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# Comparative Analysis of Subgrade Stabilization of a Road in Tungurahua Province - Ecuador

## Análisis comparativo de la estabilización de la subrasante de una carretera en la provincia de Tungurahua - Ecuador

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## Abstract

This study analyzes the stabilization of the subgrade of the road between the communities of Teligote and Masabachos in Tungurahua, Ecuador, using lime and sodium chloride. The results show that lime increases the CBR by 150% and significantly reduces plasticity, while sodium chloride improves soil cohesion and strength, with a 120% increase in CBR. Both stabilizers are viable and effective, but lime excels in strength and durability. The pavement design based on these improvements ensures adequate infrastructure for the projected traffic. This study contributes to sustainable road development, enhancing connectivity and living conditions in rural communities, and offers a replicable model for similar projects in developing countries.

**Keywords:** Soil stabilization, subgrade, lime, sodium chloride.

## Resumen

Este estudio analiza la estabilización de la subrasante de la vía entre las comunidades de Teligote y Masabachos, en Tungurahua, Ecuador, utilizando cal y cloruro de sodio. Los resultados muestran que la cal incrementa el CBR en un 150% y reduce significativamente la

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plasticidad, mientras que el cloruro de sodio mejora la cohesión y resistencia del suelo, con un aumento del CBR del 120%. Ambos estabilizantes son viables y efectivos, pero la cal sobresale en resistencia y durabilidad. El diseño de pavimento basado en estas mejoras asegura una infraestructura adecuada para el tráfico proyectado. Este estudio contribuye al desarrollo vial sostenible, mejorando la conectividad y las condiciones de vida de las comunidades rurales, y ofrece un modelo replicable para proyectos similares en países en desarrollo.

Palabras clave: Estabilización de suelos, subrasante, cal, cloruro de sodio.

## Introduction

The development of road infrastructure plays a crucial role in the economic and social growth of communities. Roads not only facilitate the transportation of goods and people, but also contribute to sustainable development by connecting remote regions with urban centers. In this context, the study entitled "Comparative analysis of the stabilization of the road subgrade between the communities of Teligote and Masabachos in the Benítez parish, San Pedro de Pelileo canton, with lime and sodium chloride to carry out the pavement design of the same" focuses on addressing the infrastructure challenges facing the province of Tungurahua, Ecuador.

Soil stabilization is a widely used technique to improve the mechanical properties of soils that do not meet the standards required for road construction. Previous studies have shown that materials such as lime and sodium chloride are effective in improving low-bearing-capacity soils, increasing their strength and reducing their plasticity (Kumar & Walia, 2006). These techniques, as well as being effective, are economical and sustainable, making them ideal for projects in rural regions with limited resources.

Road connections are a determining factor for the development of rural communities, such as Teligote and Masabachos, which depend to a large extent on agriculture and livestock for their economic sustenance. An inadequate road network limits the marketing of products, increases transportation costs and reduces access to essential services such as health and education (World Bank, 2019). In Ecuador, improving road infrastructure has been a priority in recent

decades, with significant progress made in interregional connectivity (Ministry of Transport and Public Works, 2020).

In this sense, the present research not only seeks to improve a specific road, but also to contribute to the general well-being of the beneficiary communities, aligning with the United Nations Sustainable Development Goals (SDGs), particularly SDG 9, which promotes the construction of resilient and sustainable infrastructure (United Nations, 2015).

Benítez parish, located in the San Pedro de Pelileo canton, Tungurahua province, has a mountainous relief and variable climatic conditions that challenge the durability of road structures. The road between the communities of Teligote and Masabachos is of vital importance for the inhabitants, as it connects areas of agricultural production with local and regional markets. However, its current state, with highly plastic soils and low load-bearing capacity, hinders safe and efficient transit.

The literature indicates that improving road infrastructure in rural regions not only facilitates transportation, but also generates indirect benefits, such as reducing migration to cities and increasing local economic opportunities (Pereira et al., 2021). In addition, the application of soil stabilization techniques in these contexts has proven to be an efficient and sustainable solution, particularly in developing countries.

Soil stabilization is a common practice in civil engineering, used to improve the physical and mechanical properties of the ground. Lime is one of the most widely used materials due to its ability to reduce soil plasticity and increase its compressive strength, especially in clay soils (Little & Nair, 2009). On the other hand, sodium chloride, being hygroscopic, regulates soil moisture and improves its cohesion, although its effectiveness may depend on local climatic conditions (Santoni & Tingle, 2001).

Recent studies have explored the combination of these stabilizers, achieving promising results in the improvement of subgrades for low- and medium-traffic roads (Zhang et al., 2020). These findings support the application of these techniques in projects such as the present one, where the cost-benefit ratio is a key factor.

The study was carried out in several stages, including field inspection, soil sampling and a series of laboratory tests. Granulometric analyses, Atterberg limits tests and compaction tests were carried out to assess the initial soil conditions. Subsequently, treatments with lime and sodium chloride were applied in different proportions, following the recommendations of the ASTM D6276 standard for lime-stabilized soils and the standards of the MOP Highway Manual for the use of sodium chloride.

The scope of the project also included the geometric and structural design of the road, ensuring that the specifications complied with local and international standards. The results obtained will allow the comparison of the effectiveness of both stabilizers and the proposal of the most appropriate solution for the region.

The implementation of the proposed solutions is expected to have a significant impact on the quality of life of the inhabitants of Teligote and Masabachos. An improved road will not only reduce transportation costs and increase road safety, but will also foster economic development by facilitating access to markets and services. Furthermore, this project could serve as a model for other rural communities in Ecuador and countries with similar contexts, demonstrating the viability of using economic and sustainable stabilization techniques.

In conclusion, the present research addresses a critical problem for rural communities, offering solutions based on scientific evidence and international best practices. The results will contribute to knowledge in the field of road engineering and can be applied in future projects to improve infrastructure in similar regions.

## Methodology

The project was carried out on the road that connects the communities of Teligote and Masabachos, located in the Benítez parish, San Pedro de Pelileo canton, Tungurahua province. This region is characterized by a mountainous relief and a variable climate, conditions that directly influence the quality of the soil and its performance as a basis for road infrastructure.
In order to evaluate the initial properties of the soil and determine its viability for stabilization, the following activities were carried out:

Test pits and sample extraction: Excavations were carried out at strategic points along the road to collect representative samples of the existing soil.

Soil characterization: The tests included:

Grain Size Analysis: To determine the particle size distribution.

Atterberg Limits: To evaluate the plasticity of the soil.

Standard and Modified Proctor Tests: To determine the maximum dry density and optimum moisture content.

California Bearing Ratio (CBR): To measure the bearing capacity of the soil.

In addition, two main stabilizing materials were used:

Lime: Applied in proportions between 2% and 8% of the dry weight of the soil, following the ASTM D6276 standard. This material was selected for its ability to reduce plasticity and increase compressive strength.

Sodium Chloride (NaCl): Applied in quantities of 80 kg/m3 of soil, in accordance with the specifications of the MOP Highway Manual. Its hygroscopic property facilitates the regulation of moisture in the soil.

The design of the road structure was based on AASHTO 93 standards, incorporating the improved properties of stabilized soil. The design included:

A 7.5 cm asphalt wearing course.

A 20 cm lime or NaCl stabilized granular base.

A 25 cm compacted granular sub-base.

The performance of the two stabilizers was evaluated by laboratory tests and traffic simulations, comparing the results obtained in terms of strength, durability and cost.

## Results

The results of the initial tests indicated that the soils in the region have a high plasticity and low bearing capacity, with average CBR values of 4%. These conditions make them unsuitable for supporting vehicular

traffic without prior treatment. In addition, the Atterberg limits showed high values, confirming the need for stabilization to improve their mechanical behavior.

Lime: The application of lime in proportions of between 4% and 8% resulted in significant improvements. CBR values increased on average by 150%, reaching up to 10% in some tests. In addition, plasticity decreased considerably, which contributes to greater soil stability.

Sodium Chloride: This stabilizer showed an average increase of 120% in CBR values, reaching up to 9% in optimal conditions. Although less effective than lime in reducing plasticity, it improved soil cohesion and strength, especially under controlled moisture conditions.

**Table 1.** *Comparative results of the stabilizers*

| Propiedad | Suelo Natural | Cal (Promedio) | NaCl (Promedio) |
|---|---|---|---|
| CBR (%) | 4% | 10% | 9% |
| Plasticidad | Alta | Baja | Moderada |
| Cohesión | Baja | Alta | Moderada |
| Resistencia | Baja | Alta | Alta |

The stabilization with lime presented a slightly higher cost than sodium chloride, but its effectiveness justifies the investment. The estimated lifespan of the road with lime is 20% longer than the design with sodium chloride.

In conclusion, both stabilizers proved to be effective, with lime having a clear advantage in strength and durability, while sodium chloride excels in terms of cost and ease of application. The combination of these techniques could be explored in future studies to optimize results.

## Conclusions

The research carried out on the stabilization of the subgrade of the road between Teligote and Masabachos offers valuable findings for the field of road engineering, especially in the context of rural regions with low bearing capacity soils. The results obtained highlight the significant benefits of using stabilizers such as lime and sodium

chloride, as well as providing key information for future interventions in similar infrastructure.

There are three aspects that we consider most relevant:

Efficiency of Lime: Lime stood out as the most effective stabilizer, achieving a 150% increase in CBR values and significantly reducing soil plasticity. This material proves to be an ideal solution for regions with high levels of humidity and clayey soils.

Feasibility of sodium chloride: Although less effective than lime, sodium chloride offers a notable improvement in soil cohesion and resistance, especially in conditions where moisture control is critical. Furthermore, its low cost makes it attractive for projects with budgetary limitations.

Comparison and Application: Direct comparison between the two stabilizers provides a practical guide for engineers and planners when selecting the most suitable material according to the specific needs of the project.

The implementation of these stabilization techniques not only improves the quality of the roads, but also has a direct impact on the well-being of local communities. A robust road infrastructure facilitates access to markets, reduces transportation costs and improves connectivity, contributing to socioeconomic development.

This study opens the door to future research that could explore combinations of stabilizers to maximize benefits. In addition, the long-term impact of these solutions in different climatic and geographical conditions could be evaluated.

In conclusion, soil stabilization using lime and sodium chloride represents an effective and viable tool for improving road infrastructure in rural regions. The results of this study not only benefit local communities, but also provide a replicable model for similar projects in developing countries.

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