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Determination of the Percentage Ca(OH)2 Lime Stabilization Material for Weathered Clay Shale as Road Subgrade on Serang – Panimbang Toll Road Section III STA 57+200

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ABSTRACT

Clay shale consists of thin, layered formations with irregular fractions, highly smooth, and easily separable along the layer planes. If Clay shale is exposed to sunlight, air, and water for a relatively short period, it will undergo weathering. The construction of the Serang - Panimbang Toll Road Section III is carried out by cutting the soil according to the planned contours. After the cutting process, the subgrade material undergoes a change in its characteristic properties and mechanics because the subgrade soil is Clay shale material that has weathered, commonly referred to as "Weathered Clay Shale." To transform this soil into a subgrade layer that meets the requirements, stabilization with $Ca(OH)_2$ lime is necessary; in this case, the percentage of lime and the duration of curing need to be determined to achieve optimum lime content. The soil material used is Weathered Clay Shale obtained from the Serang - Panimbang Toll Road Section III STA 57+200. The research involves identifying the initial soil properties, conducting standard proctor tests on soil mixtures with lime variations of 4%, 7%, and 10% to ascertain the optimal soil-lime mixture with $Ca(OH)_2$. Subsequently, soil properties are identified with the most optimum lime mixture, and soaked CBR tests are conducted on the optimum lime-soil mixture with curing time variations of 0, 7, and 14 days. The 7% $Ca(OH)_2$ lime mixture with weathered clay shale soil at STA 57+200 in the construction of the Serang-Panimbang Toll Road Section III has achieved sufficiently good bearing strength. The bearing capacity attained has exceeded the requirements of the Bina Marga Specifications Revision II, especially during the 14-day curing period, where the achieved bearing capacity significantly surpasses the specified standards.

Keywords : Weathered Clay Shale, Stabilization, Lime $Ca(OH)_2$, Curing, CBR

INTRODUCTION

Roads play a crucial role in sustaining the pulse of the economy. This significance is inseparable from their role in facilitating human movement and influencing distribution and logistics activities. Thus, a road should be constructed and managed using infrastructure asset

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management principles. According to Suprayitno and Soemitro (2018), the knowledge, science, or program known as infrastructure asset management is used to manage the infrastructure so that it can perform its purpose in a sustainable, effective, and efficient manner. Consequently, maintaining infrastructure in optimal functional condition is crucial. This involves adherence to the fundamental principle of infrastructure asset management (Maulidha et al, 2022). The ongoing road construction emphasizes the importance of ensuring adequate material availability (Widayanti et al, 2019). In this instance, planning, design, and feasibility studies for the Serang-Panimbang Toll Road infrastructure project are made easier by geotechnical mapping, which is in line with the concepts of infrastructure asset management. This helps to guarantee the project's successful completion. This toll road is set to connect four districts and cities within the province. The proper operation of infrastructure is one of the prerequisites that must be fulfilled for infrastructure to function effectively. (Suprayitno & Soemitro, 2020).

The regional stratigraphy of the Serang - Panimbang Toll Road area consists of sedimentary rock deposits from the BojongManik formation, characterized by interbedded layers of sandstone with clay and limestone intercalations (Tmb) dating back to the Early Miocene, indicating the presence of clay shale in the location. **Figure 1** depicts the regional geological map of the Serang - Panimbang Toll Road. The presence of clay shale is highly unstable, even on flat slopes, as it is one of the most complex and problematic geological materials. Fine-grained sedimentary rock known as clay shale is created when silt and clay-sized particles are compacted.

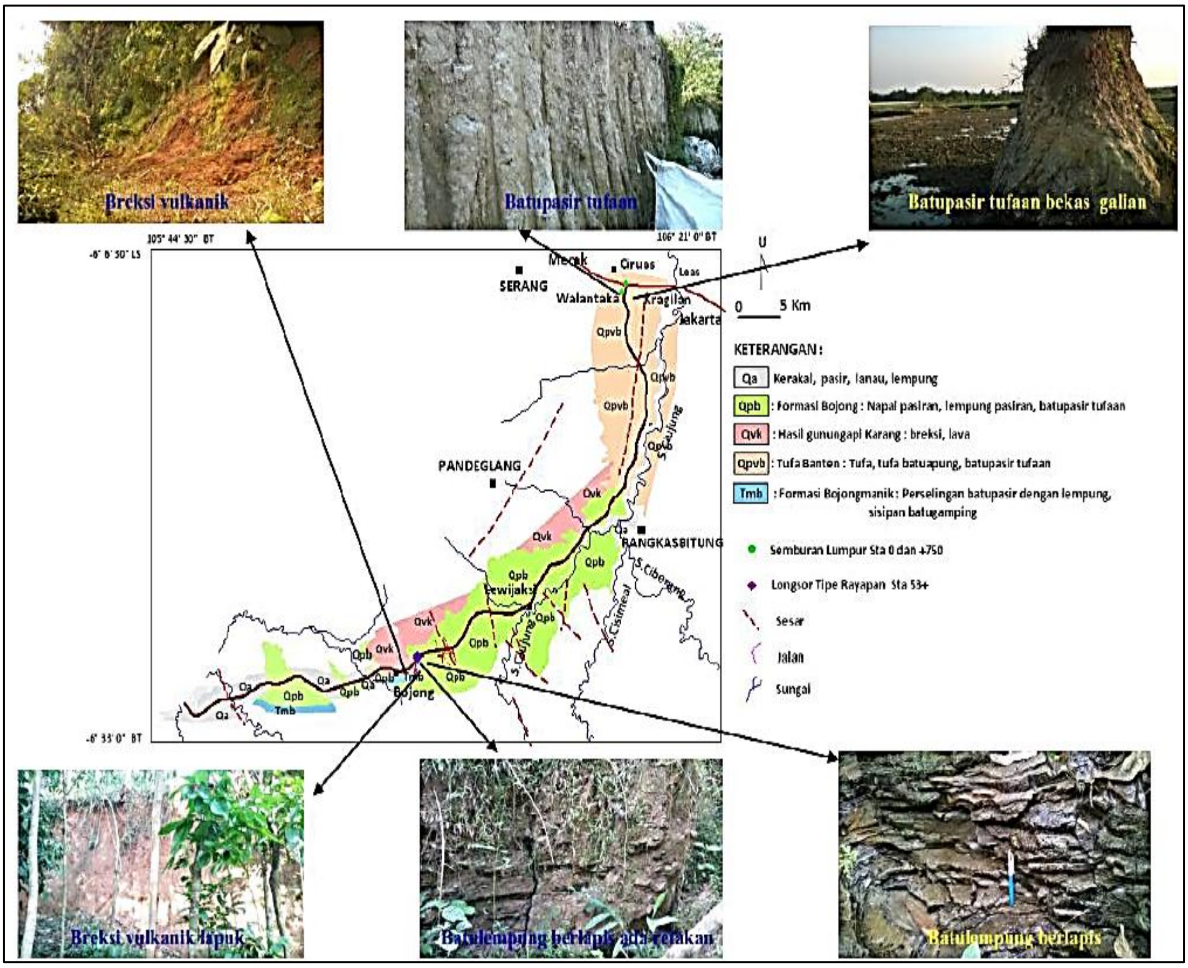

Figure 1. Regional geological map of Serang – Panimbang toll road

The x-ray diffraction testing conducted strengthens the fact that the construction site of the Serang-Panimbang Toll Road Section III from STA 51+385 to STA 57+551 is a Clay Shale area. **Figure 2** illustrates the Clay Shale region and the results of the x-ray diffraction testing. X-ray diffraction testing on the clay shale reveals the presence of quartz and albite, identified as dominant minerals, along with a quantity of montmorillonite, illite, kaolinite, and other minerals.

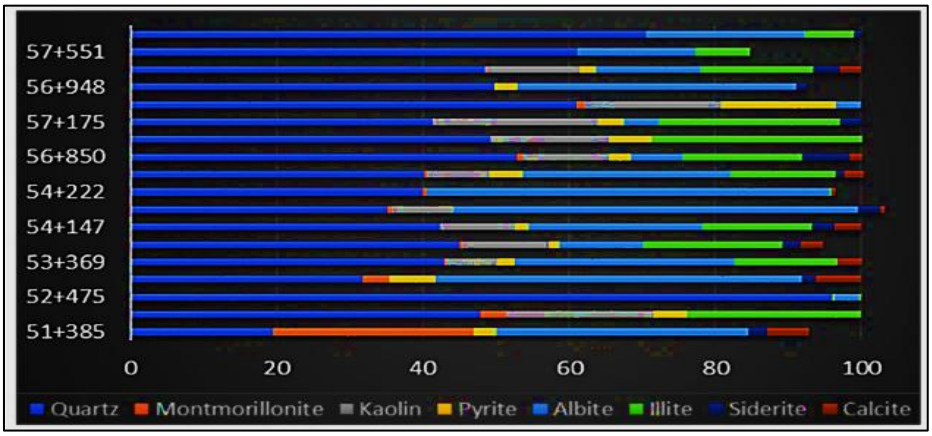

Figure 2. X-ray diffraction test results

The construction is carried out by cutting soil, slopes, and filling soil according to the planned contours. At STA 57+200, cutting is performed because the soil exceeds the planned surface elevation. **Figure 3** depicts the elevation of the cutting at STA 57+200 in the construction of the Serang-Panimbang Toll Road Section III. The subgrade material undergoes a change in its characteristic properties and mechanics because the subgrade soil is clay shale material that has weathered, commonly referred to as Weathered Clay Shale. This results in a decrease in the strength and bearing capacity of the soil. The reduction in the strength of clay shale is caused by cracks that occur due to the transition of parameters from rock to soil due to weathering (Ariesnawan, 2015).

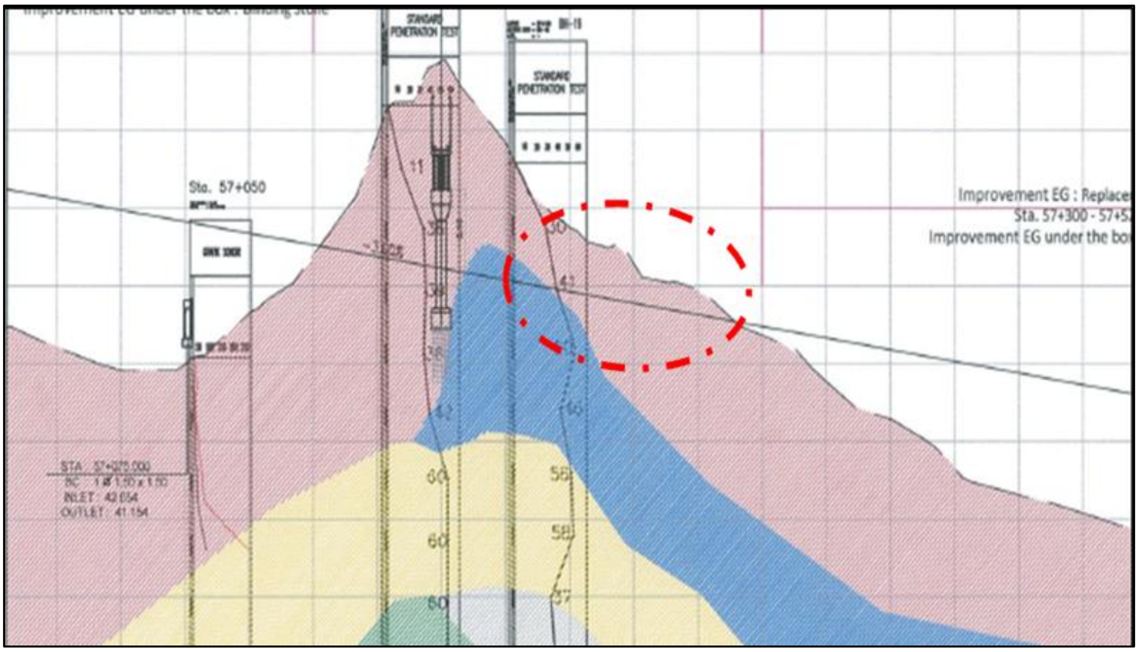

Figure 3. Elevation of the Serang – Panimbang Section III Toll Road construction plan

Weathered clay shale material cannot be used as subgrade because it does not meet the Bina Marga specifications Revision II 2018. Replacing the subgrade requires a disposal location for the material and incurs significant costs. An alternative to replacing the subgrade material is utilizing existing field materials with chemical stabilization. Two commonly used stabilization methods are mechanical stabilization and chemical stabilization. Mechanical stabilization involves improving the soil's structure and mechanical properties, while chemical stabilization strengthens the soil by reducing or eliminating unfavorable technical properties through mixing the soil with chemicals like cement, lime, or pozzolan (Harneini, 2013).

Quicklime (CaO) is a direct result of burning limestone, existing in the form of calcium or magnesium oxide. The two forms of lime that stabilize soil the best are calcium hydroxide ($Ca(OH)_2$) and calcium oxide (CaO) (Rokman, 2015). Soil-lime stabilization has been widely used in highway, airport, railroad and road works projects in the project area (Hardiyatmo, 2022). Based on previous research on soil stabilization with lime, among others, as follows:

1. Natural soil mixture with 7% lime can increase the maximum dry density (γ_{dmax}) value by 7.29% (Limbong, 2023).
2. Natural soil mixture with 8% lime can increase the maximum dry density (γ_{dmax}) value by 1.74% (Razzak, 2022).

RESEARCH METHOD

This study used a laboratory research methodology, including initial soil investigation tests followed by proctor tests to determine the optimum mixture of soil + $Ca(OH)_2$ lime. Lime mixture variations include 4%, 7%, and 10%. Laboratory CBR Soaked tests were conducted on the most optimum $Ca(OH)_2$ lime mixture with varying curing times (0, 7, and 14 days) to determine the maximum bearing capacity. Physical and mechanical property tests on various $Ca(OH)_2$ lime mixtures and curing times were also performed to identify the most favorable properties.

DATA COLLECTION

Samples of material were taken from the construction site of the Serang-Panimbang Toll Road Section III at STA 57+200 from the suspected weathered clay shale area in the subgrade. The soil samples taken consisted of disturbed soil samples. Disturbed soil samples were taken at a depth of 0,5 m from the road shoulder. The number of samples taken include the following disturbed soil samples as much as ± 350 kg.

The Laboratory of Soil and Rock Mechanics FTSPK ITS Surabaya conducts testing on the mechanical and physical characteristics of soil. Tests of physical properties carried out include: sieve and hydrometer analysis tests, volumetric-gravimetric tests and consistency tests, while for mechanical tests carried out include: proctor standard compaction test and laboratory CBR test.

RESEARCH ANALYSIS

1. Data Soil Properties Soil

Based on the results of soil properties tests taken from Serang-Panimbang Toll Road Section III at STA 57+200, it is a clay soil that is included in the clay high plasticity (CH) classification based on USCS and is included in the A-7-6 classification based on AASHTO classification. Table 1 below displays the findings from the tests conducted on soil qualities.

Table 1. Initial soil testing results

No	Types of Testing		Unit	Initial Soil
1	**Soil Physical Properties Test**			
a	Particle Size Analysis	Gravel Fraction	%	0,30
		Sand Fraction	%	6,96
		Silt Fraction	%	21,99
		Clay Fraction	%	70,75
b	Atterberg Limits	Liquid Limit (LL)	%	69,56
		Plastic Limit (PL)	%	23,95
		Placticity Index (PI)	%	45,61
c	Volumetric Gravimetry	Moisture Content	%	26,55
		Spasific Gravity		2,616
		Dry Density	gr/cm^3	1,405
		Void Ratio		0.858
		Porosity	%	46,17
2	**Soil Classification**			
		USCS		CH
		AASHTO		A-7-6
3	**Soil Mechanical Properties Test**			
	Uncondined Compressive Strength	Qu	Kg/cm^2	3,68
		Cohesion	Kg/cm^2	1,84
	Density	(γd) max	gr/cm^3	1,405
		w Optimum	%	26,55

source: Laboratory test (Author's Data), 2023

Based on Table 1 the soil investigation results indicate that the sieve analysis shows a dominant clay content, with approximately 92% of the fine fraction passing through the #200 sieve; detailed results of the sieve analysis are provided in Appendix 1. Additionally, the Bojongmanik clay shale exhibits a relatively high plasticity index of 45.61%. As noted by Das (2002), mineral groups like illite and montmorillonite tend to have higher liquid limits and plasticity indices compared to the kaolinite mineral type.

2. Standard Proctor Test Results

From Figure 4 we can see that the standard proctor compaction test was carried out on the initial Bobonaro clay and 3 (three) variations of the test object with the percentage addition of lime $Ca(OH)_2$ of 4%, 7% and 10%. The results of the proctor test on soil treated with $Ca(OH)_2$ lime obtained a higher maximum dry unit weight (γ_d) value when compared to the initial Bobonaro clay. soil treated with lime $Ca(OH)_2$ of 7% had the highest maximum dry unit weight (γ_d) value of 1.514 gr/cm^3 and optimum water content (w_c) of 24.17%. Following the addition of $Ca(OH)_2$ lime to the soil, the maximum dry unit weight (γ_d) decreased. The graph of the results of the proctor test on initial soil and soil treated with $Ca(OH)_2$ lime can be seen in **Figure 4**.

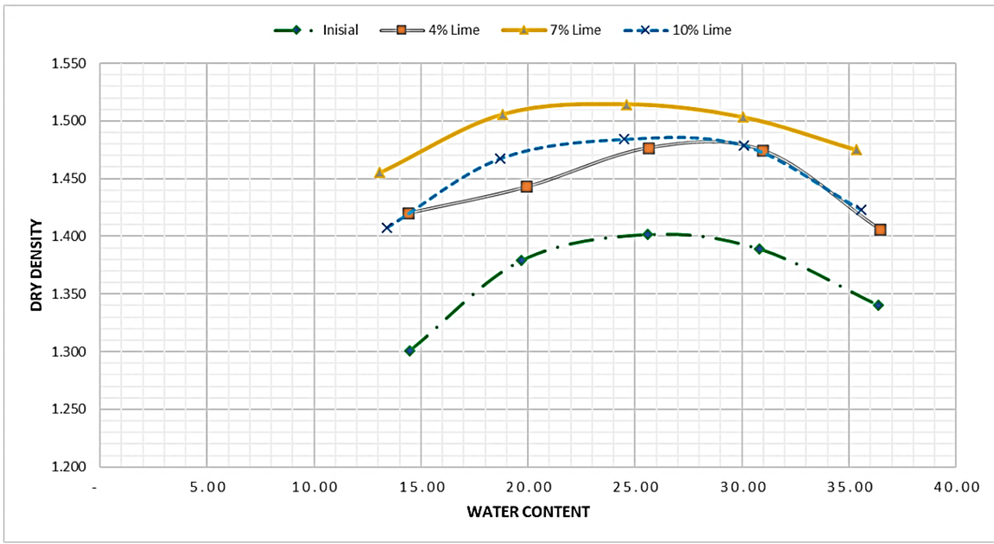

Figure 4. Proctor test results for Weathered Clay Shale and soil treated with $Ca(OH)_2$ lime of 4%, 7% and 10%

According to Rokman 2015, the two kinds of lime that work best for stabilizing soil are calcium oxide (CaO) and calcium hydroxide ($Ca(OH)_2$). This is proven in Harnaeni's research (2013) that the addition of $Ca(OH)_2$ lime to clay soils can reduce the value of pi and increase the value of shear strength, cohesion and increase the maximum dry unit weight from the proctor test results.

Firmansyah (2021) also proved that soil treated using lime Ca(OH)2 of 7% was able to increase the maximum dry unit weight (γ_d) value to 1.47 gr/cm^3 and optimum water content (wc) to 28.08%. Limbong (2023) demonstrated that soil treated with 7% $Ca(OH)_2$ lime could enhance the maximum dry density (γd) to 1.825 g/cm^3 and the optimum moisture content (wc) to 20.31%.

3. The Influence of Adding $Ca(OH)_2$ Lime and Curing Time on the Values on the Values of Sieve Analysis

The results of sieve analysis and hydrometer tests on various $Ca(OH)_2$ lime mixtures, different values were obtained for each mixture variation. The differences in sieve values for each $Ca(OH)_2$ lime mixture variation can be observed in **Figure 5**.

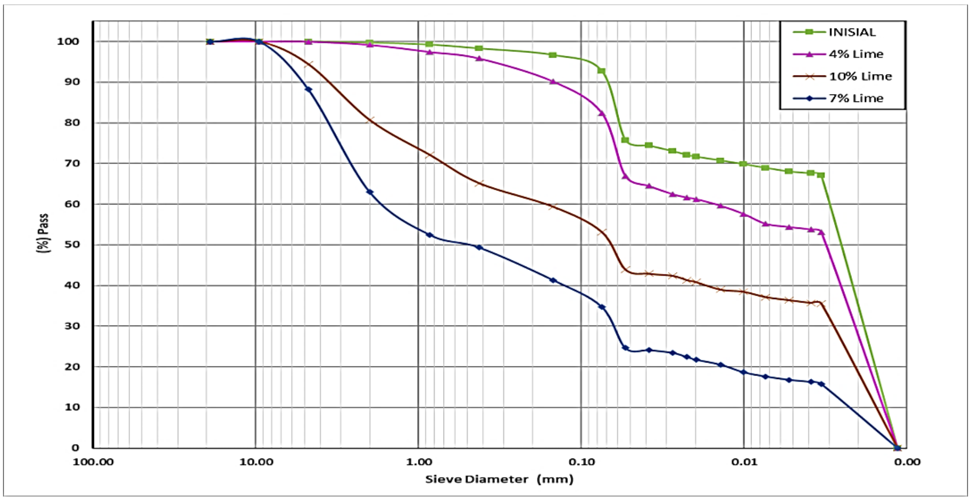

Figure 5. Graph of Sieve Analysis Values for Various $Ca(OH)_2$ Lime Mixtures

The sieve analysis results above, the initial weathered clay shale soil has a dominant clay percentage of 67.11%, with only about 7.26% retained on the #200 sieve. Subsequently, after the addition of the optimum lime mixture, which is 7% $Ca(OH)_2$ lime, the clay percentage changes to 15.77%, and the portion retained on the #200 sieve becomes approximately 65.8%. In the 7% $Ca(OH)_2$ lime mixture, the gravel and sand fractions become more dominant than the silt and clay fractions, and the differences in each fraction can be observed in **Figure 6**.

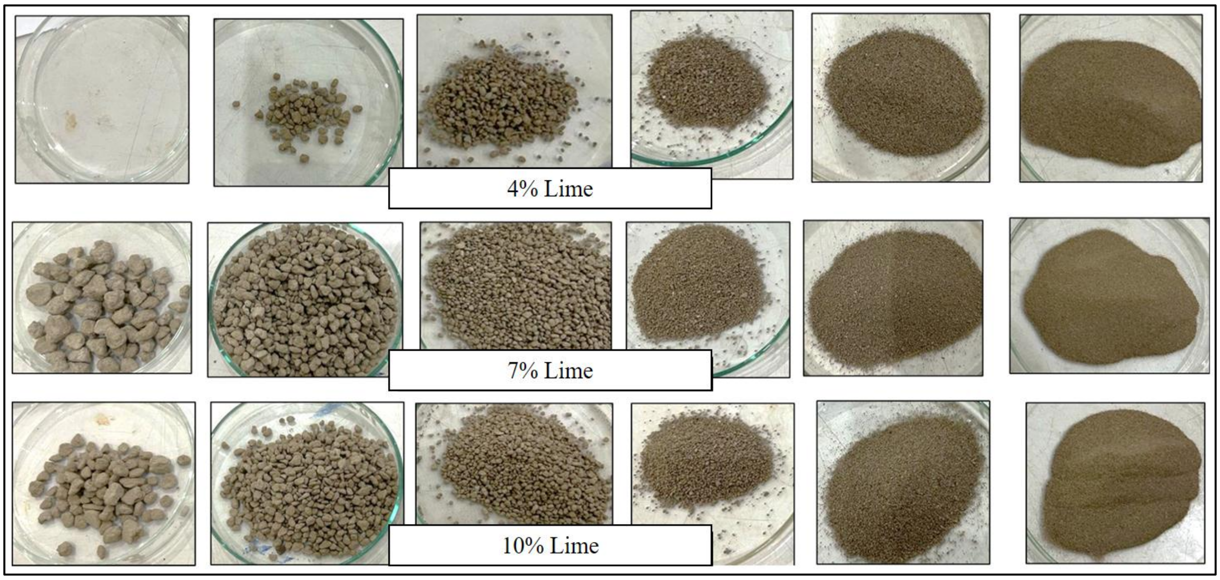

Figure 6. Differences in the percentage of soil fractions in each variation of $Ca(OH)_2$ lime mixture.

4. The Influence of Various $Ca(OH)_2$ Lime Mixtures on Plasticity Index Values

The plasticity index values of the initial weathered clay shale soil decreased in the 4% $Ca(OH)_2$ lime mixture. Subsequently, in the 7% $Ca(OH)_2$ lime mixture, there was a further decrease, resulting in a plasticity index value of 12.63%. According to Hardiyatmo (2002), the soil falls into the classification of moderately plastic clay (PI = 7-17%). Then, during testing on the 10% $Ca(OH)_2$ lime mixture, the plasticity index value increased again to 13.57%, as seen in **Figure 7**, the graph of the plasticity index values of weathered clay shale soil and various $Ca(OH)_2$ lime mixtures. It can be concluded that with the optimum lime mixture, which is 7%, the plasticity index value is lower compared to the 4% and 10% lime mixtures.

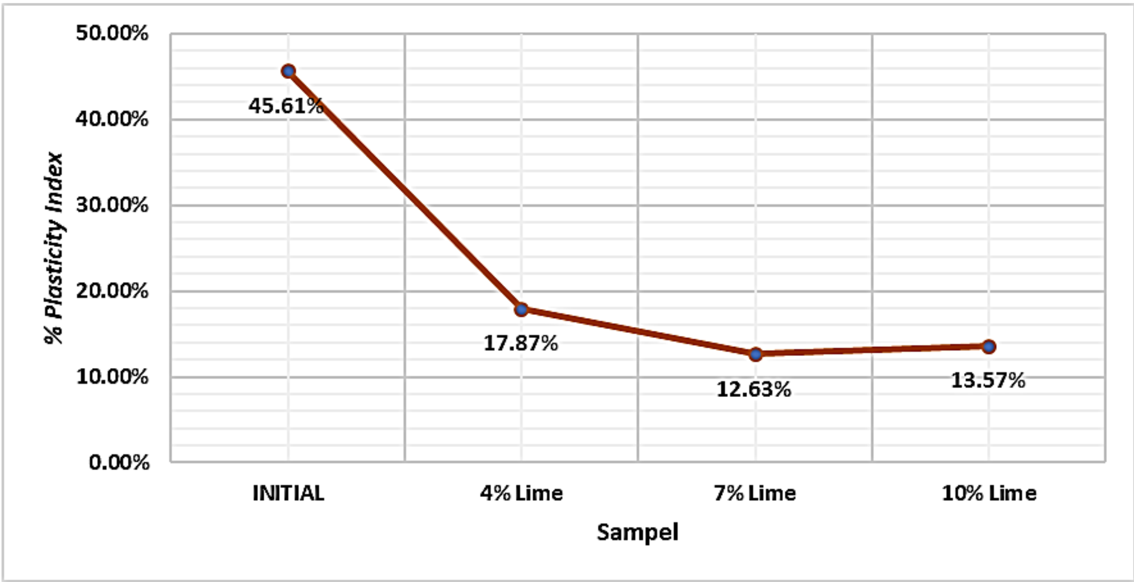

Figure 7. Graph of Plasticity Index Values of Weathered Clay Shale Soil and Various $Ca(OH)_2$ Lime Mixtures

5. The Influence of Laboratory Soaked CBR Values on Curing Time Variations

Laboratory Soaked CBR testing was conducted after obtaining the optimum lime mixture from the proctor test. Four samples underwent Laboratory Soaked CBR testing, including initial soil and a 7% $Ca(OH)_2$ lime mixture with curing times of 0, 7, and 14 days. The Laboratory Soaked CBR value for the initial soil condition increased by 9.24 times compared to the soil with a 7% $Ca(OH)_2$ lime mixture without curing or at 0 days. The initial soil's Laboratory Soaked CBR value was 1.27%, while the soil with a 7% $Ca(OH)_2$ lime mixture without curing recorded a value of 11.74%. This increase is attributed to the lime reacting with clay minerals in the soil or other fine particles (pozzolanic components such as silica hydrous) to form insoluble bonds of calcium silicate, binding soil particles together.

The Laboratory Soaked CBR value for the 7% $Ca(OH)_2$ lime mixture shows a linear increase with curing time. Specifically, after 7 days of curing, the Laboratory Soaked CBR value increased 1.4 times more than the value at 0 days. Subsequently, after 14 days of curing, the Laboratory Soaked CBR value increased 1.65 times more than the value at 0 days. The highest Laboratory Soaked CBR value was obtained for the soil with a 7% $Ca(OH)_2$ lime mixture after 14 days of curing, reaching 19.35%. The comparison of Soaked CBR values can be seen in **Figure 8**. This is because the test specimen is compacted first before undergoing curing inside the mold. The soil-lime mixture has already been compacted before any possible clumping occurs, and the interparticle voids in the soil also become compact, resulting in increased strength. The Laboratory Soaked CBR value increases with the length of the curing period.

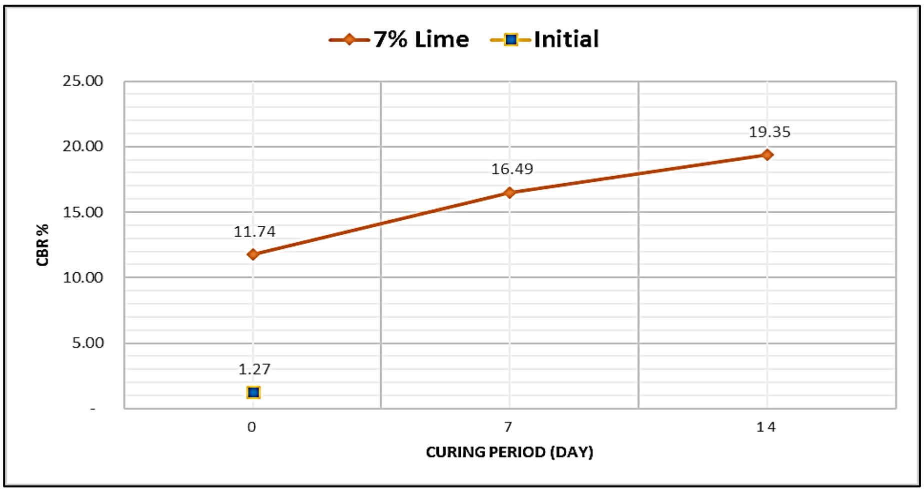

Figure 8. Laboratory Soaked CBR Values with Curing Time Variations

Based on the compaction efforts undertaken, starting from the Standard Proctor test, and the Laboratory Soaked CBR values, it is evident that the 7% $Ca(OH)_2$ lime mixture with weathered clay shale soil at STA 57+200 in the construction of the Serang-Panimbang Toll Road Section III meets excellent requirements as selected fill material. This is particularly important as the Bina Marga Specifications Revision II stipulate a minimum soaked CBR value of 10% for selected fill material. From the conducted tests, it can be concluded that the 7% $Ca(OH)_2$ lime mixture with weathered clay shale soil at STA 57+200 in the construction of the Serang-Panimbang Toll Road Section III has achieved sufficiently good bearing strength. The attained bearing capacity exceeds the requirements, especially during the 14-day curing period, where the achieved bearing capacity significantly surpasses the minimum strength requirements for selected fill material.

6. Different $Ca(OH)_2$ Lime Mixtures and Curing Times' Effects on Soil's Unconfined Compressive Strength (qu) Values

After applying various $Ca(OH)_2$ lime mixture changes, the soil's unconfined compressive strength (qu) values increased from the initial condition. In the 7% $Ca(OH)_2$ lime mixture variation, the unconfined compressive strength (qu) value was the highest; in the 10% $Ca(OH)_2$ lime combination, the value was lower.

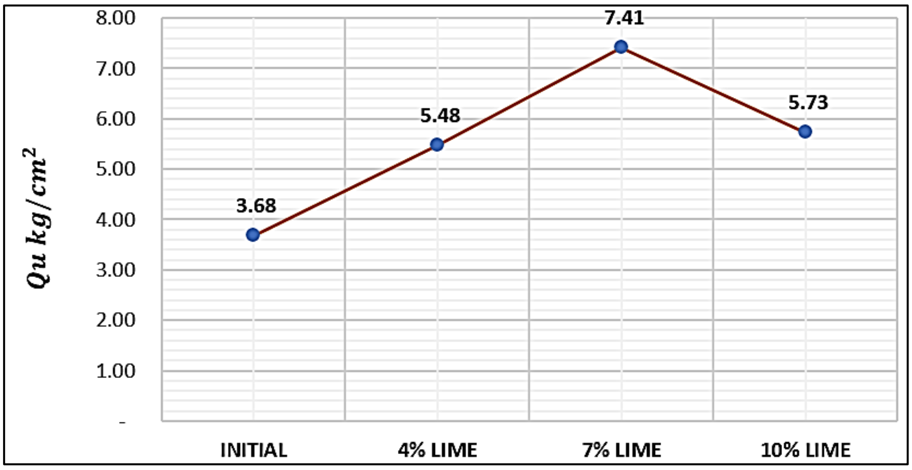

Figure 9. The Unconfined Compressive Strength Values of Initial Weathered Clay Shale Soil and Various $Ca(OH)_2$ Lime Mixtures

The results of the unconfined compressive strength (qu) values for the initial weathered clay shale soil and various $Ca(OH)_2$ lime mixtures are shown in **Figure 9**. Figure 9 displays the unconfined compressive strength (qu) values for the original weathered clay shale soil and several Ca(OH)2 lime combinations. The unconfined compressive strength (qu) value for the 7% $Ca(OH)_2$ lime mixture is 7.41 kg/cm^2. The unconfined compressive strength (qu) values influenced by curing time and lime mixture can be seen in **Figure 10**. From the curve depicting the relationship between the changes in unconfined compressive strength (qu) values and curing time for soil specimens with various lime mixtures, it is evident that the unconfined compressive strength (qu) of the soil increases linearly with the duration of curing. The soil stabilized with 7% lime before curing has a value of 7.41 kg/cm^2, which then increases to 11.56 kg/cm^2 after 14 days of curing. Soil specimens with 4% and 10% lime mixtures exhibit a similar pattern to the 7% lime mixture, showing a linear increase in the unconfined compressive strength (qu) values.

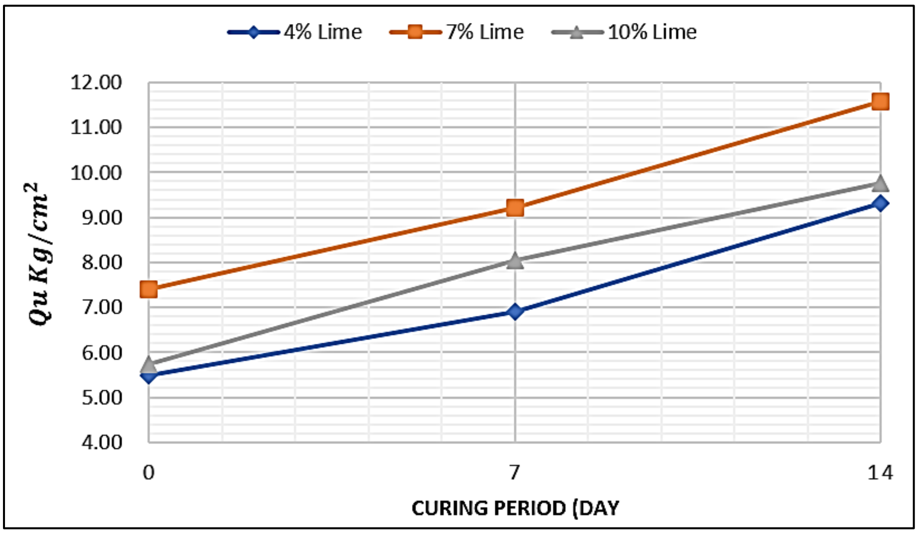

Figure 10. Unconfined compressive strength (qu) values for various lime mixture variations and curing times

CONCLUSION

Drawing conclusions from the research indicates that:

1. The initial classification of weathered Clay Shale soil falls into the category of high plasticity clay according to USCS (Unified Soil Classification System) and is classified as soil type A-7-6 according to AASHTO (American Association of State Highway and Transportation Officials).
2. The variations of $Ca(OH)_2$ lime mixture, namely 4%, 7%, and 10%, and the curing times (0, 7, and 14 days) reveal that the optimal values for physical and mechanical property parameters are obtained in the 7% $Ca(OH)_2$ lime mixture with a 14-day curing period.

   The bearing capacity values achieved in the material of weathered clay shale mixed with 7% $Ca(OH)_2$ lime have exceeded the requirements of Bina Marga Specifications 2018 Revision II, especially during the 14-day curing period.

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