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Full Length Research Paper

Behaviour of stabilised peat: A field study

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The aim of this study is to observe engineering behaviour of stabilised peat soil by deep mixing method using various types of binder. A field model study has been conducted to stabilise peat using various types of binder. Various mechanical properties of stabilised peat, like undrained shear strength, unconfined compressive strength and shear strength was determined after 14 days of curing time. Scanning electron micrograph (SEM) and energy dispersive x-ray (EDX) test were also conducted to observe the microstructure of stabilised peat soil. From the test result, it was observed that the engineering properties of peat soil can be improved by stabilisation using additives.

Key words: Column, binder, microstructure, deep mixing method, strength.

INTRODUCTION

Peat soil is not suitable for the construction of embankment, highway, building or any other load bearing engineering structures due to the fact that it is having extreme low shear strength and bearing capacity. In natural state, peat consists of water and decomposed plant fragment with virtually no measurable strength (Munro, 2004). Generally, this soil is considered as a soft soil as it has high settlement value even under moderate loading condition. In Malaysia, some 3 million hectares of land is covered with peat. West Malaysian peat exhibits very high compressibility, low strength and bearing capacity (Hashim and Islam, 2008). Peat poses serious problems in construction industry due to its long-term consolidation settlements even when subjected to a moderate load (Jarret, 1995). Hence, peat is very much unsuitable for supporting foundations in its natural state.

Edil (2003) summarizes a number of construction options that can be applied to peat and organic soils, namely: Excavation-displacement or replacement; ground improvement and reinforcement to enhance soil strength and stiffness, such as by stage construction and pre-loading, stone columns, piles, thermal precompression, and preload piers; or by reducing driving forces by light-weight fill; and chemical admixture such as cement and lime. These chemical admixtures can be applied either as deep *in situ* mixing method (lime-cement columns), or as surface stabiliser. At present, it is considered that *in-situ* improvement of peat and soft organic soils using deep mixing techniques offers economical and practical advantages over those conventional methods. In deep soil stabilisation method, columns of stabilised material are formed by mixing the soil in place with a 'binder', as a result, interaction of the binder with the soft soil takes place, which leads better engineering properties of soft soil than the original untreated one (Hebib and Farrell, 2003).

This method is often used in many geotechnical and foundation applications such as the stabilisation of deep excavations or high embankments, the reduction of settlement or the increase of soil strength for building foundation, the slope stability, the tunnel support, the water retention etc. The strength of soil-cement mixture (the most common binder that is used in DMM) is influenced from many parameters like physicochemical properties of the soil, geological and hydrogeological conditions of the area, properties and the quality of the used binder or the additive, the mixing method and consequently the mechanical equipment, and the curing conditions (Porbaha, 2000). Because of the aforementioned parameters, a significant deviation between the laboratory measurements of strength of soil-cement specimens and the corresponding one taken from *in situ*

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Table 1. Physical properties of Klang peat (Hashim and Islam, 2008).

Physical 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
Bulk density (kg m-3)	1035.66 - 1040.11	1037.720
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is usually observed.

The design philosophy for deep stabilisation is to produce a stabilised soil that mechanically interacts with the surrounding unstabilised soil. The applied load is partly carried by the columns and partly by the unstabilised soil between the columns. Therefore, a too stiffly stabilised material is not necessarily, since such a material will behave like a pile (EuroSoilStab, 2002).

A study was carried by Wong et al. (2008) and found that the unconfined compressive strength gain of the stabilised peat specimen was only significant after a minimal dosage of 250 kg m^{-3} binder with 75% cement and 25% slag in composition were added. At the dosage and composition of the binder, its unconfined compre-ssive strength reached 142.5 kPa and when the dosage of binder increased to 300 kg m^{-3}, the stabilised soil specimen yield higher unconfined compressive strength of 178.6 kPa as compared to those of other compositions and dosages of the stabilised soil specimens. The high dosage of the binders and siliceous sand required to stabilise the peat can be explained by the fact that the soil has a very low amount of solid particles to be stabilised and hence, more cement, slag and siliceous sand need to be added to the soil to form a sustainable load bearing stabilised soil.

Study was carried out by Huat et al. (2005) to examine the effect of cement on the unconfined compressive strength of the peat soil sample. However, they further examine the effect of cement content and curing period, as well as the influence of organic content on the unconfined compressive strength of the peat soil samples, and revealed that increasing the cement content increases the unconfined compressive of the soils samples. Similarly, higher strength is obtained from samples that have been cured for 28 days compared with the 3, 7, 14-days cured samples. Bergado (1996) found that pozzolanic reaction can continue for months or even years after mixing, resulting in the increase in strength of cement stabilised clay with the increase in curing time.

Deboucha et al. (2008) conducted a study to stabilise peat soil using cement, bentonite and sand as binder in different ratio and revealed that unconfined compressive strength was increased after stabilisation. Author also found that higher strength was obtained from samples that had been cured for 14 days compared with 7 days cured samples.

From literature, it was found that comprehensive research and development works have been carried out to find a proper technique for peat soil stabilisation. But all of these works were laboratory based and field experimentation was few. Hence, objectives of this study was as follows:

1. To Stabilised peat soil in field by column technique and using various types of binder.
2. To observe the effect on mechanical strength and microstructure of peat after stabilisation.

MATERIALS AND METHODS

Soil characterisation

The research was conducted from January 2008 to August 2008. The test site was Klang, Peninsular, Malaysia, which is located 35 Km North West of Kuala Lumpur city. Trial pits were excavated to a depth of 1 m below the ground surface in order to obtain both undisturbed and disturbed soil samples below the ground water table. Close examination of each trial pit indicated that the ground water table was about 0.3 m 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 (passing between fingers), it was observed that the soil was somewhat pasty with muddy water squeezed out, and the plant structure could not be identified easily. Table 1 shows the physical properties of the soils and are explained. Figures 1 and 2 show the SEM and EDX micrographs of natural peat.

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). 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, 1996). In this study, we used two types Malaysian local made cement such as YTL cement and Lafarge brand Mascrete cement.

Bentonite

Bentonite is an absorbent aluminum phyllosilicate, which in general

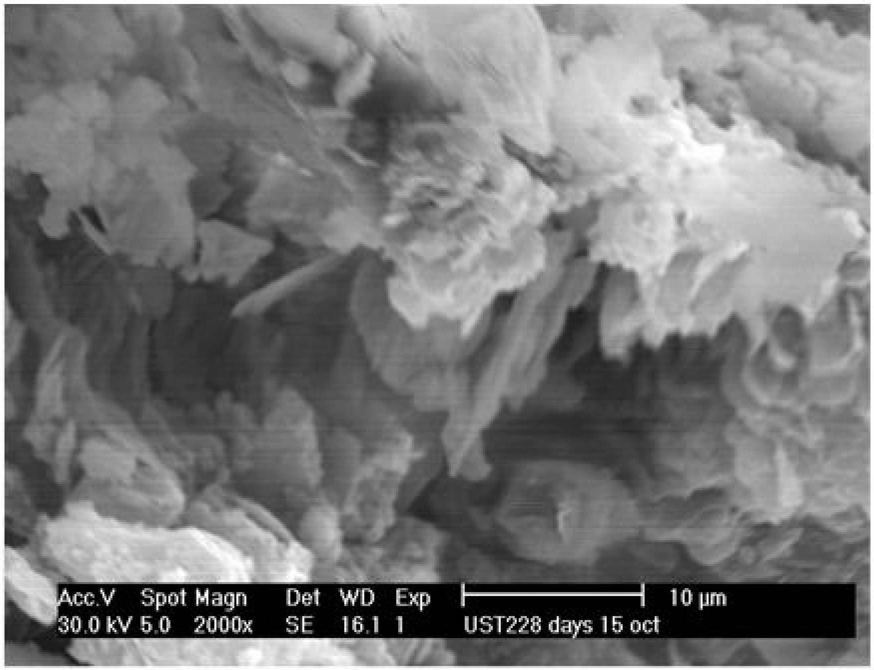

Figure 1. Scanning electron micrograph of original peat soil.

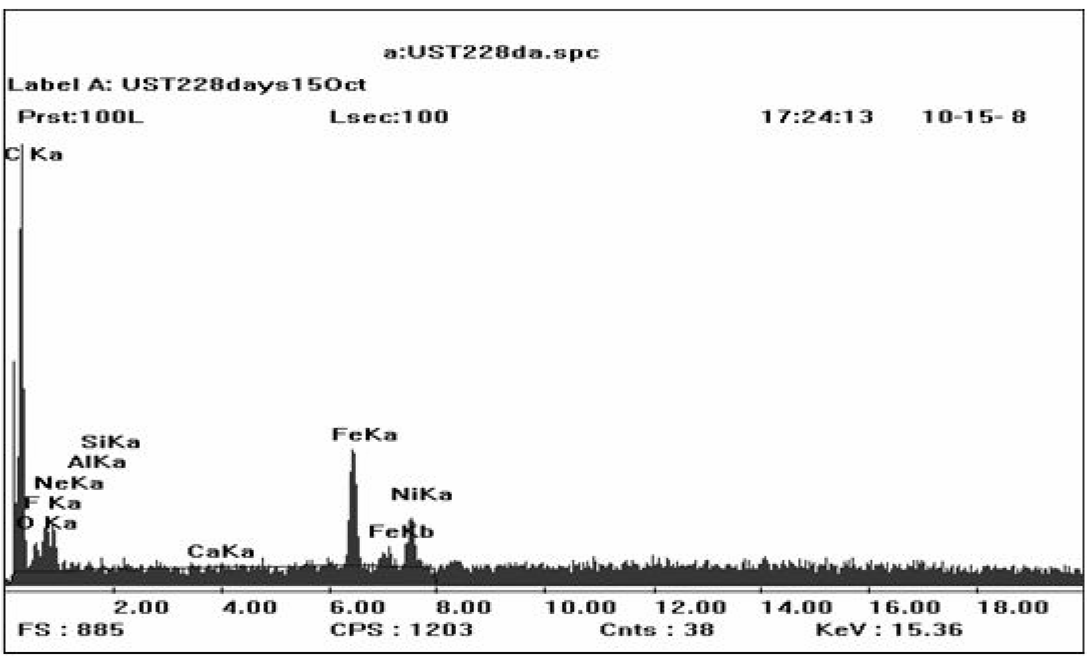

Figure 2. EDX micrograph of original peat.

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 (that is, 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 was found that grain size distribution provides a satisfactory skeleton, and the voids were 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.

Calcium chloride ($CaCl_2$)

Dehydrate Calcium chloride ($CaCl_2.2H_2O$) was used as admixture in this experiment. Minimum assay content of this substance was 74%. Maximum impurities were free alkali Iron (Fe) 0.005% and Magnesium and alkalies (sulphate) 0.5%.

Field experiment

Soil-cement column (height 1000 mm and diameter 200 mm) were constructed by using ordinary Portland cement, bentonite, calcium chloride as binder. Dosage rate of binder was 300 kg/m^3. Mixing proportion of binder was: (1) YTL Cement and bentonite in 85:15 ratio and 25% of well graded sand by volume of soil (2) 100% of Mascrete (Lafarge brand) cement, $CaCl_2$ (4 % of binder) and 25% of sand by volume of soil. Column was conducted by premixed and premixed method, in which a 200 mm diameter and 1000 mm height whole was made by drilling a hand operated auger. Soil and binder were mixed in a tray and the mixer was inserted into the bore. Plate 1 shows the procedure.

Hand operated cone penetrometer

A proving ring hand operated cone penetrometer (Plate 2) 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 manually 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 (Cernica, 1995).

Unconfined compression test

Sample was collected from stabilised column to conduct unconfined compressive strength test (UCT) in laboratory (Plate 3). The test was performed in a 50 mm diameter and 100-mm height mould according to BS 1377: 1990.

Direct shear box test

60 × 60 × 300 mm column was formed in the field using cement, CaCl2 and silica sand as binder. After 14 days of curing, the column was collected and brought to laboratory and direct shear box test was performed to determine the shear strength for different normal stress condition. The test was conducted by following BS 1377: 1990.

RESULTS AND DISCUSSION

Visual inspection

The columns were exposed after 14 days of curing period and it was found that a 200 mm diameter circular shape uniform column was formed. There was an effect of stabilising agent in the surrounding soils and the effect was in between 10 - 30 mm from the outer edge of columns. There was mechanical interaction in between column and surrounding soils and applied load was carried out by both, which was indicated in design consideration of EuroSoilStab, 2002. Plate 4 shows the formation of column both in horizontal and vertical direction.

Effect on undrained shear strength

From the cone penetrometer test, it was observed that undrained shear strength has reached 1.60 Mpa for the column stabilised by the mix design with cement, CaCl2 and sand. Binding agent of cement, bentonite and sand had a considerable effect on undrained shear strength, which was 0.86 Mpa (Figure 3). This result seems to be higher because the result of cone penetrometer sometime misleads, but nevertheless this result indicated that the bearing capacity of stabilised column increased dramatically after stabilisation.

Effect on unconfined compressive strength

Form UCS test in laboratory with the sample collected from stabilised column after 14 days of stabilisation, it was observed that unconfined compressive strength increased than original soil. Although, this result does not reflect the actual field condition because of the difficulties of collecting undisturbed samples with UCS mould from column, the results from the UCS test are the clear indication of improvement of soft peat after stabilisation. Wong et al. (2008), Huat et al. (2005) and Deboucha et al. (2008) found higher value of unconfined strength as the test was conducted in laboratory condition. Figure 4 shows UCT result.

Effect on shear strength

From direct shear box test, it was observed that the shear strength has reached upto 100 Kpa for 20 kg normal stress and for the sample tested after 14 days of stabilisation. This indicates that shear strength of peat soil significantly improved after stabilisation. Figure 5 shows the direct shear box test result.

SEM and EDX test

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 Figures 6 and 7. These figures explain that the new structure's soil appeared in stabilised soil column. SEM shows that peat soil became compacted after stabilisation. The

Plate 1. Installation of column. (a) Drilling augur, (b) Mixing soil and binder, (c) Insert mixed soil and binder, (d) Tamping by steel rod.

Plate 2. Proving ring hand operated cone penetrometer.

presence of carbon at peak implies that pozzolanic reaction takes a form of cementitious material.

Conclusion

The following conclusion can be drawn on the basis of test result obtained from peat soil stabilisation by deep mixing method using various types of binder:

1. Deep soil stabilisation process does not only form a soil-column, but also stabilise the surrounding soil, which increase bearing capacity by increasing friction between soil column and surrounding stabilised soil.
2. Undrained shear strength increases considerably after stabilisation. This result indicates that bearing capacity of peat soil can be improved by stabilisation with deep mixing method using cement, sand, bentonite and $CaCl_2$

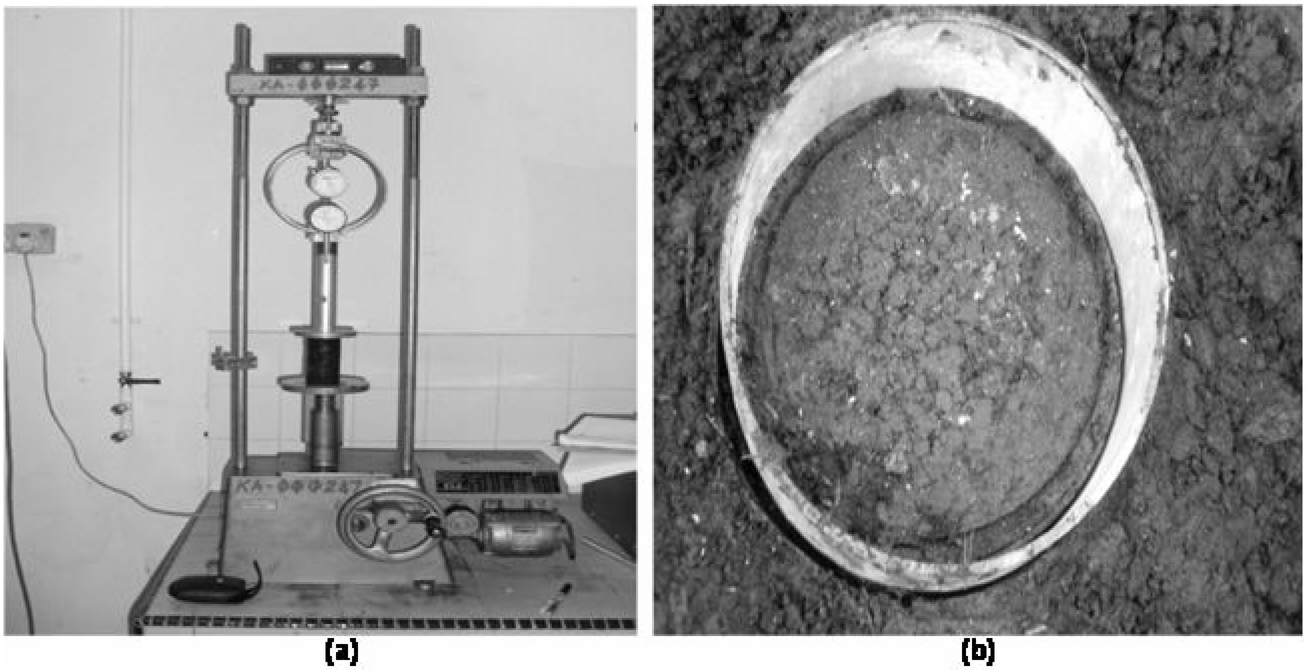

Plate 3. (a) Collecting sample for UCT, (b) UCT test in laboratory.

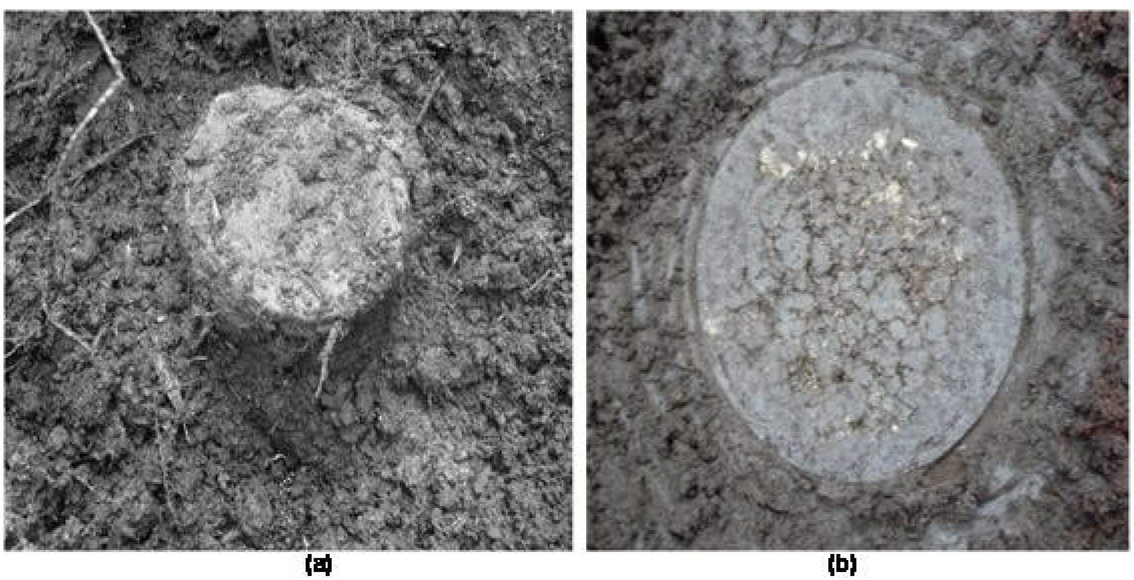

Plate 4. (a) Formation of column after 14 days, (b) vertically exposed column.

as binder.
3. Results shows that shear strength of peat soil can also be increased by stabilisation.
4. Unconfined compressive strength of stabilised peat is higher than the untreated peat, although the result of UCT test in laboratory does not reflect the actual condition.
5. Microstructure of peat totally changed after stabilisation.

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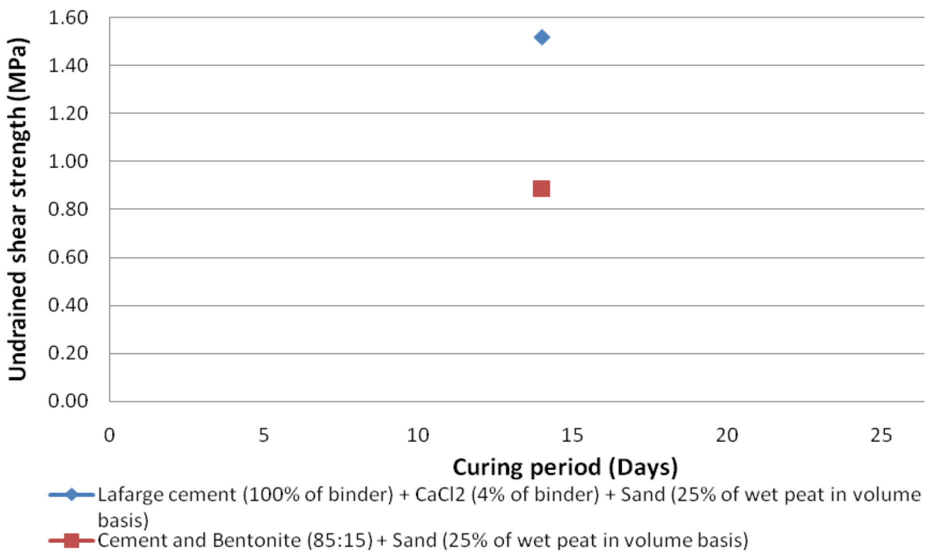

Figure 3. Undrained shear strength of stabilised column after 14 days curing time.

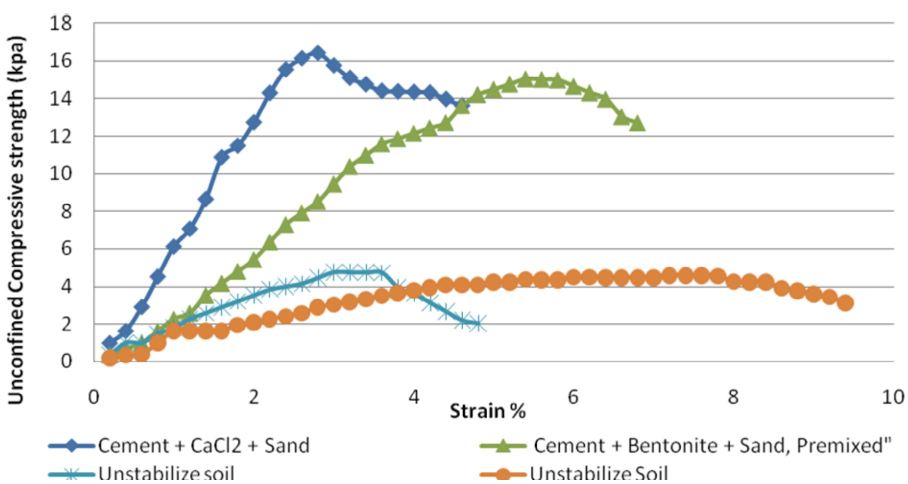

Figure 4. Unconfined compressive strength of collected sample from stabilised column.

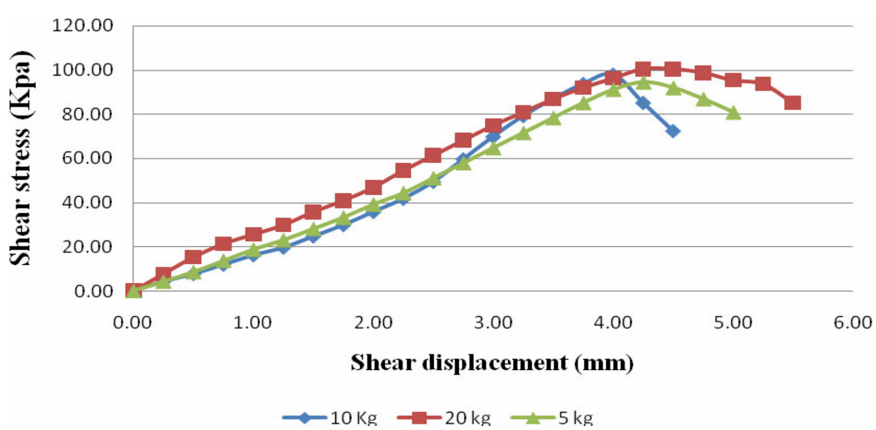

Figure 5. Shear stress of stabilised peat for different normal load condition from direct shear box test.

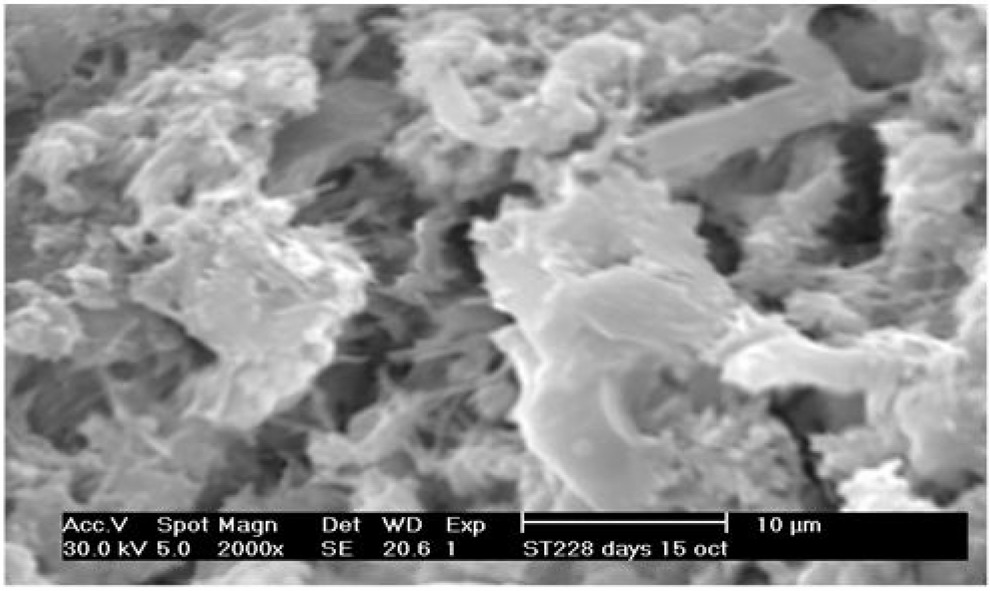

Figure 6. Scanning electron micrograph of peat stabilised with cement, CaCl2 and silica sand.

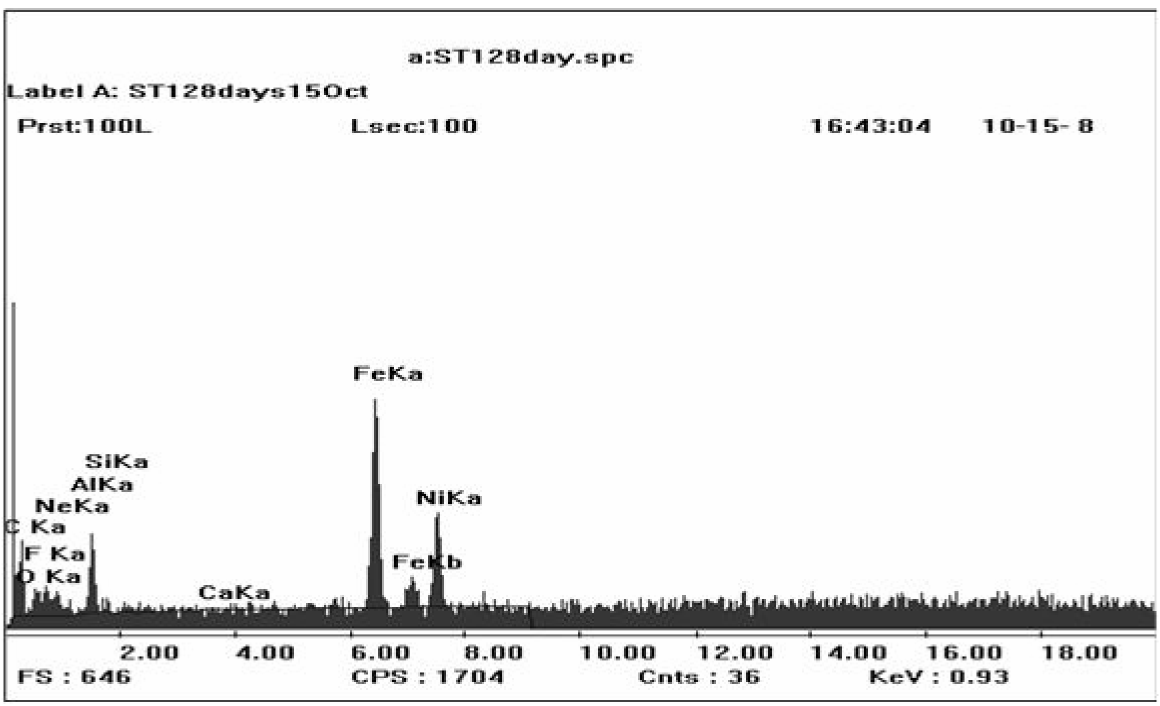

Figure 7. EDX micrograph of stabilised peat after 14 days curing period.

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