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# Effect of Formamide, calcium chloride and aluminum chloride on stabilization of peat with cement-sodium silicate grout

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**Abstract:** Peat is a good example of a problematic soil. Peat usually has very high water content which could be more than 1000% compared to mineral soils such as silt, clay and sand. Due to the fact that peat is a problematic soil, improvement methods of peat are needed. Grouting and chemical grouting are the most popular methods of peat improvement. The role of calcium chloride, Formamide and Aluminium Chloride act as the reactant and/or accelerator in the grout mix. Thus, form large particles (Flocculation Agglomerate) and stabilize the peat. In this paper, Unconfined Compressive Strength (UCS) tests were used to determine the effect of using chemical grouts on the shear strength of peat. The results showed that by increasing calcium chloride from 0 to 1%, UCS increased from 210-225 KPa. The results also showed that by increasing the percentage of formamide and aluminium chloride, UCS increased.

**Key words:** *Peat stabilization; Shear strength; Formamide; Calcium Chloride; Aluminum Chloride*

## 1. Introduction

Peat soils are geotechnically problematic soils due to their high compressibility and low shear strength. Peat is a soil with organic content of more than 75% (Kazemian and Huat; 2009). It is subject to instability, for example, localized sinking and slip failure, and massive primary and long-term settlement when subjected to even moderate load increase (Kazemian et al.; 2011).

Peat is the result of gathering of plant residue which is conserved underneath of partial ventilation and high water content. The amorphous peat particles, in which the cell structure is still visible, are the product of biochemical decomposition and breakdown of fibrous peats and other plant remains. Amorphous peat deposits are more likely to include a significant amount of inorganic matter. As compared to fibrous peat deposits, the amorphous peat fabric is likely to exist at lower void ratios and to display lower permeability anisotropy, lower compressibility, lower friction angle, and higher coefficient of earth pressure at rest (Edil, 2000). Fibrous peat is peat with high organic and fiber content with low degree of humification. The behavior of fibrous peat is different from mineral soil because of different phase properties and microstructure (Edil, 2003). (Landva and Pheeney, 1980) and (Landva and La Rochelle, 1983) described fibrous peat particles consist of fragments of long stems, thin leaves, rootlets, cell walls, and fibers, often are quite large. Stem diameters of 20 to 500μm, leaf thicknesses of 10 to 15 μm, and width and length of 100 to 1,200 μm are common. Scanning electron micro-photographs (SEMs) of James Bay peat in Figure 1(a), (b) illustrate hollow perforated cellular structures and a network of fibrous elements in vertical and horizontal section (Kazemian et al.; 2011).

Soil improvement refers to any method or techniques that improve the engineering properties of soil, like shear strength, compressibility, stiffness and permeability. (Raju, 2009) classified soil improvement methods to the following principles: (i) consolidation (e.g. prefabricated vertical drains and surcharge, vacuum consolidation, stone columns), (ii) chemical modification (e.g. deep soil mixing, jet grouting, injection grouting), and (iii) reinforcement (e.g. stone columns, geosynthetic reinforcement).

The Deep Mixing Method (DMM) is today accepted world-wide as a soil improvement method which is performed to improve the strength, deformation properties and permeability of the soil. It is based on mixing binders, such as cement, lime, fly ash, chemical grouts and other additives, with the soil by the use of rotating mixing tools in order to form columns of a hardening material, since the chemical reaction between the binder and the soil grains are developed (Costas, 2008). For stabilizing unreachable material such as if the soil is near to or underneath a building two methods can be used: injection and deep mixing. The soil's nature and the improvement that it needs can determine the stabilizer and the method that can be used to improve the soil. Injection method depends on the nature of the soil that will be injected because it's much more difficult to inject or penetrate fine

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grained soil than coarse grained soil, but for a deep mixing method, it's very useful for soft clays which are impossible to be stabilized using injection method (Rollings et al.; 1996). The benefits of soil's injection are to increase the soil's strength and to decrease their permeability for water control. The soil's nature at the site and the improvement needed from the stabilization process can be used to determine the chemicals that should be used in stabilization. There are many ways for injection of stabilization admixtures or injection of grouting. The easiest way is to inject the grouting admixture under pressure to the holes that are drilled to the desired stabilization depth.

In this paper, the effect of adding different percentages of calcium chloride, aluminium chloride and formamide was investigated on the shear strength of the peat stabilized with sodium silicate, kaolinite and cement.

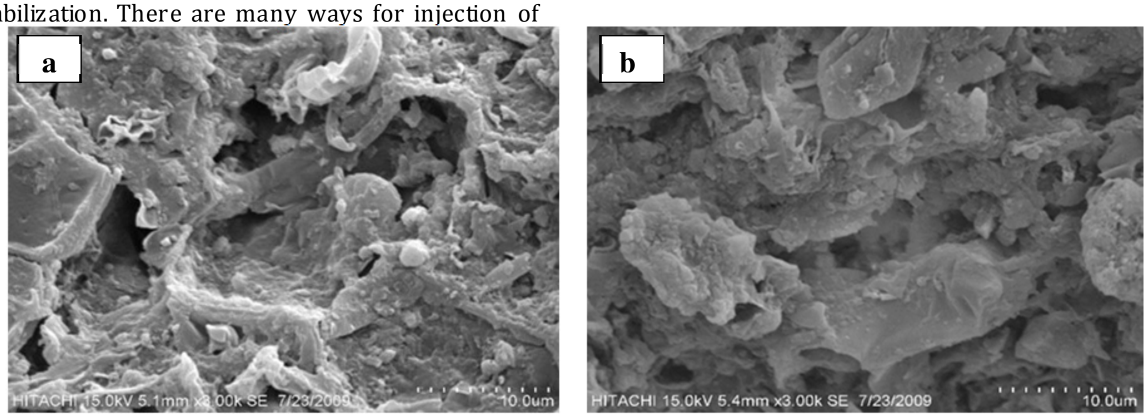


**Fig. 1:** Scanning electron microphotograph of (a) Fibrous peat; (b) Hemic peat.

## 2. Materials and methods

### 2.1. Materials

The cement used in this study (as binders) was sourced from the Anuza Enterprise Company, Malaysia respectively. The chemical composition of cement as provided by the manufacturers, are summarized in Table 1. Furthermore, calcium chloride anhydrous powder ($CaCl_2$) and kaolinite were used as a reactor/accelerator and filler respectively. The Kaolinite [$Al_2Si_2O_5(OH)_4$] structure is made up of silicate sheets ($Si_2O_5$) bonded to aluminum oxide/hydroxide layers [$Al_2(OH)_4$] called gibbsite layers. Tables 2, 3 and 4 show the chemical composition of calcium chloride, kaolinite and formamide respectively.

**Table 1:** Chemical Composition of Cement

| Constituent | (%) |
|---|---|
| $SiO_2$ | 21 |
| $Al_2O_3$ | 5.3 |
| $Fe_2O_3$ | 3.3 |
| CaO | 65.6 |
| MgO | 1.1 |
| $SO_3$ | 2.7 |
| Loss on Ignition | 0.9 |
| Fineness (% passing 45μm) | 90.5 |

**Table 2:** Chemical Composition of Calcium chloride

| Constituent | (%) |
|---|---|
| Minimum Assay | 96% |
| $SiO_4$ | 0.02 |
| $Ca(OH)_2$ | 0.04 |
| $Mg^{+2}$ | 0.6 |
| alkalis (sulfate) | 0.6 |

**Table 3:** Physico-Chemical Parameters of Kaolinite

| Constituent | (%) |
|---|---|
| $SiO_2$ | 45.80 |
| $Al_2O_3$ | 39.55 |
| $Fe_2O_3$ | 0.57 |
| CaO | 0.41 |
| MgO | 0.14 |
| FeO | 0.18 |
| $K_2O$ | 0.03 |

**Table 4:** Chemical Composition of Formamide

| Constituent | (%) |
|---|---|
| Assay | 99.95 |
| Ca | 0.041ppm |
| Cu | <0.001ppm |
| H.COOH | <0.02 |
| Fe | 0.016 ppm |
| Pb | 0.004 ppm |
| Mg | 0.003 ppm |
| K | 0.009 ppm |
| Na | 0.056 |
| P | 0.003 |
| Si | 0.042 ppm |
| S | <0.02 ppm |
| H2O | 0.02 |
| Zn | 0.004 ppm |

## 2.2. Sample preparation

In order to determine the effect of cement-sodium silicate grout with calcium chloride, aluminium chloride and/or formamide on fibrous peat, different quantities of calcium chloride and/or formamide and/or aluminium chloride were mixed with specific amounts of fibrous peat, sodium silicate, kaolinite, and cement. For preparing the samples, fibrous peat was first thoroughly homogenized at its natural water content by household mixer and then desired amount of kaolinite, cement, sodium silicate, calcium chloride and/or formamide and/or aluminium chloride were added to it. Six samples were prepared according to the percent weight of wet peat as depicted in Figure 2. The mix was transferred to PVC pipes and kept in distilled water for curing as shown in Figure 3. UCS tests were carried out on the samples at the end of 3 and 30 days of curing.


**Fig. 2:** Sample preparation

**Fig. 3:** Sample testing

**Table 5:** Different concentrations of compounds used for samples with notations

| Grout Formula (%) | Grout Formula (%) | Grout Formula (%) |
|---|---|---|
| 20K 20Ce 2.5Na 0Ca<br>20K 20Ce 2.5Na 0.1Ca | 20K 20Ce 2.5Na 0Al<br>20K 20Ce 2.5Na 0.25Al | 20K 20Ce 2.5Na 0F<br>20K 20Ce 2.5Na 0.25F |
| 20K 20Ce 2.5Na 0.25Ca | 20K 20Ce 2.5Na 0.5Al | 20K 20Ce 2.5Na 0.5F |
| 20K 20Ce 2.5Na 0.5Ca | 20K 20Ce 2.5Na 1Al | 20K 20Ce 2.5Na 1F |
| 20K 20Ce 2.5Na 1Ca | 20K 20Ce 2.5Na 2.5Al | 20K 20Ce 2.5Na 2.5F |
| 20K 20Ce 2.5Na 1.50Ca | | |
| 20K 20Ce 2.5Na 2.50Ca | | |

NB: K: Kaolinite; Ce: Cement; Na: Sodium Silicate; Ca: Calcium chloride; Al:Alominum chloride and F: Formamide

## 3. Results and discussion

The influence of different percentages of formamide, aluminium chloride and calcium chloride on UCS of peat has been investigated and the results are presented in Figure 4, 5, and 6.

### 3.1. Effect of Formamide on UCS of treated peat

The influence of formamide was studied by preparing different formamide concentrations (0, 0.25, 0.5, 1 and 2.5%) as per different grouts and performing UCS tests. The effect of formamide on the UCS of samples after 3 and 30 days of curing are presented in Figure 4. Firstly the shear strength of the samples after 3 days of curing was observed to increase with an increase in the percentage of formamide. Furthermore, with an increase in the curing time, the shear strength increased as well. The shear strength increased from 238 to 275 kPa and from 245 to 281 kPa, respectively, after 3 and 30 days of curing as shown in Figure 4. It's because of that Formamide act as a reactant to cause gelation. It neutralizes the alkalinity of sodium silicate.

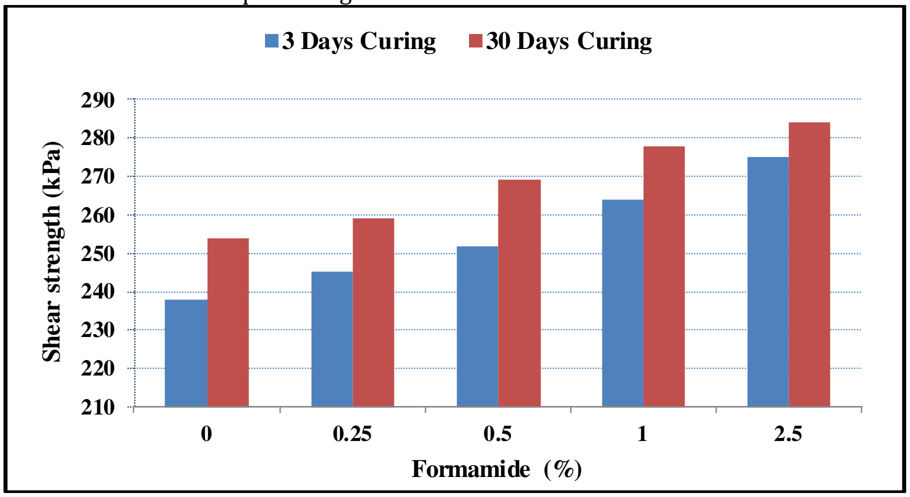


**Fig. 4:** Influence of Different Ratio of Formamide on the UCS of peat

### 3.2. Effect of Aluminium Chloride on UCS of treated peat

The influence of aluminium chloride was studied by preparing different aluminium chloride concentrations (0, 0.25, 0.5, 1 and 2.5%) by weight of wet peat while the amounts of other additives were kept constant and performing UCS tests. The effect of aluminium chloride on the UCS of samples after 3 and 30 days of curing are presented in Figure 5. Firstly the shear strength of the samples after 3 days of curing was observed to increase with an increase in aluminium chloride content. Furthermore, with an increase in the curing time, the shear strength increased as well.

The shear strength increased from 238 to 275 kPa and from 253 to 283 kPa, respectively, after 3 and 30 days of curing as shown in Fig. 5.

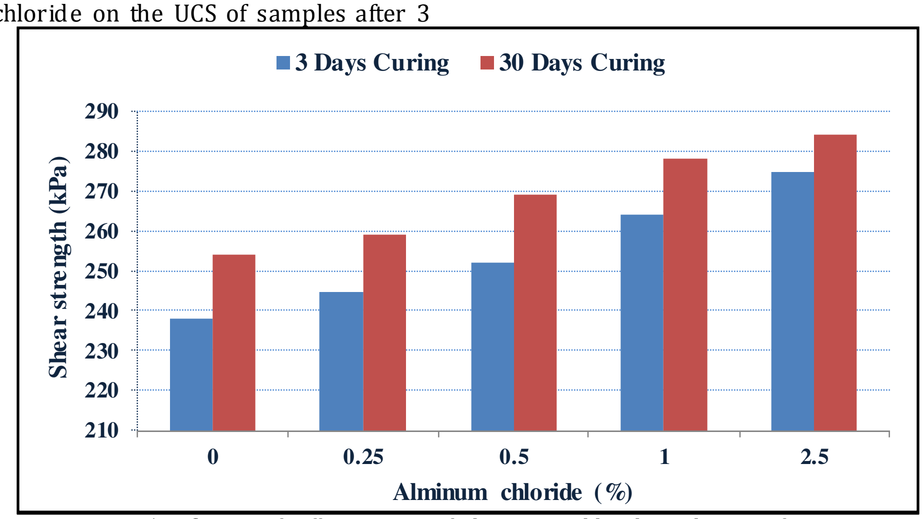


**Fig. 5:** Influence of Different Ratio of Aluminium Chloride on the UCS of peat

### 3.3. Effect of Calcium Chloride on UCS of treated peat

The influence of calcium chloride was studied by preparing different calcium chloride concentrations (0, 0.25, 0.5, 1, 2.5, 5 and 10%) as per different grouts and performing UCS tests. The effect of calcium chloride on the UCS of samples after 3 and 30 days of curing are presented in Figure 6. It's observed from Figure 6 that, by increasing calcium chloride concentration from 0 to 1% the unconfined compressive strength of samples increased from 210 to 260 kPa. Furthermore, by increasing calcium chloride up to 10% the trend of shear strength showed a reversal, i.e., the shear strength decreased from 260 to140 kPa. Similarly, the shear strength of the samples varied with an increase in curing time from 3 to 30 days.

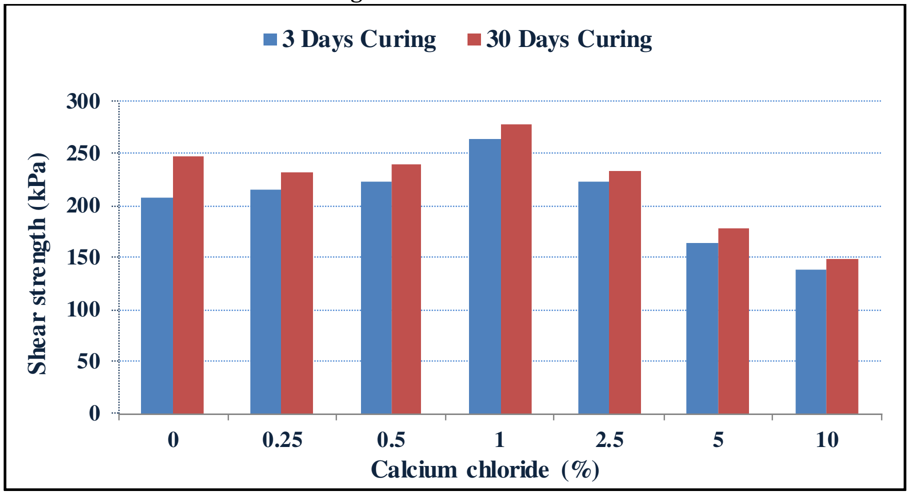


**Fig. 6:** Influence of Different Ratio of Calcium Chloride on the UCS of peat

This is because the colloidal particles can affect the rheological particles of the mixture. The calcium cations are absorbed by peat colloids due to their high CEC and the charge distribution in the fluid. By increasing the cation valence reduced the affinity of water to the organic soil surface and decrease water content due to (i) the mechanisms that increase the adsorption of organic compounds by the mineral fraction of organic soils and (ii) the changes in soil charges. At this condition, soil particles in peat water tend to the zero net charge and will not repel each other but tend to aggregate and form larger particles. This may be the reason for the increase in shear strength. Conversely, by adding extra calcium cation (more than 1%) the charge balance was affected giving a positive charge to peat and thereby leading to re-stabilization of the colloidal fraction and deflocculating of the larger particles.

## 4. Conclusions

This study was carried out to investigate the effects of the calcium chloride, formamide and aluminium chloride on UCS of treated peat. It was observed that, by increasing calcium chloride within 1% by the weight of wet peat, shear strength of peat increased, after that it was decreased due to an increased positive charge on the surface of particles, thereby leading to the re-stabilization of the particles and deflocculating of the large size particles. It was found that by increasing the formamide, UCS of treated peat increased. Similarly by increasing the concentration of aluminium chloride, UCS of treated peat increased. The effect of $AlCl_3$ as reactant on peat was more than other reactants in this study. It is because of higher capacity of aluminum in comparison with others.

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