

# California Bearing Ratio (CBR) test on stabilization of clay with lime addition

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**Abstract.** Clay is a type of soil with particles of certain minerals giving plastic properties when mixed with water. Soil has an important role in a construction, besides as a building material in a wide variety of civil engineering works, soil is also used as supporting foundation of the building. Basic properties of clay are rock-solid in dry and plastic with medium water content. In high water content, clay becomes sticky like (cohesive) and soften. Therefore, clay stabilization is necessary to repair soil's mechanical properties. In this research, lime is use as a stabilizer that contains the  $\text{Ca}^+$  element to bond bigger particles. Lime used is slaked lime  $\text{Ca}(\text{OH})_2$ . Clay used has liquid limitation (LL) value of 47.33%, plasticity index of 29.88% and CBR value 6.29. The results explain about 10% lime mixture variation gives the optimum stabilized clay with CBR value of 8.75%.

## 1. Introduction

Based on particle size, the soil is classified into four classifications that are gravel, sand, silt, and clay. In this final project report use is clay. Das (1994) explained that microscopic and sub microscopic (too small to be seen in an ordinary microscope) particles consist the most in clay. These particles are the plaque and constitute mica, clay and other fine minerals. Clay is one type of soils which often stabilized due to its plastic and cohesive properties when wet. Consequently, there is a change in volume influenced by water content and results in the soil to swelling and shrinkage relatively fast. Stabilization is necessary to repair those properties to increase bearing capacity. Soil stabilization is by mixing soil with lime and water in working site to alter soil properties to become a better material for construction as what is allowed in the planning. Lime reacts with soil water and changes its properties, reduces cohesiveness and softness in the soil. When lime and clay mineral reacts, it forms hard gel known as calcium silicate which binds with soil fine-grains or particles. Silica gel reacts by coating, and binding clay particles then covered the pores in the soil and reduces plasticity index in the soil. Plasticity index reduction is due to the increase of plastic limit and decrease of liquid limit.

Clay has plastic properties which are the ability to adjust shape changes in the soil after it is mixed with water. The soil can be liquid, plastic, semi solid or solid depends on the water content in it. Plasticity index is the difference between liquid and plastic limit in the soil:

$$\text{PI} = \text{LL} - \text{PL}$$

Compaction is a process where the air is removed mechanically from the pores, therefore, particles become solid. If the soil is solidified with varied water content, then in certain water value it will reach maximum density ( $\gamma_d \text{ max}$ ). Water value that gives maximum density is called optimum water content ( $W_{\text{opt}}$ ).



where :  $\gamma_d$  = dry unit weight in field ( $\text{kg}/\text{cm}^3$ )

$\omega$  = water content (%)

$V$  = mould volume ( $\text{cm}^3$ )

$W$  = total soil weight in mould (kg)

Sub grade strength depends on the water content in which the higher it is, the smaller the CBR value. Nevertheless, this does not mean that sub grade is solidified better with low water content because of its instability. If resistance is given to the soil, water is absorbed into the soil and decreases CBR value until a constant water level is reached which is known as balanced water content.

## 2. Material and Methods

- Clay used in the research is obtained from PTPN II, Patumbak Deli Serdang. The soil here is often used as piled soil in road construction, Binjai - Tebing Tinggi highway for instance.
- Lime used as the stabilizer is slaked lime with the composition shown in Table 2.1. Slaked lime,  $\text{CaO}$ , is a white amorphous material. During storing,  $\text{CaO}$  transforms slowly to a white powder which is  $\text{Ca}(\text{OH})_2$  because it reacts with water vapour in the air.

**Table 1.** Lime chemical composition

No.	Parameter	Result
1.	Silicon ( $\text{SiO}_2$ )	3.03 %
2.	Aluminium ( $\text{Al}_2\text{O}_3$ )	1.53 %
2.	Iron ( $\text{Fe}_2\text{O}_3$ )	0.54 %
3.	Calcium ( $\text{CaO}$ )	51.8 %
4.	Magnesium ( $\text{MgO}$ )	0.81 %

Source: Laboratory of Research and Industrial Standard Center North Sumatera

The research method used is the experimental method in Soil Mechanics Laboratory, Civil Engineering Department University of Sumatera Utara. Observation is done by using two samples; soil and soil with lime addition.

There are 21 samples in total, where one is soil and 20 are the varied mixture of soil with 1 until 20% lime addition.

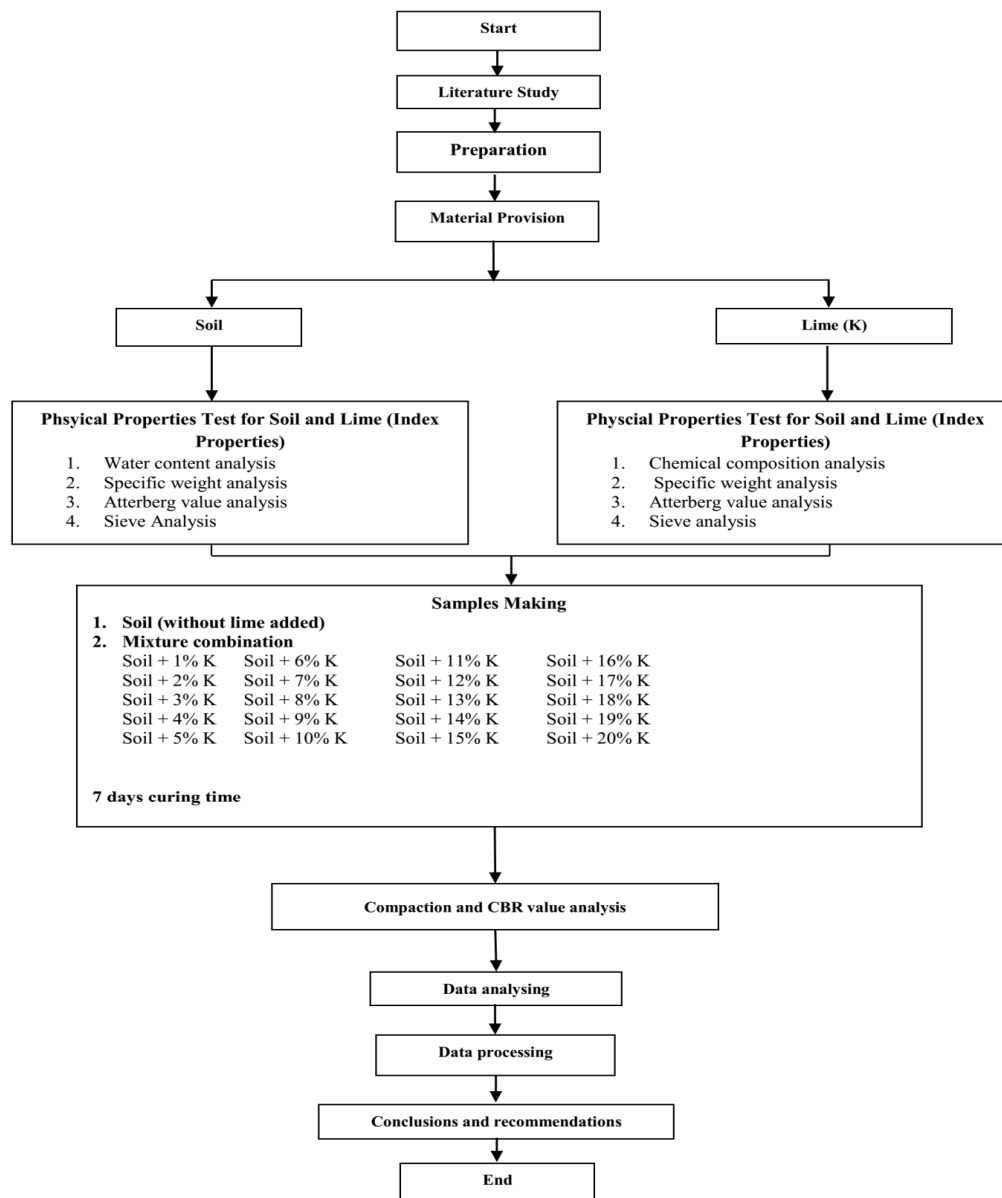
Testing conducted includes:

1. Soil index properties, includes water content, density, Atterberg value (consistency limit) and grain size distribution or sieve analysis.
2. Slaked lime index properties, include chemical composition, density, Atterberg value (consistency limit) and grain size distribution or sieve analysis.
3. Proctor Standard test to determine the optimal water content and maximum dry density.
4. A laboratory test for Proctor Standard and CBR analysis.
5. Curing time for seven days to each sample to get a homogenized mixture.

Total sample used in the research can be seen in **Table 2**.

**Table 2.** Total Sample

No	Testing	Soil	Lime Addition	Total Samples
1	Index Properties	1	20	21
2	Proctor Standard	1	20	21
3	CBR	1	20	21



**Figure 1.** Flowchart Research

### 3. Results and Discussions

#### 3.1 Soil Analysis

Physical properties tests for soil are shown in **Table 3**.

<b>Table 3.</b> Soil Physical Tests Data		
No.	TEST	RESULT
1	Water Content	34.33%
2	Specific Gravity	2.65
3	Liquid Limit	47.33%
4	Plastic Limit	17.45%
5	Plasticity Index	29.88%
6	Sieve Analysis	48.81%
7	Optimum Moisture Content	21.12%
8	Maximum Dry Density	1.340 gr/cm <sup>3</sup>

#### 3.2 Stabilizer Analysis

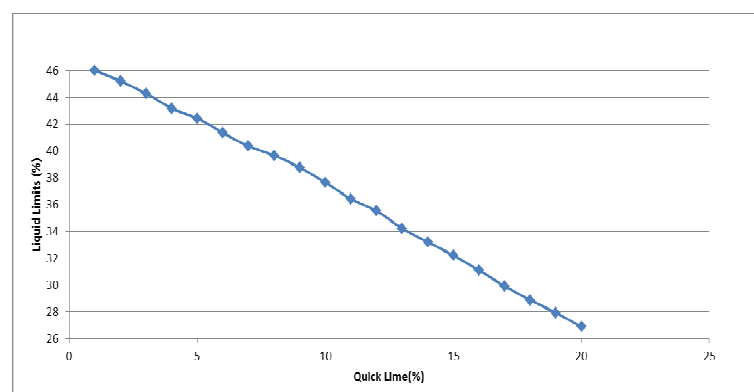
Physical properties tests for lime are shown in **Table 4**.

**Table 4.** Lime Index Properties Data

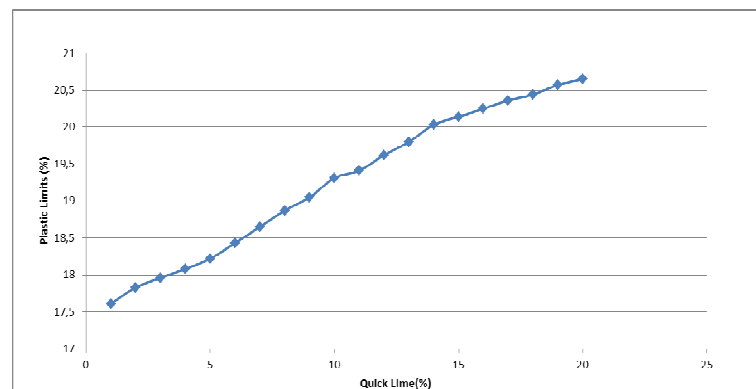
No.	TEST	RESULT
1	Specific Gravity	2.59
2	Liquid Limit	
3	Plastic Limit	Non Plastic
4	Plasticity Index	
5	Sieve Analysis	30.05%

#### 3.3 Physical Properties and Mechanic Tests for Soil with Stabilizer

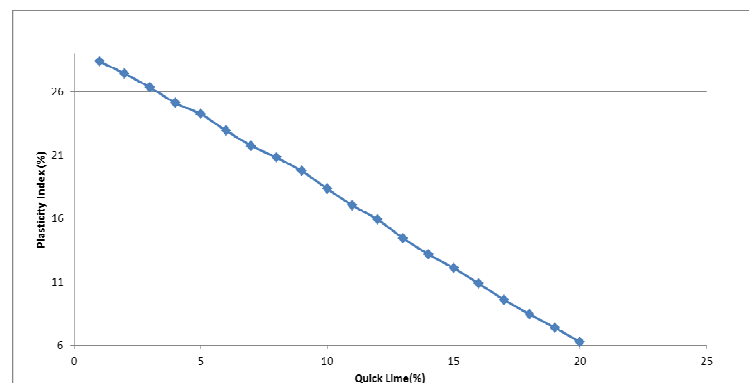
Test results for physical properties and mechanic test for soil combined with lime as stabilizer are shown in the graphs below.



**Figure 2.** Liquid Limit (LL) versus Lime Variation Graph



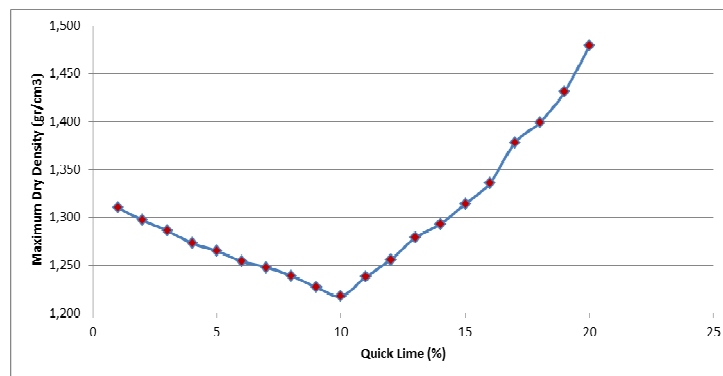
**Figure 3.** Plastic Limit versus Lime Variation Graph



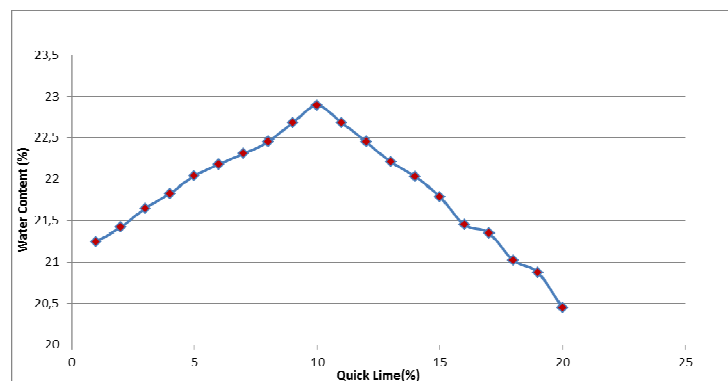
**Figure 4.** Plasticity Index versus Lime Variation of 1 – 20% in 7 Days Curing Time Graph

In **Figure 2** it is shown that due to lime stabilizer addition, liquid limitation decreases. The bigger the percentage of lime, the lower liquid limitation becomes. In soil, liquid limitation reaches 47.33% whereas the lowest value is 20% K mixture variation with seven days curing time, which is 26.87% and this is because soil underwent lime cementation process where soil becomes bigger grain that decreases attraction force between particles. **Figure 3** shows increases in plastic limitation due to lime addition. For soil, the plastic limitation is 17.45% and keeps on increasing until the highest value is shown with 20% K addition at 20.65%.

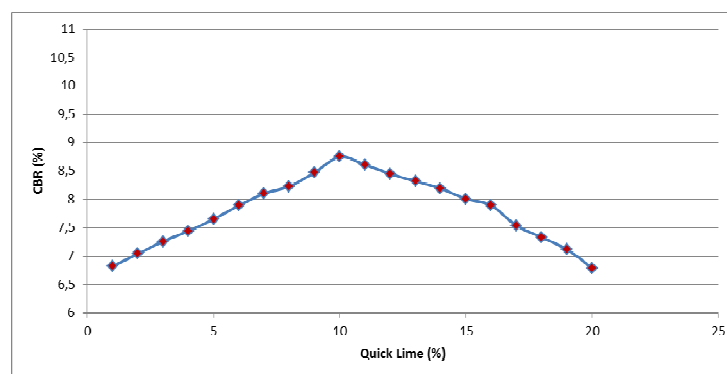
**Figure 4** shows the decreasing plasticity index due to lime addition. The decrease can reduce soil swelling and shrinking potential. This is due to hydration process in lime added to the soil. These processes strengthen bonds between particles in the soil, which forms bigger and more stable grains. With pores filled, it reduces the risk of seepage in soil-lime mixture that affects the swelling and shrinking potential. Silicate and alumina in lime combined with water to form the paste that binds clay particles and covered the pores. Pores cavity surrounded by water-penetration-proof cementation material makes the mixture last longer towards water absorption and therefore reduces its plastic properties. With the addition of lime, plasticity index keeps decreasing from 29.88% to its lowest point, 6.22% at 20% K mixture at seven days curing time.



**Figure 5.** Soil  $\gamma_{dmax}$  versus 1 – 20% Lime Variation at seven days curing time



**Figure 6.**  $w_{opt}$  versus 1 – 20% Lime variation at seven days curing time



**Figure 7.** CBR Value versus 1 – 20% lime variation at seven days curing time

In **Figure 5** it can be seen that dry unit weight decreases with lime added, where 10% lime it gives the lowest value 1.218 g/cm<sup>3</sup>. Then the value increases afterward with more lime added. The optimum water content in research done in soil is 34.33%, and it increases after lime is added. **Figure 6** shows optimum water content when reaching the maximum dry unit weight and decreases when passing maximum dry unit weight. The graph in figure 3.6 above shows the highest CBR value obtained was at 10% K variation, which is 8.75%. But with further addition, CBR value decreases and this is because soil weight volume reduced because pores are filled with lime mixture. Consequently, penetration reduces in CBR test.

#### 4. Conclusions

The result shows:

1. Based on USCS classification, the soil sample is considered as CL (Clay-Low Plasticity) which is inorganic clay with low to medium plasticity.
2. Based on AASHTO classification, the soil is considered as a type of A-7-6.
3. Water content analysis gives the water content in soil, which is 34.33%.
4. Specific gravity test shows soil specific weight is 2.65 and that of lime is 2.59.
5. Atterberg value analysis for soil gives liquid limitation (LL) and plasticity index at 47.33% and 29.88% respectively. It is then known:
  - With 20% K added gives the lowest plasticity index (PI), 6.22% with liquid limitation value is 26.87%.
6. Proctor standard test gives soil optimum content at 21.12% and maximum dry unit weight at 1.340 g/cm<sup>3</sup>, whereas maximum dry unit weight for all mixture is:
  - At 10% variation, dry unit weight is 1.218 g/cm<sup>3</sup> and optimum water content is 22.89%.
7. Laboratory CBR value test done gives the highest value for soil is at 6.29%. From the research done the highest CBR value is:
  - At 10% K variation, which gives 8.75
8. From the result at no. 7 above, it can be concluded that 10% K variation gives the most stabilized clay.

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