Geotechnical Aspects of Underground Construction in Soft Ground – Viggiani (ed)
 ISBN 978-0-415-68367-8

Effect of cement on tropical peat stabilized by deep mixing method

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ABSTRACT: Peats show high compressibility and low shear strength and hence are problematic in geotechnical engineering context. Cement is widely used for the stabilization of peat by Deep Mixing Method (DMM). This paper presents the results of the model study of the compressibility properties of peat stabilized with columns formed by DMM. Consoilidation and Scanning Electron Microscopy (SEM) were performed on peat samples stabilized with cement treated columns. The results showed that the compressibility behaviour of peats can be improved significantly by installing columns of peat stabilized with cement. The amount of cement used was observed to influence the engineering behaviour of treated tropical peats. Sapric peat showed a better response compared with hemic and fibrous peats.

1 INTRODUCTION

Deep mixing method is a widely used method for stabilizing organic soils. This method, originally developed in Sweden and Japan more than thirty years ago, is becoming well established in an increasing number of countries. Originally lime was the only binder used, but cement has been widely used since the mid 1980s, with considerably higher strength achieved (Åhnberg et al., 1995). The introduction of cement has made it possible to stabilize "problematic soils" with high organic contents and high water:soil ratios (Åhnberg, 2006; Janz and Johansson, 2002). Comprehensive trials and field works have been carried out where cement, and cement with different industrial binders have shown to improve the mechanical properties (shear strength and compressibility) of organic soils and peats (Axelsson et al., 2002; EuroSoilStab, 2002; Hebib and Farrell, 2003; Moore, 1989). Since peat already has a high water content, the required water for soil-cement reaction comes from it. Therefore, Dry Mixing Method (DMM) and Dry Jet Mixing (DJM) methods are effective for peat stabilization instead of wet mixing method (Yang et al., 1998). Berry (1983) reported that the consolidation process is complicated by the occurrence of secondary compression which appears to extend indefinitely.

In this paper, an attempt has been made to evaluate the effects of using cement by DMM method on the compressibility of tropical peats by forming stabilized cement columns and performing SEM test on treated tropical peats. This model study was initiated in order to evaluate the influence of dry cement to stabilize peats, in terms of a reduction in compressibility by performing Rowe cell tests.

2 MATERIALS AND METHODOLOGY

2.1 *Materials*

Peat was collected from various locations near Kuala Lumpur, Malaysia to have all the three varieties: fibrous, hemic and sapric peats. The physico-chemical properties of fibrous, hemic and sapric peats are presented in Table 1. Ordinary Portland cement (hereinafter called cement), used in this study as a binding agent, was obtained locally.

Table 1. Physico-chemical characteristics of untreated peats.

Parameters	Fibrous peat	Hemic peat	Sapric peat
Moisture content [%]	506.5	324.6	188.2
Specific gravity	1.26	1.302	1.42
Organic content [%]	94.23	81.3	75.31
Fiber content [%]	79.1	53.2	31.3
Bulk unit weight [kN/m^3]	9.86	10.3	11.1
pH	3.8	4.81	5.97

2.2 *Methodology*

2.2.1 *Sample preparation*

A suitable auger was designed and fabricated to collect undisturbed peat samples as per BS 1377-1 (BS, 1990). Once in the laboratory, the top cover on the cylindrical tube was opened to extract the sample. The auger enables the extraction of samples 150 mm in diameter and 230 mm in height. The top and bottom of the specimen was trimmed carefully and quickly to minimize any change in the water content of the soil sample (Figure 1(a)). According to BS 1377-8 (1990) and BS 1377-6 (1990), the height (H) of the specimen was 37.5 mm for the consolidation test.

In order to evaluate the compressibility of peat reinforced by stabilized cement column, samples of peat with cement column were prepared by inserting a PVC tube in the center of the specimen and extracting soil from within the tube. Next, the extracted peat, at its natural water content, was thoroughly homogenized by household mixer and then cement was added to it at a typical dose rate of 200 kg/m^3 (Axelsson et al., 2002). The stabilized cement columns in the composite peat samples were prepared with cement:peat ratio of 50:50, 70:30, 80:20 and 90:10 (Table 2).

The cement-peat mixture, mixing thoroughly for five minutes, was replaced back in PVC tube, and the tube was finally withdrawn forming the stabilized cement column (Figure 1 (b)). Care was taken to replace back the peat-cement mixture as soon as possible, but not later than 30 minutes; as this was the initial setting time of cement. The columns formed in peat were of diameters (R) 37.5 mm (column-area ratio = 25%). The samples were then cured for 28 days in a soaking basin before performing consolidation tests (Rowe cell).

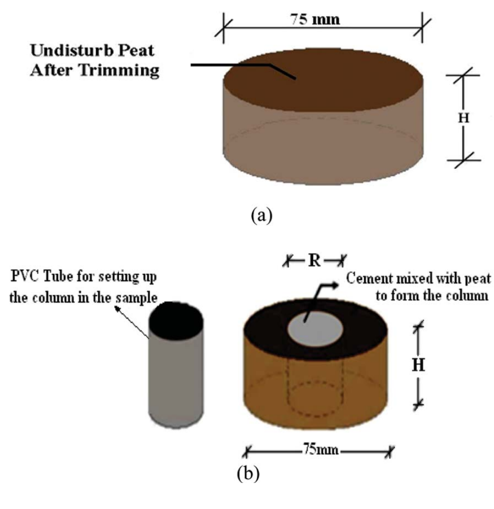


Figure 1. Sample preparation (a) cylindrical test specimen from the undisturbed soil sample after trimming and (b) method used to set up cement column in specimen.

Table 2. Various quantities of cement used in cement stabilized columns.

Samples	Condition
Control sample	Untreated peat
Sample I	Peat = 50%; cement = 50%
Sample II	Peat = 30%; cement = 70%
Sample III	Peat = 20%; cement = 80%
Sample IV	Peat = 10%; cement = 90%

Holm (2000) presented several case histories of deep mixing and the typical column-area ratios (cement column area to treated peat area) being used in practice are between 5–35%. In this study, the cement column diameter was 37.5 mm and the column-area ratio was 25%.

2.3 *Experimental methods*

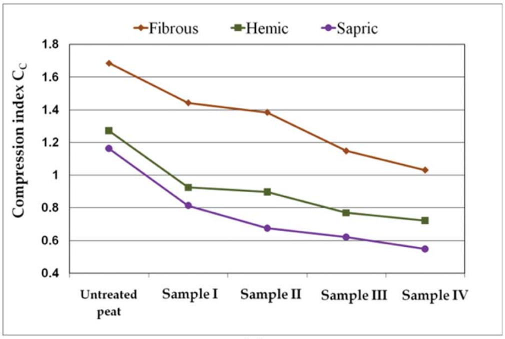
Physical properties of peat and treated peat columns with different cement ratio were determined and are mentioned in Table 1. The compressibility characteristics of peats determined are: (i) Compression index (C_c), and (ii) Coefficient of secondary compression (C_α).

3 RESULTS AND DISCUSSION

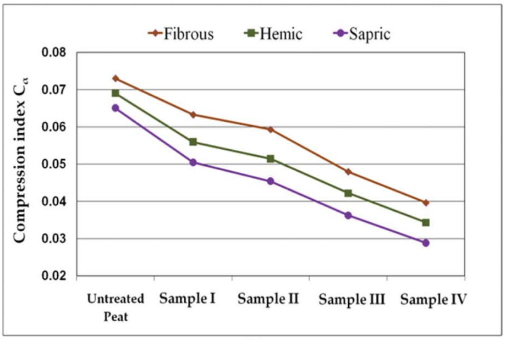
3.1 *Compressibility characteristics of cement columns of stabilized tropical peat*

The compressibility characteristics of peats with cement stabilized column were studied by Rowe cell for pressures of 50, 100, 200, and 300 kPa. The compression index (C_c) of fibrous, hemic and sapric peats for pressures of 50 kPa is shown in Figure 2(a). As expected, the C_c for peats decreased with an increase in the cement content. The C_c for untreated fibrous peat with a column-area ratio of 25% was 1.68 and it decreased to 1.03 with 90% cement. Similarly, the C_c for untreated hemic and sapric peats with a column area ratio of 25% were lower at 1.27 and 1.16 respectively and they decreased to 0.72 and 0.547 respectively.

The nature of curves of C_c for fibrous, hemic and sapric peats for consolidation pressures of 100, 200 and 300 kPa were similar to those for 50 kPa. This is due to the fact that the cement particles bind together the soil particles causing an increase in shear strength and a decrease in compressibility. Fibrous peat shows a higher reduction in C_c compared with hemic and sapric



(a)



(b)

Figure 2. Consolidation results: (a) Compression index (Cc), and (b) Secondary compression index (Cα) of treated fibrous, hemic and sapric peats at 50 kPa consolidation pressure.

peats. The reasons for this behavior are higher void ratio and nature of fibres in fibrous peat that allow for higher compression and bending.

The secondary compression index (C_α) was evaluated for different peat samples and are presented in Figure 2(b) for a consolidation pressure of 50 kPa. It was observed that C_α decreases with an increase in cement content for all; fibrous, hemic and sapric peats.

The C_α of untreated fibrous peat with a column area ratio of 25% was 0.073 and as expected, it decreased to 0.040 with 90% cement. Similarly, the C_α of untreated hemic and sapric peats were 0.069 and 0.065 respectively, which is lower than that of fibrous peat. They decreased to 0.034 and 0.028 for hemic and sapric peat respectively with 90% cement. However, it agrees well with the findings reported in the literature (Holm, 2000; Kazemian et al., 2009; Mesri and Castro, 1987).

The nature of curves of C_α for fibrous, hemic and sapric peats at a consolidation pressures of 100, 200 and 300 kPa were observed to be similar to those at 50 kPa. The compressibility of peats stabilized with cement treated columns decreased with an increasing cement amount. This is quite obvious as the mass of binder is increasing per unit volume of the peat; cement increases the strength and transforms peat into a stiffer state as mentioned earlier. The effect of cement on compressibility parameters of sapric peat is higher among others as stated above as well.

The above findings are justified for the fact that when water comes in contact with cement, three reactions take place: (i) cement reacting with water called hydration, (ii) pozzolanic reactions between calcium hydroxide [$Ca(OH)_2$] from burnt cement and pozzolanic minerals in the soil, and (iii) ion exchange between calcium ions (from cement) with ions present in the colloids of peats, which leads to an improvement in the strength of the treated soil strength. Cement initiates chemical reaction with water (called hydration) and tricalcium silicate (C_3S) and dicalcium silicate (C_2S) (from cement) are mixed with water, calcium ions are quickly released into the solution with the formation of hydroxide ions. When the concentration of calcium and hydroxide ions reaches a certain threshold value, calcium hydroxides crystallizes out of solutions and finally leads to the production of calcium silicate hydrate (C–S–H) and thus, bonding the particles and increasing the shear strength (Janz and Johansson, 2002).

3.2 *Microstructural study of treated tropical peat*

Figure 3 shows the different effects of cement ratios on treated fibrous peat. The amount of fibrous-acicular C–S–H gel in sample I (with 50% cement) was much less than in sample IV (with 90% cement), proving the effect of cement on cementation and pozzolanic reactions. Furthermore, there were few spherical C–S–H particles or other types of C–S–H morphologies of cementation in treated fibrous peat with 50% cement (sample I) that exhibited nominal hydration, and more C–S–H gel was produced in treated fibrous with 90% cement (sample IV) [Figures 3(a) and 3(c)]. The SEM results were consistent with the Rowe cells results, such that at low cement ratios, the compressibility parameter of the treated fibrous peat was low because of the lower production of C–S–H gel.

Figures 3(b) and 3(d) show the SEM micrograph of treated sapric peat cured in distilled water. It was observed that the amount of C–S–H gel in treated sapric peat with 90% cement (sample IV) was much higher than in compare with sapric treated with 50% cement (sample I). Furthermore, it was observed [Figures 3(b) and 3(d)] that abundant massive and spherical or coralloid aggregations of C–S–H gels were produced in treated sapric peat with 90% cement (sample IV) in comparison with treated sapric peat with 50% cement (sample I).

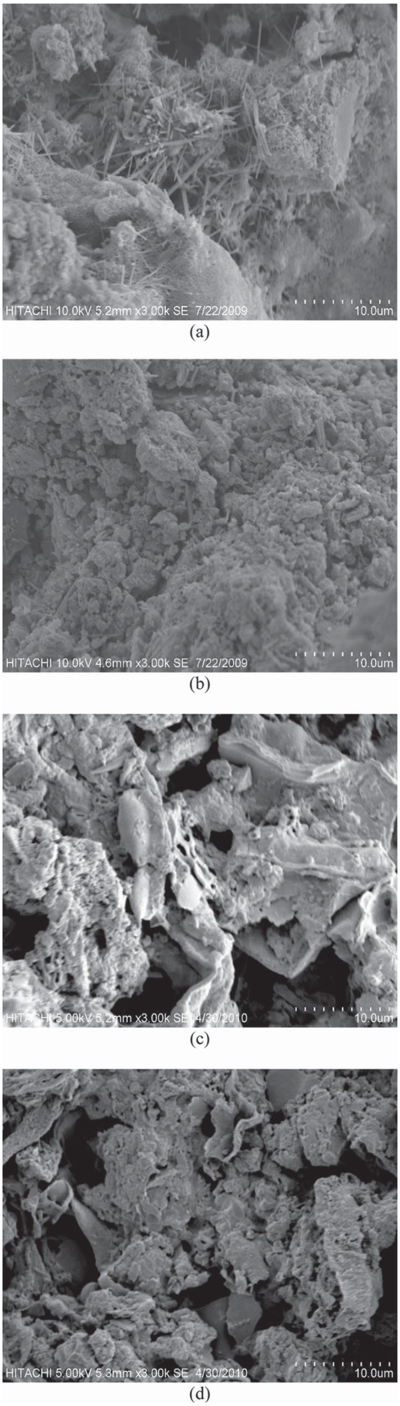


Figure 3. (a) Fibrous peat treated with 90% cement (sample IV); (b) Fibrous peat treated with 90% cement (sample IV); (c) Fibrous peat treated with 50% cement (sample I); (d) Fibrous peat treated with 50% cement (sample II).

This implies that the effect of cement on sapric the same fibrous cause to decrease the compressibility parameters of treated peat. In addition, by comparison of Figures 3(b) and 3(d), it is cleared that the effect of cement of sapric is much higher than fabrious which has been explained before. These findings are consistent with the findings presented in the literature (Hebib and Farrell, 2003), who reported that cement decreases the compressibility of tropical fibrous peat and that this will be more effective when sapric peat are treated by cement.

4 CONCLUSIONS

The following conclusions can be drawn from this study:

1. The compressibility parameters (C_c and C_α) decrease with an increase in the cement content. This is due to the fact that the hardened soil-cement matrix formed due to the hydration reaction, pozzolanic reaction, and cation exchanges that take place when cement comes in contact with water.
2. The production of C–S–H gels is the maximum in sapric peat. This is because as the mass of binder is increasing per unit volume of peat; cement increases the strength and transforms peat into a stiffer state.
3. Fibrous peat shows a higher reduction in C_c compared with hemic and sapric peats. The reason for this behavior is the presence of higher voids and the nature of fibers that allow higher compression and bending.
4. The effect of cement is the maximum on sapric peat.

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