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Subgrade Soil Stabilization for Road Construction Using Limestone and Soil Stabilizer Additives in Arso XIV

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ABSTRACT

Low subgrade bearing capacity is one of the major challenges in road construction, particularly in areas dominated by high-plasticity clay soils that are vulnerable to water saturation and structural deformation. The Arso XIV road section in Keerom Regency, Papua, experiences similar problems due to poor soil characteristics, resulting in low California Bearing Ratio (CBR) values that require stabilization treatment. This study aims to determine the physical and mechanical characteristics of the existing subgrade soil, evaluate the effect of limestone addition at various proportions, and analyze the effectiveness of Soil Stabilizer additives in improving soil bearing capacity. A quantitative experimental method was applied through laboratory testing using native soil, limestone variations of 10%, 20%, and 30%, and an additional 2% Soil Stabilizer additive. The tested parameters included Atterberg limits, specific gravity, standard Proctor compaction, and submerged California Bearing Ratio (CBR) based on applicable technical standards. The results showed that limestone and Soil Stabilizer combinations significantly improved soil properties by reducing the plasticity index, increasing maximum dry density, and enhancing CBR values. The highest performance was achieved in the mixture of 30% limestone and 2% Soil Stabilizer, which increased the CBR value from 2.20% to 7.60%, representing an improvement of approximately 245%. The study concludes that the combination of local limestone and Soil Stabilizer is an effective and sustainable alternative for improving subgrade quality and supporting road construction in Arso XIV, Keerom Regency.

INTRODUCTION

The construction and maintenance of road infrastructure is still faced with a classic problem that is universal, namely the low carrying capacity of the subgrade soil layer. The base layer is the lowest layer where the entire road pavement structure (subbase course, base course, and surface course) is placed, so that its physical and mechanical properties greatly determine the thickness and overall quality of the pavement (Hadmoko & Suryadarma, 2020). In many developing countries, including Indonesia, roads are built on high-plasticity clay soils that are shrink-resistant, easily lose strength when saturated with water, and have a California Bearing Ratio (CBR) value well below the technical requirements (Gazali et al., 2022; Purwati et al., 2019). This condition is exacerbated by climate change that increases the intensity of rainfall so that the wetting-drying cycle in the subsoil is becoming more extreme. This issue encourages the development of soil stabilization studies based on local materials as a global effort towards more economical and sustainable road construction (Kurniawan & Hadimuljono, 2021).

There are several factors that cause these problems. The first factor comes from the characteristics of the soil itself. Soil is defined as a collection of solid mineral grains, weathered organic matter, as well as liquids and gases that fill the cavities between solid particles (Das, 1995), and are relatively loose deposits located on bedrock (Hardiyatmo, 2010). Clay soils with active mineral content have a high melting limit and plasticity index so they are sensitive to changes in moisture content. The second factor is geographical conditions and material availability. In the Papua region, standard materials such as crushed stone for coarse aggregates are not available in sufficient quantities around the work site and must be imported from outside the region (Anggara et al., 2021; Iqbal & Rokhman, 2018). The third factor is the implementation factor, namely compaction that does not reach the maximum dry density at the optimal moisture content, as well as inadequate drainage systems so that the subsoil is in a submerged condition. The fourth factor is the repetitive traffic load that works beyond the bearing capacity of the base soil (Nugroho & Satibi, 2022; Putra et al., 2019). The excess content of plastic material in the layer above the subsoil has also been proven to significantly reduce the value of CBR (Pokaton, 2015).

The accumulation of the above factors has a chain impact, both technically and economically. Technically, the base soil with low CBR is not able to bear the load of the vehicle so that there is permanent deformation, cracks on the pavement surface, non-uniform settlement, rutting, and reduced road service life long before the planned life is achieved (Miswar et al., 2017; Pahrida et al., 2021). The potential for development (swelling) in clay soil causes waves on the road surface during the rainy season and cracks during the dry season. Economically, the impact is in the form of swelling construction costs because the thickness of the pavement must be increased or the soil must be replaced with imported materials, the increasing frequency and cost of maintenance, as well as the inhibition of the distribution of goods and community mobility (Amran et al., 2022; Amran & Permadi, 2021). In areas such as Keerom Regency, this impact has led to the unhandled number of roads even though natural resources in the area are abundant. Therefore, efforts to improve the subsoil through stabilization are a much more rational alternative to replacing materials as a whole (Dwina et al., 2021).

The variables studied in this study consist of limestone materials, Soil Stabilizer additives, and basic soil carrying capacity parameters. Limestone is a sedimentary rock composed mainly of calcium carbonate (CaCO3) of about 98.9% and magnesium carbonate (MgCO3) of about 0.95%, geologically known as chemical sedimentary rocks formed from organic materials. Limestone deposits are scattered in large quantities in Jayapura, Sorong, Fak-Fak, Manokwari, Biak, and Serui, including in the Arso I quarry, Keerom Regency. The use of lime as a stabilizing material has been regulated in SNI 03-3437-1994 concerning Procedures for Making Limestone Soil Stabilization Plans for Highways and SNI 03-4147-1996 concerning Lime Specifications for Soil Stabilization. The second variable is Soil Stabilizer, which is a fine powder-shaped additive of inorganic mineral composition that works chemically to compact and stabilize soil, similar to additives that have been proven to increase free compressive strength in the stabilization of clay soils (Muda, 2016). The bound variables are the characteristics of the subsoil measured through the Atterberg boundary test (SNI 1966-

2008 and SNI 1967-2008), specific gravity, standard Proctor compaction test, and submerged CBR test according to SNI 03-1744-1989 concerning Laboratory CBR Test Methods. The CBR value was chosen as the main indicator because this parameter is directly used in the planning of road pavement thickness (Wijaya, 2016).

The novelty of this research lies in the combination of materials, composition, and study locations that have never been researched before. Sikowati (2018) studied the potential of lime in South Sorong Regency as a material for stabilizing clay soils and obtained an increase in CBR from 46.48% to 48% with the addition of 6% lime, but experienced a decrease in lime content above 6%. Syaifuddin and Amani (2017) stabilized the clay soil using cement and lime and obtained an increase in submerged CBR with the addition of 18% lime. Kusuma et al. (2022) used wood charcoal as an additive and obtained an optimal CBR value of 20% in a mixture of 8% with three days of drying, while Soewignjo (2022) utilized cement and base ash on high plasticity clay. The previous studies generally used a single binding material in the form of lime or cement and were carried out outside the Keerom Regency area. This study offers a different approach, namely combining local limestone from the Arso I quarry in variations of 10%, 20%, and 30% with Soil Stabilizer additives of 2% on the bedrock of the Arso XIV road section, so that the synergistic effect between local materials and chemical additives on the submerged CBR value and soil plasticity, which has never been reported on the soil characteristics at the location, can be known.

The urgency of this research is very strong judging from the real needs in the field. The Arso XIV STA 7+600 road section to the Jayapura City Border Junction/Keerom Regency is a provincial road section based on the Decree of the Governor of Papua Number 188.4/113 of 2023, so that its reliability is the strategic responsibility of the local government in supporting the mobility and distribution of natural resource products in the border area with Papua New Guinea. On the other hand, the base soil on the section is clay soil with low carrying capacity that is not able to accept vehicle loads without special handling. If the road work continues to be carried out without repairing the basic soil, premature damage is almost certain to occur and the regional budget will continue to be absorbed for repeated maintenance. Meanwhile, bringing in standard materials from outside Papua significantly increases construction costs. This research is important because it provides a scientific basis for the use of locally available materials in abundance around the work site, so that the handling of the subsoil can be carried out effectively, economically, and sustainably (Yasin, 2018).

Based on this description, this study aims to determine the value of the California Bearing Ratio (CBR) and the physical characteristics of the original subsoil on the Arso XIV road, Keerom Regency; analyze CBR values on the mixture of subsoil with limestone at variations of 10%, 20%, and 30% to dry soil weight; and analyzed the effect of the addition of 2% Soil Stabilizer additive on the CBR value in the mixture of subsoil and limestone. Through these three objectives, it is hoped that a mixed composition can be determined that provides the best increase in carrying capacity as well as a decrease in the plasticity index and potential for soil development, so that the basic soil at the research site can meet technical requirements as a supporting layer for road pavement.

This research is expected to provide benefits in three stages. Theoretically, this study adds scientific knowledge and references regarding the behavior of Arso XIV clay soil stabilized with a combination of limestone and Soil Stabilizer additives to increase the value of submerged CBR, as well as a reference for further research in the field of soil improvement. Practically, the results of this study can be considered for practitioners, consultants, contractors, and related agencies such as the National Road Implementation Center and the Public Works Office in choosing the right soil stabilization method to increase the carrying capacity of the base soil in road works. Economically and policy-wise, this research supports the use of limestone as an alternative material with useful value that is abundantly available in Keerom Regency, so that it can reduce construction costs due to the procurement of materials from outside Papua while encouraging the optimization of local resources in the development of road infrastructure in Papua Province.

METHOD

Types and Research Approaches

This research was quantitative research with a laboratory experimental approach. This approach was chosen because the problem raised, namely the low carrying capacity of the subsoil on the Arso XIV road, can only be answered through empirical proof of changes in the physical and mechanical properties of the soil due to certain treatments, not through the interpretation of social phenomena. The strategy developed is to compare the condition of the untreated subsoil (control) with the condition of the subsoil that has been treated in the form of the addition of limestone and Soil Stabilizer additives at a certain level, so that the amount of improvement that occurs can be measured measurably and can be repeated. This logic is in line with the principle of soil improvement which places laboratory testing as the basis for technical decision-making before it is applied in the field (Hadmoko & Suryadarma, 2020; Kurniawan & Hadimuljono, 2021), and follows the pattern that has been used in previous soil stabilization studies (Syaifuddin & Amani, 2017; Scott, 2018; Kusuma et al., 2022).

Research Location and Time

This research was conducted on three interrelated locations and was deliberately chosen because it represents the source of the problem as well as the source of the solution. Soil samples were taken on the Arso XIV STA 7+600 road section to the Jayapura City Boundary Junction/Keerom Regency, which has the status of a provincial road based on the Papua Governor's Decree Number 188.4/113 of 2023. Limestone material is taken from PT Mitra Infrastruktur quarry in Arso I, as a representation of local materials that are abundantly available around the work site (Hendarsin, 2002), while Soil Stabilizer additives are obtained from PT DIFA Mahakarya. All testing activities are carried out at the Laboratory of the National Road Implementation Center (BPJN) Jayapura, Tanah Hitam, Abepura, with the consideration that the laboratory is accredited and routinely used for quality control of road work, so that the results obtained have reliability that can be accounted for. The research was carried out in the first week of October 2024 to the end of August 2025, which was divided into the stages of preparing proposals, managing administrative permits, collecting data, analyzing and discussing, and preparing reports.

Aspects Examined

This research concerns several aspects that are arranged in stages in order to explain the mechanism of soil improvement in its entirety. The first aspect is the identification aspect, which is to ensure the type and behavior of the soil base at the research site as a starting point, because soil is basically a collection of mineral grains, weathered organic matter, and liquid substances and gases that fill the cavities between them (Das, 1995; Hardiyatmo, 2010). The second aspect is the treatment aspect, namely the variation in limestone and additive content as an independent variable. The third aspect is the response aspect, which includes changes in plasticity, maximum dry density and optimal moisture content, as well as the submerged California Bearing Ratio (CBR) value as the bound variable. The CBR value is placed as the main indicator because this parameter is directly used in the planning of road pavement thickness (Wijaya, 2016; Yasin, 2018), while plasticity is observed because the content of plastic materials has been proven to have an effect on the decrease in CBR values (Pokaton, 2015). The fourth aspect is the critical condition aspect, namely the behavior of the soil in a state of water saturation, which is represented through the immersion of the test specimen so that the results of the study describe the most unfavorable conditions in the field.

Population and Research Sample

The population in this study is all the basic soil found on the Arso XIV road section, Keerom Regency, along with limestone material in the Arso I deposit. The research sample consisted of seven treatment groups, namely original soil without mixture as a control, soil with the addition of limestone 10%, 20%, and 30% to the dry weight of the soil, and the next three groups in the form of each of the lime variations with the addition of Soil Stabilizer additives of 2% of the dry weight of the soil. Each mixed composition is made three test specimens as a repetition, so that the reported value is the average value and deviations due to a single test error can be minimized. To keep the samples representative, the integrity of the material is maintained during the transportation process from the site to the laboratory, accompanied by documentation of coordinates and transportation processes to secure the validity of the data.

Data Collection Instruments and Techniques

This research instrument is a set of soil mechanics laboratory test tools and the reference standards that bind them, which function as a measuring tool as well as a guarantor of data objectivity. The instrument includes a set of strainers for gradation analysis (ASTM D 422), a Casagrande tool and a plastic boundary kit for Atterberg boundary testing (ASTM D-423C, ASTM D-424, and ASTM D-427; SNI 1966-2008 and SNI 1967-2008), picnometer for specific gravity testing (SNI 03-1964-2008), standard Proctor compaction tool (SNI 1742:2008), and CBR Test along with mold and immersion tub for laboratory CBR testing (SNI 03-1744-1989), with soil classification referring to AASHTO M145. The design of the lime mixture refers to SNI 03-3437-1994 and SNI 03-4147-1996. The data collected consists of primary data and secondary data. Primary data were obtained directly from the results of testing the characteristics of soil, limestone, and additives in the laboratory, while secondary data were obtained from the results of previous research related to soil stabilization using lime and additives (Muda, 2016; Dwina et al., 2021; Soewignjo, 2022), which functions as a comparator as well as a saver of research resources without reducing the validity of the findings.

Treatment Design and Data Analysis

The treatment strategy is arranged in stages so that the contribution of each ingredient can be clearly separated. The first stage tests the original soil to establish a baseline and ensure that the soil does need stabilization. The second stage added limestone at three levels of grade to determine the influence of local materials in a single way (Asfian, 2017). The third stage is to add a 2% additive to each lime content to find out its synergistic effect. The entire mixture was homogenized, fermented for 24 hours for the reaction between the ingredients to take place, molded in a mold, and then soaked for four days before being tested, following the practice common in similar studies (Syaifuddin & Amani, 2017). Data analysis was carried out in a quantitative descriptive and comparative manner by presenting results in the form of tables and graphs of the relationship between the content of added materials to the CBR value, plasticity index, and maximum dry density, then compared to the technical requirements of the subsoil as well as to the findings of previous research (Sikowati, 2018; Kusuma et al., 2022). From this comparison, the composition of the mixture was determined that provided the best increase in carrying capacity, which subsequently became the basis for drawing conclusions and research suggestions. With this line of thinking, the entire series of methods in this study does not stop at the test results, but is directed to produce technical recommendations that can be directly used in handling basic soil based on local materials, both on the Arso XIV road section and on other sections with similar soil characteristics.

RESULTS AND DISCUSSION

Research Profile and Data Overview

This research resulted in findings obtained entirely from laboratory testing on the bedrock of the Arso XIV STA 7+600 road section, limestone material from the Arso I quarry, and Soil Stabilizer additives, all of which were carried out at the Laboratory of the National Road Implementation Center (BPJN) Jayapura. The data analyzed included seven groups of test subjects, namely native soil as a control, soil with the addition of 10%, 20%, and 30% limestone to the dry weight of the soil, and the three variations with an additional 2% additive. Each composition is represented by three test objects, so that in total 21 test objects were analyzed, each of which went through a series of analysis tests of sieve analysis, Atterberg limits, specific gravity, standard Proctor compaction, and CBR submerged at three levels of compaction energy (10, 35, and 65 impacts). The findings are presented sequentially following the flow of the method, starting with the identification of the characteristics of the original soil as the baseline, followed by the response of the soil to the addition of lime, then the response to the combination of lime and additives, and ending with the determination of the optimal composition. Such a presentation order is necessary because technical decisions regarding the feasibility of the subsoil are only valid if they are based on a series of physical and mechanical properties that explain each other (Hadmoko & Suryadarma, 2020).

Characteristics of Original Groundland

The results of the sieve analysis test according to SNI Revision 03-3423-1994 show that Arso XIV subsoil has a percentage that passes sieve No. 200 of 11.12%, so it is classified as fine-grained soil, while limestone material has a percentage that passes sieve No. 200 of 10.04%. Atterberg boundary testing (SNI 1966-2008 and SNI 1967-2008) gave a liquid limit value (LL) of 31.18%, plastic limit (PL) of 10.29%, and plasticity index (IP) of 20.89%, with a specific gravity of 2.086 gr/cm^3. Based on SNI 03-6797-2002, the combination of values places the soil in the classification A-6, which is clay soil which is generally considered poor to moderate as a basic soil material. These findings reinforce the definition of soil as a set of mineral grains and weathered organic matter whose behavior is highly determined by water filling the interparticle cavity (Das, 1995; Hardiyatmo, 2010). This condition is in line with the results of the compaction test which only produced a maximum dry content weight of 1.33

gr/cm³ at a very high optimum moisture content, which is 35.02%, and a very low submerged CBR value. With a plasticity index close to 21% and a CBR well below the requirements, the subsoil at the research site proved to be indirectly usable as a pavement support layer and absolutely required stabilization (Kurniawan & Hadimuljono, 2021).

Atterberg Boundary Test Results of All Mixed Variations

The first important finding was the change in soil consistency due to treatment. The addition of limestone consistently lowered the plasticity index from 20.89% in the original soil to 18.78%, 15.66%, and 13.64% respectively in the lime content of 10%, 20%, and 30%. The addition of Soil Stabilizer additives by 2% strengthens this tendency noticeably, so that the plasticity index decreases to 11.41%, 9.70%, and 7.59% at each lime content. This decrease indicates the work of the cation exchange mechanism and flocculation of clay grains that are common in calcium-based stabilizations (SNI 03-3437-1994; Dwina et al., 2021). The only deviation was recorded in the 10% lime mixture which actually raised the melting limit to 38.87%, allegedly due to the high-water absorption capacity of limestone material at low levels that had not been compensated by adequate binding reactions. The recapitulation of the test results is presented in Table 1 and Figure 1 below.

Table 1. Recapitulation of the Atterberg Boundary Test Results of All Mixed Variations

Mixture Variations	LL (%)	PL (%)	IP (%)	IP Degradation (%)
Natural Soil	31,18	10,29	20,89	—
Soil + Coral 10%	38,87	20,09	18,78	10,10
Soil + Coral 20%	29,67	14,01	15,66	25,04
Soil + Coral 30%	25,38	11,73	13,64	34,71
Soil + Coral 10% + Additive 2%	30,06	18,65	11,41	45,38
Soil + Coral 20% + Additive 2%	24,47	14,76	9,70	53,57
Soil + Coral 30% + Additive 2%	22,02	14,43	7,59	63,67

Source: BPJN Jayapura laboratory test results, 2025

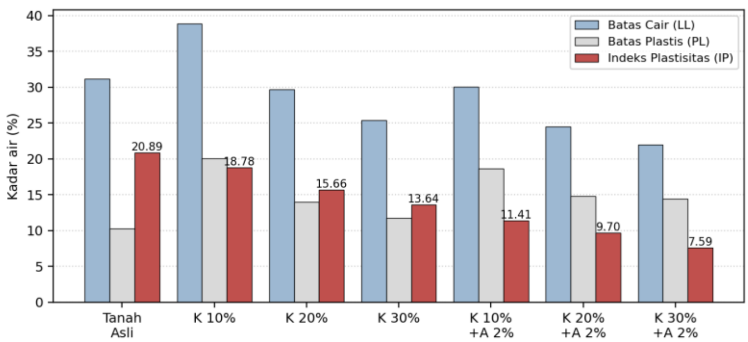

Figure 1. Comparison Chart of Liquid Limits, Plastic Limits, and Plasticity Index of All Mixed Variations

Source: Analysis results, 2025

Specific Gravity Test Results

The second finding relates to the basic physical properties of the mixture. The specific gravity of the original soil of 2.08 increased to 2.42, 2.44, and 2.52 respectively with the addition of 10%, 20%, and 30% lime. This increase occurs because limestone material has a greater density than real clay grains, as the character of limestone is composed predominantly of calcium carbonate. In contrast, the addition of a 2% additive did not significantly change specific gravity; The value is relatively the same as that of a mixture without additives. These findings are important because they confirm that Soil Stabilizers do not work by increasing the mass of grains, but rather through chemical reactions that improve the bonds between grains and the mechanical properties of the soil, in line with the behavior of similar additives that increase compressive strength without meaningfully altering the physical properties of the soil (Muda, 2016).

Standard Compaction Test Results (Proctor)

The third finding concerns the compaction characteristics tested referring to SNI 1742:2008. The maximum dry content weight increased from 1.33 gr/cm³ in the original soil to 1.53 gr/cm³, 1.64 gr/cm³, and 1.78 gr/cm³ with the addition of 10%, 20%, and 30% lime, then increased again to 1.62 gr/cm³, 1.77 gr/cm³, and 1.82 gr/cm³ when 2% additives were added. At the same time, the optimum moisture content dropped sharply from 35.02% to only 6.00% in a mixture of 30% lime with 2% additives. These two opposite tendencies are strong indicators of improvement: the soil becomes denser and much more water-efficient to reach its maximum density, so the soil becomes less sensitive to changes in the moisture content in the field. The highest density values and the lowest water requirements were both achieved in a mixture of 30% lime + 2% additives, which confirms the effectiveness of the combination in improving the compaction characteristics (Dwina et al., 2021). The recapitulation of the results is presented in Table 2 and Figure 2.

Table 2. Recapitulation of Specific Gravity and Standard Compaction Test Results

Mixture Variations	Specific Gravity	γd maks (gr/cm³)	Optimal Moisture Rate (%)
Natural Soil	2,08	1,33	35,02
Soil + Coral 10%	2,42	1,53	17,37
Soil + Coral 20%	2,44	1,64	14,83
Soil + Coral 30%	2,52	1,78	10,60
Soil + Coral 10% + Additive 2%	2,42	1,62	12,47
Soil + Coral 20% + Additive 2%	2,45	1,77	8,80
Soil + Coral 30% + Additive 2%	2,52	1,82	6,00

Source: BPJN Jayapura laboratory test results, 2025

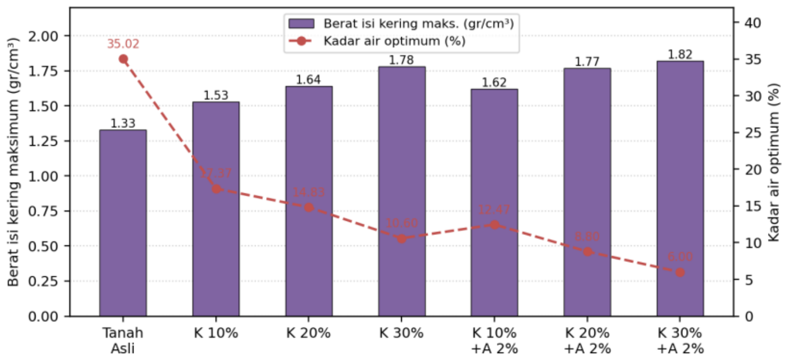

Figure 2. Comparison Graph of Maximum Dry Fill Weight and Optimal Moisture Rate of Mixture

Source: Analysis results, 2025

Submerged CBR Test Results

The fourth finding is the main answer to the formulation of the research problem. Submerged CBR testing refers to SNI 1744:2012, with values taken from the largest ratio between 0.1 inches and 0.2 inches of penetration. The CBR value of the original basic land plan is only 2.20%, far below the minimum requirement of 6% of the basic land. The addition of limestone increased the value to 3.10%, 4.60%, and 6.30% at 10%, 20%, and 30%, while the addition of 2% additive increased it again to 4.00%, 6.40%, and 7.60%. Thus, only two compositions managed to exceed the 6% threshold, namely 20% lime + 2% additives and 30% lime + 2% additives, with the highest value of 7.60% or the equivalent of an increase of about 245% against the original soil. The CBR value is placed as a determinant because this parameter is directly used in the planning of pavement thickness (Wijaya, 2016; Yasin, 2018).

Table 3. Recapitulation of Submerged CBR Values of All Mixed Variations

Mixture Variations	CBR 10 Tumb. (%)	CBR 35 Tumb. (%)	CBR 65 Tumb. (%)	CBR Plan (%)
Natural Soil	1,30	2,06	3,10	2,20
Soil + Coral 10%	1,52	2,97	4,54	3,10
Soil + Coral 20%	2,01	3,50	4,62	4,60
Soil + Coral 30%	3,28	4,83	7,31	6,30
Soil + Coral 10% + Additive 2%	2,10	3,70	5,30	4,00
Soil + Coral 20% + Additive 2%	3,60	5,80	7,50	6,40
Soil + Coral 30% + Additive 2%	4,10	7,00	8,90	7,60

Source: BPJN Jayapura laboratory test results, 2025

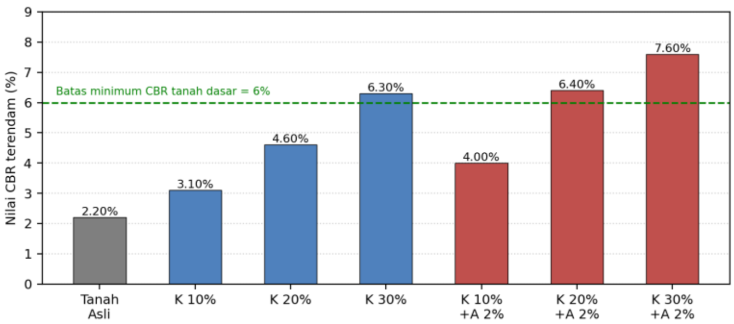

Figure 3. Comparison Chart of CBR Values of Whole Mixed Variation Plan to Minimum Requirements

Source: Analysis results, 2025

Judging from the compaction energy, all variations of the mixture show a consistent pattern: the CBR value increases as the number of collisions increases from 10, 35, to 65. In the original soil, the CBR value moved from 1.30% to 2.06% and 3.10%, while in the 30% lime mixture + 2% additive the value reached 4.10%, 7.00%, and peaked at 8.90% on 65 impacts. This pattern shows that the improvement of materials and the energy of compaction work together, so that the best results can only be achieved if the right mixture composition is carried out in conjunction with strict compaction control in the field (Yasin, 2018).

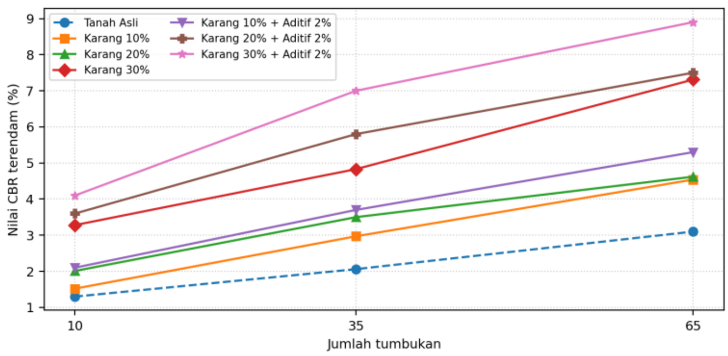

Figure 4. Graph of the Relationship of the Number of Collisions to the Value of the Submerged CBR of All Mixed Variations

Source: Analysis results, 2025

All of the above findings confirm each other and form a complete explanation. A decrease in the plasticity index of up to 7.59%, an increase in the maximum dry content weight of up to 1.82 gr/cm³, a decrease in the optimum moisture content of up to 6.00%, and an increase in the CBR value of up to 7.60% all achieved their best condition in the same composition, namely 30% lime + 2% additive. This cross-parameter consistency reinforces the belief that the improvement that occurred was not the result of a test chance, but rather the result of a real mechanism, namely the filling of the cavity by chalk grains that improve the gradation as well as the chemical reaction of the additives that bind the grains. The inverse relationship between the plasticity index and the CBR value that is clearly seen in this study also reaffirms the finding that the content of plastic materials is the main depressing factor of carrying capacity (Pokaton, 2015).

When compared to previous studies, these results show a similar pattern and have differentiators. Sikowati (2018) reported that lime from South Sorong was only effective up to 6% and lowered CBR at higher levels, while in this study the addition of lime of up to 30% still continued to increase the CBR value without any symptoms of decrease. This difference is natural because the material used is in the form of granular limestone which acts as a filler and gradation repair, not just a chemical bonding material. Syaifuddin and Amani (2017) obtained an increase in submerged CBR through a combination of cement and lime at 18%, while Kusuma et al. (2022) achieved an optimal CBR of 20% using wood charcoal on high plasticity clay soils with a natural CBR of 4.8%. Soewignjo (2022) also reported an increase in CBR of high plasticity clay through cement and base ash. This study completes the series by showing that inorganic mineral-based additives in very small levels, namely 2%, are able to provide an additional CBR value equivalent to the addition of 10% lime, as can be seen from the comparison of 20% lime mixture + 2% additives (6.40%) against 30% lime without additives (6.30%). This finding confirms the role of additives as a reinforcement of the efficiency of using local materials, not just additives (Muda, 2016).

Practically, these findings provide immediate applicability implications. The composition of 20% lime + 2% additive can be recommended as a minimum economical choice because it meets the requirements of the CBR of the subsoil with less local material requirements, while 30% lime + 2% additive is recommended as the optimal composition if a larger bearing capacity reserve is desired on the Arso XIV road section. These two recommendations prove that the handling of the basic soil in Keerom Regency can be carried out without bringing in materials from outside Papua, according to the direction of the use of local resources that are the basis of this research (Kurniawan & Hadimuljono, 2021).

However, there are some limitations that need to be noted honestly. Testing is carried out on one type of soil and one additive rate, so the actual optimal additive rate cannot yet be determined. In addition, all values are obtained on a laboratory scale with controlled conditions, so verification through field tests is still required before applying it to the actual work (SNI 03-4147-1996).

CONCLUSION

Based on the results of the study on subgrade soil stabilization in Arso 14 using a mixture of limestone and Soil Stabilizer additives, the following conclusions can be drawn: 1.) The results of the California Bearing Ratio (CBR) test of the subsoil are 2.20% and the results of the test results of the soil properties of the liquid limit are 31.18%, the plasticity index is 20.89% and the specific gravity is 2.086 gr/cm³. 2.) California Bearing Ratio (CBR) test results of soil mixture and new limestone 10%, mixture of base soil and limestone 20%, mixture of base soil and limestone 30%. The CBR values in these three mixtures were 3.10%, 4.6%, and 6.3%. The addition of limestone to the soil affects the CBR value. 3.) The California bearing ratio (CBR) test result with the addition of 2% additive to the mixture of subsoil and limestone is 4% for subsoil and 10% limestone. The CBR value for 20% bedrock and limestone is 6.4%. Meanwhile, the CBR value for 30% bedrock and limestone is 7.60%.

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