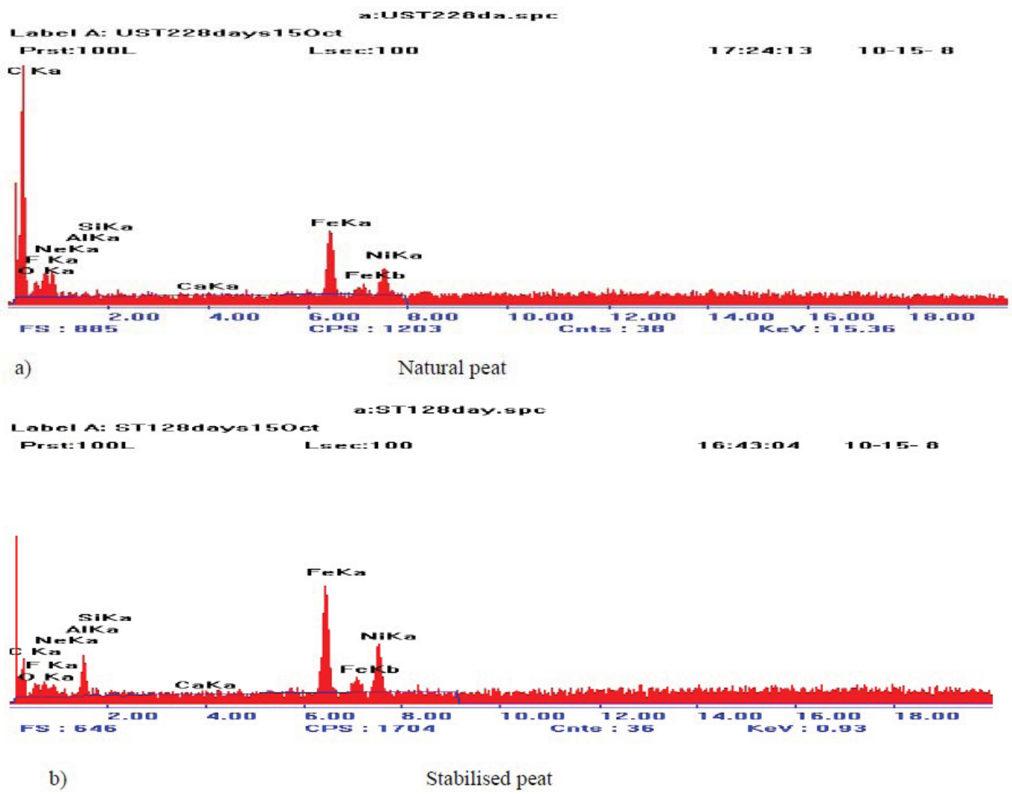

Fig. 4: X-ray diffraction graph of stabilised peat soil

This experiment was a model study and hand mixing method for soil stabilisation does not reflect actual construction procedure. Usualy this soil is stabilised by using big rig machine which obtains a plant to inject binder into the soil and a mixing blade to mix the binder to the soil. So, further research requires conducting field experiment with mixing equipments.

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