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Experimental study of the improvement of the properties of the subgrade of a clayey soil of Pucallpa with a mixture of crushed PET and lime

Estudio experimental del mejoramiento de las propiedades de la subrasante de un suelo arcilloso de Pucallpa con una mezcla de PET triturado y cal.

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ABSTRACT: The excessive use of plastic poses a severe environmental threat, primarily stemming from the society's unchecked consumption and the lack of implementation of the circular economy principles in Peru. The absence of a well-established recycling ethos compounds to this challenge. Conversely, numerous studies have explored the use of crushed plastic bottles or polyethylene terephthalate (PET) to enhance the mechanical properties of soil for pavement applications, promoting the use of alternative materials. Additionally, the use of additives such as lime enhances the mechanical properties of clays by serving as a stabilizing agent owing to its water absorption capacity, thereby increasing the load-bearing capacity of soil. This study aims to evaluate the impact of crushed PET (1–2 mm, 2.5%) and lime (6.25%, 8.75%), measured in percentages by the weight of soil, on the reinforcement of high-plasticity clay soil in Pucallpa, a tropical region in Peru, with a focus on enhancing subgrade quality of the roads via laboratory tests. Fourier-transform infrared spectroscopy (FTIR) was utilized to assess the type of lime used. Furthermore, test for physical and chemical characterization, modified proctor compaction tests, and California bearing ratio (CBR) tests were performed, and the resilient modulus was theoretically determined with respect to the CBR value. This research concluded that clay soil mixed with crushed PET and lime can be used as an alternative material for pavement material, provided the PET size does not exceed 1–2 mm and an appropriate lime concentration of greater than 6.25% and 8.75% is available.

KEYWORDS: Crushed PET, high plasticity clay, lime, soil reinforcement, subgrade.

1 INTRODUCTION

Engineering techniques that enhance and develop pavement construction have witnessed steady growth, marked by technological innovations and material implementations, in finding alternatives for construction materials with a better cost-benefit ratio while enhancing strength and durability. Simultaneously, a heightened focus has been placed on reusing generated waste such as polyethylene terephthalate (PET).

Globally, population growth and industrial advancements have led to an increase in the exploration of natural resources and goods production, resulting in a substantial increase in waste generation. Among these wastes are PET containers, introduced to the market in the 1970s, offering various consumer benefits. The relentless exploration and exploitation of the advantages of PET have propelled the PET container production to approximately 390 million tons in 2021 (Janssens, 2022). However, this surge in production also led to a remarkable disadvantage: the extensive generation of PET waste, often improperly disposed of in nature, causing severe environmental consequences due to its prolonged degradation time, which is estimated at approximately 700 years (Crawford et al., 2013).

In the geotechnical engineering field, efforts are underway to improve the mechanical properties of materials and soils used for road construction. This is because the natural soil of a region often does not meet the required specifications to serve as a pavement subgrade, which can result in the deterioration or instability of pavements. The incorporation of PET in these soils is a promising alternative because it is an inert, resistant material with good chemical stability (Gil & Nuñez, 2018; Álvarez & Sosa, 2020; Astorayme & Ramon, 2021).

Additionally, it is imperative to conduct studies on this mixture's static and dynamic behavior as the latter can evaluate the mixture's recovery capacity for effective application. This analysis, commonly referred to as resilient behavior, is essential for validating the suitability of PET application in pavements, thereby offering a means to improve the mechanical behavior of roads and mitigate the environmental impacts caused by improper PET disposal (Mourão, 2018; Carvalho, 2019).

Subgrades serve as bases for various paved structures or unpaved routes, such as dirt and gravel roads, and are often composed of clays with high plasticity. This soil type is known for its low mechanical capacity and high moisture sensitivity, presenting considerable challenges in pavement construction due to its tendency to undergo plastic deformation under traffic loads (Álvarez & Sosa, 2020; Amena & Kabeta, 2022).

The soil stabilization technique employing lime, widely successful in various countries, has demonstrated its ability to prolong the lifespan of roads, thereby reducing the need for long-term maintenance and establishing them as economically competitive solutions. Additionally, lime-stabilized roads offer improved riding surfaces and superior performance, particularly in rainy and extremely humid conditions (Badillo & Elizondo, 2010; Ccansaya & Tello, 2022). Similar to the Peruvian jungle, roads in Pucallpa encounter challenges due to clay soil, complicating their construction and maintenance. This clay exhibits low shear strength and high plasticity and is prone to expansion or contraction with changes in moisture (López & Quevedo, 2022).

Asphalt pavement expands due to heat during heavy rains and contracts rapidly when rain falls, resulting in cracks extending to the underlying clay. The high water absorption capacity of the clay affects roads at their core, causing movements, deformations, and pavement cracks, thereby incurring additional costs for constant maintenance and repairs (Ardiansah et al., 2022). Generally, when interacting with medium- and high-plasticity soils, lime reduces the plasticity index, enhances workability, reduces expansion, and augments strength (López & Ortiz, 2018; Machado et al., 2018).

The main objective of this research is to analyze the behavior of high-plasticity clay sourced from the tropical city of Pucallpa in Peru. This analysis will be conducted with a constant 2.5% PET and lime as pavement components, within dosages set at 6.25% and 8.75%, respectively, calculated relative to the soil weight. The aim is to determine the optimal percentage for use in subgrade structures on roads.

2 MATERIALS AND METHODS

2.1 *Soil*

The selected study area encompasses the department of Pucallpa (Callería district, Coronel Portillo province), located in the Peruvian jungle. This area, utilized as a cultivation zone, primarily resides on a river terrace. The predominant soil composition in this region is clay, characterized by a pH of 5.11 and a reddish hue attributed to its mineral content, notably iron oxide (Fe2O3). Additionally, the presence of aluminum oxide (Al2O3) contributes to its acidity (Lopez & Quevedo, 2022).

Undisturbed soil samples were obtained and subjected to tactile-visual assessment to ensure the absence of substantial organic matter levels in the sample. The presence of the latter is not recommended due to its unfavorable properties, such as low soil strength and high compressibility. Subsequently, the samples were dried to facilitate the disintegration process for physical and mineralogical characterization analyses. Figure 1a illustrates the crushed high-plasticity clay used for laboratory testing purposes.

2.2 *Crushed PET*

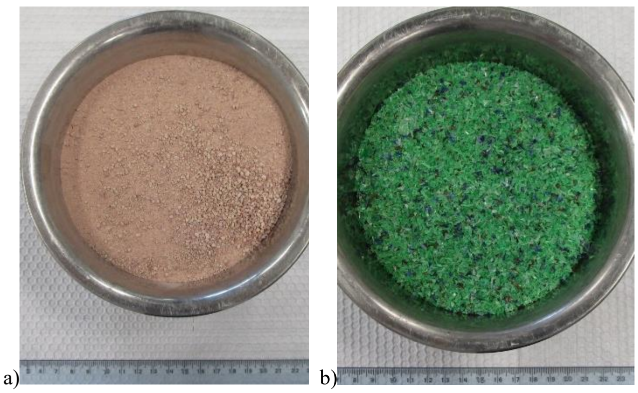
The procedure for obtaining PET is outlined as follows:

1. The label and spout of the bottle are removed, followed by a grinding process to produce crushed PET. Subsequently, an agglomeration process reduces its volume and increases its density.

2. Upon completion of the grinding process, the crushed PET is sorted into different sizes through sieving to achieve a more uniform shape and texture in the material.

3. The material undergoes a disinfection process involving the use of caustic soda, industrial detergent, and water at a temperature of 70°C. This is followed by centrifugation to remove any remaining moisture.

Note that despite PET being an inert material, it may contain biological residues and/or contaminants that affect the soil quality. Therefore, the polymer is thoroughly washed (Sánchez et al., 2018). Figure 1b depicts crushed PET measuring 1–2 mm in size.



a) b)

Figure 1. Sample of (a) natural soil and (b) crushed PET.

2.3 *Lime*

Lime, a binding material derived from the calcination of limestone (Moale & Rivera, 2019), primarily comprises calcium carbonate (CaCO3) and is recognized as one of the most abundant aggregates in nature. Lime also encompasses a compound formed by a mixture of calcium oxide and magnesium (CaO and Mg) or a combination of calcium hydroxide and magnesium hydroxide (Ca(OH))2 and Mg(OH)2) (Ccansaya & Tello, 2022).

According to the Ministry of Transport and Communications (2008), the application percentage of hydrated lime should range between 2% and 4% for clayey soils. However, for highly clayey soils like those prevalent in the city of Pucallpa, lime dosage typically ranges between 5% and 10%. Regarding resistance, as per the California bearing ratio (CBR) ratio, a minimum value exceeding 6% is recommended. The specifications of the lime used in this study adhere to those outlined in the materials testing manual (2016). Figure 2 illustrates the hydrated lime utilized.

2.4 *Mixtures*

The clayey soil was initially mixed with 2.5% PET and 6.25% lime. Subsequently, the soil was dosed with 2.5% PET and 8.75% lime. Table 1 delineates the designations of the samples and materials utilized.

Table 1. Abbreviations used for soil and mixtures.

Material	Clay (%)	PET (%)	Lime (%)	Identification
Natural soil	100	0	0	CH
Mixture 1	91.25	2.5	6.25	C-P2.5-L6.25
Mixture 2	88.75	2.5	8.75	C-P2.5-L8.75

Figure 2. Sample of hydrated lime.

3 EXPERIMENTAL PROCEDURES

3.1 *Atterberg Limits*

Atterberg limits were determined for the three mixtures according to the ASTM D4318 standard. For clay, the liquid limit (LL) was obtained as 58, plastic limit (PL) was 25, and plasticity index (PI) was calculated to be 33, indicating the high compressibility of clay, according to the Casagrande chart.

Table 2 illustrates the results of Atterberg Limits for CH and mixtures (C-P2.5-L6.25 and C-P2.5-L8.7). A decreasing trend was observed in the PI across the obtained results. When assessed with respect to the plasticity chart, they were classified as low-compressibility clays (CL). This behavior change is attributed to the impermeability of PET to clay, restricting the passage of water between the clay grains and consequently reducing the soil's plasticity. Additionally, the inclusion of lime induces a transformation in the internal structure and properties of clay as lime accelerates the drying of clay, reducing its plasticity (Moale & Rivera, 2019).

Table 2. Atterberg limits of analyzed samples.

Atterberg limits	CH	C-P2.5-L6.25	C-P2.5-L8.75
LL	58	47	35
LP	25	22	24
IP	33	25	11

3.2 *Granulometric Analysis and Specific Gravity*

Figure 3 depicts the particle size distribution of clay, PET, and lime obtained through sieve analysis, while only clay underwent the sedimentation analysis using a hydrometer. Both tests were conducted in accordance with the ASTM D422 standard.

According to the SUCS classification, clay is categorized as high-compressibility clay (CH). Its particle size distribution comprises 10.2% sand, 38.7% silt, and 51.1% clay. According to the AASHTO classification, CH falls under A-7-5 (20), which is considered poor behavior for its application on pavements.

The sieves utilized for the particle distribution analysis for PET and lime included sieves No. 20, 40, 60, 140, and 200.

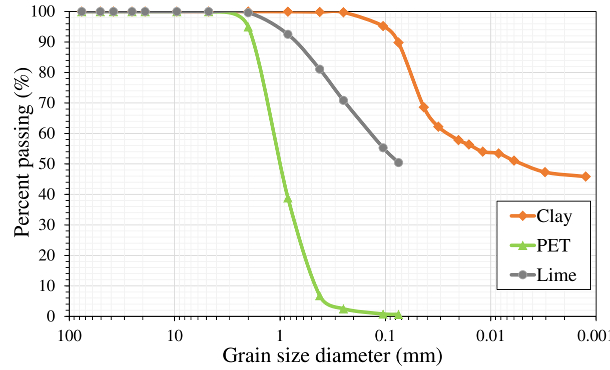


Figure 3. Particle size distribution.

Table 3 illustrates the variation in the specific gravity of the solids (Gs) of the clay and the mixtures concerning the PET and lime content. The specific gravity of the mixture decreased due to the inclusion of ground PET and lime. It was further observed that with higher lime content, the specific gravity increased among the two mixtures.

Table 3. Specific gravity of soil and mixtures.

	CH	C-P2.5-L6.25	C-P2.5-L8.75
G_s	2.60	2.38	2.46

3.3 *Potential of Hydrogen*

The evaluation of how soil pH varies with the addition of lime is crucial. Elevating the pH of acidic soil with lime reduces plasticity while enhancing soil-bearing capacity. This improvement in resistance to moisture changes reduces the risks of deformation. Lime also reduces chemical activity that could jeopardize soil stability. Furthermore, it enhances soil compaction, facilitating a more solid and stable base for road construction (Pezo & Alva, 2021).

Soil pH was quantitatively evaluated using a pH meter, an electronic device featuring a glass electrode sensitive to pH levels. This method involves preparing a soil sample with water, immersing the electrode, and directly reading the numerical pH value, thus providing precise soil acidity or alkalinity measurements. In contrast, qualitative measurement uses reactive strips that undergo a color change corresponding to pH levels. Dipping the strip into a soil and water sample can compare the resulting color with the provided scale. Although less precise than a pH meter, this technique quickly estimates pH levels. While the pH meter ensures exact measurements, reactive strips provide a rapid approximation and prove useful when exact precision is not paramount. The choice of method hinges on the required precision and the purpose of measurement, with the pH meter being preferable for numerical precision and reactive strips being suitable for quick estimates. Figure 4 showcases the instruments used for both methodologies and in Figure 5, samples for evaluation using the quantitative method are presented. Finally, Table 4 presents the pH values obtained through the quantitative method.

Table 4. pH values of soil and mixtures.

	CH	Lime	C-P2.5-L6.25	C-P2.5-L8.75
pH	5.11	13.23	13.02	13.15

Figure 4. Determination of pH: Quantitative and qualitative Analysis

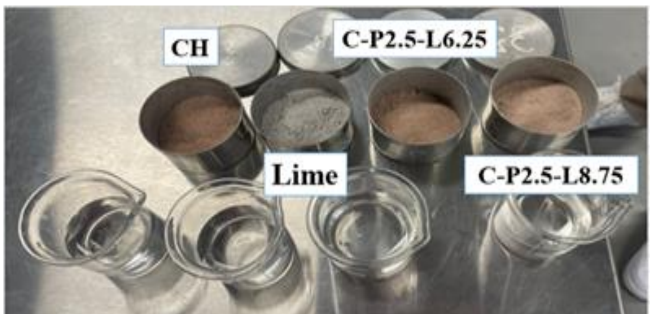


Figure 5. Samples to be tested an electronic device.

3.4 *Fourier-Transform Infrared Spectroscopy*

Fourier-transform infrared spectroscopy (FTIR) is essential in pavement subgrade clay studies. This technique aids in identifying the present chemical components, including functional groups and molecules, which are crucial for understanding their composition and interactions (Mondragón, 2017). The FTIR analysis provides insights into the molecular structure of the evaluated material and presence of any contaminants, which is relevant in this study because it allows for determining the purity of lime. When combined with clay, pure lime reacts positively, preventing any adverse effects on the quality of the clay's properties as a subgrade material (Galván & Velázquez, 2011).

Figure 6 shows the FTIR spectrum of hydrated lime, validating the values presented in the technical data sheet. It is evident that calcium oxide (CaO), the primary component of lime, prominently stands out. In this assay, we observe a characteristic peak between 2000 and 2400 cm^{-1}, with a transmittance level of approximately 60%, characterizing the lime sample.

3.5 *Modified Proctor*

The modified proctor compaction test (ASTM D1557) was performed on natural soil and soil mixtures containing PET and lime to conduct the CBR tests. This test determines the maximum dry unit weight of compaction and optimum moisture content for subsequent specimen testing. Saturation curves are essential for understanding changes in volume, density, and soil strength in response to hydration. Additionally, they play a crucial role in understanding the soil's behavior under loads and fluctuations in the water content (Duque & Escobar, 2016). The maximum saturation curve was obtained for different specific weights using the following formula:

$$\gamma_d = \frac{G_s * \gamma_w}{\frac{\omega * G_s}{S} + 1} \tag{1}$$

where γ_d denotes the soil-specific weight, G_s is the specific gravity of solids, γ_w represents the specific water weight ω signifies the moisture content, and S is the saturation.

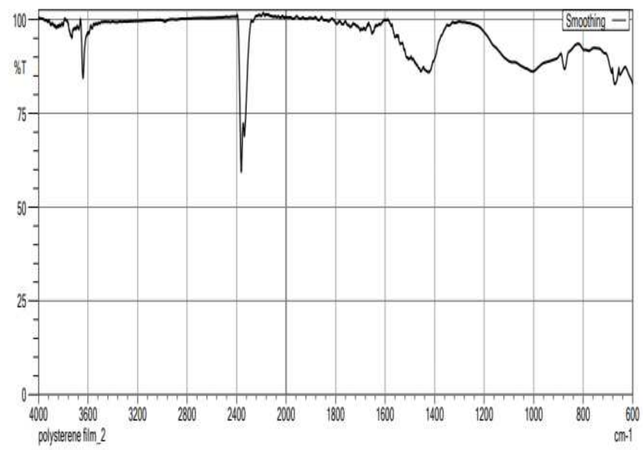


Figure 6. FTIR spectrum of hydrated lime.

3.6 *CBR*

The CBR test is a pivotal soil quality assessment, measuring its strength on a plate test scale. CBR values close to 0% indicate soils of low or poor quality, whereas those exceeding 50% are deemed suitable (Valdez, 2016).

According to ASTM D1883 guidelines, the laboratory version of the CBR test comprises two variants: CBR for optimum moisture and CBR for a range of water contents. The CBR variant for optimum moisture, known as the three-point CBR, is the most widely recognized. This method involves creating three compacted soil samples with varying compaction energies: 5 soil layers compacted with 12, 25, and 56 blows per layer (Ministry of Transport and Communications, 2008).

The moisture content used for soil mixing corresponds to the optimum level defined by the modified proctor employed in this study. The energy application was executed using an automated piston model 33-T3613 from the controls brand (Figure 7a) for the three soil-PET-lime mixture percentages arranged in a cylinder. Subsequently, extensometers were integrated to measure soil expansion during the immersion period in water (4 days) and finally to penetrate 5.08 mm using the Humboldt Model HM-5030.3F Marshall Press, as depicted in Figure 7b.

Furthermore, according to the Ministry of Transport and Communications (2008), subgrades can be classified based on quality according to the obtained CBR value. Table 5 illustrates the CBR ranges used to determine subgrade quality.

Table 5. Subgrade quality according to CBR value.

Quality	Range
S0: Very poor subgrade	CBR < 3%
S1: Poor subgrade	3% < CBR < 6%
S2: Regular subgrade	6% < CBR < 11%
S3: Good subgrade	11% < CBR < 20%
S4: Very good subgrade	CBR > 20%


a) b)

Figure 7. Equipment used for CBR testing.

3.7 *Resilient modulus (Mr)*

Cyclical triaxial tests are commonly employed to study the resilient behavior of granular materials. These tests encompass constant confining pressure (CCP) and variable confining pressure (VCP). The most prevalent test procedure for determining the resilient modulus of such materials is outlined in AASHTO T-307 (2007), which utilizes CCP-type tests.

During the test, the material undergoes different deviator stresses and confinement pressures to simulate typical loads experienced when forming pavement layers. Additionally, it is observed that after a certain number of loading cycles (N), the material tends to primarily undergo resilient deformations (Garnica et al., 2001).

The resilient modulus test in the field is inherently challenging, necessitating specialized laboratory equipment. This equipment includes a triaxial chamber for cyclic tests, a loading frame equipped with a servo-controlled dynamic actuator to generate a medium sinusoidal wave at specified periods and frequencies, a control panel, pressure measurement devices for chamber, pore, and effective pressures, and a data acquisition unit equipped with processing software.

Rondón and Reyes (2015) compile correlations to determine the resilience modulus (Mr) from CBR tests. The most widely used equations in Peruvian pavement engineering are those of Lister and Powell (1987), Ayres (1997), and MOP (2004), presented as equations (2)–(4), respectively.

$$\mathrm{Mr} = 17.62\mathrm{CBR}^{0.64}\ (MPa)\ , \mathrm{CBR} < 10\% \quad (2)$$

$$\mathrm{Mr} = 21\mathrm{CBR}^{0.65}\ (\mathrm{MPa}) \quad (3)$$

$$\mathrm{Mr} = 22.1\mathrm{CBR}^{0.55}\ (\mathrm{MPa}), 12\% < \mathrm{CBR} < 80\% \quad (4)$$

4 RESULTS AND DISCUSSION

The results of the compaction tests are depicted in Figures 8–10 for the natural soil and two mixtures. Three saturation curves (at 80%, 90%, and 100%) are computed for each compaction curve. The 100% saturation curve asymptotes to the proctor compaction curve, indicating that at this point, no void volumes are present where unsaturated soil exists, signifying the loss of the soil's ability to retain water.

For CH, as illustrated in Figure 8, the optimal moisture content for compaction is approximately 15.80% and dry unit weight is 1789 kg/m³.

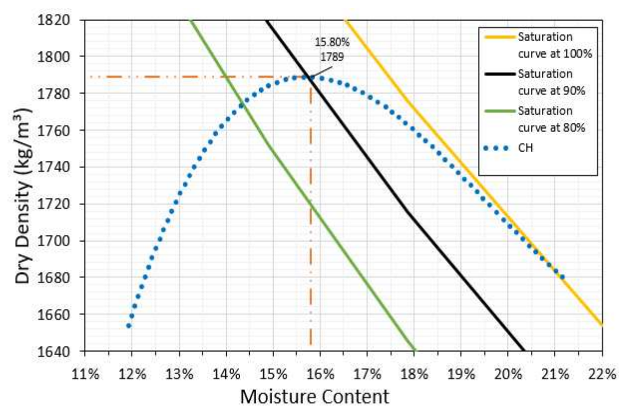


Figure 8. Compaction and saturation curve of the CH sample.

The soil with the addition of 2.5% PET and 6.25% lime (C-P2.5-L6.25), as depicted in Figure 9, displays an optimal moisture content close to 14.32% and a dry unit weight of approximately 1736.5 kg/m³ once compacted.

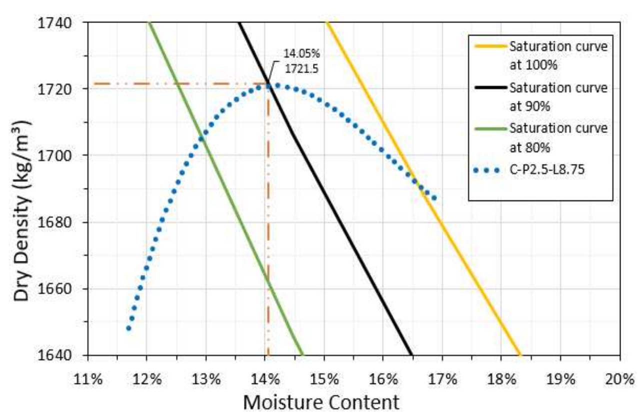


Figure 9. Compaction and saturation curve of the C-P2.5-L6.25 mixture.

Meanwhile, compaction of the soil with 2.5% PET and 8.25% lime (C-P2.5-L8.75), as depicted in Figure 10, yielded an optimal moisture content of approximately 14.05% and a dry unit weight of approximately 1721.5 kg/m^3.

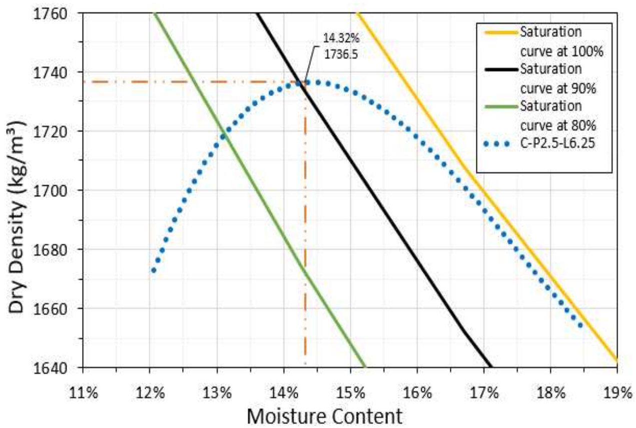


Figure 10. Compaction and saturation curve of the C-P2.5-L8.75 mixture.

After analyzing the compaction results of the three samples, it can be concluded that the greater the addition of lime to the soil, with a constant PET value, the lower its optimal moisture level, as depicted in Figure 11. This is attributed to lime acting as a drying agent, and its addition reduces the dry specific weight because the granulometry of the PET is greater than that of the clay with which it was mixed.

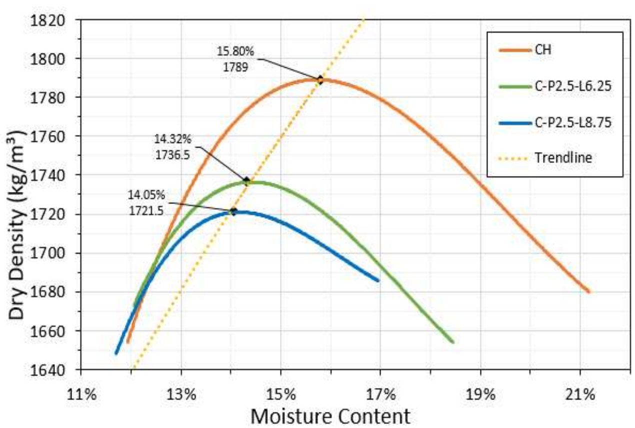


Figure 11. Compaction curves for different mixtures.

Furthermore, CBR compaction was conducted in three magnitudes, corresponding to the number of blows; 12, 25, and 56 blows resulted in low, medium, and high compaction, respectively. The expansion values, load vs. penetration, and the percentage of CBR for the different densities obtained were determined over time.

Figures 12 and 13 show a trend where greater compaction leads to a lower expansion percentage. This phenomenon is attributed to the greater cohesion and interlocking of the clay particles. However, in Figure 14, medium compaction proves to be more effective. This result is attributed to the higher percentage of lime in this mixture.

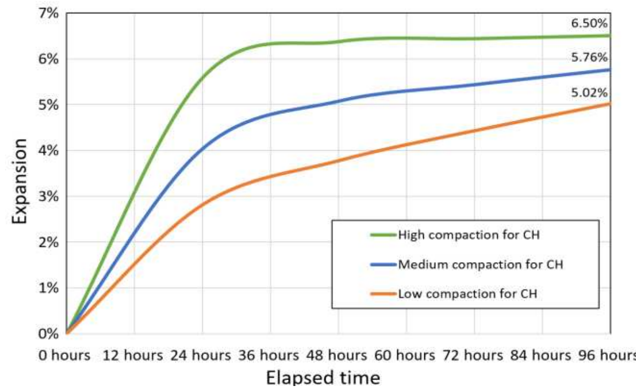


Figure 12. CH expansion from 0 to 96 h.

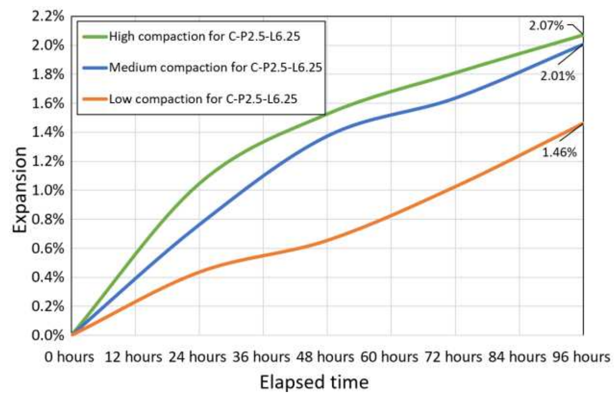


Figure 13. Expansion of C-P2.5-L6.25 from 0 to 96 h.

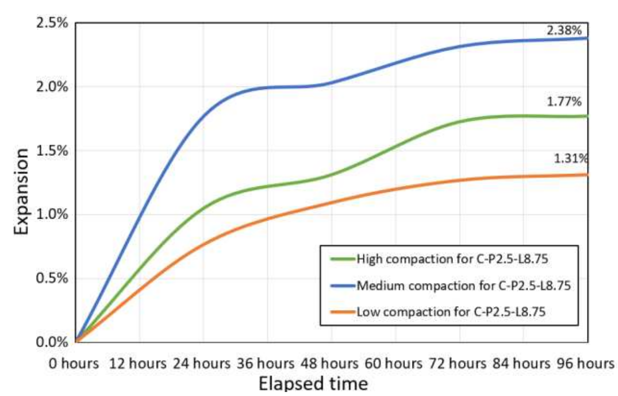


Figure 14. Expansion of C-P2.5-L8.75 from 0 to 96 h.

The lowest expansion index of 2.07% was achieved by combining clayey soil, 2.5% PET, and 6.25% lime with high compaction, rendering it the most suitable mixture for reducing expansion. However, the combination with a lime content of 8.75% for medium compaction shows a decrease in expansion of only 0.31% compared to the 6.25% lime content with medium compaction.

Regarding compaction, the clay specimens mixed with lime in the mentioned dosages exhibit a greater increase in penetration resistance compared to the standard samples and those reinforced with PET and lime, as demonstrated in Figures 15–17.

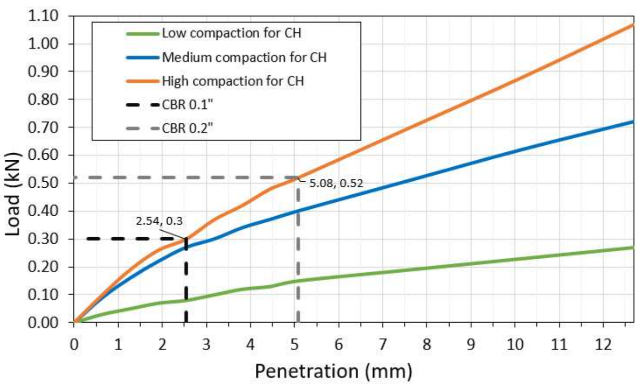


Figure 15. Load vs penetration of CH.

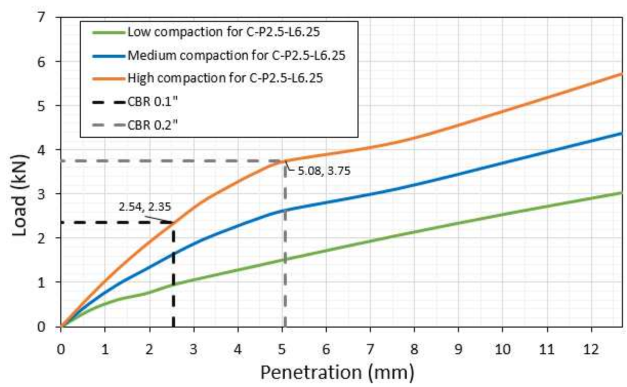


Figure 16. Load vs penetration of C-P2.5-L6.25.

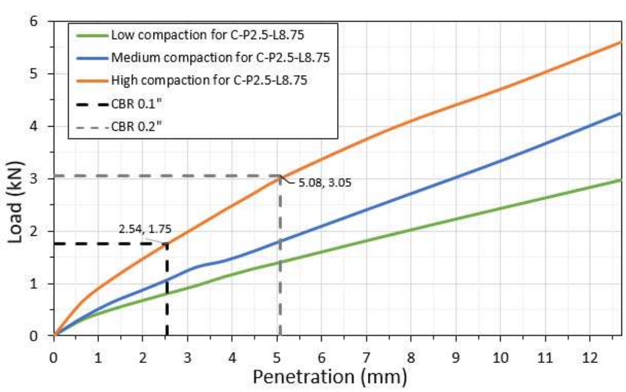


Figure 17. Load vs penetration of C-P2.5-L8.75.

Penetration stresses were measured for the clay sample at 0.30 kN, while for the mixtures containing PET and lime at 6.25% and 8.75%, values of 2.35 and 1.75 kN were recorded, respectively. Additionally, a decrease in penetration stresses was observed with increased lime percentages. The maximum stress value occurred with a lime percentage of 6.25% at a penetration depth of 2.54 mm (0.1 inches).

The increase in the lime content correlates with enhanced bearing capacity and resistance of the stabilized soil. Furthermore, this enhancement is accentuated with higher compaction percentages, improving material densification and reinforcing the positive effects of lime addition.

Subsequently, the obtained CBR values were assessed to determine the subgrade quality based on Table 5 for various compaction energy levels. Specifically, only the values corresponding to a penetration depth of 2.54 mm were considered, as outlined in Table 6.

Table 6. Subgrade quality according to the CBR value.

Soil type	Compaction degree	CBR (%)	Subgrade quality
CH	Low	0.6	S0: Very poor
	Medium	2	S0: Very poor
	High	2.3	S0: Very poor
C-P2.5-L6.25	Low	7.1	S2: Regular
	Medium	12.5	S3: Good
	High	17.5	S3: Good
C-P2.5-L8.75	Low	5.8	S1: Poor
	Medium	8.1	S2: Regular
	High	13	S3: Good

The results show that the CBR values obtained at various compaction levels for the natural soil depict inadequate subgrade quality, reaching a maximum of 2.3%, as depicted in Table 6.

The durability of road infrastructure greatly depends on the required compaction level and inclusion of PET with lime. In cases where budgetary constraints limit compaction, a maximum CBR value of 7.1% is established under low compaction conditions, resulting in the substandard subgrade quality of the roads. This threshold is achieved through a specific combination of 2.5% PET and 6.25% lime.

Under medium compaction level, the sole viable solution presenting good subgrade quality entails a CBR value of 12.5%, for a standard composition of 2.5% PET alongside 6.25% lime.

The highest CBR levels are attained for scenarios involving high compaction, which involve higher costs and logistical challenges. These results demonstrate that to comply with road subgrade design regulations, the CBR values exhibited by natural soil are not adequate, requiring physical and/or chemical stabilization. In this context, either of the two mixtures, comprising 2.5% PET with 6.25% or 8.75% lime, substantially enhances the CBR values, resulting in a high-quality subgrade. However, across all three scenarios, it is consistently observed that the highest values were achieved with a consistent mixture of PET and lime at 6.25%, indicating its optimal value for this research.

Meanwhile, in road design, the CBR value serves as the initial basis for calculating the resilient modulus, which is indispensable for multilayer elastic analysis. Along with Poisson's ratio, it is an essential variable for predicting the mechanical response of materials such as stresses, strains, and deflections within a flexible pavement (Rondón & Reyes 2015).

The resilient modulus is defined by a range of values obtained, this value was calculated solely based on the maximum number for each compaction and each mixture, with different correlations detailed in Eqs. (2)–(4).

The correlation of Lister and Powell (1987) is most commonly used in Peru; however, the restriction applied in its evaluation is only helpful for a CBR value lower than 10% as it loses precision beyond this value. However, in the MTC manual, a CBR value of up to 30% is accepted for road works. Moreover, the MOP equation (2004) can only be used for CBR values between 12% and 80%.

Finally, the Ayres (1997) correlation does not have restrictions on its application.

According to the Ayres relationship, the resilient modulus results indicate that the mixture containing 6.25% lime achieves the highest value with high and medium compaction. In contrast, the CH mixtures obtain the lowest values, as depicted in Table 7.

Table 7. Correlations to determine the M_r value.

Soil type	CBR (%)	Lister y Powell (1987)	Ayres (1997)	MOP (2004)
CH	0.6	12.71	15.07	-
	2	27.46	32.95	-
	2.3	30.03	36.09	-
C-P2.5-L6.25	7.1	61.77	75.08	-
	12.5	-	108.45	88.65
	17.5	-	134.96	106.68
C-P2.5-L8.75	5.8	54.27	65.83	-
	8.1	67.21	81.80	-
	13	-	111.25	90.59

5 CONCLUSIONS

Based on the results obtained from this investigation, the following conclusions can be inferred:

The increase in the lime content correlates with higher load-bearing capacity and resistance in stabilized soil. This improvement is further amplified by increasing the compaction percentage, which directly affects the effective material densification process and maximizes the beneficial effects of lime addition.

Compaction tests show that the addition of PET and lime reduces the dry density value as the percentages increases, compared with the standard sample. This decrease is because PET has a lower density than the soil. In terms of CBR value, the inclusion of lime in conjunction with PET leads to a considerable increase, improving from an inadequate subgrade to a good subgrade according to the reviewed literature.

The appropriate selection of correlation is crucial for accurately estimating the Mr value. Additionally, it is important to emphasize that the addition of PET and lime, irrespective of the proportions used, consistently enhances Mr values, thereby directly influencing the design and quality of subgrades.

Soil layers reinforced through chemical and/or physical methods are advised to use an insulator, such as geocells, to ensure the confinement of the improved layers.

An appropriate compaction process in the field and laboratory settings is essential to truly demonstrate the benefits of lime stabilization.

For the implementation of lime as a chemical stabilizer, it is advisable to employ various curing times (1, 3, and 7 days) when homogenizing clay with lime. This approach allows for evaluating and analyzing the clay's behavior after being allowed to rest before conducting the respective tests.

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