SEj
Vol. 6, N° 2, 2022

Journal of Sciences and Engineering

A publication of
CINCADER
Centre of Research and Training for Regional Development
Online at www.journals.cincader.org

ISSN 2523-9503
DOI: https://doi.org/10.32829/sej.v6i2.183

Evaluation of the efficiency in the use of anionic polyacrylamide, organosilane and sulfonate for the stabilization of roads with traffic low volume in the Peruvian highlands above 2000 m.s.n.m [Evaluación de la eficiencia en la utilización de poliacrilamida aniónica, organosilano y un sulfonatado para la estabilización de carreteras de bajo volumen de tránsito en la sierra peruana sobre los 2000 m.s.n.m]

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Received: 26 november 2022; Accepted: 20 december 2022; Published: 09 January 2023

Resumen

El objetivo de la investigación fue evaluar la eficiencia en la utilización de poliacrilamida aniónica, organosilano y un sulfonatado para la estabilización de carreteras de bajo volumen de tránsito en la sierra peruana sobre los 2000 m.s.n.m. Se realizaron ensayos con los materiales seleccionados; Subrasante, Cantera 1 y Cantera 2, con los estabilizadores, los cuales se obtuvo valores de CBR por encima de 40% minino para afirmados en caminos. La mejor opción de estabilización en cuanto a su comportamiento físico mecánico, se logró empleando una dosificación de la poliacrilamida aniónica de 1kg/m^3.

Palabras clave: Vías, estabilizadores, carreteras.

Abstract

The objective of the research was to evaluate the efficiency in the use of anionic polyacrylamide, organosilane and a sulfonate for the certainty of low volume traffic roads in the Peruvian highlands above 2000 m.s.n.m. Tests were carried out with the selected materials; Subgrade, Quarry 1 and Quarry 2, with the stabilizers, which obtained CBR values above 40% minimum for paved roads. The best expression option in terms of its mechanical physical behavior was used using an anionic polyacrylamide dosage of 1kg/m^3.

Keywords: Tracks, stabilizers, roads.

1. Introduction

The problem is focused because, in various sections of the tracks, deterioration and premature wear is very critical, it does not meet the objective of its designed and/or projected useful life. Caused by various factors, as well as the physical-mechanical composition of the affirmed materials used from our own quarries located along the sections to be rehabilitated.

Some quarry materials, prior to a soil mechanics laboratory analysis, do not meet the characteristics and parameters of their content of the affirmed material, established in the general technical specifications (EG) 2013.

Please cite this article as: Villanueva S.M., Evaluation of the efficiency in the use of anionic polyacrylamide, organosilane and sulfonate for the stabilization of roads with traffic low volume in the Peruvian highlands above 2000 m.s.n.m, Journal of Sciences and Engineering, vol. 6, no 2, 2022, pp. 28-36. https://doi.org/10.32829/sej.v6i2.183

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In the rehabilitation of roads, quarry material has been used for affirmation work along the platform of the roads, in mountainous areas where natural adversities occur, in the months of January to April with the presence of rainfall with greater intensity, temperature changes and other factors typical of the area, causing premature wear of the track. The roads due to lack of maintenance; cleaning of ditches, sewers, landslides, the rolling layer deteriorates and increased costs in the periodic maintenance stage or that a new intervention is required before completing the projected useful life.

Choque Sánchez, H. (2012), studied the application of soil treatment, with a chemical additive (calcium chloride and the PZ-22X enzyme), a mixture with quarry material, in order to improve, maintain the moisture content and increase and increase cohesion and waterproofing. The author concludes that at 80 days the deterioration is accelerated where there are potholes and with considerable roughness due to the presence of continuous rainfall, and from 117 days after applying the additive they presented a greater variation of the IRI compared to the application of the first days, where the material each time presents washing of fines and with formation of strips of mud, the additive material used was not effective.

Contreras Camacho, M. (2011), studied a soil stabilizer (Base - Seal) to guarantee a resistant and impermeable soil at the level of the first solid waste body of a sanitary landfill, using, providing an adequate functioning of the site, In this way, the objective is to improve the soil in which it provides a resistant layer that prevents settlement or deformation in the future and guarantees its useful life. The author concludes that the silty sand of low plasticity that was tested in the laboratory under simple compression obtained a load capacity of 7.01 Kg./cm2 in its natural state that same soil, when stabilized, reached a load capacity of 17.65 Kg/ cm2. In other words, its load capacity has increased by 151%. With this new value, the sanitary landfill has improved its level of displacement by applying the Base - Seal soil stabilizer, which would have the capacity to support a load of 176 meters of solid waste, considering a volumetric weight of this waste of 1000 Kg/m without suffering deformations or fractures that would put the aquifer at risk due to leachate seepage. By applying soil stabilizer at the level of a sanitary landfill, it is possible to avoid settlements and deformations of the land, as well as seepage or alteration and obtained the same coefficient of permeability.

Jiménez Lagos, M. (2014), used non-destructive structural diagnostic methods applying and/or stabilizing the affirmed with magnesium chloride mixing intimately and homogeneously with the soil to be treated and cured according to the product's own technical specifications, with the objective of The main objective is to transfer the treated soil in a defined thickness with certain characteristics tending to improve its performance properties in the service stage. The author concludes that the chemical stabilization of soils treats the natural soil transforming it into an impermeable, resistant and flexible base, for this process the soil requires study in such a way to dose the additive, the initial investment of a stabilized affirmation is higher than a common affirmation, however considered in a period of 10 years with permanent maintenance and periodic maintenance is more economical, within which constant maintenance is recommended, depending on the volume of vehicles and the location of the road where it is going to be applied , referring to the reconstruction cost is 05 times higher than the maintenance cost considered in a period of 10 years.

On the Peruvian coast, the magnesium chloride stabilizer performs favorably, but as the humidity increases, the road becomes slippery and usually becomes viscous, which causes deterioration of the road reflected in small and numerous potholes reaching the conclusion permanent maintenance.

There is a variety of soil stabilizers, in the investigation three stabilizers were studied; Anionic polyacrylamide, organosilane derivatives and sulfonated.

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2. Materials and Methods

The type of the present investigation regarding the approach is quantitative, oriented to results, with deductive reasoning, to contrast the hypothesis.

The type of the present investigation regarding the scope is descriptive, since it is intended to analyze how the soil stabilization variable behaves before the addition of the stabilizers anionic polyacrylamide, organosilane and a sulfonate.

The design was experimental, which consisted in the execution of field work, laboratory work and development in the office.

Fieldworks

- Compilation and evaluation of existing information.
- Geotechnical prospecting of the area.
- Location and execution of exploratory test pits.
- Sampling altered subgrade.
- Location of quarries and sampling of material from each quarry.

Sampling was carried out in the field through test pits in the quarries for the affirmation work. In the sampling, the exploration records were made, in which the different characteristics of the underlying strata are indicated, such as type of soil, thickness of the stratum, color, plasticity, consistency and/or compactness, etc.

Laboratory Works

- Subgrade and natural quarry tests.
- Dosage quarry tests.

Laboratory tests were carried out in order to identify and determine the characteristics of the materials along the section, on the samplings based on the Manual of Testing of Materials for Highways of the Ministry of Transport and Communications (MTC) version 2000 and the Standard from the American Society for Testing and Materials (ASTM).

Laboratory tests

Physical Characteristics:

- Granulometric analysis
- Limits of Consistency
- Shrinkage Limits
- Moisture Content

Mechanical Characteristics

- Modified Proctor

-C.B.R.

CBR with 03 dosages for each stabilizer, to determine the best dosage.

Description of laboratory tests:

- Granulometric Analysis of Coarse and Fine Aggregates

It consisted in determining, quantitatively, the particle sizes of coarse and fine aggregates of a material, by means of square opening sieves.

The distribution of the particle sizes of a dry sample of the aggregate, by separation through sieves arranged successively from largest to smallest opening.

- Soil Liquid Limit Test

The liquid limit of a soil is the moisture content expressed as a percentage of the oven-dried soil, when it is in the limit between the plastic state and the liquid state.

- Plastic Limit and Plasticity Index Test

It consisted in the determination in the laboratory of the plastic limit of a soil, and the calculation of the plasticity index (PI) if the liquid limit (L.L.) of the same soil is known.

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Plastic limit (PL) is the lowest humidity at which soil bars of about 3 mm (1/8") in diameter can be formed, said soil between the palm of the hand and a smooth surface (ground glass), without these bars crumbling.

Test to Determine the Moisture Content of a Soil

The moisture or moisture content of a soil is the ratio, expressed as a percentage, of the weight of water in a given mass of soil, to the weight of solid particles.

- Test to Determine the C.B.R. of a soil

It consists of determining a soil resistance index called the value of the support ratio, which is known as CBR (California Bearing Ratio). The test is normally carried out on soil prepared in the laboratory under determined conditions of moisture and density.

With the affirmed quarry materials and with stabilizers, the procedure indicated above was carried out with curing at 4 days, 7 days to verify the increase in the support capacity of the stabilized affirmation.

Cabinet Jobs

It consisted of processing data from field work, results; comparison of the use of the affirmed material versus with material applying each stabilizer, analysis with comparison of results, discussion and conclusions.

The study population focused on a section of road located in the department of Ancash, at an altitude of over two thousand meters above sea level.
C.P Poncos 3281 m.s.n.m.

Altitude: 3281 meters above sea level
Department: Ancash
Country: Peru

Figure 1. Map of the study

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3. Results

Soil characteristics

The soil characteristics are:
- In subgrade; GC – GM silty clayey gravel, with a percentage of fines of 23.82%, with a plasticity index (PI) = 6%; in quarry 1 Clay gravel with GC sand, with a percentage of fines 30.38%, with a plasticity index (PI) = 12% and in quarry 2 Clay gravel with GC sand, with a percentage of fines 30.38%, with a plasticity index (PI) = 11%.
- The support capacity (CBR) using anionic polyacrylamide at 0.02% by weight in subgrade was: CBR 100% 50.2%
- The support capacity (CBR) using anionic polyacrylamide at 0.02% by weight in quarry 1 was: CBR 100% 79.8%
- The support capacity (CBR) using organosilane at 0.05% by weight in quarry 2 was: CBR 100% 86.3%
- The support capacity (CBR) using organosilane at 0.05% by weight in subgrade was: CBR 100% 76.7%
- The support capacity (CBR) using organosilane at 0.05% by weight in quarry 1 was: CBR 100% 74.3%
- The support capacity (CBR) using organosilane at 0.05% by weight in quarry 2 was: CBR 100% 80.1%
- The bearing capacity (CBR) using 0.02% sulfonate by weight in subgrade was: CBR 100% 69.5%
- The support capacity (CBR) using sulfonate at 0.02% by weight in quarry 1 was: CBR 100% 63.5%
- The support capacity (CBR) using sulfonate at 0.02% by weight in quarry 2 was: CBR 100% 74.3%
- From the durability test:
- The durability index using anionic polyacrylamide for fine aggregate was 40%. Coarse aggregate 40%
- The durability index using organosilane for fine aggregate was 35%. coarse aggregate 60%
- The durability index using anionic polyacrylamide for fine aggregate was 45%. Coarse aggregate 70%

It can be verified in table 1 and figure 2, that the CBR value increases with respect to the natural material from Quarry 1 from 55.4 % to a CBR value of 50.2% with polyacrylamide stabilizer, to 76.7% with organosilane stabilizer and to 69.5% with sulfonated stabilizer.

Table 1. Results of laboratory tests with quarry material 1 and chemical stabilizers with 3 dosages

CBR	CBR 95%	CBR 100%	CBR 95%	CBR 100%	CBR 95%	CBR 100%
Quarry 1 + Polyacrylamine stabilizer	24.2	37.9	31.4	39.6	31.8	50.2
Quarry 1 + Organosilane stabilizer	40	25.2	40.6	59.5	46.8	76.7
Quarry 1 + Sulfonated stabilizer	22.8	38.1	35.1	46	49.1	69.5
Quarry 1 Natural	18.6	55.4	0	0	0	0

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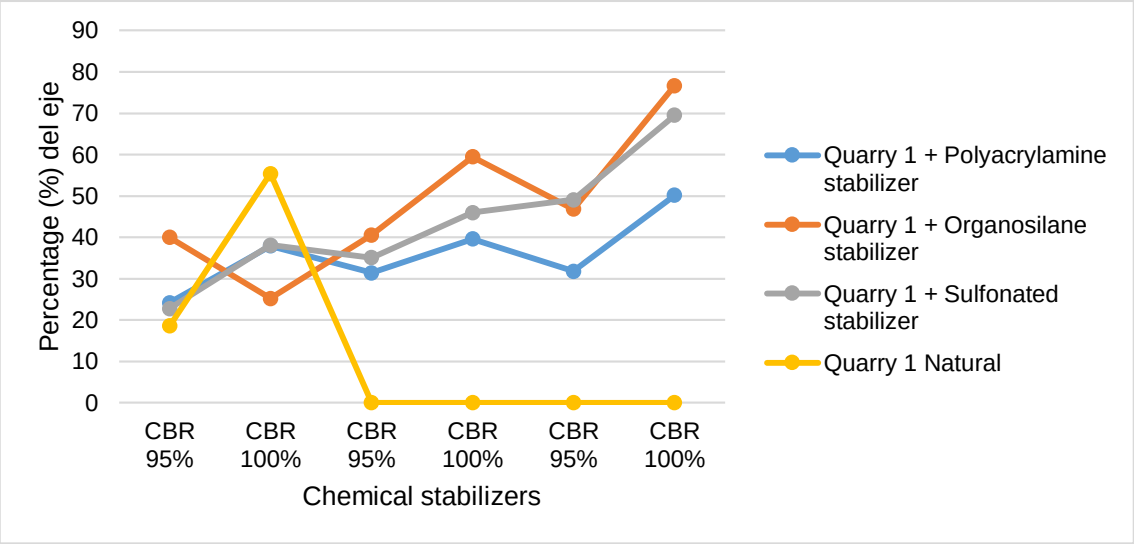

Figure 2. Comparison of Quarry 1 with Outriggers

It can be verified in Table 2 and Figure 3 that the CBR value increases with respect to the natural material from Quarry 2 from 27.4% to a CBR value of 86.3% with polyacrylamide stabilizer, to 80.1% with organosilane stabilizer and to 74.3%. % with sulfonate stabilizer.

Table 2. Results of laboratory tests with quarry material 2 and chemical stabilizers with 3 dosages

CBR	CBR 95%	CBR 100%	CBR 95%	CBR 100%	CBR 95%	CBR 100%
Quarry 2 + Polyacrylamine stabilizer	25	34.4	32	57.6	54.2	86.3
Quarry 2 + Organosilane stabilizer	21.8	36.4	43	66.5	54	80.1
Quarry 2 + Sulfonated stabilizer	19.4	33.3	39	63	45.1	74.3
Quarry 2 Natural	17	27.4	0	0	0	0

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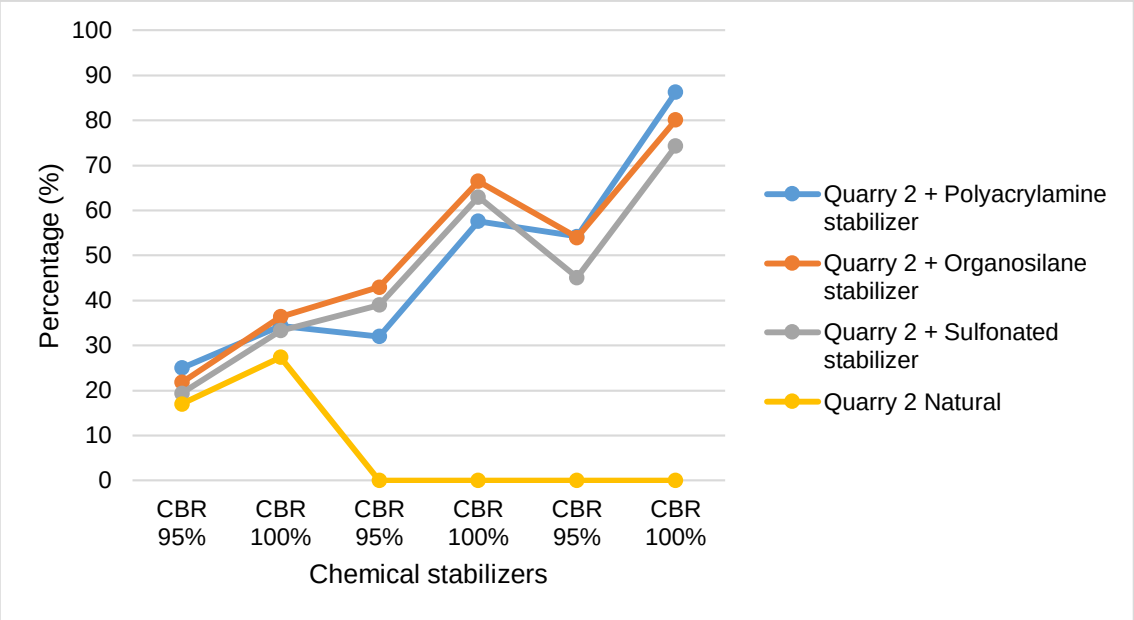

Figure 3. Comparison of Quarry 2 with Outriggers

It can be verified in table 3, that the CBR value increases with respect to the natural material of the subgrade from 45% to a CBR value of 50.2% with polyacrylamide stabilizer, to 76.7% with organosilane stabilizer and to 69.5% with sulfonated stabilizer.

Table 3. Results of laboratory tests with subgrade material and chemical stabilizers studied

CBR	CBR 100%	Affirmed spec.	Affirmed spec.stab.
Subgrade + anionic polyacrylamide	50.2	40	100
Subgrade + organosilane stabilizer	76.7	40	100
Subgrade + sulphonated stabilizer	69.5	40	100
Natural subgrade	45.4	40	100

The cost of affirmed with the stabilization per kilometer achieves a saving of 30% equivalent to S / 28, 226.78 soles in a period of 10 years. Therefore, for the entire neighborhood network, which is approximately 100,000 km, we would have savings of S/ 2' 822,678,406.90 (Two trillion eight hundred twenty two thousand seven hundred seventy eight thousand four hundred six with 90/100 soles)

The hypothesis was confirmed. Considering the natural properties of the affirmed material and quarries 1 and 2, as well as the operation and maintenance costs, the best stabilization option in terms of its physical-mechanical behavior would be with anionic polyacrylamide.

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4. Discusion

The characteristics of the investigated soils do not meet the technical specifications to be considered as affirmed material, in terms of granulometry, fine content and plasticity index.

The anionic polyacrylamide stabilizer with the three study soils increases bearing capacity and a better result is achieved in clayey gravel material with sand (GC) with an PI of 11 and with an PI = 14 it shows an increase in bearing capacity, which it does not occur with subgrade material with an PI =6.

The Organosilane stabilizer with the 3 soils at 0.05% by weight increases the bearing capacity and a better result is achieved in clayey gravel material with sand (GC) with an PI of 11.

The sulfonated stabilizer with the 3 soils at 0.02% by weight increases the bearing capacity and a better result is achieved in clayey gravel material with sand (GC) with an PI of 11.

The material of the subgrade, it was determined that a better behavior is achieved with the organosilane stabilizer, using the three dosages, CBR at 100% equal to 55.4%.

Quarry material 1 (GC), it was determined that a better behavior is achieved with the anionic polyacrylamide stabilizer, CBR at 100% equal to 50.2%.

The quarry material 2 (GC), it was determined that a better behavior is achieved with the anionic polyacrylamide stabilizer, CBR at 100% equal to 86.3%.

From the durability tests, it was verified that the stabilizer derived from Sulfonate and the polymer respond better than the stabilizer derived from Organosilane.

In Table 1 and Figure 2, the CBR value increases with respect to the natural material from Quarry 1 from 55.4% to a CBR value of 50.2% with polyacrylamide stabilizer, to 76.7% with organosilane stabilizer and to 69.5% with sulfonated stabilizer. Greater increase is obtained with the organosilane stabilizer.

In Table 2 and Figure 3, the CBR value increases with respect to the natural material from Quarry 2 from 27.4% to a CBR value of 86.3% with polyacrylamide stabilizer, to 80.1% with organosilane stabilizer and to 74.3% with sulfonated stabilizer. Greater increase is obtained with the polyacrylamide stabilizer.

In table 3, the CBR value increases with respect to the natural material of the subgrade from 45.4% to a CBR value of 50.2% with polyacrylamide stabilizer, to 76.7% with organosilane stabilizer and to 69.5% with sulfonated stabilizer.

With the stabilization per kilometer, a saving of 30% was calculated, equivalent to S/ 28, 226.78 soles in a period of 10 years. Therefore, for the entire neighborhood network, which is approximately 100,000 km, we have savings of S/ 2,822,678,406.90 (Two trillion eight hundred twenty-two thousand seven hundred seventy-eight thousand four hundred and six with 90/100 soles).

5. Conclusions

Tests were carried out with the selected materials; Subgrade, Quarry 1 and Quarry 2, with the stabilizers, which obtained CBR values above 40% minimum for affirmed roads. In the road manual "General technical specifications for construction" (EG-2003). However, they do not meet

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the technical specifications of CBR where it specifies 100%. Not meeting the quality requirements. In the road manual "General technical specifications for construction" (EG-2003). In chemical stabilizers.

The best stabilization option in terms of its physical-mechanical behavior would be achieved using an anionic polyacrylamide dosage of 1kg/m^3.

Considering the natural properties of the affirmed material from the quarries of the Poncos - Kochayoc (Ancash) section, the best stabilization option in terms of its physical, mechanical behavior and costs, would be achieved using an anionic polyacrylamide dosage of 1kg/m^3. Likewise, as the road was located at a height of 3000 masl, a sulfate durability test was carried out, resulting in two stabilizers that were suitable, it was verified that the stabilizer derived from Sulfate and the polymer respond better than the stabilizer derived from Organosilane.

It is concluded that the subgrade can be stabilized by scarifying a thickness of 20cm or more according to the vehicle load, taking into account that gravel greater than 2 inches must be scarified and removed and this represents a volume.

For neighborhood roads at heights greater than 2000 meters above sea level, there is the presence of rainfall, so it is recommended that it have a protective layer and a good drainage system, recommending ditches lined with concrete.

Likewise, due to the topography in curved sections, make it concrete or paved to have greater durability and less wear before vehicles pass.

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