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Analysis of high plasticity clayey soil improvement at subgrade level through Portland cement added to decrease volumetric change

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Abstract. This research includes the potential for resistance and the expansion that the soil presents, this evaluation was carried out through CBR tests. The soil cement technique was used to improve the physical and mechanical characteristics; this process consists in mixing the material with Portland cement type I. That combination forms soil cement 10%, 15% y 20%, which present an increase of the CBR (max: 138.7% and min: 91.9%) achieving a type of extraordinary subgrade to resist the structure of the pavement and a reduction of 7.18% in the expansion of the samples.

1. Introduction
In Peru, as in much of Latin America, there is a large deficit in road infrastructure, to a greater extent the absence of paved routes for regional connections is highlighted, reaching a total of 141,603.00 km of unpaved road network [1]. One of the most frequent problems, especially in road construction, is the presence of highly cohesive soils, which represents a challenge for civil and geotechnical engineers around the world. By improving the mechanical characteristics of these soils it is possible to enable an unpaved road.
Various investigations conducted in cohesive soils, such as high plasticity clays [3] [5] and soft clays [4] [6] [7] were studied by adding various additives, slag-based superfine cement, cement mixed with polypropylene fibers, lime and Portland cement. The improvements were seen with the increase in unconfined compression [3] [4] [5], the reduction in settlements [6] and the increase in CBR [7].

The previously mentioned studies provide an overview of the soil-cement technique to achieve increased shear strength and its importance for the improvement of subgrade or support soil. Under this background, the aforementioned technique is adopted to stabilize the clayey soil of high plasticity in a regional route of the Peruvian jungle, in order to resist the vehicular load and reduce the volumetric changes.

2. Materials and methods
Clayey soil of high plasticity (CH) extracted in unaltered samples from a regional road in the province of Oxapampa, Pasco, Peru was evaluated. Portland cement Type I was used.

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Figure 1. Unaltered soil sample.

Figure 2. Sample cement soil 15%.

Figure 3. Sample cement soil 20%.

The tests carried out were: the limits of Atterberg, Compaction and CBR. The mixtures evaluated were those containing 10%, 15%, and 20% cement in relation to the dry weight of the soil. Figures 1, 2 and 3 present the natural soil in an unaltered state and the mixtures of 15 and 20%, respectively.

3. Results

The results of the programmed tests are shown in Tables 1, 2, 3, 4, 5 and 6, together with Figures 4, 5, 6, 7, 8 and 9.

3.1. Natural soil

Table 1. Characterization tests of natural soil.

	Atterberg limits				Classification		Modified Proctor	
	Liquid limit	Plastic limit	Plasticity index	Humidity content	SUCS	AASHTO	OCH	MDS (gr/cm3)
Natural soil	66.10%	26.90%	39.20%	29.37%	CH	A-7-6 (45)	14.30%	1.827

Table 2. Maximum dry density (MDS)

Penetration	2.54 mm (0.1”)	5.08 mm (0.2”)
100% MDS	3.30%	3.00%
95% MDS	2.60%	2.30%

Table 3. Natural soil expansion

N° Hits	Expansion	Average expansion
57	7.21%	
25	7.00%	8.12%
12	10.14%	

3.2. Cement soil

Table 4. Modified proctor test on cement soil.

	Modified Proctor	
Cement soil	OCH	MDS (gr/cm3)
10%	14.60%	1.831
15%	15.00%	1.832
20%	15.20%	1.833

Table 5. CBR test on cement soil.

	Cement soil 10%		**Cement soil 15%**		**Cement soil 20%**	
Penetration	2.54 mm (0.1”)	5.08 mm (0.2”)	2.54 mm (0.1”)	5.08 mm (0.2”)	2.54 mm (0.1”)	5.08 mm (0.2”)
100% MDS	130.80%	105.80%	116.70%	111.80%	153.60%	146.30%
95% MDS	105.40%	91.90%	108.00%	104.70%	138.70%	129.30%

3.3. Compaction curves

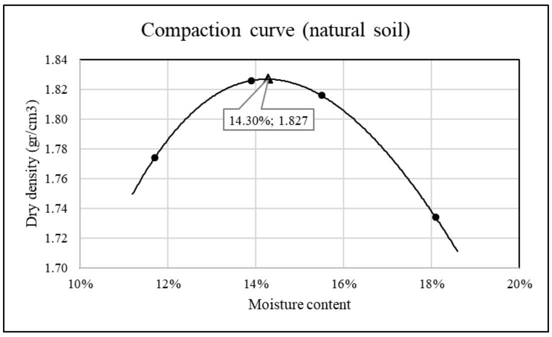

Figure 4. Natural soil compaction curve.

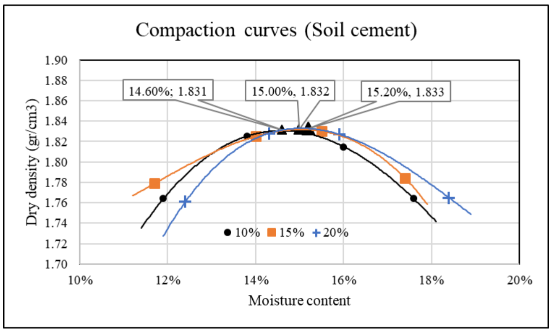

Figure 5. Soil cement compaction curves.

3.4. Comparative

3.4.1. Modified Proctor

The curve in Fig. 7 shows the behavior of the optimum humidity content (O.C.H.) according to the percentage of Portland cement in the cement soil mixture.

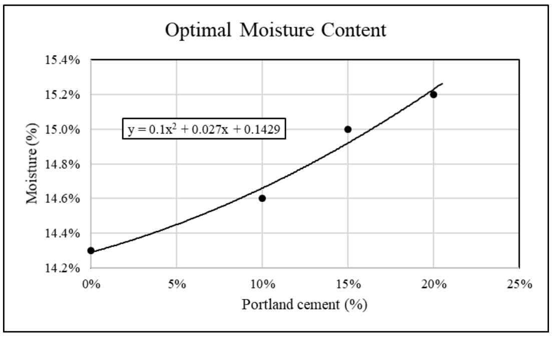

Figure 6. Portland cement v. Humidity.

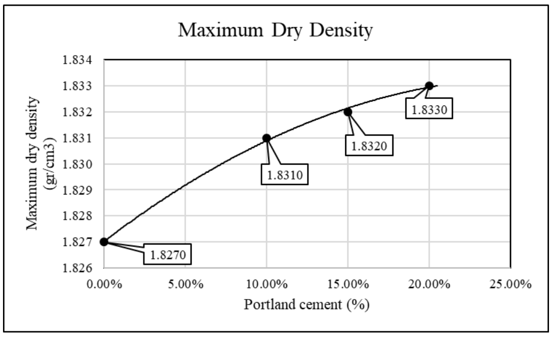

Figure 7. Portland cement v. MDS.

3.4.2. CBR

For the curve of Fig. 8, the CBR values corresponding to 95% of the MDS were related to the percentage of Portland cement added.

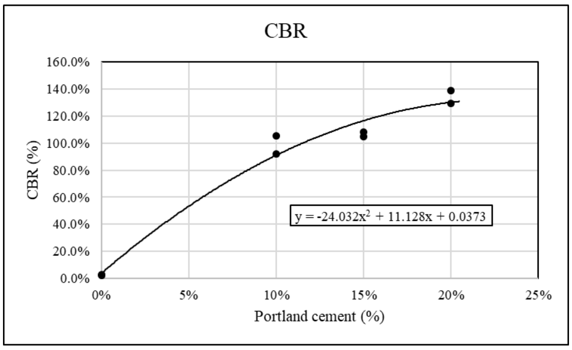

Figure 8. Portland cement v. CBR.

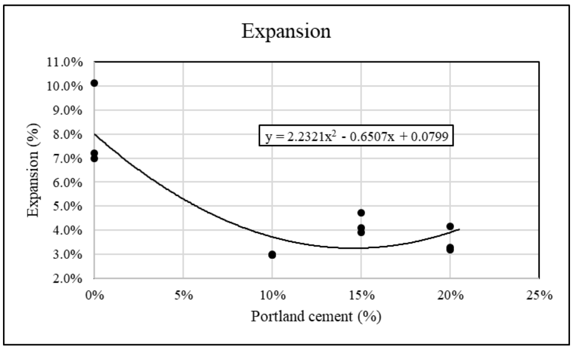

Figure 9. Portland cement v. Expansion.

4. Discussion

It is observed in Fig. 7 that the optimum humidity content varies almost linearly, presents a little magnitude change in the humidity value, the lowest value being 14.3% when the soil is in natural conditions, and reaches to 15.2% maximum when 20% cement is added to the soil. Therefore, a variation of 0.9% humidity between the samples is obtained and indicates that the greater the amount of cement, the greater the water requirement will be to achieve the maximum density of the sample. The additional humidity necessary to develop maximum consistency is due to the hydration of the cement, action necessary for the components react and forge occurs. The more cement is present in the cement soil, the greater the amount of water. The amount of water in the mixture is important to achieve greater resistance in the improved soil. Likewise, a comparison of the MDS in relation to the percentage of Portland cement added is shown in Fig. 8. As a result, it is observed that the value of the MDS remains almost unchanged as Portland cement increases to the mixture. On the other hand, Fig. 9 shows the variation of the CBR due to the percentage of cement added. A quadratic trend line with direct proportionality between the variables is presented. The more cement is added to the soil, the higher the CBR of the cement soil.

The natural soil being a clay of high plasticity has a low CBR value (2.3%) which, according to the above, does not meet the resistance necessary to support the pavement structure or the vehicle load. Portland cement together with the clayey soil achieves very high CBR values, from 91.9% with 10% cement to 129.3% with 20% cement, becoming characterized as extraordinary subgrade. However, there is a growth that is decelerating as the percentage of cement added to the clayey soil increases, that is, a limit of resistance contribution by the cement is reached. Finally, the variation of the expansion with respect to the percentage of cement added is shown in Fig. 10. This curve shows an inversely proportional relationship, where it can be seen that, the greater the amount of cement in the mixture, the lower the expansion of the material during the four days under saturated conditions. It is possible to reduce the expansion of the material up to 7.18% by adding Portland cement. However, it should be noted that the expansion of cement soil samples remain within the same range that is not related to the amount of cement, this range ranges from 2.96% to 4.72%, that is, the volumetric change that the clay presents decreases by the presence of Portland cement and not by the amount of it. In the same way that was exposed about the CBR limit that is reached by the cement soil, it is emphasized that the expansion reaches a limit in which the volumetric change remains relatively unchanged.

5. Conclusion
According to the results obtained from the compaction tests and CBR, the high plasticity clayey soil used when combined with Portland cement is improved.

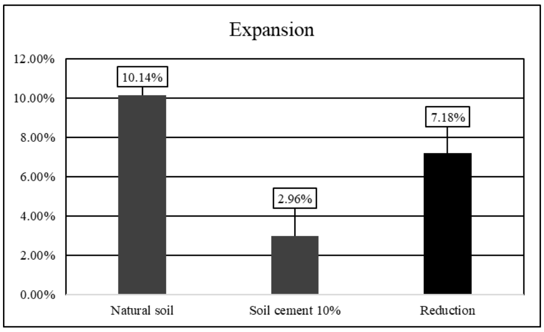

Figure 10. Samples expansion in CBR test.

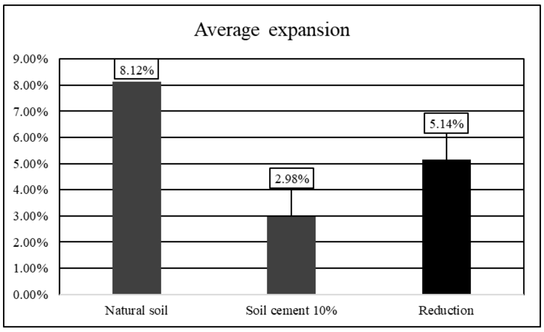

Figure 11. Average Samples expansion in CBR test.

The largest reduction in expansion is 7.18% and occurs when the mixture contains 10%. Likewise, the highest average of volumetric change reduction also occurs in cement soil 10%, reducing from a value of 8.12% expansion in natural soil to 2.98% in cement soil, so the variation is equivalent to 5.14%. The reduction of the volumetric change could be due to the Portland cement particles reacting with the water molecules and as a consequence the contact of said molecules with the clayey soil particles of high plasticity is avoided, causing the clayey part of the mixture to be less reactive The decrease of the expansion in clayey soils of high plasticity is of great importance to reduce settlement and swelling in the subgrade. By using the cement soil technique, the expansion is reduced, so that settlements and swellings in the road are avoided and as a consequence the condition of the pavement and the serviceability of it are preserved. The cement soil technique greatly increases the value of the CBR, achieving an extraordinary subgrade from the 10% cement soil. Finally, according to the tests carried out, it is observed that the behavior of the cement soil adopts a tendency to increase the value of the CBR by containing more cement. This parameter maintains a relationship with the volumetric change which indicates that, while the value of the CBR is greater, the expansion of the sample will be reduced and both the water requirement, expressed in the optimum humidity content, as the MDS will go increase.

6. References
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