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# Stabilization of organic soil using sodium silicate system grout

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**Cation binding by organic matter content (OMC) in soils has consequences for the behaviour of the organic compounds themselves, influencing adsorption, aggregation, and solubility, and thereby soil structure, translocation of organic matter within soils, and transport to waters. The study reported here involved a number of experiments using composition of alkaline earth metals grout to treat organic soils, in order to provide a better understanding of the engineering behaviour of this soil after stabilization. Besides, it provides a series of the laboratory mix design and testing which in turn provide an essential guide regarding the choice, dosage and economical amount of chemical binders. We carried out a series of batch test using composition of sodium silicate system binders to find their effects on physic-chemical properties of the organic soil. The results show that in the batch tests unconfined compressive strength (UCS), increases of up to 220% of the soil's baseline strength can be achieved by adding the 3 mol/L  $\text{Na}_2\text{SiO}_3$ , while UCS results enhanced to 270% having an activator  $\text{CaCl}_2$  and/or  $\text{Al}_2(\text{SO}_4)_3$  additives. Moreover, using higher molarities of  $\text{CaCl}_2$  (for example, 1mol/L) did not show any remarkable effect on the UCS results.**

**Key words:** Organic soil, soil improvement, cationic stabilizer, cementation, unconfined compressive strength, sodium silicate grout system.

## INTRODUCTION

Since engineering properties of organic soil are inferior to those of other soft soils, it is often viewed as problematic. Organic soil is generally associated with high magnitude and rates of creep and high compressibility. They may also be associated with a risk of large deformation and poor strength characteristics (Kalantari et al., 2011). That is why in recent years, concern about organic soil improvement and its difficulties from the geotechnical and geoenvironmental points of view have led to the generating of many new chemical grouts as well as

injection techniques. The improvement of organic soil is affected by a number of factors, namely, water content, chemical, physical, and mineralogical properties (Mitchell, 1993; Kalantari et al., 2010; Kazemian et al., 2011a, 2011c).

According to the American Standard for Testing and Material (ASTM), organic soil is a soil having organic matter content (OMC) of more than 25% (Huat, 2004). It is generally formed under anaerobic conditions through the action of fungi, bacteria, and chemical compounds on plant remains (Asadi et al., 2009; Moayedi et al., 2010, 2011a). Highly organic soils naturally have very high water content compared by mineral soils. However, in many countries of the world, including Malaysia, this material covers a substantial area and is called tropical land. In Malaysia, about 8% of the country's land area is covered with this type of soil (Edil, 2001; Huat, 2004; Asadi et al., 2009).

On the other hand, soil improvement refers to any method or techniques that improve the engineering

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**Abbreviations:** OMC, Organic matter content; UCS, unconfined compressive strength; ASTM, American Standard for Testing and Material; EDL, electrical double layer; DDL, diffuse double layer; CEC, cation exchange capacity; BS, British Standard Institution.

properties of soil, like compressibility, shear strength, stiffness and permeability. Raju (2009) classified the soil improvement methods to the following principles: (i) chemical modification (for example, jet grouting, deep soil mixing, injection grouting), (ii) consolidation (for example, vacuum consolidation, prefabricated vertical drains and surcharge, stone columns), (iii) reinforcement (for example, geosynthetic reinforcement, stone columns), and (iv) densification (for example, dynamic compaction, vibro-compaction, compaction grouting) (Raju, 2010).

Kruyt (1952), Adamson (1982) and Kwak et al. (1986) reported that solid-liquid or liquid-liquid interfaces can acquire an electrical charge through (i) the existence of an inherent excess charge in the dispersed phase, and (ii) preferential adsorption of ions at the interface (Kruyt, 1952; Adamson, 1982; Kwak et al., 1986). The development of a net electrical charge at the particle surface affects the distribution of ions in the surrounding interfacial region, resulting in an increased concentration of counter ions and ions of opposite charge to that of the particle close to the surface. Thus an electrical double layer (EDL) exists round each particle which is called diffuse double layer (DDL) (Bear, 1964; Hunter, 1993; Mitchell, 1993; Yu, 1997; Moayedi et al., 2011c).

The DDL occurs at the interface between the soil solution and the active surface. It is because of the negative charge of the active part of organic soil (clay and colloid parts) and the cations or counterions in the soil solution that balance the negative charge. The counter-ions are affected by two equal but opposing forces - the electrical force attracting the positive ion to the negative surface, and the diffusive or thermal forces (responsible for Brownian motion) which tend to move the cations away from the surface. The balance of these two forces gives rise to a distribution of cations in water adjacent to the active surface. As stated, this distribution, described as a DDL, is made up of the negative active surface and the spread-out (diffuse) distribution of the counter-ions (Sparks, 1986; Yu, 1997; Mitchell and Soga, 2005; Ou et al., 2009).

The DDL, cation exchange capacity (CEC) and the charge distribution in the fluid adjacent to soil surface play key roles in determining the flow (Acar, 1993; Asadi et al., 2009; Moayedi et al., 2011b). An important characteristic of organic soil is their high CEC, which is defined as the degree to which a soil can absorb and exchange cations or the quantity of negative charges in soil existing on the surfaces of both clay (for example, kaolinite fraction of the organic soil), and organic matter (for example, humus substances). CEC is highly dependent upon organic content and soil texture. The CEC range of soils with a low fibrous content is more than the CEC range of soils with a high fibrous content (Hunter, 1981; Sparks, 1986; Kaya and Yukselen, 2005; Asadi et al., 2009, 2010; Moayedi et al., 2011d, 2011e). It is reported as milli-equivalents per 100 g of solid (meq/100 g).

Axelsson et al. (2002) observed an increase in the Unconfined Compression Strength (UCS) of fibrous peat soil specimen from below 40 to 660 kPa when mixed with 250 kg/m<sup>3</sup> of cement after 28 days of curing with an 18 kPa surcharge load (Axelsson et al., 2002). Kuno et al. (1989) presented results of tests conducted on 35 soft soils from Japan. The humic acid content remarkably affects the soil improvement effect produced by the binder mixed with the soil (Kuno et al., 1989). Hebib and Farrell (2003) observed that the 28 days UCS results of fibrous peat soil specimens, stabilized with various cement, fly ash, and lime contents, increased from 20 to 670 kPa (Hebib and Farrell, 2003).

Cation-humic interactions exert control on the reactivity of the cation, including its bioavailability. But this is a two-way process, since cation binding influences the physico-chemical state of the humic matter, and thereby its interactions with other components of the environmental system. Therefore it is important to describe how cations influence humic substances (Tipping, 2002). The main objective of present research is to optimizing compounds of sodium silicate system grout in order stabilize organic soil to provide a better understanding of the engineering behaviour of treated organic soil with sodium silicate mixed with two different activators.

## MATERIALS AND METHODS

### Materials

Organic soil samples were collected and sealed to maintain soil moisture in accordance with the British Standard Institution (BS) methods of test for soils (BS 1377-1:1990) from several locations of Kg. Jawa Klang, Selangor, Malaysia (Keynes, 1990). The soil samples were prepared according to BS 1377-1 (1990) to evaluate the soil properties such as organic content (BS 1377-3: 1990), liquid limit (BS 1377-2 1990), water content (BS 1377-2-3: 1990), specific gravity (BS 1377-2-8.4: 1990), pH (BS 1377-3-9:1990), and CEC. Mineralogical analysis of the soils showed the presence of kaolinite as a main clay fraction in organic soil. The physico-chemical properties of baseline soil are presented in Table 1.

### Design of binders

In choosing binders, there are technical as well as economic aspects and to an increasing degree, also environmental aspects to consider, which will affect the final choice of binder. However, the effect of the different binders can vary considerably, depending on the type of soil. The binders can be expected to act somewhat differently depending on the type of binder reactions that take place in the soil. Processes such as ion exchange, cement reactions and pozzolanic reactions proceed to varying extents and at different rates depending on the type of binder used (Kazemian et al., 2010, 2011b; Moayedi et al., 2011a). These processes are also affected by the chemical constituents of the soil and by the temperature (Mitchell, 1993). It should also be noted that the different binders often interact, yielding somewhat higher strengths with mixed binders than the expected strengths from interpolating between the corresponding measured strengths using the separate binder ingredients respectively (Larsson, 2001; Lindh, 2001; Åhnberg et

**Table 1.** Physico-chemical properties of organic soil.

Parameter	Standard followed	Value
Moisture content/ %	BS 1377-2-3 (1990)	158
Bulk density/ kN/m <sup>3</sup>	BS 1377-2-7 (1990)	9.72–10.05
Specific gravity	BS 1377-2-8.4 (1990)	1.13
Organic content/ %	BS 1377-3-4 (1990)	57
Hydraulic conductivity: m/s	BS 1377-6-4 (1990)	3.35×10 <sup>-6</sup>
Fiber content/ %	ASTM-1997-91	41.94
CEC	Gillman and Sumpter	54
pH	BS 1377-3-9 (1990)	5.63

**Table 2.** Chemical composition of calcium chloride and aluminum sulfate.

Constituent	Calcium chloride	Aluminum sulfate
Chemical formula	CaCl <sub>2</sub>	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> * 18H <sub>2</sub> O
Molar mass (g/mol)	110.98	666.42
pH value (20 g/l, H <sub>2</sub> O, 20 °C)	8 - 10	2.5 - 4.0
Assay (complexometric)	≥ 90 %	51.0 - 59.0 %
SiO <sub>4</sub>	0.02	--
Ca(OH) <sub>2</sub>	0.04	--
Mg <sup>2+</sup>	0.6	--
Alkalis (sulfate)	0.6	--

al., 2003; Kazemian et al., 2011a; Moayedi et al., 2011d).

### Sodium silicate

Sodium silicate grouts are the most popular grouts because of their environmental compatibility and safety (Larsson, 2001; Lindh, 2001). They are developed into a variety of different grout systems. Generally the grout systems are based on reacting a silicate solution to form a colloid which polymerizes further to form a gel that binds soil or sediment particles together and fills voids. Besides, sodium silicate is a white powder or colorless solution that is readily soluble in water, producing an alkaline solution (Moayedi et al., 2011b). It has also been considered for use as a peptising agent to improve the mixability of the soil in situ and in this way increase the homogeneity and strength of stabilized soils. The sodium silicate should be mixed with the soil before the binder is added. It is important that this admixture in itself does not have a negative effect on the hydration processes. Sodium silicate is sometimes used in applications where a reduction in the bulk density is desired, and may thereby have a certain negative effect on strength. Different investigations have shown that sodium silicates can increase the strength and durability of sandy and silty soils, but they only increase the short-term strength of clays stabilized with cement, lime or lime-fly ash (Hurley and Thornburn, 1972; Larsson, 2001; Lindh, 2001; Åhnberg et al., 2003; Jegandan et al., 2010). The sodium silicate proved to have only a small, though mostly negative, effect on the cement–lime stabilized soils. Sodium silicate is often used in alkali activated slag cements to obtain rapid hardening and high strength properties in concrete (Lindh, 2001; Åhnberg et al., 2003; Kazemian et al., 2011b; Moayedi et al., 2011d). Hydrous sodium silicate, a syrupy

liquid, was used as the second binding agent. It consisted of SiO<sub>2</sub>. Sodium silicate was also obtained from Merck Sdn. Bhd., Malaysia. (28.7%), Na<sub>2</sub>O (8.9%) and the silica ratio (SiO<sub>2</sub>/Na<sub>2</sub>O) was 3.22. As reported by the manufacture, the density of sodium silicate was 1.38 Mg/m<sup>3</sup> and pH was 11.3.

### Calcium chloride and aluminum sulfate

Calcium chloride anhydrous powder (CaCl<sub>2</sub>) was used as one of the reactors/accelerators, with a minimum assay content equal to 96%. The maximum impurities were free alkalinity [Ca(OH)<sub>2</sub>] 0.04%, sulphate (SO<sub>4</sub>) 0.02%, magnesium and alkalis (sulphate) 0.6%. On the other hand, aluminium sulfate is commonly used in water purification and as a mordant in dyeing and printing textiles. In water purification, it causes impurities to coagulate which are removed as the particulate settles to the bottom of the container or more easily filtered. This process is called coagulation or flocculation. Calcium chloride and aluminum sulfate were also obtained from Merck Sdn. Bhd., Malaysia. Chemical composition of calcium chloride and aluminum sulfate are presented in Table 2.

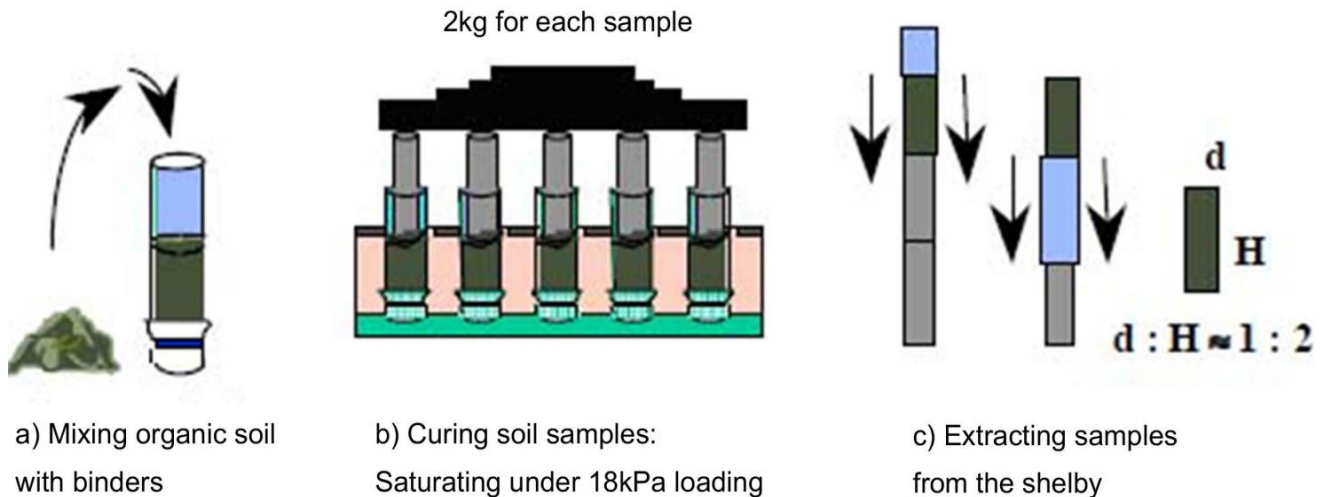
### Binder formula

These systems consist of sodium silicate and reactor/accelerator (such as aluminium sulfate and calcium chloride) which can be compatible with cement to get strong bonding properties in two-compound system. Sodium silicate and the reactant solution can be injected separately in two steps. Two-compound system has been used in grouting below a water table and produces a high-strength, permanent grout if not allowed to dry out (Kazemian et al., 2011c).

**Table 1.** Different concentrations of sodium silicate compounds used for samples and grout formulate with notations.

Grout code	Grout formula (%)	Grout code	Grout formula (%)	Grout code	Grout formula (%)
N1-A0-C0	1.0N- 0Ca- 0 Al	N3-A0-C0	3.0Na- 0Ca- 0 Al	N5-A0-C0	5.0Na- 0Ca- 0 Al
N1-A0.1-C0	1.0Na- 0Ca- 0.1 Al	N3-A0.1-C0	3.0Na- 0Ca- 0.1 Al	N5-A0.1-C0	5.0Na- 0Ca- 0.1 Al
N1-A0-C0.1	1.0Na- 0.1Ca- 0 Al	N3-A0-C0.1	3.0Na- 0.1Ca- 0 Al	N5-A0-C0.1	5.0Na- 0.1Ca- 0 Al
N1-A0.1-C0.1	1.0Na- 0.1Ca- 0.1 Al	N3-A0.1-C0.1	3.0Na- 0.1Ca- 0.1 Al	N5-A0.1-C0.1	5.0Na- 0.1Ca- 0.1 Al
N1-A0-C1	1.0Na- 1.0Ca- 0 Al	N3-A0-C1	3.0Na- 1.0Ca- 0 Al	N5-A0-C1	5.0Na- 1.0Ca- 0 Al
N1-A0.1-C1	1.0Na- 1.0Ca- 0.1 Al	N3-A0.1-C1	3.0Na- 1.0Ca- 0.1 Al	N5-A0.1-C1	5.0Na- 1.0Ca- 0.1 Al

N: Sodium silicate, A: aluminum sulfate and C: Calcium chloride.

**Figure 1.** Curing the organic soil samples.

The ratios which are commonly used for sodium silicate grout system for soils have been reported by CIRIA (CIRIA., 2000; Soil, 2009). Binder formulas with their notations are provided in Table 3.

## METHOD

A laboratory experimental program was conducted to assess the method's effectiveness in improving soil shear strength. The baseline soil was mixed in batches with stabilizer reagents in various dosages and solutions to assess their impacts on shear strength, and pH of the mix. In addition, the unconfined compression tests were performed in order to study differences in strength level and rate of strength increase between different types of binder, rather than to find the optimal binder composition for the three soils. The optimal binder composition found for one soil would not be directly applicable to another soil as it varies considerably with the soil type.

### Sample preparation for UCS test

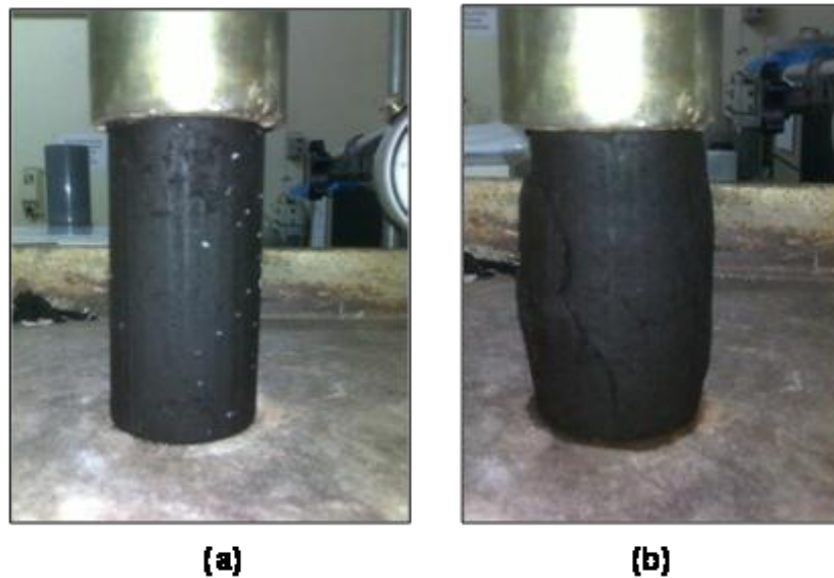
The organic soil was screened in order to eliminate the larger size of vegetable fibers using a 6.3 mm sieve. For preparing the samples, organic soil was first thoroughly homogenized (for example, to reduce the differences in soil sample properties) at its natural water content by household mixer and then desired amount of designed stabilizers were added to it. The samples were then compacted and stored in plastic tubes with an inside diameter of 38

and 76 mm height. The treated soil were placed into the plastic tube within the three layers. Each layer was given 10 constant full thumb pressures of about 10s to compact the treated samples (Axelsson et al., 2002). The unit weight were almost considered constant about 11.5 to 12.3 kN/m<sup>3</sup> for whole specimens. The mixing procedure and curing system used in this study project was that adopted in the EuroSoilStab project. The Design Guide: Soft Soil Stabilization, which was prepared as part of the EuroSoilStab Project, describes the different methods of stabilizing soft organic soils, the design approaches that are normally adopted, the tests methods to determine the appropriate binder, and the site equipment and installation procedure to be used (EuroSoilStab, 2002).

According to Eurosoilstab (2002), vertical load of 18 kPa (represents about 1 m of fill normally laid out on top of stabilized columns in the field) were applied during curing time on. The test procedure is described as following (See also Figure 1): (a). A textile was taped over the bottom of the plastic tube to permit the soil specimen to take up water during curing time; (b). The organic soil was blended with binders to form a homogeneous mass and then compacted into the plastic tubes by hand. In order to to subject a dispersed pressure of 18 kPa a total load of 2 kg was required for each sample (Figure 1b). The specimens were then placed in a unique design sample box which consist of a plastic tray positioned in order to store specimens vertically. The tray was then filled with water up to 5 cm to simulate the insitu condition; (c) After 14 days at room temperature the specimens were extracted from the plastic tubes and the UCS tests performed (Figure 1c).



**Figure 2.** Curing soil samples (a) before saturation, (b) After saturation and under 18 kPa loading.



**Figure 3.** Samples under UCS test, (a) Before loading (b) After loading.

The samples were 76 mm long and 38 mm in diameter. They were cured for 14 days (Figure 2). As stated, the effectiveness of the treatment was evaluated by measuring the shear strength by performing UCS test (BS 1377: Part 7: 1990, Clause 7) after curing for 14 days (Figure 3).

## RESULTS

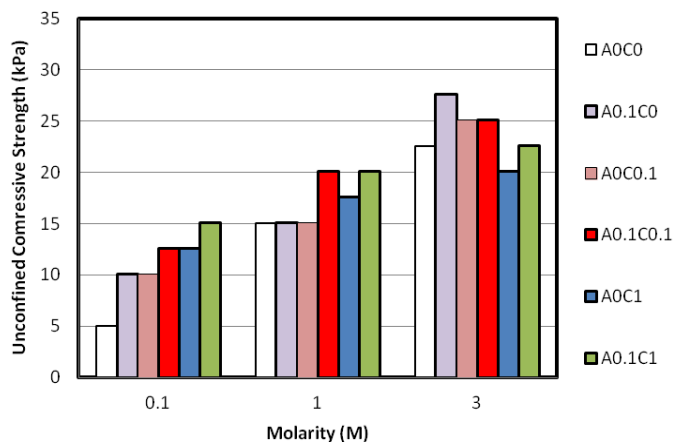
As a rule, the strength of a soil stabilized with a specific binder increases with decreasing water content. However, there is no unique correlation between the water content and strength of stabilized soils, as this varies with the soil as well as with the type of binder used. Just as in natural soils, the behaviour of the stabilized soil is affected not only by its water content but also by its liquidity or consistency index. The water content after stabilization can be calculated from the

quantity of binder used, but the liquid limit and plasticity limit will change to varying degrees depending on the effect of the binder. The plasticity limit normally increases after stabilization (Larsson, 2001; Lindh, 2001; Åhnberg et al., 2003; Jegandan et al., 2010; Kazemian et al., 2011a, 2011b; Moayedi et al., 2011d).

The influence of sodium silicate system grout on organic soil has been investigated and the results, for more clarification, in terms of the ratio of undrained shear strength of samples cured in 14 days time, are presented.

### Effect of sodium silicate system on organic soil strength

As stated, the 14 days undrained shear strength of treated organic soil samples were recorded from UCS



**Figure 4.** The 14 days UCS results for treated organic soil with sodium silicate system grouts, (N: Sodium silicate, A: aluminum sulfate and C: Calcium chloride).

test. Sodium silicate increased the UCS values of the soils due to injecting silicate minerals. The more sodium silicate used, the higher UCS results observed. Within the same usage of  $\text{Al}_2(\text{SO}_4)_3$  (for example, 0.1 M) and  $\text{Na}_2\text{SiO}_3$  (for example, 3.0 M) the UCS value for 0.1 mol/L of  $\text{CaCl}_2$  at 0.1, 1, were equal to 12.06, 20.09, and 25.1 kPa, respectively (Figure 4).

#### Effect of $\text{CaCl}_2$ and $\text{Al}_2(\text{SO}_4)_3$ on organic soil strength

Comparing the different usage of  $\text{CaCl}_2$  additives, there is no significant difference in the UCS results of treated organic soil when admixed with more than 0.1 mol/L. It means using 0.1 mol/L  $\text{CaCl}_2$  presented tangible effects on the UCS results like 1.0 mol/L  $\text{CaCl}_2$  (Figure 5). On the other hand, with the same  $\text{CaCl}_2$  admixture, the higher UCS results observed for treated organic soil when 0.1 mol/L  $\text{Al}_2(\text{SO}_4)_3$  solution used rather than without  $\text{Al}_2(\text{SO}_4)_3$ . Having 0.1 mol/L  $\text{Al}_2(\text{SO}_4)_3$  the UCS values for 1.0 mol/L of  $\text{CaCl}_2$  at 0.1, 1, and 3 mol/L  $\text{Na}_2\text{SiO}_3$  were equal to 15.07, 20.09, and 22.6 kPa, respectively (Figure 5).

In the absence of  $\text{Al}_2(\text{SO}_4)_3$ , the UCS value for 1.0 mol/L of  $\text{Na}_2\text{SiO}_3$  at 0, 0.1, and 1 mol/L  $\text{CaCl}_2$  were equal to 30.14, 30.14, and 35.16 kPa, respectively (Figure 6). However having 0.1 mol/L of  $\text{Al}_2(\text{SO}_4)_3$ , the UCS for same molarities of  $\text{Na}_2\text{SiO}_3$  at 0, 0.1, and 1 mol/L  $\text{CaCl}_2$  were 15.07, 20.09, and 20.09, respectively, which means using  $\text{Al}_2(\text{SO}_4)_3$  increase 25% the unconfined compression results (Figure 6).

#### DISCUSSION

Knowledge of cation-humic interactions is a key requirement for the understanding and prediction of transport, retention and bioavailability of solutes and

other components in natural systems. The chemical knowledge has to be combined with knowledge about biological and physical processes to describe dynamic aspects.

As mentioned earlier,  $\text{Na}_2\text{SiO}_3$  is basic and will be precipitated as a gel by neutralization. Thus, a dilute  $\text{Na}_2\text{SiO}_3$  solution mixed with certain acids or acid salts will form a gel after a time interval, related to the chemical concentrations. Yonekura and Kaga (1996) and Karol (2003) have also reported that if alkaline solution with sodium silicate ( $\text{Na}_2\text{SiO}_3$  solution are alkaline) concentration above 1 or 2 percent by volume is neutralized by reactants (calcium chloride and/or aluminum sulfate), colloidal silica will aggregate to form a gel (Yonekura et al., 1996; KAROL, 2003). In addition, the increase in pH certainly accelerates the formation of cementitious compounds. It is known that alkali silicates and aluminates which are formed at high pHs react with calcium which leads to the formation of mixed calcium sodium silicate.

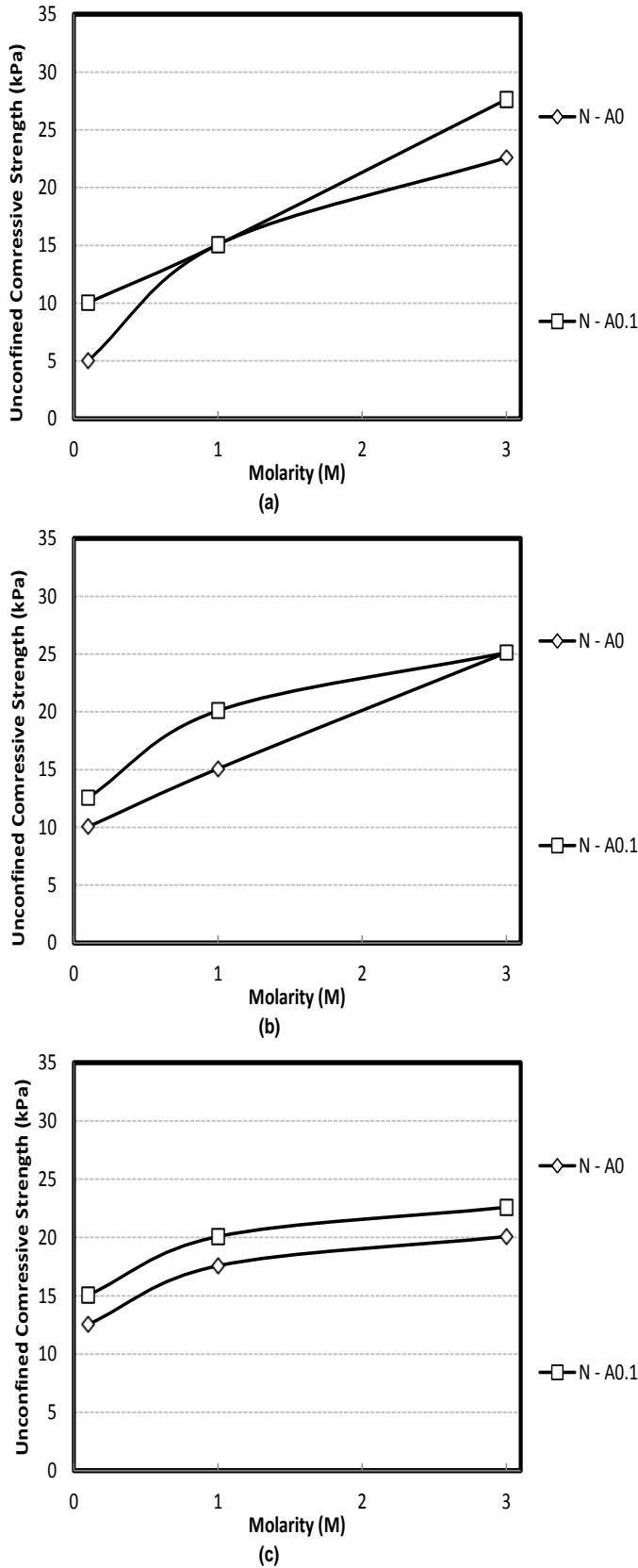
The strength changes that resulted from acid addition can be explained by considering the physico-chemical changes and mineralogical composition of organic soil. The primary mineral component of used soil was kaolinite. Kaolinite [ $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ ] structure is composed of silicate sheets ( $\text{Si}_2\text{O}_5$ ) bonded to aluminum oxidelhydroxide layers [ $\text{Al}_2(\text{OH})_4$ ] called gibbsite layers. It consisted predominantly of  $\text{SiO}_2$  (45.8%) and  $\text{Al}_2\text{O}_3$  (39.55%). Stevenson (1994) reported that humic substance (for example, organic parts of the soil) connect with mineral fraction in the following ways: (i) salt of humic substance with alkaline cations, (ii) action of acids on minerals or salts of minerals, (iii) as substances held on clay mineral surfaces (van der Waals force, bonding by cation bridge, and H-bonding), and (iv) chelate with metal ions (Stevenson, 1994; Yu, 1997; Mitchell and Soga, 2005; Kazemian et al., 2011c).

#### Conclusions

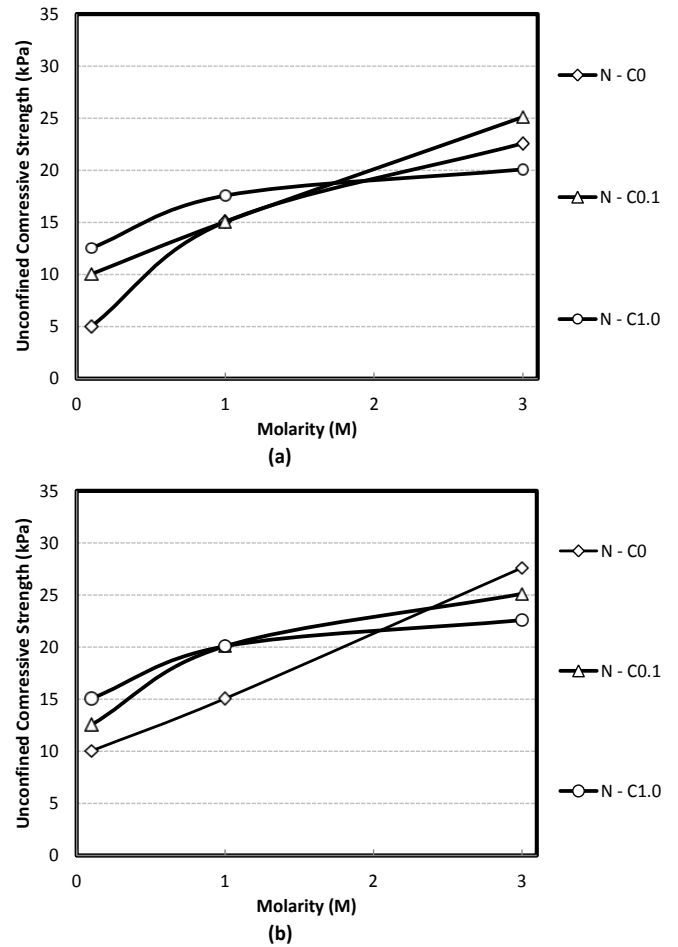
The strength changes that resulted from chemical stabilizer addition can be explained by considering the physicochemical changes and mineralogical composition within the organic soil. Based on the results of this research, the following conclusions may be drawn:

i) The results show that UCS results increases up to 270% comparing with the UCS of the untreated organic soil samples. Such improvement in the UCS was achieved by having 3 mol/L  $\text{Na}_2\text{SiO}_3$  as main stabilizer as well as a 0.1 mol/L activator/reactor (for example,  $\text{CaCl}_2$  and/or  $\text{Al}_2(\text{SiO}_4)_3$ ).

ii) Adding  $\text{CaCl}_2$  at 0, 0.1, and 1 mol/L as well as  $\text{Al}_2(\text{SO}_4)_3$  at 0, 0.1 mol/L were mixed as secondary additive with  $\text{Na}_2\text{SiO}_3$  at 0.1, 1, and 3 mol/L as main stabilizer for stabilizing organic soil. Although, higher



**Figure 5.** Effect of electrolyte concentration on undrained shear strength of organic soil, (a) Without CaCl<sub>2</sub>, (b) 0.1 mol/L CaCl<sub>2</sub>, and (c) 1.0 mol/L CaCl<sub>2</sub>.



**Figure 6.** Effect of sodium silicate and calcium chloride on the UCS of organic soil (a) Without Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> (b) With Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>.

molarities for Na<sub>2</sub>SiO<sub>3</sub> as binders led to higher UCS values, using Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> improved considerably the UCS even at lower Na<sub>2</sub>SiO<sub>3</sub> concentrations. This could be due to better interaction between particles breakage in organic soil and Na<sub>2</sub>SiO<sub>3</sub> in presence of Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>. In addition, using higher molarities of CaCl<sub>2</sub> (for example, 1 mol/L) did not show any remarkable effect on the UCS results.

iii) The results can be used for guidance in choosing the type of binder for stabilisation of an organic soil. Their display of ranges of stabilizing effects can be considered as more important than the measured absolute strength levels. It should be noted that the strength achieved by a certain binder will vary with the type of soil, and will also depend on how the soil–binder complex is handled: that is mixed, compressed, heated and drained/saturated.

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