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PEAT SOIL STABILIZATION IN RAWA PENING SALATIGA CENTRAL JAVA USING SYNTHETIC GYPSUM AND SALT

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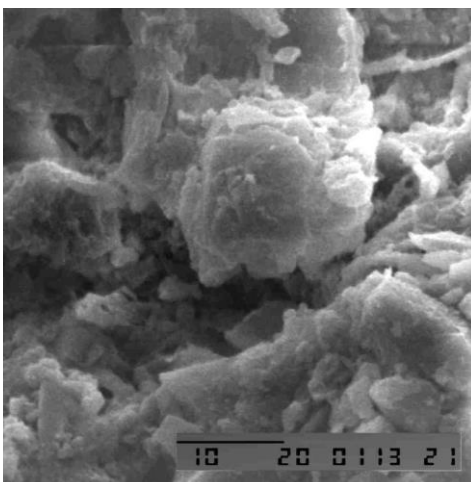
Graphical abstract



Abstract

Peat is known as a problematic soil due to its low bearing capacity as well as its high and long settlement process. Necessary treatment is needed to improve peat soil capability. One of the methods to improve peat soil characteristics is by adding mixed materials. In this study the added materials are synthetic gypsum (CaSO4.2H20) and salt (NaCl). The research was conducted in a Soil Mechanics Laboratory using a consolidation test and direct shear tests. This research aims to find out the effect of CaSO4.2H20 and NaCl on consolidation and shear strength parameters. The soil samples taken for consolidation and direct shear tests were original and treated peat soil. The gypsum synthesis doses varied between 10%, 15%, and 20%, whereas the salt varied between 2%, 4%, and 6%, calculated from the dry weight of peat soil. The mixing of soil and the added materials was carried out under optimum water conditions of Standard Proctor compaction results. After the consolidation and direct shear tests were completed, the Scanning Electron Microscope (SEM) test was performed on the soil samples to determine the components of the peat soil on micron size. The addition of synthetic gypsum and salt resulted in the smallest Cc value of 0.0302 at 4% salt + 20% gypsum and the highest Cv value of 0.130 cm^2/s at 6% salt + 20% gypsum. The addition of synthetic gypsum and salt mixture resulted in the highest cohesion, c value of 61,55 kPa at 6% salt + 15% gypsum and the greatest friction angle, ϕ value of 52.24° at 4% salt + 20% gypsum. NaCl gave better results than Gypsum in improving shear strength. A composition of 4%-6% of NaCl and 15%-20% of Gypsum is recommended, if NaCl and gypsum were to be applied simultaneously to improve shear strength.

Keywords: Peat, synthetic gypsum, salt, consolidation test, direct shear test, SEM

1.0 INTRODUCTION

Peat soil is considered as one of problematic soil types. Peat soil is the result of weathering organic materials with high organic contents. The characteristics of peat soils are a high compressibility, because peat soils have high water content and soil permeability, and ongoing decomposition process, due to microbiological bacteria activities. Another unfavorable characteristic of peat soils is low shear strength. The shear strength of peat soil depends on several factors including moisture content, decomposition rate, and mineral content. The higher the moisture content and the decomposition rate, the lower the shear strength [7, 18].

Effort to improve peat soil is by adding mixed materials that can react with peat soil. Some of the added ingredients include: silica [3], Portland Cement [5, 15], gypsum and fly ash [8], hydrated lime [10], [14], tire chips [11], and gypsum and PC [13].

One of the areas with peat soil on Java Island is Rawa Pening, a swamp located in Salatiga, Central Java. A previous study of peat soils conducted in Rawa Pening used a mixture of synthetic gypsum with sugar resulting in the doubling of CBR value and decreasing the swelling value to eight times the original value [17]. Another study of Rawa Pening's peat soil stabilization used rice husk ash and synthetic gypsum which decreased the swelling value by ten times the original value and increased the CBR value two times [19]. Another study related to the stabilization of Rawa Pening's peat soils used portland cement and synthetic gypsum which increased the CBR value two-fold [12].

Based on these studies, further research was conducted on Rawa Pening's peat soils using synthetic gypsum and salt as added materials. Consolidation and direct shear tests were conducted. The reason for choosing salt as the added material, among others, was because salt can increase the cohesion force between soil particles and lead to an increase in bonds of particles; salt is also useful in soil compaction work. Salt has the same properties as other stabilizing agents using other chemicals and the benefits derived from the use of salt (NaCl) is to increase density and soil strength. Soils with high *LL* (Liquid Limits) usually give a good reaction with salt addition.

2.0 METHODOLOGY

2.1 Sample Preparation

The test specimens consisted of a variety of mixtures of peat soils and synthetic gypsum, peat soils and NaCl, and a mixture of peat soils, synthetic gypsum, and NaCl. The amount of the materials (synthetic gypsum and NaCl) added to peat soils was equal to the dry weight of the peat soils. The mixing method for making these specimens was by adding the materials using optimum water content based on the Standard Proctor test. A variety of soil sample mixtures are presented in Table 1. A sample soil stabilized with additive materials is shown in Figure 1.

Figure 1 Peat soil mixed with additive materials

All tests performed in the Soil Mechanics Laboratory used the following standards: Water Content Test (ASTM D 2216-92), Ash and Organic Matter Content Test (ASTM D 2974-87), Specific Gravity Test (ASTM D 854-91), Density Test (ASTM D 4253-91), Grain Size Analysis Test (ASTM D 422-63), Consolidation Test (ASTM D 2435–90), and Direct Shear Test (ASTM D 3080-90). Whereas, Photo Testing with Scanning Electron Microscope (SEM) was done at the Borobudur Conservation Center located in Borobudur, Magelang city.

Table 1 List of soil sample mixtures

I. Untreated peat soils (no mixture)
II. Peat soils + synthetic gypsum (10%, 15%, 20%)
III. Peat soils + NaCl (2%, 4%, 6%)
IV. Peat soils + 2% Salt + Gypsum (10%, 15%, 20%)
V. Peat soils + 4% Salt + Gypsum (10%, 15%, 20%)
VI. Peat soils + 6% Salt + Gypsum (10%, 15%, 20%)

In this study experimental laboratory were conducted on peat soil with partial replacement by salt and gypsum based on each dose. Salt and gypsum were added in different proportions (see Table 1) to peat soil by dry weight of natural soil.

2.2 Specimen Preparation for Consolidation

The specimens for the consolidation test were the compaction results based on the optimum water content in the Standard Proctor of soil mixtures. The test used a one-armed consolidation tool and was administered at the Soil Mechanics Laboratory of the Faculty of Engineering, Sebelas Maret University, Surakarta Indonesia.

2.3 Specimen Preparation for Direct Shear

The direct shear test was conducted by compressing the soil and then lubricating the tool with oil and moulding the soil samples by pressing the mould on the pure soil. The mould had a diameter of 6 cm and t = 1.85 cm. Both edges of the mould (top and bottom) were flattened with a knife and then the soil samples were taken out from the mould. The shear box was then removed from the direct shear apparatus and the bottom of the tube was cleaned and lubricated to create a slippery base so that there was no friction between the soil sample and the box. The soil samples were inserted into place in the direct shear apparatus, after being coated with a stone slab and pore paper for drainage. Then the equipment and tools for direct shear test were prepared.

3.0 RESULTS AND DISCUSSION

Table 2 presents the property index testing results of the soil samples. Based on water content, ash content, and organic matter content, the tested soil samples can be classified as peat soils.

Table 2 The results of Property Index of Rawa Pening peat soils

No.	Descriptions	Results
1	Water content (*w*), (%)	279.70
2	Ash content (*a*), (%)	28.38
3	Organic matter content (*o*) (%)	71.62
4	Fiber content (*FC*), (%)	39.27
5	Specific gravity (G_s)	1.67
6	Maximum Dry Weight ($\gamma_{d\ maks}$), (kN/m^3)	0.47
7	Bulk Density (γ_b), (kN/m^3)	0.98
8	Optimum water content (w_{opt}), (%)	118

The general behaviour of peat soils added with gypsum and salt are shown in Figures 2 to 7.

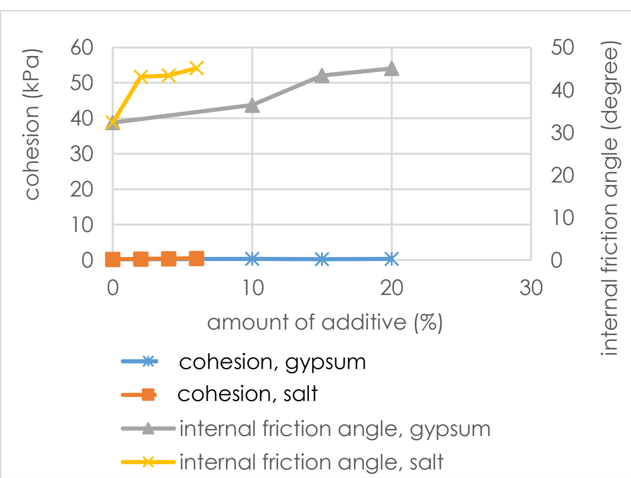


Figure 2 The effect of gypsum and salt additions on cohesion and internal angle friction (gypsum and salt materials were added to peat soils separately)

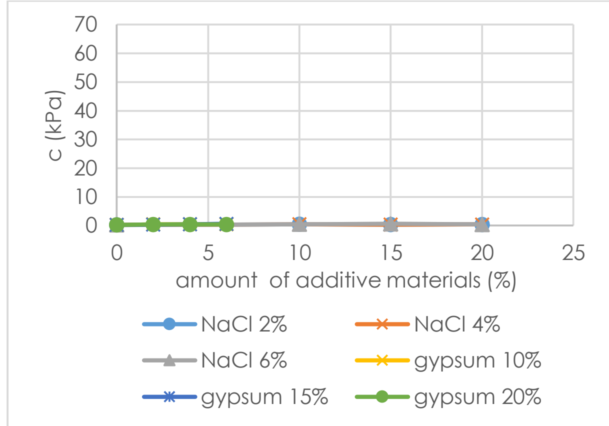


Figure 3 The effect of gypsum and salt additions on cohesion (c) (gypsum and salt materials were added to peat soils simultaneously)

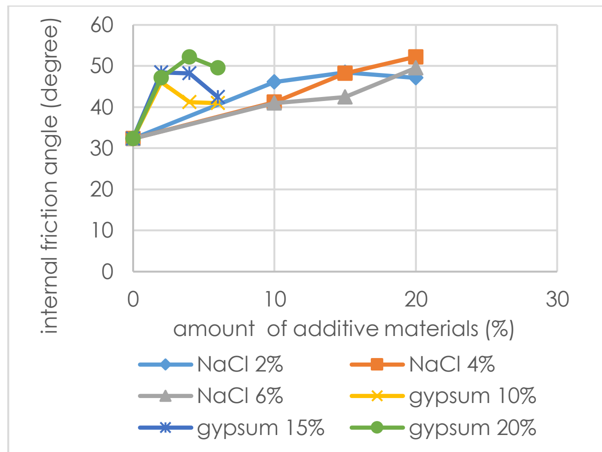


Figure 4 The effect of gypsum and salt additions on friction angle in (ϕ) (gypsum and salt materials were added to peat soils simultaneously)

Figures 2 to 4 show the changes in technical properties of peat soils in terms of shear strength parameters c and ϕ. When mixing was administered separately, salt had a larger increase compared to gypsum. Optimum composition of the added materials was not discovered when gypsum and salt were added separately. However, when gypsum and salt were added simultaneously to peat soils, the highest values achieved for shear strength parameters c, ϕ, and unconfined soil strength (q_u) were obtained with gypsum and salt compositions as follows: (15%: 6%); (20%: 4%); and (20%: 4%). In other words, the gypsum composition was about 15-20% and the salt composition was about 4-6% for the best results in this study.

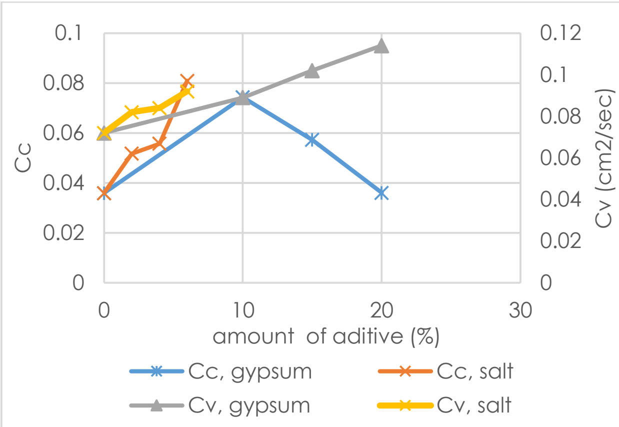


Figure 5 The effect of gypsum and salt additions on Cc and Cv (gypsum and salt materials were added to peat soils separately)

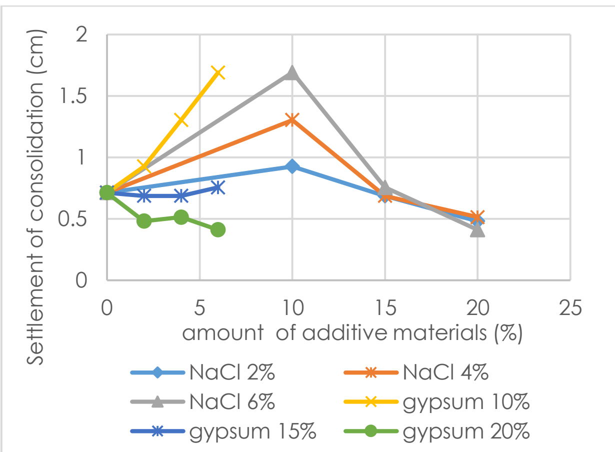


Figure 6 The effect of gypsum and salt additions on consolidation settlement (gypsum and salt materials were added to peat soils simultaneously)

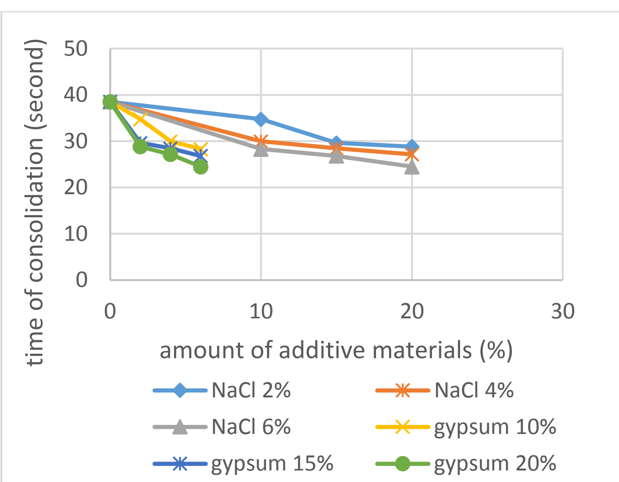


Figure 7 The effect of gypsum and salt additions on consolidation decrease stage (gypsum and salt materials were added to peat soils simultaneously)

Figures 5 to 7 show the changes in technical properties of peat soils in terms of consolidation settlement parameters C_c and C_v. The amount of salt needed increased by more than 10% in order to know the behaviour of peat soil after being mixed with salt, to compare with gypsum material. From Figures 6 and 7, it can be seen that the trends of changing settlemet of consolidation and time of consolidation were unstable. The addition of NaCl heightened the consolidation decline, whereas the addition of gypsum reduced the consolidation decline. Addition of NaCl and gypsum reduced the consolidation decline duration. This means that the process of consolidation will take longer. One of the purposes in soil stabilization is to increase consolidation settlement proccess, so using NaCl and gypsum is not good for peat soil in the case of settlement consolidation. In general, the simultaneous addition of gypsum and NaCl increased the consolidation decline. All additions of material reduced the time required for the decline. The decline in peat soils is a complex event because the main constituents of peat material are organic materials that continue to decompose.

Figures 8 to 11 show the results of the Scanning Electron Microscope (SEM) test. SEM testing was performed to examine the microscopic structure of the soil samples.

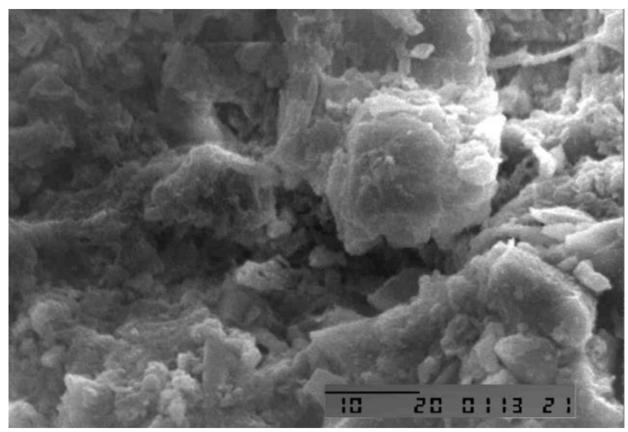


Figure 8 SEM test results of untreated soil sample magnified 2000 times

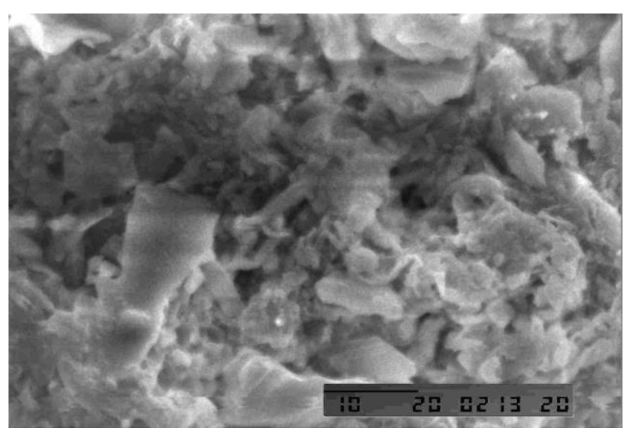


Figure 9 SEM test results of peat soil samples mixed with 6% salt magnified 2000 times

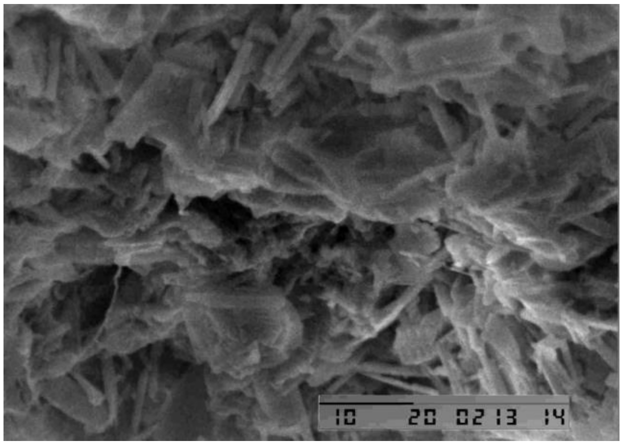


Figure 10 SEM test results of peat soil samples mixed with 20% gypsum magnified 2000 times

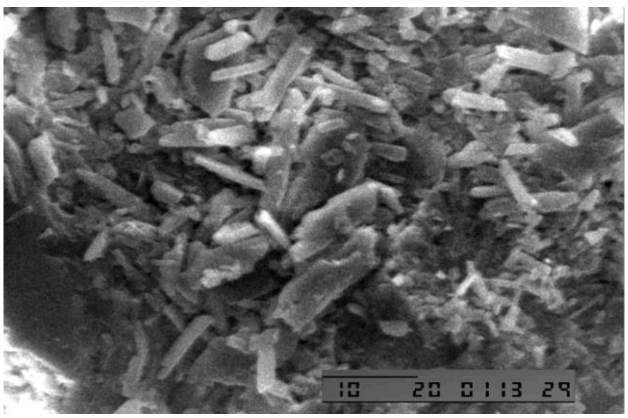


Figure 11 SEM test results of peat soil samples mixed with 20% gypsum and 6% salt magnified 2000 times

The SEM test results of pure peat soils in a compacted condition magnified 2000 times is shown in Figure 8. Based on the microscopic picture of the peat soil structure, it can be seen that the size of the ground grain consisted of small to large grains; and the grain shape was not uniform, i.e., round and pointed. The round shape is the ground grain and the pointed one is the fibre contained in the peat soils.

The SEM test results of peat soils added with 6% salt in a compacted condition magnified 2000 times is shown in Figure 8. The addition of salt made cavities between the particles become more dense than the particles in pure peat soils and increased the c-value of the peat soils. Salt added with water created a salt solution. The salt solution is an electrolyte that has a larger movement than pure water, so it can reduce the water content in peat soils. A reduction in water content causes the peat soil to become more compact and easier to compact. This more dense soil condition increases the value of peat soil cohesion. In Figure 9 it can be seen that peat soils become more dense and contains more pointed particles than the pure peat soils. The condition of the pointed particles causes high friction to form a higher internal angle (ϕ) than the pure peat soils.

SEM test results of peat soils added with 20% of gypsum in a compacted condition magnified 2000 times is shown in Figure 10. The addition of gypsum created air space between particles filled with gypsum particles. The gypsum particles absorb water for the binding and hardening of the peat soil particles so when the soil compaction phase comes, the samples become more compacted. The increased soil compaction after the addition of gypsum resulted in increased cohesion values (c). The peat soil particles that were stabilized using gypsum became more visible and sharper than those in the pure peat soils. This causes an increase in the shear angle value in (ϕ) because it is caused by a horizontally oriented fibre effect resulting in high friction between particles.

The SEM test result of peat soils added with 20% of gypsum and 6% of salt in a compacted condition magnified 2000 times is shown in Figure 11. The simultaneous addition of gypsum and salt caused the air space between the particles to be filled with gypsum and salt. Gypsum and salt worked interconnectedly. The salt solution emitted water from the peat soils and was absorbed by the gypsum for the binding and hardening of the particles. This caused the value of cohesion (c) to increase due to the denser soil condition than the pure peat soil. From Figure 11, it can be seen that a clump of particles from peat soil appeared on the outer side of the peat. The condition of the pointed particles caused the shear angle value in (ϕ) generated by friction between the particles to be greater than that in pure peat soil.

4.0 CONCLUSION

Based on the laboratory test resuts obtained, the following conclusions are drawn. Rawa Pening's soil samples are classified as peat soils with water content (w) = 279.70%; ash content (a) = 28.38%; organic material content (O) = 71.62%; soil dry weight (γb) = 0.980 gram/cm^3 and specific gravity (G_s) = 1.67. The consolidation parameters of peat soil are as follows: C_c = 0.0359 and C_v = 0.072 cm/s^2; while the shear strength parameters are as follows: c = 0.2276 kg/cm^2 and f = 32.33 °. From the peat soil mixture with 4% salt + 20% gypsum, a C_c value of 0.249 is obtained (the smallest value). From the peat soil mixture with 6% salt +20% gypsum, a C_v value of 0.130 cm/s^2 is obtained (the largest value). From the peat soil mixture with 6% salt + 15% gypsum, a c value of 0.6155 kg/cm^2 is obtained (the largest value). From the peat soil mixture with 6% salt + 15% gypsum, a f value of 52.24° is obtained (the largest value). Based on the Scanning Electron Microscope (SEM) test, Rawa Pening's peat soils in terms of visual properties have a non-uniform texture as well as large and small grain sizes. Grain shape is also non-uniform with round and pointed shapes. The addition of synthetic gypsum and salt causes the peat soil particles to become denser than the untreated soil.

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