Lime–Clay Stabilization to Modified the Characteristic of Mechanical Properties and Reduce the Swelling Sub grade

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Abstract

Subgrade is basement soil of a road. The aim of this study was to determine the characteristics of the soil and the effect caused by a mixture of the lime as a stabilizing agent toward the improvement of the mechanical properties of subgrde. The lime mixture can increase the bearing capacity of soil and the California Bearing Ratio (CBR) value, so it can be used as road subgrade material.Soil material for the research taken from Glee–Genteng quarry, Aceh Besar District. The material from this quarry, known as Glee–Genteng Clay is one of the wrong material embankment used as road preparation subgrade. Roads construction used soil from this quarry as subgrade had experienced many damages in many places around Aceh Besar. Than, this study was to determine the effect of a mixture of extinguished lime as a stabilizing agent of expansive clay soil toward mechanical properties improvement to reduce the swelling. The method used was a laboratory test according to several American Standard for Testing mAterial (ASTM).The results of the study from natural soil where compacted at Optimum Moisture Content (OMC), it was swelling soaked value of 5.0%. The test results after stabilization witha mixture of lime 3%, 6%, 9% and 12%,the swelling soaked value was reduced respectively rounding of 3.00%, 2.00%, 1.50%and0.87%.

Keywords:*Lime stabilization,Plasticity Index,Moisture Content,Swelling Subgrade.*

Introduction

Krebs (2002), subgrade importantto structural design and pavement life of road. Sub–grade quality is very important in planning a road construction because it can determine the thickness of road pavement. Department of Public Works has determined a limit value for the strength of CBR (California bearing ratio) for sub–grade of at least CBR=6%. Sub–grade my *consist* of materials in excavations(*cut*)orembankments (*fill*), as show in Figure 1.

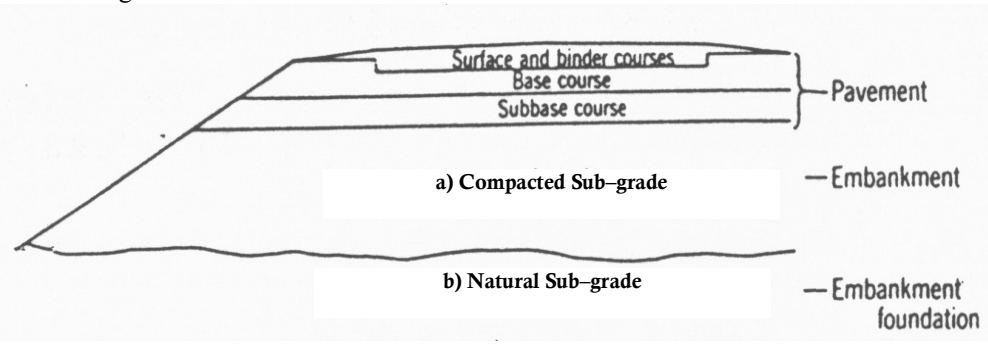

Figure 1. Type of embankment sub–grades, a) natural sub–grade and b) compacted sub–grade

The soil that was the object of this study was the soil taken from Glee Geunteng hill, Beraden,Aceh Besar District, is one of the embankment material used as road sub–grade. This material is commonly used in the construction of village and housing complexes roads around Banda Aceh City.

Currently, the constraints of limited knowledge, human sources, and the results about road pavement are starting to be used to embank the District, Provincial and National roads.After it was studied, the type of soil in the site is very sensitive to the effects ofmoisture content changes, causing weak bearing capacity that

can damage the road construction on it. From the characteristics of the physical nature, the soil is classified to expansive clay soil based on the ASTM criteria. Expansive soil has a quite large surface area and it is very easy to absorb and store water in large quantities. Therefore, this type of soil is considered inappropvalue used as road sub–grade because it has a high plasticity index and swelling.From the characteristics of the physical nature, the soil is classified to expansive clay soil based on the ASTM criteria. Expansive soil has a quite large surface area and it is very easy to absorb and store water in large quantities. Therefore, this type of soil is considered inappropvalue used as road natural sub–grade also embankment sub–grade because it has a high plasticity index and swelling.

Based on these problems, the authors conducted a research about Glee Geunteng's clay soilstabilization with the addition of a mixture of $Ca(OH)_2$ lime. The aim of this study was to determine the characteristics of the soil and the effect caused by a mixture of the lime as a stabilizing agent toward the improvement of the physical and mechanical properties. The lime mixture can increase the bearing capacity of soil and the CBR value, so it can be used as road sub–grade material.

Bowles (1993), stated that a soil must be stabilized if the soil is very loose or very easily depressed on the field, or it has an inappropriate consistency index, and its permeability is too high, or other undesirable properties. The stabilization can be one of the following actions, are; increasing the soil density, adding an inactive material to increase soil shear strength, adding materials to cause chemical and physical changes in the soil, lowering the soil water level and replacing the poor soil.

Characteristics of clay soil

Hold and Kovacs (1981) stated that a clay soil can be defined as a collection of mineral particles that has a plasticity index according to the above Atterberg limit that when it dries to form a unified mass that required force to specific surface value each microscopic grain. Usually a clay soil can be expected to have a large (expansive) volume change if the plasticity index IP $\geq$ 20. Concluded that the content of clay minerals, as show in Table 1, all the minerals have suction and bonding behaviors of ions in double diffuse systemas show in Figure 2.

Table 1. Physical properties of clay minerlogy.

Mineral of clay	Activity (A)	Thickness (ή m)	Diameter (ή m)	Specific Surface (km^2/kg)
Montmorillonite	1 – 7	3	100–1000	0.8
Illite	0.5 – 1	30	10000	0.08
Chlorite	0.5	30	10000	0.08
Kaolinite	0.5	50–4000	300–4000	0.015

Hold and Kovacs, (1981)

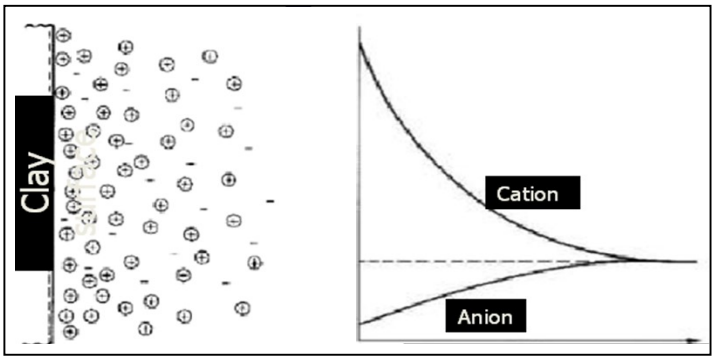

Figure2. Interaction between clay and ion of the water Physical properties of aggregate

One of the soil strength properties associated with the roadway is the strength of California Bearing Ratio (CBR) value which obtained from laboratory tested and graph of CBR as show in Figure 3. Inless and Metcalf (1992), when the lime reacts with clay minerals, it will form a strong and hard gel that is called silicate calcium that binds the soil grains or particles. Silica gels react by immediately coat and bind clay particles and close the pores of the soil in order to minimize soil plasticity index. Impairment of plasticity index is caused by the increacing of plastic limit value and is accompanied by a decrease in liquid limit**.**

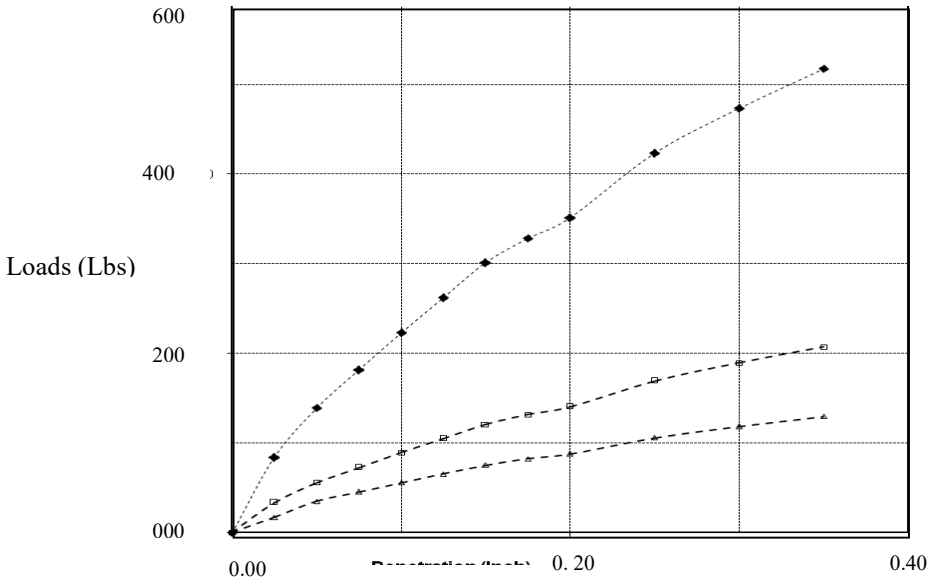

Figure3. CBR Laboratory value and load–penetration relationships

The use of lime as stabilization material can cause a weak ion exchange of sodium by calcium ions that are on the surface of the clay, so the percentage of fine particles tend to become coarse particles. Ion exchange reaction, namely clay particle in the soil content is finely shaped and negatively charged. Positive ions such as hydrogen ions (H+), sodium ions (Na+), calcium ions (K+), as well as polarized water, all attached to the surface of the soil particle, as show in Figure 2 above.

California bearing ratio

Wesley (1977), California Bearing Ratio (CBR) testing is an empirical method for assessing soil deformation on bearing. CBR is a penetrating measuring instrument that, a standard piston, the widht of its end region is 3 inches^2. It is penetration valued into the soil at a speed of 0.05 inches/minute. CBR calculated value on the penetration value of 0.1 inches and 0.2 inches by dividing the load on each penetration, with a load of3000 pounds and4500 pounds. This load is the standard load obtained from experiments on crushed stonein California that has CBR 100%(Wesley, 1977).

According to Sukirman (1999), the CBR value used is the largest CBR value in the penetration of0.1 or 0.2 inches. To calculate the CBR value on the penetration of 0.1 inches and 0.2inches, the following equation is (1) and (2) used.

$$CBR_{0,1} = \frac{Bearing value\ on\ 0,1\ inches}{3000\ lb} \times 100\% \quad \text{.....(1)}$$

$$CBR_{0,2} = \frac{Bearing value\ on\ 0,2\ inches}{4500\ lb} \times 100\% \quad \text{.....(2)}$$

According to Ismail (1995), the swelling value of the soil is calculated by the following equation (3):

$$\text{Swelling value} = \frac{S_i - S_0}{H} \times 100\% \quad \text{.....(3)}$$

where:

S_i : dial read figure after soaked;
S_0 : dial read figure before soaked;
H : high of soil samples.

Methods

Compaction testing is a way to get the optimum moisture content and maximum dry volume weight. The compaction testing was conducted by using the standard Proctor based on ASTM D 698–70.CBR is a comparison between test load and standard load and expressed in percentage.The testing was conducted

according to procedure defined by ASTM D 1883–73. CBR testingwas conducted in two conditions, the unsoaked and 4 (days) soaked soil. The equipment of CBR laboratory and its related test in this research, as show in Figure 4.

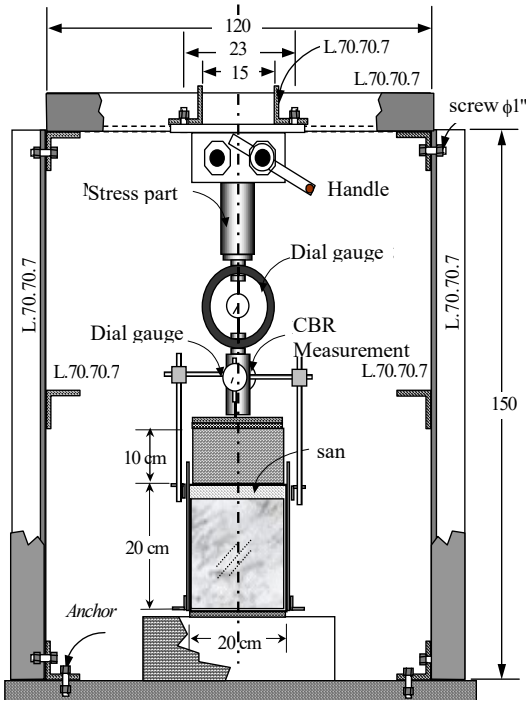

Figure 4. CBR laboratory equipment

Laboratory CBR test result needs heavy equipment to be applied in the site. The clay soil which is needed to be treated by lime is spread along the sub–grade line. Furthermore, the additive lime is mixed with the clay soil with mixer truck as shown in Figure 5 and then compacted with compactor roller.

Figure 5. Sub–grade In–situ Lime Mixing Method

CBR is a comparison between test load and standard load and expressed in percentage.CBR testingwas conducted in two conditions, the unsoaked and 4 (days) soaked soil.The testing was conducted according to procedure defined by ASTM D 1883–73.

Results and Discussion

The effect of lime addition on soil physical propertiestesting of lime mixture in Glee Geunteng's clay, as show in Table 2.

Lime effect to specific gravity

Kezdi (1979), stated that the mixing of soil and lime will produce accumulation that glue among particles, pore cavities which exist will be partially surrounded by sedimentation material that is harder and impermeable to pass by water. The pore cavity insulated by impermeable sedimentation layer will be

measured as the volume of grain that increasing the volume of grain and reduce the specific weight of the mixture soil. The reduction of the mixture soil's specific gravity as shown in Figure 6.

Chen (1975), revealed a decrease in the liquid limit and the plastic limit caused by the strong Ca+ ions from lime interchage with weak positive sodium ions on the surface of the particles. This change makes the balance of ion particles become better, so that it decreases the level of water absorption. The addition of Ca+ ions also increases the ion density that creates the particle capacity become smaller.

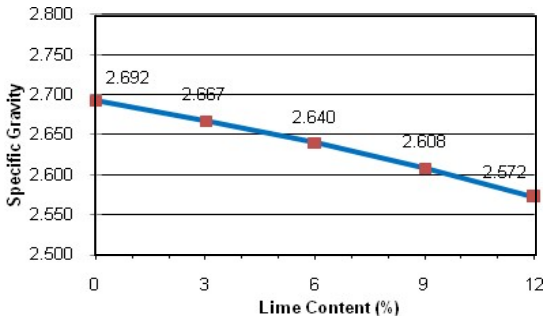

Figure 6. Correlation between Soil Specific Gravity and Level of Lime

Based on the results of Atterberg limits in Table 2 above, it showed that the liquid limit tends to decrease with the increasing lime percentage from 84.2% to 72.2%, while for the plastic limit tends to increase with the increasing lime percentage from 27.3% to 30.0%. From the change of the liquid limit and the plastic limit, so the plasticity index reduced from 56.9% to 42.2%, the correllation can be seen in Figure 7.

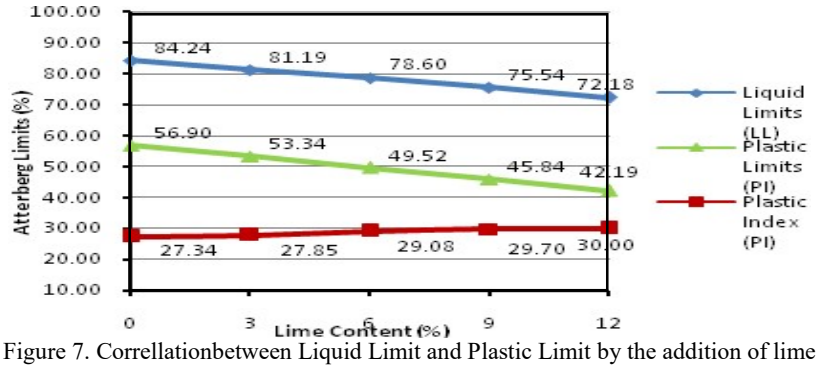

Figure 7. Correllationbetween Liquid Limit and Plastic Limit by the addition of lime

The effect of lime addition toward the soil mechanical properties

Results of the mechanical properties testing of a mixture of Glee Geunteng's clay and lime, as show in Table 2.Soil compaction test results are as shown in Table 2, the maximum dry weight (MDD) showed an increasedvalue from 31.13 g/cm^{3}to 25.63 g/m^3. While the optimum moisture content (OMC) showed a decreased valuefrom 1.295% to 1.606%. This is because the lime mixed in the Glee Geunteng's soil can increase the bearing capacity or increasing inter granular holding ability among the particles. In addition existing pore cavities, it will be partially surrounded by harder cementation thereby reducing clay particle that binds water, so the moisture content in the soil will decrease. The results of unsoaked CBR has increased from 4.93% to 18.48%, and results of soaked CBR test also increased from 3.09% to 10.43%. At the optimum moisture content, water can have a function as a lubricant so that the composition of the grain is better, the grain filling each content, easily solidified which will increase the soil density.

Table 2. Results of the mechanical properties of lime soil mixture testing

Testing Parameter	Original soil	Soil Mixture + Lime Variations			
		3%	6%	9%	12%
Compaction					
– MDD	31.13	29.88	27.38	26.29	25.63
– OMC	1.29	1.34	1.44	1.52	1.61
CBR Value					
– Un–soaked	4.93	9.59	14.85	17.06	18.48
– Soaked	3.09	5.11	7.52	8.97	10.43
– Swelling	5.01	3.05	2.21	1.49	0.87

CBRresult from stabilization

Increasing the soaked CBR value was not as many as increase in unsoaked CBR value because the soil had been soaked in saturated condition for 4 days. While the swelling value reduced from5.0 % to 0.9%.As shows in Figure 8, the trend of an increase in the CBR value along with the addition of lime.The increasing of unsoaked CBR or soaked CBR value is caused by the cementation due to the addition of lime.

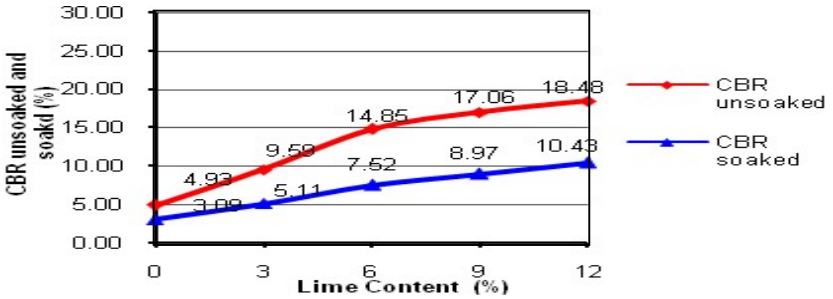

Figure 8. Correlation between CBR value wih the addition of lime

The increasing of binding ability among the grains, it will increase the ability of the interlocking among the grains. In addition, the existing pore cavities partly will be surrounded by harder cementation material, so that increasing of CBR value is influenced by the soil density, it can be said that the more increase the density, the CBR value will also increase.

Krebs and Walker (1971), described the reaction that led to the increasing soil strength effect that is expected due to an environment of high alkaline soil particles, so that it forces calcium ions, causing severe flocculation.

Conclusions

It can be concluded that the addition of lime in expansive clay soil can increase the bearing capacity, reduce the plasticity index and swelling. Thus, the lime as a stabilizing agent may modified the characteristics of the physical and mechanical properties of the soil that qualifies as a sub–grade material. The addition of lime mix of the best in this soil is 12%. The result of the stabilization of expansive clay Glee Geunteng with a mixture of lime can meet the requirements of CBR sub–grade of at least 6 % .

The addition of lime in this expansive Glee Geunteng clay caused a chemical reaction between lime and silica in the clay that is called *Pozzolanic* reaction. This reaction will lead to the unification and hardening, thereby increasing the soil strength characteristics and the CBR value. The formation of cementation in the structure of Glee Geunteng clay will prevent the absorption of water thus decreasing the plasticity index (PI) of soil, and reducing swelling value from 5.01% before stabilization to 0.87% after stabilization of 12% lime.

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