Study of lime addition to sewer sedimentation soil to improve the soil properties for use as construction materials

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Abstract. Sewer sedimentation in general cannot be used directly as construction materials due to the behaviour which is hard when it is dry and weak and soft when it is wet. Several engineering treatments that can be taken to improve the soil properties including adding a chemical stabilization using a mixture of materials. The stabilized soil samples came from Lam Glumpang Village, Ulee Kareng District, Banda Aceh. The purpose of this study was to obtain mechanical soil parameters before and after stabilization with lime. This research was conducted by mixing lime and lime soil with variations of 2%, 4%, 6%, and 8% of the dry weight of the soil. According to the AASHTO classification system, the soil is classified as A-4 (8) soil type, namely moderate to poor silt soil with an index group of 8, and according to the USCS classification system it is classified as an inorganic silt soil type with the symbol ML, namely silt soil with low plasticity. The results showed some good improvement in soil properties. In general, the addition of lime which has a good effect on sewer sedimentation soil in the mixture proportion of 6%.

1. Introduction

Sewer sedimentation soil is a soil/mud that is deposited at the bottom of the drainage system. Based on the transportability, sewer sedimentation is the same as river sedimentation, which occurs aquatically. In big cities silting the sewers is a common problem because along with the population growth rate and the increasing needs of life, people make drainage system as a place to collect or dispose of all types of community liquid waste, even apart from liquid waste, there are also people who throwing household waste through it. Basically, sewer sedimentation soil is a type of clay or silt soil that has a low bearing capacity and is very sensitive to water content changes, and if the soil is used for infrastructure, it can cause instability. The soil's low bearing capacity causes the soil to be unable to support the load of construction that is applied to it. Therefore, repair of the soil, including improvements made by soil stabilization, is necessary [1]. The previous work on soil characteristics was also carried out and presented in several up-to-date research studies, measured the uplift force value of red clay soil. The optimum moisture content of the uplift force and swelling pressure of the Pidie Jaya clay was 2.466 kg and 0.868 cm, respectively [2].

Soil stabilization is an enhancement of the soil that makes it possible to improve the soil so that the soil is practically suitable for building. Soil stabilization may be carried out in two ways [3]. Mechanical stabilization, which is carried out by compacting the soil with mechanical means or by combining poor soil with strong soil. Next, chemical stabilization, by applying chemical combining
materials to the soil to be stabilized. The stabilizing material for sewage sedimentation soil used in this research is lime. The use of lime as an added material is due to the initial theory that the soil is clay-to-silt, so lime is a more suitable stabilizing agent for use than cement, asphalt, or other added materials.

Several previous research on stabilization of soil try to use affordable or industrial-waste based material to be added into soil have conducted research on the use of agricultural and household waste for geotechnics [4][5]. The effect of a palm oil clinker concrete pile with a foamed concrete pile as a soft soil floating base was studied by [1], for expansive soil treatment, studied bagasse fiber mixed with hydrated lime [6]. The result was that the compressive strength of the expansive soil improved by rising the soil to fiber-lime. The effect of lime-rice husk ash and waste plastic fiber was investigated by Muntohar on the engineering properties of silty soil [7]. They found that the mixture could increase the value of the compressive, tensile, and shear strength of silty soil properties from 0.4-08 percent of dry mass.

![Figure 1. Collecting of sewer sedimentation soil.](image)

In general, soil stabilization with lime will increase the strength, stiffness, and resilience of fine-grain soils [3]. Lime is also used to improve the properties of granular soils with fine fractions. Lime has also been used under the base layer of the pavement system, under concrete foundations, on embankment slopes, and channel linings, as a stabilizer for soils. In addition, Sulaeman [1] and Al-Rawas [3] suggested that applying lime to the soil would result in a lower maximum density and a higher optimum content of water than the untreated soil. Furthermore, lime results in a plasticity index decrease. To decrease swelling potential and swelling stresses in clay soils, lime stabilization has been commonly used. In a double layer around the clay particles, the addition of lime creates strong calcium ions, thereby decreasing the attraction to water [8].

2. Materials and Method
The experiment materials to be used in the research namely drainage sediment soil, lime, and water. The soil was collected from Lam Glumpang Village, Ulee Kareng District, in Banda Aceh. Lime was obtained from material stores building materials, and water used are available at the Soil Mechanics
Laboratory Faculty of Engineering, Universitas Syiah Kuala. This research consists of testing the physical properties of the soil, experiment of compaction, and direct shear test. In testing the physical properties of the soil, the equipment used consists of a flask, vacuum hood, scale, one set sieve, Casagrande bowl, hydrometer, thermometer, mixer, and oven with ASTM D-4318-93 standard method. Moreover, Atterberg limit testing, ASTM C-127 for specific gravity testing, ASTM C-29 for volume weight testing, and ASTM D-421 for granular division testing. Compaction test using the standard ASTM D698 proctor method using a proctor mold tool (mold) made of cylindrical iron with a diameter of 10.15 cm and a height of 11.65 cm.

### Table 1. Soil physical parameter result.

| No | Laboratory Test          | Result          |
|----|--------------------------|-----------------|
| 1  | Unit Weight of Soil      | 1.619 gr/cm³    |
| 2  | Specific Gravity         | 2.618           |
| 3  | Atterberg Limit          |                 |
|    | a. Liquid Limit (LL)     | 39.86%          |
|    | b. Plastic Limit (PL)    | 29.86%          |
|    | c. Plasticity Index (PI) | 10.00%          |
| 4  | Sieve Analysis           | 77.43%          |
| 5  | Soil Classification      |                 |
|    | a. AASHTO (Group Index)  | A-4 (8)         |
|    | b. USCS                  | ML              |

A sampling of soil to be used in this study is in the form of a disturbed soil sample, taking directly the sewer sedimentation soil that has been previously dredged by the Department of Public Works using a hoe and then put it in a sack. The soil is then taken to the Soil Mechanics Laboratory of the Universitas Syiah Kuala, and then the waste is separated from the soil. After the waste separation process is complete and all that remains is the soil, then the soil is spread out on the floor which has been covered with thick plastic and left for a few days until the ground is air-dry. The lime used is quicklime (CaO) which has been mashed and filtered using sieve number 200. The physical parameter result of soil can be seen in table 1.

### 3. Result and Discussion

Table 1 shows the recapitulation of the physical properties of untreated soil. The test parameter analyze are specific gravity, liquid limit, plastic limit, plasticity index, and sieve passing #200. The result of soil classification shows that the soil is classified as ML (low plasticity silt) for USCS method and A-4 (8) for AASHTO method. Table 2 shows with the increasing percentage of lime, the liquid limit tends to decrease from 39.86% to 37.94% and the plastic limit tends to increase from 29.86% to 33.05%, so the plasticity index is reduced from 10.00% to 4.88%.

### Table 2. Result of Atterberg Limit for Lime Addition Variation.

| Lime Percentage (%) | Atterberg Limit (%) |
|---------------------|---------------------|
|                     | PL      | LL      | PI   |
| 0                   | 39.86   | 29.86   | 10.00|
| 2                   | 39.24   | 31.14   | 8.10 |
| 4                   | 38.45   | 32.75   | 5.70 |
| 6                   | 38.18   | 33.00   | 5.19 |
| 8                   | 37.94   | 33.05   | 4.88 |
Figure 2 shows that the addition of lime to soil sewer sedimentation soils very clearly affects the Atterberg Limit parameter. As the percentage of lime increases, the liquid limit tends to decrease from 39.86% to 37.94% and the plastic limit tends to increase from 29.86% to 33.05% so that the plasticity index is reduced from 10.00% to 4.88%. These results are following that stated by Al-Rawas [3], namely the addition of the percentage of lime will cause a decrease in the liquid limit (LL) and an increase in the plastic limit (PL). This may be due to the exchange of ions in the soil by Ca + ions and those contained in lime. The decrease in the liquid limit and the increase in the plastic limit may also be due to the exchange of strong Ca + ions from lime with weak positive soil ions on the surface of the particles so that the ionic balance of the particles is better and reduces water absorption.

![Figure 2. Relationship between Atterberg Limit and Lime Percentage.](image)

| Lime Percentage (%) | Shear Strength Parameter |
|---------------------|-------------------------|
|                     | Friction Angle (°)      | Cohesion (kg/cm²) |
| 0                   | 15.62                   | 0.29               |
| 2                   | 18.25                   | 0.31               |
| 4                   | 21.62                   | 0.32               |
| 6                   | 23.48                   | 0.35               |
| 8                   | 24.90                   | 0.28               |

Figure 3 shows that there is a significant increase in the value of soil friction angle (ϕ) for 4% of lime, which is 21.62°. The increase in the value of the shear angle (ϕ) may because of an increase in the contact area between the grains due to the addition of lime. Due to the increase in the contact area between the particles, the shear strength that occurs is greater and causes the value of the shear angle to increase. Figure 4 shows that the addition of lime to a percentage of 6% causes an increase in the cohesion value from 0.29 kg/cm² to 0.35 kg/cm², then at the percentage of 8%, the lime mixture causes the cohesion value (c) to decrease to 0.28 kg/cm². The increase in cohesion value (c) may be due to a change in the reaction between soil particles and lime grains. Lime has a binding power and decreases its sensitivity to water and has a fine grain so it can absorb water due to its low pore density. This may cause lime to reduce the moisture content in the soil and make it denser, but the addition of excess
lime will cause a loss of binding strength between soil particles so that the cohesion value decreases. The construction material choice is certainly necessary, especially in Aceh geographical position which is in earthquake prone areas [9-11].

![Figure 3. Relationship between soil friction angle and lime percentage.](image1)

![Figure 4. Relationship between soil cohesion and lime percentage.](image2)

4. Conclusion
The addition of lime can increase the value of the shear angle ($\phi$) up to 8% of lime. The highest shear angle ($\phi$) value achieved in the addition of 8% lime is 24.90°, while the lowest shear angle ($\phi$) value achieved on soil without lime mixture is 15.62°. The addition of lime to a soil causes an increase in the cohesion value ($c$) to the percentage of the 6% lime, from 0.29 kg/cm$^2$ to 0.35 kg/cm$^2$, then the addition of the 8% lime mixture percentage causes the cohesion value ($c$) to decrease to 0.28 kg/cm$^2$. In general, the addition of lime which has a good effect on the lime soil of Lam Glumpang Village is the mixed percentage of 6%. 

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