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Improvement of California Bearing Ratio (CBR) Value of Clay Soil in Limau Manis Area, Padang by Using Lime and Rice Husk Ash

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Abstract

Clay soil is known for its low bearing capacity, causing cracking or even collapse in construction. Soil improvement is needed before embanking into building on this type of soil. Methods to increase the bearing capacity of clay soil include compacting the soil or mixing it with additive materials that can improve soil properties. This study aimed to analyze the CBR value of clay soil in the Limau Manis hilly area, Padang City, with the addition of 5% lime and 2%, 4%, 6%, and 8% rice husk ash (RHA). The type of the soil is Organic Silt and Silty Clay (OL). This study conducted physical and mechanical properties of soil testing, i.e. sieve analysis, specific gravity, plastic limit, liquid limit, and CBR value. The results showed that adding 5% lime increased the CBR values of 0-day and 7-day cured soil, both in soaked and unsoaked conditions. The CBR value of the soaked and unsoaked 0-day cured soil sample increased by 189% and 168% respectively, while the CBR value of the soaked and unsoaked 7-day cured soil sample increased by 259% and 215% respectively. However, the addition of rice husk ash decreased the CBR value.

Keywords
Clay Soil, CBR, Lime, Rice Husk Ash

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INTRODUCTION

Around 20 million hectares or more than 10% of the land area in Indonesia is soft soil consisting of soft clay and peat soil. Soft clay soil in Indonesia is spread along the north coast of Java Island, Sumatra Island, and the west, south, and east coasts of Kalimantan Island. One of the areas with this soft clay soil is the Limau Manis area, in Pauh District, Padang City, which is the location of 2 large campuses, namely Universitas Andalas University and Politeknik Negeri Padang. This area is a rapidly developing area, infrastructure development in the form of roads and buildings continues to take place.

Soil is an important part of construction such as buildings and roads because it functions as the main supporting part[1]. This function requires soil with good bearing capacity. For soil with low bearing capacity, soil improvement or soil stabilization can be carried out [2][3][4].

Clay soil is known for low bearing capacity, causing cracking or even collapse in construction. Low bearing capacity can cause instability of a building foundation built on this type of soil. The shrinkage and expansion properties of clay soil can cause cracks in highway pavements, and also ruptures or breaks in the base of dams. The low bearing capacity of clay soil can be seen from its low California Bearing Ratio (CBR) value [5]. The shear strength of the base soil and CBR value of the soil have a major influence on the planning of a construction structure [6]. For this reason, soil with disadvantage properties such as clay soil needs to be improved in terms of stability, including by increasing its CBR value.

Utilization of various improvement methods for soft soil particularly soft clay is used in a wide range [7]. Methods to increase the bearing capacity of clay soil include compacting the soil or mixing it with additive materials that can improve soil properties. One of the additive materials that can be used in soil stabilization is rice husk ash [8].

In Indonesia, rice is a staple food source for Indonesians. The part of rice that is underutilized and tends to only become waste is rice husks. Therefore, the utilization of rice husks will also be an effort to reduce environmental waste. To utilize rice husks in soil stabilization, rice husks must first be converted into ash [8]. In addition to rice husk ash, chemical substances in the form of lime are also often studied for their effects on soil stability [9].

This study aimed to analyze the CBR value of clay soil with the addition of lime and rice husk ash (RHA). The soil studied was soil sample from the Limau Manis hilly area, in Pauh District, Padang City. The test was carried out using disturbed soil sample, performed at the Soil Mechanics Laboratory of Universitas Andalas. The study was conducted by analyzing the CBR of this clay soil with the addition of 5% lime, and 2%, 4%, 6%, and 8% rice husk ash.

California Bearing Ratio (CBR) Test

California Bearing Ratio (CBR) is a comparison between the penetration load of a type of material and the standard load at the same depth and penetration speed [10]. CBR, expressed as a percentage, is the ratio of force required to penetrate a soil mass with a standard circular piston to a specific depth at the rate of 1.25 mm/min, to the corresponding force required to penetrate a standard material [11]. The CBR test is one of the most common methods used to assess soil stability, especially on clay soil. The purpose of the CBR test is to determine the value of the soil bearing capacity in maximum density, compare different soil types, and design the thickness of the road pavement [12][13].

The higher the CBR value, the thinner the pavement layer above it will be, conversely, the lower the CBR value, the thicker the pavement will be. The following is the classification of CBR value [14].

Table 1. Soil classification based on CBR value

CBR %	Level	Objective
0 -3	*Very poor*	*Subgrade*
3-7	*Poor to fair*	*Subgrade*
7-20	*Fair*	*Subbase*
20-50	*Good*	*Base or subbase*
>50	*Excellent*	*Base*

CBR testing is divided into 2 conditions [10]:

1. Soaked Design CBR: a CBR test that represents the soil in its worst condition, conducted by soaking the soil sample for at least 4 days before testing
2. Unsoaked Design CBR: a CBR test that represents the soil in normal field condition. The test is carried out directly after compaction.

RESEARCH METHODS

Research Location

The sample of soil studied was taken from the Limau Manis hilly area, in Pauh District, Padang City. The physical properties tests of the original soil and the CBR test on all soil samples were conducted at the Soil Mechanics Laboratory of Universitas Andalas.

Soil Sampling

The disturbed soil sample was taken by initially cleaning the soil surface from grass, then the soil was dug 20 cm from the top surface. The soil sample was then dried to saturated surface-dry (SSD) condition.

Figure 1. Soil sampling

Sample Mixing

Sample mixing was conducted in the Soil Mechanics Laboratory by mixing the original soil sample with stabilization material in a test box. The number of test boxes was in accordance with the planned mixture variation.

Table 2. Composition of the specimen mixture

Composition		
Soil (%)	**Lime (%)**	**Rice Husk Ash (%)**
100	0	0
95	5	0
93	5	2
91	5	4
89	5	6
87	5	8

Physical Properties Tests

Physical properties tests were carried out on the original soil samples. The tests include sieve analysis, moisture content (w), specific gravity (Gs), liquid limit (LL), plastic limit (PL), and plasticity index (PI) tests. These tests are needed as a reference in viewing and analyzing changes that occur in soil properties, both physical and mechanical (CBR). The tests procedure is shown in Figure 2, Figure 3, Figure 4, and Figure 5.

Figure 2. Sieve analysis test

Figure 3. Moisture content test

Figure 4. Specific gravity test

Figure 5. Liquid limit and plastic limit test

Laboratory CBR Test

Laboratory CBR test aimed to determine the CBR value of the soil when it is obtained and tested in the laboratory, then compare the penetration load of the soil with the penetration load of standard materials. This method was used to evaluate the quality of the base soil. The strength of a particular base soil depends largely on its moisture content. The initial moisture content in this CBR test was taken from the optimum moisture content in the compaction test. CBR value is usually applied in the planning of road pavement systems, in order to find the bearing capacity of the base soil. The soil used was surface soil because it is the part of the soil that is directly related to the pavement or that supports the load of the structure above.

CBR tests were performed on the same day as the sample mixing (0-day cured) and 7 days after (7-day cured) to observe the effect of the curing period on CBR value. Curing period is one of the most important influential factors of soil stabilization [15]. Curing the sample is a way to obtain stabilized soil sample with higher shear strength. Previous study showed that 7 days of curing was enough to start immediate reactions between soil and stabilization materials [16].

The CBR testing steps are as follows [10]:

1. Preparation of equipment and materials:
   a. Cylindrical CBR mold
   b. Compaction tool
   c. Water content measuring instrument
   d. Load and penetration measuring instrument
   e. Soil sample
2. Preparation of test sample:
   a. Take a representative soil sample from the site.
   b. Mix the soil with water until it reaches the optimum moisture content (OMC).
   c. Put the soil that has been mixed with water into the CBR mold and compact it according to the specified standards.
3. Determination of wet mass and moisture content of test sample:
   a. Weigh the CBR mold containing wet soil.
   b. Take a soil sample from the mold and test the moisture content.
   c. Calculate the dry mass of soil using the formula: Dry mass = Wet mass - (Moisture content x Wet mass)
4. Soaking: For soaked condition, soak the CBR mold containing soil in water for 4 days.
5. Penetration test:
   a. After soaking, place the CBR mold on the penetration testing machine.
   b. Apply penetration load gradually at a rate of 1.27 mm/min.
   c. Record the load and penetration at each specified interval.
6. Depiction of relationship curve between load and penetration: Plot the relationship curve between load and penetration on a semi-logarithmic graph.
7. Determination of CBR value: Read the CBR value on the relationship curve between load and penetration at a penetration of 2.54 mm.

The CBR test procedure is shown in Figure 6.

Figure 6. CBR test at the laboratory

The CBR value is determined by using CBR formula:

$$CBR = \frac{PT}{PS} \times 100 \quad (1)$$

where PT is corrected test load corresponding to the specified penetration, and PS is standard load for the same penetration [17].

RESULTS AND DISCUSSION

Physical Properties of the Original Soil

The result of the original soil physical properties tests is presented in Table 3.

Table 3. Original Soil Physical Properties

Test	Unit	Result
ɔisture Content (w)	(%)	55,775
ecific Gravity (Gs)	-	2,634
ɿuid Limit (LL)	(%)	48,952
ıstic Limit (PL)	(%)	39,265
ısticity Index (PI)	(%)	9,687

Based on the tests result above, a USCS soil classification graph can be drawn as shown in Figure 7 [1].

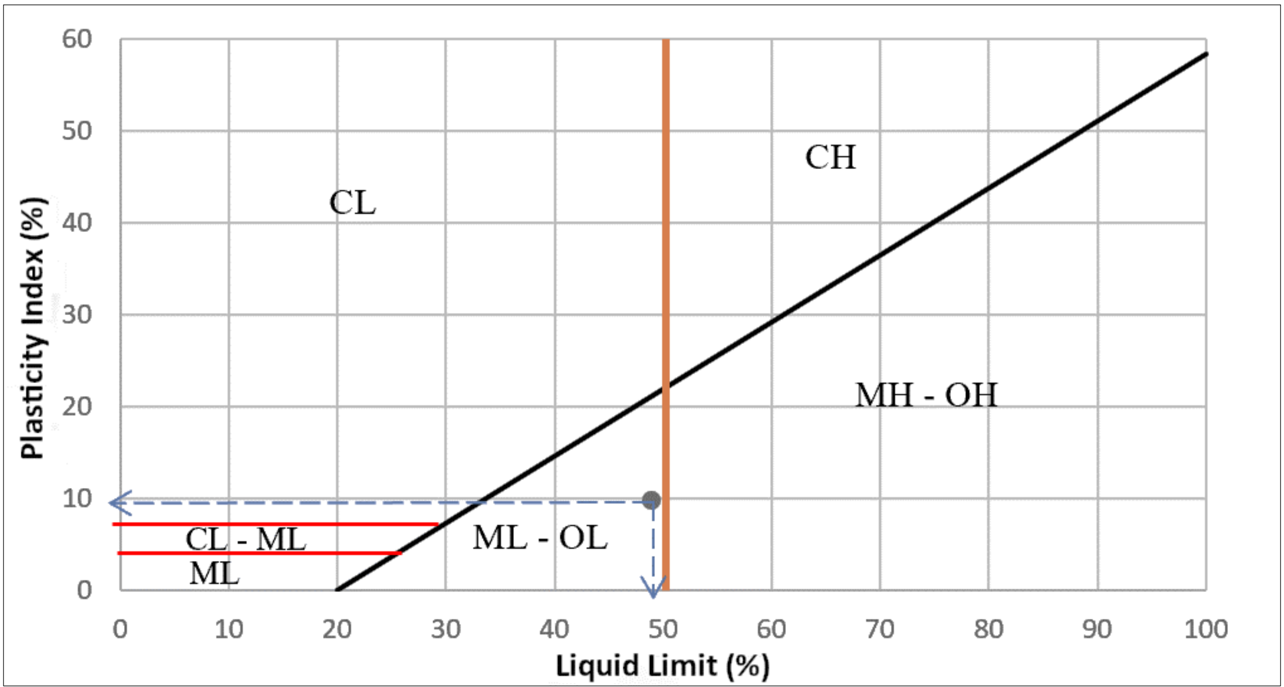

Figure 7. Soil classification based on USCS

From the graph of soil classification, it can be concluded that the original soil at the study location is classified in the ML - OL classification [1]. The type of soil is Organic Silt and Silty Clay [18].

CBR Value Calculation

CBR testing is divided into 0-day and 7-day cured soil samples, both in soaked and unsoaked conditions. The results of the 0-day cured soaked and unsoaked CBR test for soil with additional lime and rice husk ash (RHA) can be seen in Table 4.

Table 4. CBR value of 0-day cured soil

	Original Soil	Soil + 5% Lime	Soil + Lime 5% + RHA2%	Soil + Lime 5% + RHA4%	Soil + Lime 5% + RHA 6%	Soil + Lime 5% + RHA 8%
CBR 0-day Soaked	10.723	30.94	20.42	15.369	10.482	10.124
Increase Percentage		189%	90%	43%	-2%	-6%
CBR 0-day Unsoaked	12.272	32.942	31.675	18.092	12.055	11.948
Increase Percentage		168%	158%	47%	-2%	-3%

The results of CBR testing in soaked and unsoaked conditions of 0-day cured soil had almost the same graph pattern. The comparison of soaked and unsoaked CBR values is shown in Figure 8.

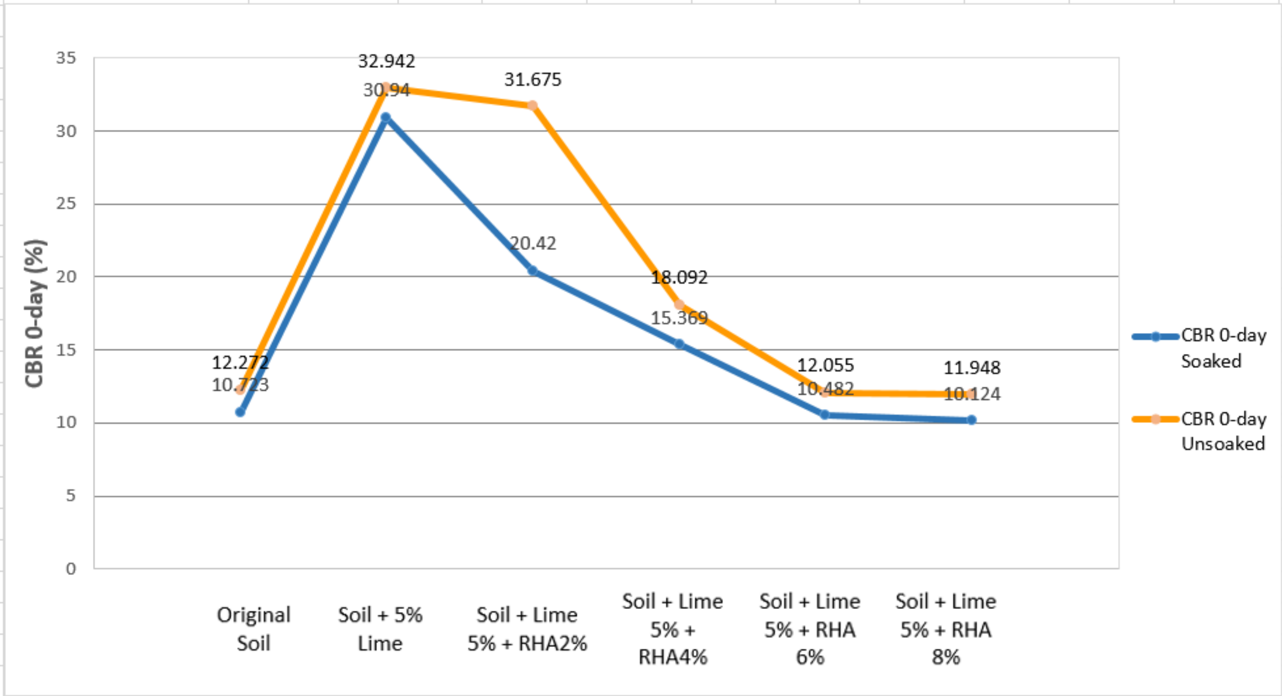

Figure 8. Graph of CBR test results of 0-day cured soil

The highest increase of CBR value occurred with the addition of 5% lime. In soaked condition, the original soil CBR value was 10.723%, while with the addition of 5% lime, the CBR value increased up to 30.94% or equal to 189% increase. In unsoaked condition, the original soil CBR value was 12.272%, while with the addition of 5% lime, the CBR value increased up to 32.942% or equal to 168% increase.

However, the CBR value became lower with the addition of rice husk ash, and the decrease is quite significant. With the addition of 2% and 4% rice husk ash, the CBR value was still higher than the original soil CBR value, but with the addition of 6% and 8% rice husk ash, the CBR value became lower than the original soil CBR value.

The results of 7-day cured soaked and unsoaked CBR test for soil with additional lime and rice husk ash (RHA) can be seen in Table 5.

Table 5. CBR value of 7-day cured soil

	Original Soil	Soil + 5% Lime	Soil + Lime 5% + RHA2%	Soil + Lime 5% + RHA4%	Soil + Lime 5% + RHA 6%	Soil + Lime 5% + RHA 8%
CBR 7-day Soaked	10.723	38.47	34.114	20.496	17.936	15.832
Increase Percentage		259%	218%	91%	67%	48%
CBR 7-day Unsoaked	12.272	38.65	38.013	25.552	19.227	18.752
Increase Percentage		215%	210%	108%	57%	53%

The comparison of CBR values of soaked and unsoaked 7-day cured soil is shown in Figure 9.

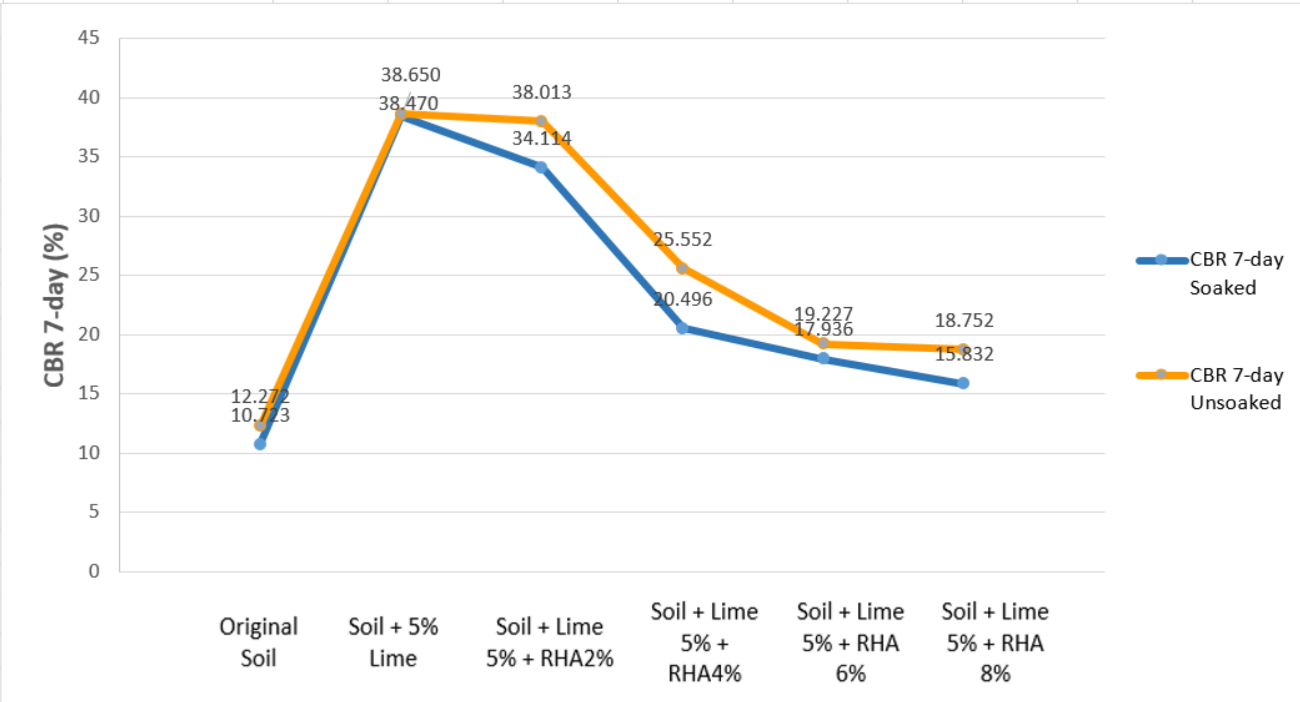

Figure 9. Graph of CBR test results of 7-day cured soil

The results of CBR testing in soaked and unsoaked conditions of 7-day cured soil showed that the highest CBR value of the soil was obtained with the addition of 5% lime, where the CBR value in soaked condition was 38.47% and unsoaked was 38.65%, equal to 259% and 215% increase, respectively. As in the results of 0-day cured soil samples, the addition of 5% lime and 2%, 4%, 6%, and 8% rice husk ash resulted in a decrease of the CBR value of 7-day cured soil samples, both in soaked and unsoaked conditions. The higher the percentage of rice husk ash, the higher the decrease in the CBR value. However, the CBR value of the 7-day cured soil with the addition of lime and rice husk ash, both in soaked and unsoaked conditions, remained higher than the original soil CBR value.

CONCLUSION

Conclusion

From the research results conducted on clay soil samples taken from Limau Manis hilly area, in Pauh District, Padang City, it can be concluded that the addition of 5% lime increased the CBR values of 0-day and 7-day cured soil, both in soaked and unsoaked conditions. The CBR value of the soaked 0-day cured soil sample increased by 189% and the unsoaked 0-day cured soil sample increased by 168%, while the CBR value of the soaked 7-day cured soil sample increased by 259% and the unsoaked 7-day cured soil sample increased by 215%. However, adding rice husk ash decreased the CBR value for all soil samples. The more rice husk ash was added, the lower the CBR value.

Future Works

In this study, the combination of lime and rice husk ash resulted in lower CBR values for all samples. Further research can be conducted on other combinations of additive materials. Research can also be conducted with a longer curing period of soil samples. As the development in Limau Manis area continues to spread, soil improvement and stabilization will become an important aspect of infrastructure construction work.

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