The effect of additional limestone on expansive soil at Summarecon Emerald East Karawang

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Abstract. Expansive clay soils are soils that have large shrink and swell properties, and their behaviour is affected by water. The purpose of this study was to determine the physical properties and mechanical properties of expansive clay soil. In this study, land samples were taken at the Summarecon Karawang Project. Clay soil in stability with calcium carbonate (CaCO₃) of 2%, 4%, 6%, and 8%. The location of study is at Summarecon Emerald Karawang Timur. The soil character is potential to expand 7.4602%, type CH (Clay - High Compressibility). The result of study is by using carbonate content (CaCO₃) the plastic limit increased 7.75%, cohesion increased by 19.44%, the plasticity index decreased by 45%, the specific gravity decreased by 2.8%, the CBR decreased by 58.78%, the swelling decreased by 66.35%. (R).

Keywords: Soil, physical properties, mechanical properties, stabilization, limestone.

1. Introduction

Expansive soil is a soil that changes volume due to changes in moisture content in the soil. Usually, expansive soil contains clay minerals such as smectite and montmorillonite that are able to absorb water. When the mineral absorbs water then the volume of soil will increase. The more water absorbed, the more soil volume increases. This volume change can damage the strength of the building structure that occupies the land.

Expansive soils are prevalent in dry and semiarid climates where evaporation surpasses precipitation on a yearly basis. The production of these soils is frequently linked to a hot climate and inadequate drainage conditions. These soils range in hue from deep black to grey, and occasionally even reddish to yellowish [1].

The difference between expanding and non-expanding soils is more of a matter of degree than of nature. There is currently no commonly accepted simple method for identifying expansive soils. Though there are numerous thorough laboratory techniques for identifying expanding and non-expanding clay minerals, these approaches are not practical for practicing engineers, and many attempts have been made to link simple identification tests with expansive features [2].

Cracks in a building structure are feature of damage caused by expansive soil. The damage can occur when there is significant movement in the soil structure. When expansive soil dry up, there will be shrinkage. Shrinkage can reduce soil bearing capacity so that there will be damage to the structure.
of the building. Cracks in the soil can facilitate the penetration of water, resulting in a shrinkage cycle and swelling that will produce repetitive stresses on the soil structure.

Handling of expansive soil structure in principle is to keep the water content changes not too high or by changing the nature of expansive clay so as not expansive. With the change of water content is not too high and changes in land expansive properties during the rainy and dry season, there is no significant volume change.

If expansive soils are discovered in a project, proper remedial steps must be taken to change the soil or lessen its negative impacts. Planning and designing stages and post-construction stages may require distinct remedial procedures. Many stabilization approaches are in use for improving expansive soils, in which the soil characteristics are altered, or problematic soils are removed and replaced. These techniques can be employed alone or in combination with certain design alternatives. Lime, cement, calcium chloride, rice husk, fly ash, and other additives are also utilized to change the characteristics of expansive soils. Permeability, compressibility, and durability are three properties that design engineers are concerned about [3].

The most important handling effort is to make the expansive soil not cause damage to the structure of the building. Therefore, handling must be done with some alternative to know the nature of expansive soil (expansive soil) which will be prevented or changed its character. Many stabilization chemicals have been employed to improve the strength of expansive soil as well as its ability to swell and shrink. Various studies have been conducted in the field of improving soil characteristics using various additions such as fly ash, slag, rice husk, lime, and other materials. Lime is a typical stabilizer in the building sector [4].

The use of expansive ground stability method with limestone aims to change the expansive soil properties into better soil by reducing the percentage of fine grains.

2. Research methods

Research and testing of sample expansive clay soil was conducted at the Laboratory of Soil Mechanics of Civil Engineering of Bina Nusantara University by taking samples of expansive clay soil ± 170 kg from Summarecon Emerald East Karawang project as shown in Figure 1.

The expansive clay soil used for the study was taken at the Summarecon Emerald East Karawang location at the point of boring DB VII with a depth of 50 cm, using pure calcium carbonate (CaCO_3). The amount of lime required is ± 7 kg.

The data were collected by conducting tests on 5 soil samples taken from the same site with different lime content (0%, 2%, 4%, 6%, and 8%) and each consisting of 3 samples. All soil samples will be tested in a laboratory that refers to ASTM standards.

Tests of soil properties by XRD (X-Ray Diffraction), liquid limit, plastic limit, plasticity index, specific gravity, internal shear angle, cohesion, CBR (California bearing ratio), and for development properties were conducted by CBR method (California bearing ratio).

3. Results and discussion

3.1. Soil properties at Summarecon Emerald East Karawang

Drilling was done 8 (eight) point spreaders to conduct land investigation on the field. The ground investigation consists of:

- Drilling - In as many as: eight points (Table 1)
- Soil and core sampling: "Undisturbed sample" soil samples, disturbed soil samples and cores for hard layers
- Determination of Groundwater (water level): position in drill hole is measured for 24 hours after drilling reaches 6.00 meters (only as an indication)
Figure 1. Site Plan Summarecon Emerald East Karawang (a) Drilling Location (b)

Table 1. Boring log data location

| No  | Depth (m) | Soil Type | Water level (m) |
|-----|-----------|-----------|-----------------|
| DB I| 0.00 - 3.00 | SILT, MH, grey, brown, silt clay with fine sand, moderate activity, insensitivity. | 1.7 |
|     | 3.00 - 8.00 | SILT, chocolate, silt clay and fine sand, very stiff. | |
|     | 0.00 - 1.50 | CLAY, CH, chocolate, clay, silt and fine sand, moderate activity, insensitivity. | |
| DB II| 1.50 - 8.00 | SILT, MH, grey, brown, yellow, silt clay and fine sand, hard. | 1.75 |
|     | 0.00 - 1.50 | CLAY, CH, brown, grey, yellow, silt clay, and fine sand. | |
|     | 1.50 - 4.50 | CLAY, grey, brown, silt clay and fine sand with gravel. | |
|     | 4.50 - 6.00 | SAND, brown, black, coarse sand with gravel, coral, very dense. | 1.6 |
| DB III| 6.00 - 8.00 | SILT, MH, brown, reddish, brown, grey, yellow, silt clay and fine sand, very stiff, moderate activity, insensitive sensitivity, | |
| DB IV| 0.00 - 8.00 | SILT, MH, brown, grey, silt clay and fine sand, moderate activity, insensitive sensitivity | 2.85 |
|     | 0.00 - 4.50 | CLAY, CH, brown, grey, yellow, silt clay and fine sand. | |
|     | 4.50 - 5.50 | SAND, brown, black, fine + coarse sand | |
|     | 5.50 - 8.50 | SAND, black, brown, coarse sand with gravel, coral, very dense. | 2.1 |
| DB V| 6.00 - 8.00 | SILT, MH, brown, grey, yellow, silt clay and fine sand, medium activity, insensitive sensitivity | |
|     | 0.00 - 6.00 | SAND, grey, black, coarse sand with gravel, very dense. | 1.75 |
|     | 0.00 - 2.00 | CLAY, CH, brown, grey, silt clay and fine sand, moderate activity, insensitive sensitivity | |
|     | 2.00 - 5.00 | SILT, MH, grey, brown, yellow, Silt clay and fine sand. | |
|     | 5.00 - 6.00 | SILT, grey, silt brown silt and fine sand with coral. | |
|     | 5.50 - 8.50 | SAND, brown, black, coarse sand with gravel, coral, very dense. | 1.75 |
| DB VII| 6.00 - 8.50 | SILT, MH, brown, grey, silt clay and fine sand, | 2.15 |
| DB VIII| 0.00 - 2.50 |  | |
moderate activity, insensitivity.

2.50 - 8.00 SILT, grey, brown, yellow, fine, hard sand silt.

3.2. Identification of expansive soil

The collection is carried out in 2 ways:
1. Conventional, form of land disturbed used for testing liquid limit, plastic limit, plasticity index, specific gravity, angle of friction, cohesion, CBR (California bearing ratio), and development.
2. Hand Boring, in the form of undisturbed soil used for XRD (X-Ray Diffraction) mineral testing.

To identify expansive soils, the author uses 3 methods:
1. The Plasticity Method, obtained a plastic limit of 39.5597% with a clay fraction of 91.449%, then the soil activity (Ac) of 0.433 (low activity land) was obtained according to Skempton (1953);
2. Development Test Method, the soil is allowed to expand with a constant surface load of up to 4 days, obtained a percentage of development of 7.46% (high expansion potential) according to Seed and Das (1955);
3. Mineralogy XRD (X-Ray Diffraction) Method, XRD performed on the National Nuclear Energy Agency Serpong (BATAN), levels of montmorillonite in soil samples as much as 24.74%, using the theory Skempton (1953) of the liveliness of the soil (Ac) identified mineral dominant is kaolinite.

Table 2. Soil identification test result

| Expansive soil type | Plasticity Index (%) | Activity (Ac) | Swelling Potential (%) | Montmorillonite levels (%) |
|---------------------|----------------------|---------------|------------------------|--------------------------|
|                      | 39.559               | 0.433         | 7.46                   | 24.74                    |

From Table 2, the results of clay identification method, the soil at DB VII point Summarecon Emerald East Karawang, can be identified as low active (Ac) soil and has a high expansion potential.

3.3. The effect of lime stabilization

Testing the effect of calcium carbonate (CaCO₃) against characteristics of the soil in this study, conducted at several trial:

3.3.1. Atterberg limit

Table 3. Test result atterberg limit

| Atterberg Limit | Calcium Carbonate (CaCO₃) (%) | 0 | 2 | 4 | 6 | 8 |
|-----------------|-------------------------------|---|---|---|---|---|
| Liquid Limit    | 59.0357                       | 54.149| 48.049| 45.2867| 42.8056|
| Plastic Limit   | 19.476                        | 19.579| 19.942| 19.68| 20.99|
| Plastic Index   | 39.5597                       | 34.57| 28.107| 25.3187| 21.8156|

Atterberg limit test in accordance with ASTM D4318-10 standard, from the data of Atterberg limit test results, can be seen with additional calcium carbonate (CaCO₃) some parameters of
Atterberg limit test results change. Decreased 27.49% on the initial liquid limit, increased by 7.75% on the original plastic limit, and decreased 45% in the original plastic index (Table 3).

3.3.2. Specific gravity

| Characteristics  | Calcium Carbonate (CaCO₃) (%) |
|------------------|-------------------------------|
|                  | 0 | 2 | 4 | 6 | 8 |
| Specific Gravity | 2.592 | 2.555 | 2.531 | 2.523 | 2.519 |

Test specific gravity according to ASTM standard D854-10, mixture of calcium carbonate (CaCO₃) and cause a reaction clay caption exchange and flocculation, making soil more resistant to the effects of water and increase soil particles that cause the decrease in specific gravity of 2.82% of beginning (Table 4).

3.3.3. Compaction

![Figure 2. Graph of compaction test](image)

Compaction test according to ASTM D698-07, from Figure 2 can be seen the peak relationship of moisture content and dry density was found at optimum moisture content 35.8% and with maximum dry weight 1.34 g/cm³.

3.3.4. Direct shear test

| Characteristics  | Carbonate Calcium (CaCO₃) (%) |
|------------------|-------------------------------|
|                  | 0 | 2 | 4 | 6 | 8 |
| φ (°)            | 27.447 | 27.499 | 27.447 | 27.342 | 27.600 |
| c (kN/m²)        | 36 | 38 | 40 | 42 | 43 |

Direct shear test is performed according to ASTM D3080 standard, it can be seen that the internal shear stress in soil (φ) behaves stable, although it increases or decreases not more than 1, while soil cohesion has increased by 19.44% from its original cohesion. The increase in cohesion is influenced by the reaction of flocculation between particles of soil particles.
3.3.5. *California bearing ratio*

**Table 6. Test result of California Bearing Ratio (CBR)**

| Optimum Water Content Samples | Carbonate Calcium (CaCO₃) (%) |
|------------------------------|--------------------------------|
| Unsoaked                     | 5.92 6.18 6.50 2.51 2.44      |

CBR test conducted according to ASTM D1883-07 standard, from Table 6 the CBR value tends to decrease, a decrease occurred by 58.78% from the original CBR value.

3.3.6. *Swelling*

![Graph relations percentage swelling of the carbonate calcium supplement (CaCO₃)](image)

**Figure 3.** Graph relations percentage swelling of the carbonate calcium supplement (CaCO₃)

Carbonate (CaCO₃) Performed swelling test using CBR method according to ASTM D1883-07 standard, with 0%, 2%, 4%, 6%, and 8% calcium carbonate (CaCO₃) mixing. From the test result, the value of the percentage of swelling decreases with the increase of calcium carbonate (CaCO₃), with a decrease of 66.36% from the original swelling value of the soil (Figure 3).

3.3.7. *Soil classification*

From the results of the sieve analysis test (ASTM D422-63), hydrometer (ASTM D422-6), and atterberg limit (ASTM D4318-10), soil classification using USDA (US Dept. of Agriculture) and USCS (unified soil classification system). Appropriate USDA system (Figure 4), the soil is classified in clay, since the dominant particles are clay by 91.419%. Whereas according to USCS system (Figure 5), soil is classified in clay with high compressibility (CH).
3.4. Comparison of characteristics and swelling of research soil and previous research

Comparison of characteristics and swelling of soil research with previous research has different conditions:
1) The soil samples used originated from different locations;
2) Unequal soil characteristics;
3) Differences in use of lime types.

3.4.1. Atterberg limit and specific gravity

From Figure 6, it can be seen that:
1) Liquid limit decreases (28% Abass, 16.18% Utami, 27.49% Analyze Results), except on Damianto;
2) Damianto's soil classification is different from other studies;
3) The decreasing almost same (28% Abass and 27.49% Analysis Results);
4) CaO and CaCO$_3$ can reduce liquid limit.

From Figure 7, it can be seen that the addition of CaO and CaCO$_3$ has a similar ability to decrease the specific gravity. Can be seen a decrease of 2.8% in Analysis Results and 2.5% in Abass.
3.4.2. Direct shear test

![Graph showing cohesion analysis comparison](image)

**Figure 8.** Comparison of cohesion analysis [5] [6] [7]

From Figure 8, it can be seen that there was an increase in cohesion (57.14% Sabbath, 19.44% Research Results), except Damianto and the soil classification used by Damianto is different.

3.4.3. California bearing ratio

![Graph showing CBR analysis comparison](image)

**Figure 9.** Comparison of CBR analysis [5] [6] [7]

From Figure 9 it can be seen that:
- CBR Damianto value increased 205.3%;
- The value of CBR Utami, Palar, and Result Analysis tend to be unstable;
- CBR value of Damianto is higher than other studies;
- The addition of CaO and CaCO₃ can affect the value of CBR;
- The addition of CaCO₃ can increase the CBR value well.
3.4.4. Swelling

![Swelling Chart](image)

**Figure 10.** Comparison of swelling analysis [5] [6] [7]

From Figure 10 it can be seen that:
- swelling value decreased (13.04% Utami, 36.36% Abass, 86.84% Kate, 66.35% Analyze Results).
- CaO or CaCO₃ can reduce the swelling index.

4. Conclusion

Based on the results of the test of the effect of additional lime (0%, 2%, 4%, 6%, and 8%) on the characteristics and swelling on expansive soil at Summarecon Emerald East Karawang, obtained soil characteristics and swelling value, conclusion:
- Type of clay at point DB VII at Summarecon Emerald Karawang Timur location is clay with low activity (0.433), expansion potential 7.4602 which is high, and type of soil CH (Clay - High Compressibility).
- With the addition of calcium carbonate (CaCO₃) as much as 8%, soil properties have increased. 7.75% increase in plastic limit, and 19.44% in soil cohesion.
- With the addition of calcium carbonate (CaCO₃) as much as 8%, soil properties also decreased. Decrease of 27.49% at liquid limit, 45% on plasticity index, 2.8% in specific gravity (Gs), 58.78% on CBR value, and 66.35% on development value.
- With the addition of calcium carbonate (CaCO₃) limestone, the shear properties of the soil in the soil (φ) increased and the decrease was not large (not exceeding 1), identifying lime calcium carbonate stabilization against the inner (φ) shear angle was not very influential.
- The effect of calcium oxide (CaO) and calcium carbonate (CaCO₃) on clay soil have the same ability to influence liquid limit, plasticity index, specific gravity (Gs), cohesion (c), CBR value, and Development value for clay soil. For plastic limits, the use of calcium oxide (CaO) lime is better than calcium carbonate (CaCO₃).
- The effect of calcium oxide (CaO) and calcium carbonate (CaCO₃) on clay soil reacts better and more stable than in sandy clay soils, but lime can increase the value of CBR in sand of clumps.
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