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Performance Testing Of Sand And Lime As Subgrade Stabilizing Materials For Roads

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Abstract—Abstract Soil stabilization is a method used to increase the carrying capacity of a layer of soil, by giving special treatment to that layer of soil. Soil is one of the factors that can affect the structure of road construction. The CBR value is one of the parameters to determine soil carrying capacity, if the CBR value is high then the soil carrying capacity is good, whereas if the CBR value is low then the soil needs to be stabilized. The purpose of this study was to determine the characteristics and classification of soil, determine the results of the grain gradation test, sieve analysis and hydrometer analysis, consistency limits (Atterberg limits) before and after stabilization, compaction results (Proctor) before and after stabilization, determine the CBR value of the soil before and after stabilization. This research included water content test, wet soil unit weight test, specific gravity test, sieving analysis, hydrometer analysis, Atterberg limit test, compaction test (Modification), and immersion CBR test and CBR without immersion. In this test, variations in the addition of 20% sand and lime content were 5%, 10%, and 15% of the dry weight of the soil. Based on the test results, the original soil samples exhibited soil classification A-7-6 according to AASHTO, with maximum dry density (MDD) values of 1.70 g/cm³ after 1 day of curing, 1.64 g/cm³ after 7 days of curing, and 1.77 g/cm³ after 14 days of curing. There was an increase in the maximum dry density (MDD) value for the original soil when stabilized with 20% sand and 5% lime, resulting in a value of 1.78 g/cm³ after 1 day of curing, 1.86 g/cm³ after 7 days of curing, and 1.82 g/cm³ after 14 days of curing. Additionally, the test results revealed that the original soil samples, according to AASHTO classification, had CBR values of 3.15% after 1 day of soaking, 3.68% after 7 days of soaking, and 4.21% after 14 days of soaking. There was an increase in the soaked CBR values for the native soil when stabilized with 20% sand and 5% lime, resulting in CBR values of 37.19% after 1 day of curing, 42.10% after 7 days of curing, and 30.29% after 14 days of curing.

Keywords – *sand, lime, stabilization, compaction, CBR*

I. Introduction

Soil stabilization is a method employed to enhance the characteristics of soil layers in order to achieve the desired load-bearing capacity. It can be categorized into various types, including chemical stabilization, which involves the use of additives to enhance soil properties. This is achieved by mixing the soil with specific additives in a prescribed ratio.

In the construction of highway structures, the subgrade plays a crucial role as the foundation or support for the road. However, due to varying geographical locations and conditions, not all land can be directly utilized as a suitable foundation for road construction. To address this, additives are often employed to modify the properties of the soil. The material mixed with these additives must be evenly distributed and compacted appropriately. Commonly used additives include lime, Portland cement, fly ash, and other similar materials. The ratio of the mixture depends on the desired quality of the mixture. If the purpose of mixing is solely to alter the gradation, plasticity, and workability of the soil, a small amount of additional material is sufficient. However, if the aim is to achieve high soil strength through stabilization, a greater quantity of added material is required.

Soil is a significant factor that influences the construction of roads. The CBR (California Bearing Ratio) value serves as a parameter for determining the load-bearing capacity of the soil. A higher CBR value indicates good soil carrying capacity, whereas a lower CBR value suggests the need for soil stabilization.

During this test, sand sourced from the eruption of Mount Merapi in Lumajang was utilized, along with the addition of 20% sand and lime with variations of 5%, 10%, and 15% of the dry weight of the soil.

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II. Research Methodology

In conducting this experiment, it was necessary to take soil samples in the Bangil area of East Java. From the soil sample, data was generated based on research or testing in the laboratory.

This research commenced by obtaining soil samples, which were subsequently subjected to testing to assess various soil characteristics, such as water content (ASTM D 2216-80), bulk density test (ASTM D 4318-84), specific gravity test (ASTM D 854-33), Sieve Analysis test (SNI C136:2012), Hydrometer test (ASTM D 422-72), Atterberg Limit test (SNI 1967-2008, SNI 1966-2008), Compaction test (SNI 1743-2008), and CBR test (SNI 1744-2012).

The research involved conducting tests to evaluate the physical and mechanical parameters of the soil before and after stabilization. For this purpose, 20% sand and lime were added to the original soil sample, with variations of 5%, 10%, and 15% based on the weight.

The process began with a soil grain gradation test to determine the initial soil classification [1]. This was followed by the Atterberg limit test, which helped determine the values of the liquid limit and plastic limit, enabling the calculation of the plasticity index for both the original and stabilized soils [2]. Next, a modified compaction test was conducted to determine the maximum dry density (MDD) and optimum moisture content (OMC) values for both the original and stabilized soils [3]. Finally, CBR testing was performed, both soaked and unsoaked, to determine the CBR values in the original and stabilized soils [4].

III. Results and Discussion

A. Examination of original soil sample

The laboratory research conducted to examine the characteristics of the original soil involved several tests, the findings of which are summarized in Table 1.

Based on the laboratory test results, it was observed that the original soil, without the inclusion of sand and lime, exhibited a relatively high water content value. Additionally, the soil classification, as per AASHTO (American Association of State Highway and Transportation Officials), fell under A-7-6, indicating its classification as clay soil.

Table 1. Characteristics of Original Soil

Testing	Symbol	Unit	Result
Water content	w	%	51,24
Soil weight	γ_{wet}	gr/cm^3	1,75
Specific gravity	Gs	-	2,64
Liquid limit	LL	%	72,5
Plastic limit	PL	%	51,66
Plasticity index	PI	%	20,84
Soil classification			A-7-6 (Clay soil)

B. Analysis of Original Soil and Mixture of sand and lime

Based on the laboratory testing, the results of evaluating the consistency limits (Atterberg limits) of the original soil, stabilized with sand and lime, are presented in Table 2 below.

Table 2. Summary of Consistency Limit Test (Atterberg Limits)

Soil Composition	Testing		
	LL	PL	IP
Original soil	72,50	51,66	20,84
Original Soil + 20% Sand + 5% Lime	62,60	49,59	13,01
Original Soil + 20% Sand + 10% Lime	59,90	49,26	10,64
Original Soil + 20% Sand + 15% Lime	60,55	53,59	6,96

From the test results above, the original soil without being stabilized with sand and lime has a plasticity index (IP) value above 10%, so that the soil can be categorized as an expansive clay soil.

The testing outcomes of the original soil, stabilized with sand and varying percentages of lime, revealed a reduced plasticity index (IP) value. As the lime percentage increased, it had an impact on reducing the water content of the original soil, consequently leading to a decrease in the plasticity index (IP) value. This relationship is illustrated in Figure 1.

As depicted in Figure 1, the plasticity index value of the original soil sample, when stabilized with 20% sand and lime with varying lime content of 5%, 10%, and 15%, exhibited a decreasing trend. This is supported by the results of the liquid limit and plastic limit tests, which indicated a reduction in the plasticity index value. Regarding the compaction test, both the original soil

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without stabilization and the original soil stabilized with sand + lime yielded Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) values, as outlined in Table 3.

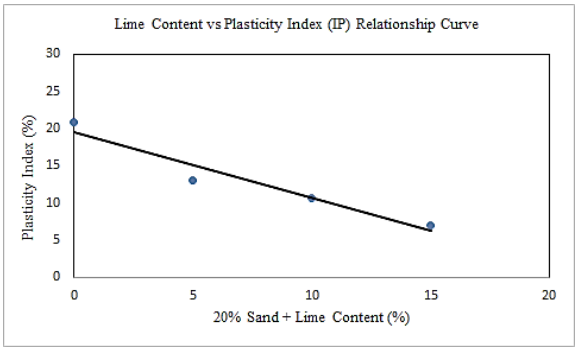

Figure 1. Relationship Curve Lime Content vs Plasticity Index (IP)

Table 3. Compaction Test Results (modified) on the Mixed Composition of Addition of Sand and Lime.

Compaction Testing	curing time	OS (0%)	Composition of a Mixture of Sand and Lime		
			OS + 20% Sand + 5% Lime	OS + 20% Sand + 10% Lime	OS + 20% Sand + 15% Lime
MDD (Gr/cm^3)	1	1,70	1,78	1,79	1,87
	7	1,64	1,86	1,82	1,90
	14	1,77	1,82	1,78	1,85
OMC (%)	1	22,00	18,00	20,00	20,00
	7	22,00	22,00	22,00	20,50
	14	20,00	22,00	20,50	18,50

In Table 3, the original soil samples were examined after being stabilized with sand and lime. The results indicated a decrease in the optimum moisture content (OMC) within 1 day of curing for all lime mixture compositions. Furthermore, after 7 days of curing, the OMC value decreased specifically for the 15% lime mixture composition. Similarly, at 14 days of curing, the OMC value decreased for the 10% and 15% lime mixture compositions. Moreover, the maximum dry density (MDD) value exhibited a significant increase in the presence of sand and lime stabilization during 1, 7, and 14 days of curing. This increase was particularly notable in lime mixture compositions ranging from 5% to 15% of the original soil MDD value without stabilization. The changes in MDD and OMC values between the natural soil without stabilization and the natural soil with stabilization are illustrated in Figure 2 and Figure 3, respectively.

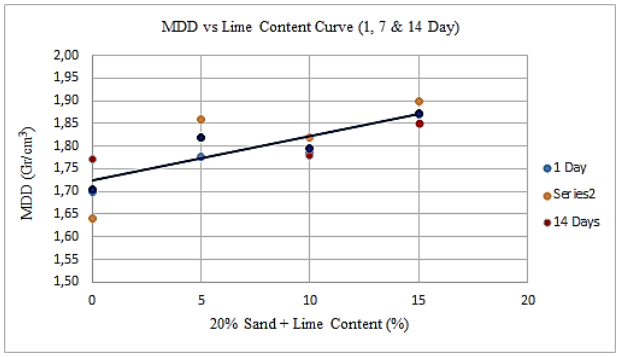

Figure 2. Relationship Curve MDD vs 20% + Lime (%).

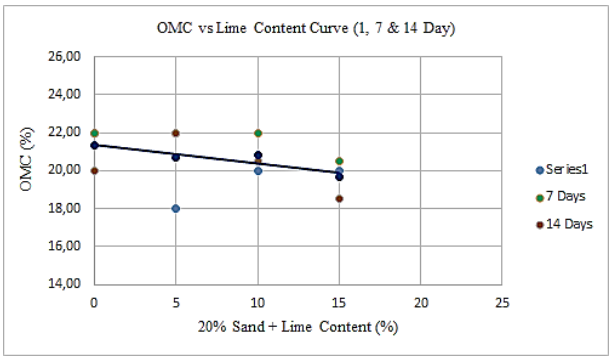

Figure 3. Relationship Curve OMC vs 20% + Lime (%).

The results of conducting CBR testing, which included both unsoaked and soaked CBR testing, were used to assess the soil's California Bearing Ratio (CBR). Table 4 presents the outcomes of the CBR tests performed on the natural soil without stabilization and the original soil samples stabilized with a mixture of 20% sand and lime. Various lime compositions, namely 5%, 10%, and 15%, were utilized in the stabilization process.

Table 4. CBR Test Results (soaked & unsoaked) on the Mixed Composition of Addition of Sand and Lime

CBR	curing time	OS (0%)	Composition of a Mixture of Sand and Lime		
			OS + 20% Sand + 5% Lime	OS + 20% Sand + 10% Lime	OS + 20% Sand + 15% Lime
Soaked	1	3,15	37,19	70,87	103,85
	7	3,68	42,10	42,63	80,17
	14	4,21	30,29	18,07	36,66
Unsoaked	1	29,64	46,49	61,92	71,75
	7	48,24	66,13	95,60	92,80
	14	34,21	49,99	70,17	93,50

The findings presented in Table 4 indicate that the incorporation of sand and lime stabilization resulted in notable improvements in both soaked and unsoaked CBR values during 1, 7, and 14 days of curing. These enhancements were particularly evident in the mixture

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compositions ranging from 5% to 15% of the original soil without stabilization. The alterations in the soaked and unsoaked CBR values between the natural soil without stabilization and the stabilized original soil are graphically depicted in Figure 4 and Figure 5, respectively.

The results presented in Figure 4 and Figure 5 demonstrate an upward trend in the CBR value of the original soil sample when subjected to sand and lime stabilization with varying lime content. In the case of the CBR test conducted with soaking for 1 day of curing, the original soil exhibited a CBR value of 3.15% with a swelling value of 6.04%. Conversely, the stabilized original soil with 20% sand and 5% lime showcased a substantially higher CBR value of 37.19% along with a reduced swelling value of 3.72%. Likewise, for the unsoaked CBR test conducted for 1 day of curing, the original soil yielded a CBR value of 29.64%, whereas the stabilized original soil with 20% sand and 5% lime displayed an elevated CBR value of 46.49%. Similar increments in the soaked and unsoaked CBR values were observed in the original soil stabilized with 20% sand and 5%, 10%, and 15% lime.

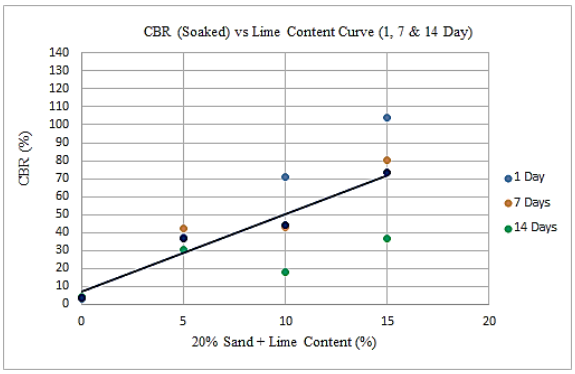

Figure 4. Relationship Curve CBR (Soaked) vs 20% + Lime (%)

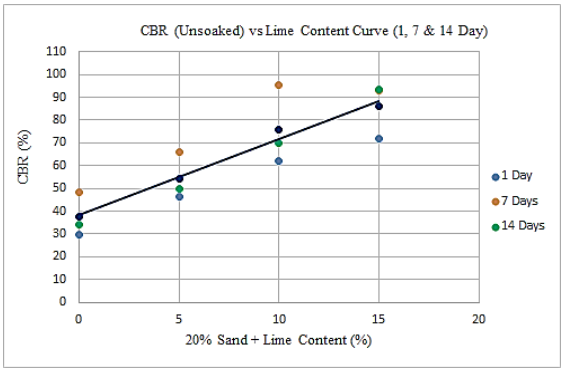

Figure 5. Relationship Curve CBR (Unsoaked) vs 20% + Lime (%)

The relationship between the CBR (California Bearing Ratio) value and the variations of sand and lime in the soil is directly proportional, indicating an increase. As the percentage of sand and lime in the soil mixture increases, the amount of water absorbed by the stabilizing agent also increases. This, in turn, reduces the water entering the soil pores, leading to a decrease in the swelling value. These observations are illustrated in Figure 6.

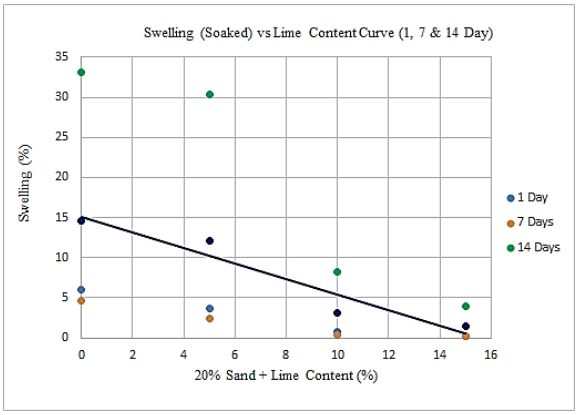

Figure 6. Relationship Curve Swelling (Soaked) vs 20% + Lime (%)

Based on the results of the soaked CBR test, it is observed that the variations in the addition of sand and lime, ranging from 5% to 15%, meet the requirements for stabilizing subgrade soil layers. In particular, for the 1-day curing period, the CBR values range from 70.87% to 103.85% for the 10% to 15% variation. These values exceed the minimum CBR requirement of 50% for the base layer. However, when considering the variation of 20% sand and 5% lime, which yields a CBR value of

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37.19%, it satisfies the subgrade requirements as specified in the 2017 Road Pavement Design Manual.

IV. Conclusion

Based on the conducted experiments and data analysis, the following conclusions can be drawn:

1. The grain gradation test, including sieving analysis, hydrometer analysis, and Atterberg limits, reveals that the original soil sample can be classified as A-7-6, which corresponds to Clay Soil according to AASHTO (American Association of State Highway and Transportation Official).
2. The Atterberg limits test demonstrates that the plasticity index (IP) tends to decrease when comparing the original soil sample without stabilization to the stabilized samples with 20% sand and varying lime compositions. The IP values for the stabilized samples are as follows: 20% sand and 5% lime (13.01%), 20% sand and 10% lime (10.64%), and 20% sand and 15% lime (6.96%). These values indicate a decrease compared to the original soil sample's IP value of 20.84%.
3. The modified compaction test conducted on the original soil samples without stabilization shows that in 1-day curing, the maximum dry density (MDD) is 1.70 gr/cm3. However, the MDD tends to increase when the original soil samples are stabilized with 20% sand and a 5% lime mixture, resulting in an MDD value of 1.78 gr/cm3.
4. Similarly, the compaction test conducted on the original soil samples without stabilization reveals an optimum moisture content (OMC) value of 22% in 1-day curing. However, the OMC tends to decrease when the original soil samples are stabilized with 20% sand and a 5% lime mixture, resulting in an OMC value of 18%.
5. The CBR (Soaked) testing results obtained from the laboratory indicate that the original soil samples without stabilization exhibit a CBR value of 3.15% after 1-day curing, 3.68% after 7-day curing, and 4.21% after 14-day curing. On the other hand, the original soil samples stabilized with 20% sand and 5% lime demonstrate an increased CBR (Soaked) value of 37.19% (1 day curing), 42.1% (7 days curing), and 30.29% (14 days curing).
6. The Laboratory CBR (Unsoaked) testing reveals that the stabilized original soil samples exhibit a CBR value of 29.64% after 1-day curing, 48.24% after 7-day curing, and 34.21% after 14-day curing. Similarly, the original soil samples stabilized with 20% sand and 5% lime demonstrate an increased CBR (Unsoaked) value of 46.49% (1 day curing), 66.13% (7 days curing), and 49.99% (14 days curing).

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