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# The Effect of Lime Content on the Bearing Capacity and Swelling Potential of Expansive Soil

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**Abstract** Soil properties are poor and less profitable when used as the basis of a building or construction. This is due to, among others, high plasticity, low shear strength, great congestion and potential shrinkag. This condition can cause harm, especially in the structure with lightweight construction and road highway. The prelimenary tests has conducted to obtain the physical properties and the Califonia Bearing Ratio (CBR) value of the original soil. The test has also conducted to stabilize 0%, 2%, 4%, 6%, 8%, and 10% of lime. The results of tests shows that by adding the lime to the clay sourced from Tanjung Beringin Langkat, North Sumatra, can improve the physical properties. This successfuly increase the bearing capacity and decrease the swelling potential of the soil base.

**Keywords** Stabilization, Lime, Swelling potential, Bearing capacity

## 1. Introduction

Expansive soil has a high degree of sensitivity and have the nature and expansion of shrinkage that can cause damage to buildings. This soil also has the competence to expand and contract very high due to changes in moisture content in the soil. Inflate the value of land has a low bearing capacity needs to be improved so that the ground swell to get a more stable ground. Low soil bearing capacity is very unfavorable when used as a subgrade to support a building.

### 1.1. Clay Soil

According to Wiqoyah [1] level of soil plasticity is divided into 4 levels based on plasticity index values that exist in the interval between 0% and 17%. Limits on plasticity index, properties, kinds of soil, can be seen in Table 1.

**Table 1.** Value and Plasticity Index of soils

| PI | Various | Soil Properties |
|---|---|---|
| 0 | Non plastis | Sand |
| < 7 | Low plasticity | Silt |
| 7 – 17 | Medium plasticity | Silt clay |
| > 17 | High plasticity | Clay |

According to Chen [2], soil with IP > 35, SL > 11, and LL > 63 is a clay that has swelling potential was high. Of relationship plasticity index of the swelling potential given Chen [2] can be stated the greater a mineral soil plasticity index, the greater swelling potential (see Table 2).

**Table 2.** Relationship swelling potential with plasticity index

| Swelling the potential | Plasticity index (IP) |
|---|---|
| low | 0 - 15 |
| medium | 10 - 35 |
| high | 20 - 55 |
| very high | > 55 |

Ingles and Metcalf [2], provides criteria for the award of lime in the mixture as in Table 3.

**Table 3.** Criteria for the granting of lime in the mix [2]

| Type of soil | Modification | Stabilitation |
|---|---|---|
| Fine crushed rock | (2% - 3%) | - |
| Well graded clay gravels | (1% - 3%) | 3% |
| Sands | - | - |
| Sands clay | - | 5% |
| Silty clay | (1% - 3%) | (2% - 4%) |
| Heavy clay | (1% - 3%) | (3% - 8%) |
| Very heavy clay | (1% - 3%) | (3% - 8%) |
| Orgznic soil | - | (3% - 8%) |

### 1.2. California Bearing Ratio (CBR)

Bearing capacity of soil connected with the CBR then can the values found in Table 4.

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**Table 4.** The bearing capacity of soil associated with the CBR value

| CBR | Bearing capacity of soil |
|---|---|
| 2 % - 5 % | Ugly |
| 6 % - 9 % | Medium |
| > 9 % | Good |

### 1.3. Swelling Potential

Swelling potential that is the percentage of development under the pressure of 6.9 kPa (1psi), the soil samples loaded laterally confined. Soil samples were used dpadatkan the optimum water content so as to achieve maximum dry weight of the volume according to AASHTO standards. Way to describe the nature of the soil expands with development potential are generally tested with test development. Seed et al. [3] suggest classification of the degree of expansion are shown in Table 5.

**Table 5.** Classification of the degree of expansion [3]

| Degree of Expansion | Swelling Potential, S(%) |
|---|---|
| Low | 0 – 1,5 |
| Medium | 1,5 - 5 |
| High | 5,0 - 25 |
| Very High | > 25 |

## 2. Research of Methodology

Tests were performed on the preliminary research stage include:

- Atterberg limit
- Spesific gravity
- Seive analysis
- Compaction test

Further testing is done by mixing 0%, 2%, 4%, 6%, 8%, and 10% with lime on clay and soaked CBR testing done and unsoaked to determine the bearing capacity and swelling potential of soil policy.

## 3. Results and Discussion

### 3.1. Physical Properties and Soil Classification Clay of Tanjung Beringin LANGKAT

Soil used in testing is a soil of Tanjung Beringin LANGKAT, and are classified as inorganic clay with high plasticity (CH) in the AASHTO soil classification: A-7-6 namely clay with high plasticity index, thus classified as clay soil with high plasticity because Plastis Index ≥ 17%, to variations lime 2%, 4%, 6%, 8% and 10%, including the group ML - OL namely inorganic clay with plastis low up to now, according to a unified classification. Whereas according to the AASHTO classification: A-7-5. Physical properties of original clay are shown in Table 6.

**Table 6.** Physical properties of original clay

| No | Nature of soil | Unit | The original clay |
|---|---|---|---|
| 1 | Specific Gravity (Gs) | - | 2.66 |
| 2 | Plastic Limit (PL) | % | 20.78 |
| 3 | Shrinkage Limit (SL) | % | 54.47 |
| 4 | Liquid Limit(LL) | % | 40.23 |
| 5 | Plastic Index (PI) | % | 19.43 |
| 6 | Sieve Analysis | % | 52.30 |
| 7 | Dry weight contents (γd maks) | gr/cm³ | 1.363 |
| 8 | Optimum Moisture Content (Wopt) | % | 21.00 |

### 3.2. Physical Properties of Original Soil, Stabilized with Lime

Effect of lime on soil physical properties of clay (the original) is very dependent on the percentage mix of lime used. Variations as a percentage addition of lime stabilization on clay soils can alter his physical attributes.

### 3.3. Testing Results Atterberg Limits

Test results Atterberg limits on boundary clay stabilized with lime can be seen in Table 7 and the graph in Figure 1.

Table 7 and the graph in Fig. 1 shows the percentage of the addition of lime to 2% value of plastic limit increased, but for liquid limit, shrinkage limit and plastic index decline of the value of Atterberg limits testing clay without lime mixture (native soil). With increasing addition of lime percentage is 4%, 6%, 8% and 10%, plastic limit value is increasing and liquid limit, shrinkage limit, plastic index decreases. In addition the percentage of 4% of the value of the IP is below 17%, ie 16.64%, but the percentage of lime addition of 10% value of its IP that low of 10.67%. Atterberg limit test results for an increase in the value of the plastic limit.

In Table 7 and Fig. 1 shows the test results plastic index decreased due to the addition of lime and a decrease in the optimal occurred on addition of 4% lime. This decrease causes a decrease in the value of the development potential of soil clay. Plastic index values obtained from the experiment results that Table 1 classified the nature of high plasticity and on a high swell potential, according to Chen [2]. The addition of lime is good for stabisasi material clay with lime rate 3 - 8% and for this test are eligible according to Ingles and Metcalf [5].

### 3.4. Testing Results Specific Gravity

Specific gravity test results on clay stabilized with lime can be seen in Fig. 2 shows the result of this test influence the addition of lime clay soil, clay soil density decreased with increasing percetage of the addition of lime. Based on the results of tests performed in table 8, about the physical properties of the original soil. that the specific gravity of the soil decreases, this is due to lower specific gravity than the lime heavy soil types tested, so that the specific gravity of the

mixture of soil with lime and the resulting decline in shrinking pores and soil particles more glue.

### 3.5. Results of Testing Standard and Modified Proctor Compaction

Soil of compaction test results will be obtained optimum water content and maximum dry unit weight. Soil compaction testing laboratory using the modified Proctor compaction, compacted with 56 blows and 25 blows with a standard proctor. The results of testing the original clay soil compaction and clay stabilized with lime can be seen in Table 8.

Compaction test results to the addition of lime obtained optimum moisture content and dry weight in Table 8 in the laboratory compaction test results with standard methods proctor on native soil obtained optimum moisture content of 21.00% and a maximum dry weight of 1,363 g / $cm^3$ and a modified method obtained proctor optimum moisture content of 19.00% and a maximum dry weight of 1,632 g / $cm^3$.

In Table 8, it is seen that the maximum dry weight content increased with the addition of lime and dry weight of proctor compaction modifified higher than standard proctor, but the optimum water content in modified proctor lower than the standard proctor. There will be more compact density by modified proctor.

**Table 7.** Results of Atterberg Limit Testing Soil Clay + Lime (%)

| No | Properties Soil | Unit | Clay soil + Lime (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 0 % | 2 % | 4 % | 6 % | 8 % | 10 % |
| 1 | Plastic Limit (PL) | % | 20,78 | 22,69 | 28,69 | 29,11 | 30,98 | 31,56 |
| 2 | Liquid Limit (LL) | % | 50,18 | 48,72 | 45,33 | 42,58 | 42,31 | 42,23 |
| 3 | Plasticity Index (PI) | % | 29,40 | 26,03 | 16,64 | 13,47 | 11,33 | 10,67 |
| 4 | Shrinkage Limit (SL) | % | 54,47 | 48,98 | 47,59 | 46,33 | 45,86 | 44,97 |
| 5 | Specific Gravity (Gs) | - | 2.66 | 2.65 | 2.60 | 2.58 | 2.57 | 2.56 |
| 6 | Sieve Analysis (%) | % | 52.30 | 50.20 | 49.18 | 48.06 | 47.87 | 46.58 |

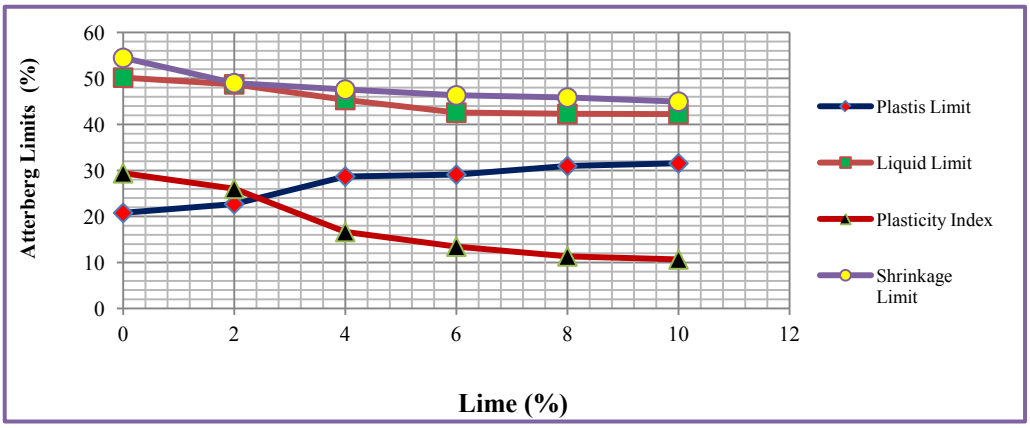


**Figure 1.** Graphs the relationship the addition of lime to the Atterberg limits

**Table 8.** Results of Testing Standard and Modified Proctor Compaction is stabilized with lime

| No. | Percent of Lime(%) | Standard Proctor | | Modified Proctor | |
|---|---|---|---|---|---|
| | | Optimum Moisture Content (%) | Dry Weight Content γd ($gr/cm^3$) | Optimum Moisture Content (%) | Dry Weight Content γd($gr/cm^3$) |
| 1 | 0 | 21.00 | 1.363 | 19.00 | 1.632 |
| 2 | 2 | 20.50 | 1.370 | 17.50 | 1.673 |
| 3 | 4 | 19.80 | 1.374 | 17.15 | 1.726 |
| 4 | 6 | 18.70 | 1.396 | 15.80 | 1.780 |
| 5 | 8 | 18.00 | 1.404 | 14.60 | 1.811 |
| 6 | 10 | 17.00 | 1.420 | 13.23 | 1.868 |

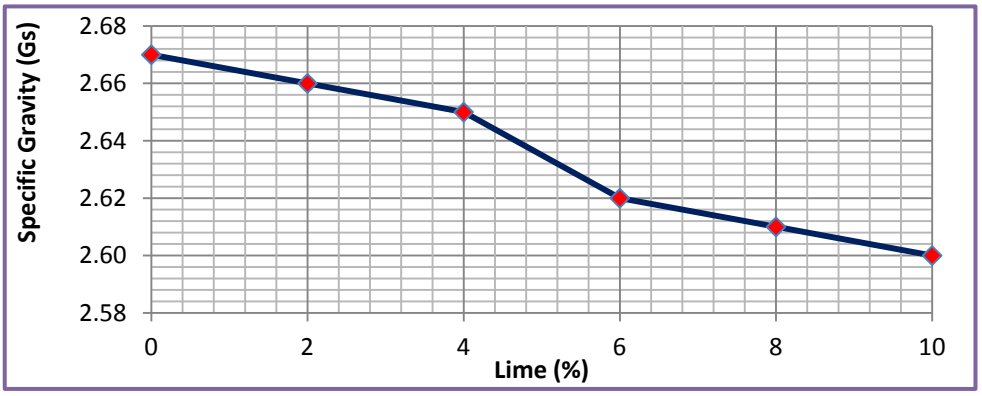


**Figure 2.** Graphs the relationship the addition of lime to the specific gravity

It can be influenced by the chemical composition of lime contained in alumina and silica active especially if mixed with CaO derived from limestone that forms a strong bond when added to water, the chemical reactions that occur due to events that meet the hydration of CaO with active silica. Because lime is heated, so the water in the clay decreases. So it can be concluded that each additional lime can reduce the water content and increase the weight of the optimal cleaning up will be more compact, and the pores of the soil will be getting smaller.

### 3.6. CBR Testing on Original Soil and when Mixed with Lime (2, 4, 6, 8 and 10%)

Table 9 shows that the original soil with a CBR value obtained was 4.18% standard proctor and modified proctor at 4.56%. CBR test results to the addition of lime variation of 4% can be stated that the increase in CBR value increased more optimal with modified proctor but the addition of 6% for the standard proctor still can not qualify good. CBR testing with modified proctor showed that the CBR value is higher than the standard proctor and already qualified according to AASHTO subgrade bearing capacity either because the CBR values > 9%. CBR testing with standard proctor still bearing capacity of the soil is classified as CBR values ranged between 6 - 9% with the addition of 6% lime.

**Table 9.** Laboratory CBR Test Results with the Standard Proctor and Modified Proctor

| No. | Percent of Lime (%) | CBR Value (%) | |
|---|---|---|---|
| | | Standard Proctor | Modified Proctor |
| 1 | 0 | 4.18 | 4.56 |
| 2 | 2 | 4.46 | 6.57 |
| 3 | 4 | 5.84 | 10.04 |
| 4 | 6 | 6.51 | 27.10 |
| 5 | 8 | 6.68 | 46.22 |
| 6 | 10 | 6.81 | 54.19 |

Terashi et al. [7] suggested the use of the lime content of 3% - 10% and more than 10% addition of lime does not affect or cause a reduction in strength and mixing lime also lowered its permeability.

### 3.7. Effect of Lime Addition to Soaked CBR and Swelling Potential Value with Modified Proctor)

Soaked CBR test results with the addition of lime 0%, 2%, 4%, 6%, 8% and 10% and the soaked time 1,4,7 and 14 days can be seen in Fig. 3 and 4.

Based on Fig. 3 and 4, it is known that the longer the soaking done coming down the soaked CBR compacted by 56 blows. This is because the longer the soaking occurs then the soil could grow and the amount of water come into the mold and soaked the more, then when do penetration value obtained will be declining. Table 11 can be seen that the addition of 4% lime have shown the CBR qualified good soil bearing capacity according to AASHTO, because the CBR > 9% in the 1 - 14 day soaking. Increasing the CBR is higher with the addition of lime between 4 - 6%.

### 3.8. Soaked Time Relationship with the Swelling Potensial

Swelling potential laboratory test results on clay with the addition of lime 0%, 2%, 4%, 6%, 8% and 10% with the time of immersion 1, 4, 7 and 14 days can be seen in Fig. 5 and 6. Adding lime can reduce increase or decrease the swelling. The results obtained from testing, that with the addition of lime 6% most optimal to reduce the rise in the swelling potential of the clay.

Figure 5 and 6 show that the original clay swelling potential or before the addition of lime increased the soaking time 1, 4, 7 and 14 days. The addition of lime to the soil clay percentage causes increased swelling in soak time 1, 4, 7 and 14 days can be reduced. The bigger the more diminished levels of lime or decrease the value of swelling potential, starting from 2% lime content soak time 1 and 4 days.

Value largest the swelling potential that occurs in native soil (lime 0%) with a soaking time of 14 days is 7.01%, according to Seed et al [3] value of 7.01% is the swelling potential is between 5-25%, the soil is classified as has a

degree of expansion of "high". Swelling potential value has reached < 1.5% with the addition of lime optimal levels, which is 4% and according to Seed et al [3] swelling potential value from 0 to 1.5%, the soil has been classified as having degrees low expansion.

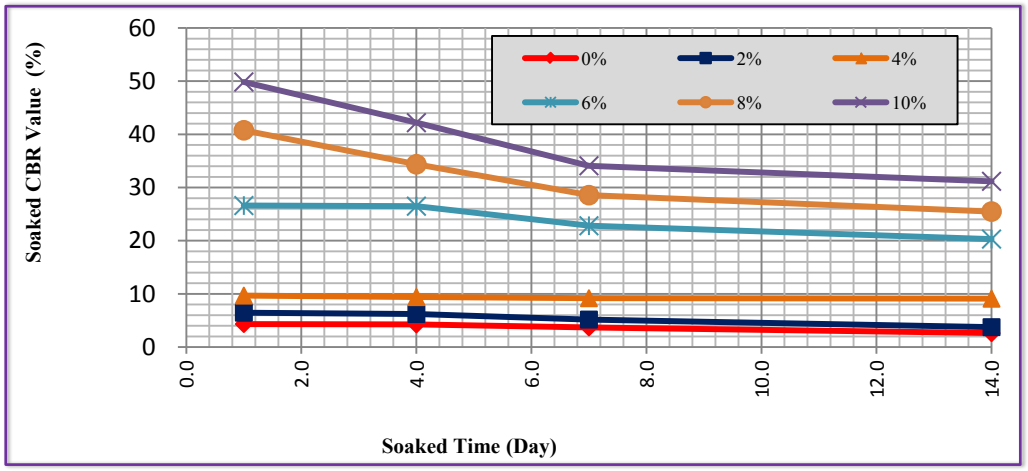


**Figure 3.** Soaked time relationship with the soaked CBR

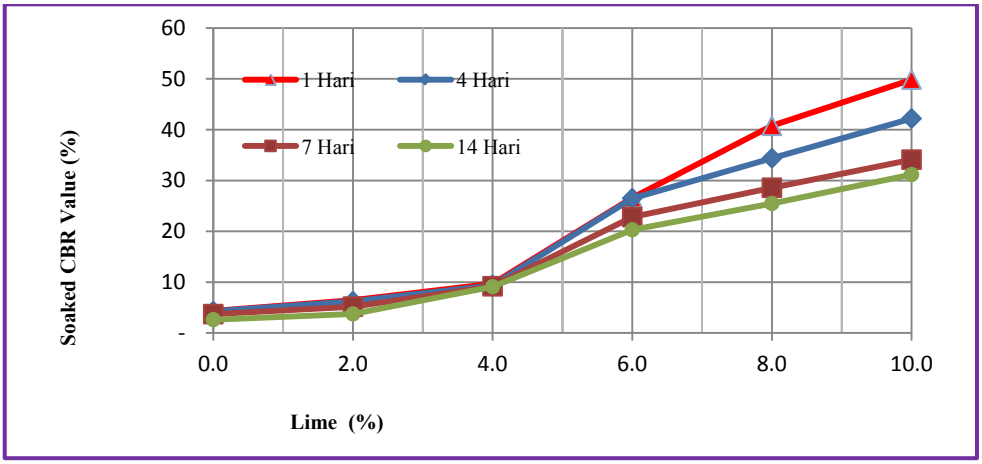


**Figure 4.** Lime relationship with the soaked CBR value

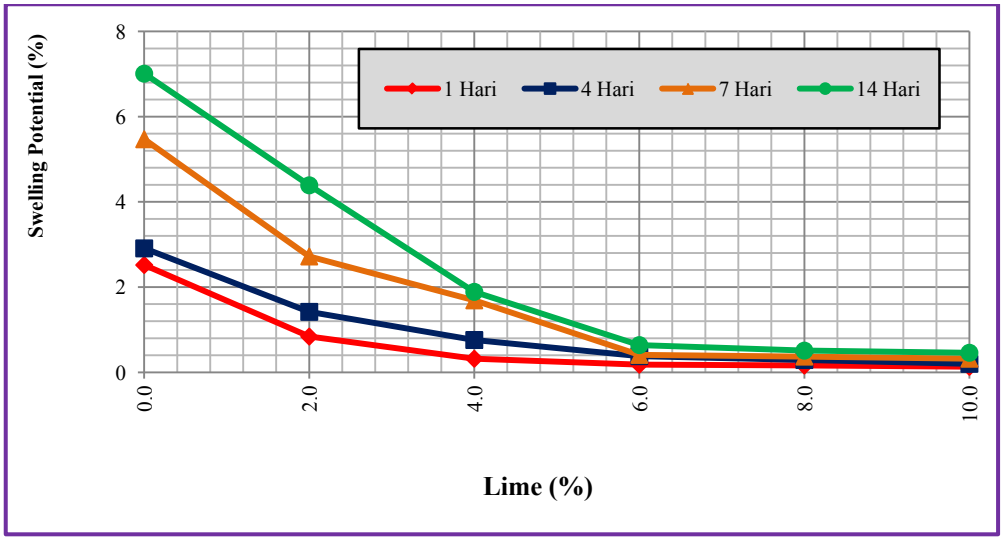


**Figure 5.** Swelling potential relationship with lime (%)

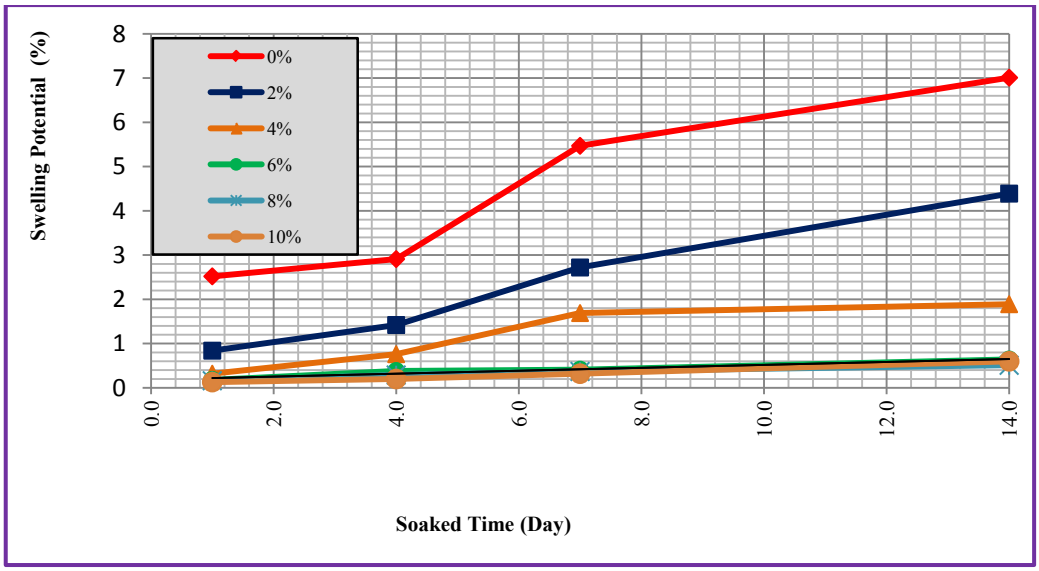


**Figure 6.** Swelling potential relationship with soaked time

### 3.9. Effect of Lime Addition to Soaked CBR and Swelling Potential Value with Standard Proctor

Tests with standard proctor compaction obtained optimum water content obtained 21.00%, so that the water used in the CBR test is 21.00% of the dry weight of the test specimen compaction. Soaked CBR test results can be seen in Table10. From Table 10, it appears that the increase in the percentage of lime as stabilizing agent then increasing CBR values obtained. Based on the percentage variation of the addition of lime on CBR test can be seen that the increase occurred in the CBR value is not too large. The increase in CBR values higher with the addition of lime 4 - 6%, but the value of the standard proctor CBR are still medium categorized according to the bearing capacity of the soil are AASHTO, because the CBR values ranged between 6 - 9% with the addition of 6% lime.

**Table 10.** Results of Testing Soaked CBR with Addition of lime

| Variation of Lime (%) | Nilai CBR rendam (%) | | | |
|---|---|---|---|---|
| | 1 (day) | 4 (day) | 7 (day) | 14 (day) |
| 0% | 4,08 | 3,87 | 3,26 | 2,39 |
| 2% | 4,15 | 4,03 | 3,92 | 3,48 |
| 4% | 5,03 | 4,89 | 4,31 | 4,14 |
| 6% | 6,41 | 6,28 | 6,19 | 6,06 |
| 8% | 6,53 | 6,35 | 6,21 | 6,10 |
| 10% | 6,64 | 6,54 | 6,33 | 6,23 |

The results of swelling potential testing clays in 25 compaction blows with soaking time 1, 4, 7, and 14 days can be seen in Table 11.

Value of the largest swelling occurred in the original soil (lime 0%) soaking time of 14 days is 9.24%, according to Seed et al [3] value of 9.24% swelling potential is between 5-25%, the soil is classified as having the degree of expansion "high". Swelling potential that already reaches 0 - 1.5% is the optimal addition of lime content of 8%, and swelling potential value from 0 to 1.5% by Seed et al [3] have been classified as having a low degree of expansion.

**Table 11.** Relationship with the soaking time with value of swelling potential

| Variation of Lime (%) | Value of swelling potential (%) | | | |
|---|---|---|---|---|
| | 1 (day) | 4 (day) | 7 (day) | 14 (day) |
| 0% | 7,30 | 8,42 | 8,14 | 9,24 |
| 2% | 3,84 | 4,20 | 4,22 | 4,36 |
| 4% | 2.83 | 2,54 | 2,32 | 2,07 |
| 6% | 1,40 | 1,51 | 1,74 | 1,93 |
| 8% | 0,51 | 0,77 | 1,03 | 1,04 |
| 10% | 0,37 | 0,65 | 0,83 | 0,91 |

## 4. Conclusions

Based on the results of testing that has been done a few conclusions can be drawn as follows:

- Soil clay of Tanjung Beringin Langkat, having a plasticity index according to the Unified Soil Classification System (USCS) high, this native land includes land that the CH group with plastic inorganic clays (high plasticity), whereas according to the American of State Highway and Transportation Official (AASHTO) of the soil in the a-group A-7-6, the clay soil is not good or bad, if used as a basic foundation. Once stabilized with lime including the group ML - OL according to USCS and A-7-5 in the group according to AASHTO.
- The results of testing the limits of consistency with the addition of lime 0%, 2%, 4%, 6%, 8% and 10% decline

in the value of the plasticity index, but value increase s liquid limit, shrinkage limit and plastic limit.

- Value of swelling potential with a modified proctor CBR value is higher than the standard proctor because more congested, increasing the value of CBR with the addition of lime content of 4-6% and the addition of 4% lime content of the CBR value already qualified good soil bearing capacity according to AASHTO, because the value of CBR > 9%.
- According to AASHTO, that the CBR value associated with the bearing capacity of between 6 - 9%, but the highest increase in CBR value addition of lime occurs in 4 - 6%.
- Value largest the swelling potential that occurs in native soil (lime 0%) with a soaking time of 14 days is 7.01%, which is the swelling potential is between 5-25%, the soil is classified as has a degree of expansion of "high". Swelling potential value has reached < 1.5% with the addition of lime optimal levels, which is 4% and according to Seed et al (1962) swelling potential value from 0 to 1.5%, the soil has been classified as having degrees low expansion.
- Value of the largest swelling occurred in the original soil (lime 0%) soaking time of 14 days is 9.24%, which is the swelling potential is between 5-25%. This soil is classified as having the degree of expansion "high". Swelling potential that already reaches 0 - 1.5% is the optimal addition of lime content of 8%, and swelling potential value from 0 to 1.5% have been classified as having a low degree of expansion .

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