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Improvement of physical, mechanical and strength behavior of cohesive soils with natural pozzolana and brick dust

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Abstract: This research project seeks to improve soil properties through experimentation with geotechnical purposes. For this, will be used natural volcanic pozzolana in 5%, 10%, 15% and brick dust in 10% giving it a second reuse. The soil improvement will be analyzed with the proposed additions and its influence on the results. It is concluded that the addition improves the behavior of the soil by decreasing its plasticity index, increases the compaction index and improves the geotechnical parameters.

1. Introduction

Nowadays there are many methods for the improvement and stabilization of soils, whose objectives are aimed at improving the performance and behavior of the properties. These methods are related to the improvement of physical and chemical mechanisms, which are widely related to the various fields of civil engineering. According to R. J. Gallardo [1], they investigated about the behavior of high plasticity soils with the addition of residue material in brick making. The addition of 10% brick significantly decreased the plasticity index and the optimum humidity was reduced by 14.29%. The CBR value only increased by 3%. On the other hand, S. Aref al and H. Ibrahim [2] carried out their research in order to know the effect of the addition of natural pozzolana on clayey soils stabilized with lime. They used a clay of high plasticity (CH), consisting of kaolinite, montmorillonite and ilite with percentages of 23%, 7% and 14% respectively, with 95% of its passant particles of the mesh No. 200, plasticity index was 28.8% and CBR of 2.89%. They obtained a decrease in the plasticity index by adding the natural pozzolana, moving from a clayey soil CH to one of type ML. The CBR increased by 90% compared to the soil with lime without pozzolana.

This article presents the experimental evaluation of the effect on the physical and mechanical properties of a clayey soil improved with natural pozzolana and brick dust.

2. Soil

The geology that characterizes the samples extraction zone is constituted by red silty clays interspersed with white sandstones and gray limestones. According to the SUCS, it is a low plasticity clay (CL) that has 70% of passant material of the mesh No. 200.

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3. Natural pozzolana

Natural pozzolans come from volcanic eruptive rocks such as rhyolites, traquites, andesites and basalts. Natural pozzolans mainly consist of a vitreous mass that cements fragments of pumice, slags, small crystals of augite, mica, pyroxenes, etc. [3].

The extracted natural pozzolan has the chemical composition shown in Table 1. Due to the high contents of silica (SiO_2) and alumina (Al_2O_3), it is sought that they react resulting in the formation of crystals that when occupying the voids of the soil increase the shear strength of itself [4]. It is worth mentioning that natural pozzolana has lime which enhances the chemical reaction.

Table 1. Chemical composition of natural pozzolana (Ingemet 2016)

Chemical element	**Al_2O_3**	**CaO**	**Fe_2O_3**	**K_2O**	**MgO**	**MnO**	**NaO**	**P_2O_5**	**SiO_2**	**TiO_2**	**LOI***
Percentage (%)	14.26	1.29	1.34	4.8	0.77	0.08	2.47	0.05	60.03	0.18	6.14

4. Brick dust

The brick dust is classified as an artificial pozzolana, for this investigation the material was collected from the residue of the distributor trucks of craft bricks.

5. Experimental methodology

For the analysis of physical and mechanical properties, granulometric distribution tests were performed. Limits of Atterberg, Modified Proctor and shear strength. Likewise, mixtures with percentages of 5%, 10%, 15% natural pozzolana (PN) and 10% brick dust addition (PL) were prepared. Table 2 presents the symbology of the mixtures and the clayey soil.

Table 2. Symbology of the mixtures

MATERIAL	**ABBREVIATION**
Soil	S100%
Pozzolana and brick dust	S+PN5%+PL10%
	S+PN10%+PL10%
	S+PN15%+PL10%

6. Analysis and results

6.1. Atterberg limits

Table 3 presents the results obtained. The plasticity index is reduced to a greater amount of natural pozzolana.

Table 3. Liquid limit, plastic limit and plasticity index

TESTS	**LL**	**LP**	**IP**
S100%	36.3	18.9	17.4
S+PN5%+PL10%	34.7	22.18	12.52
S+PN10%+PL10%	27.7	21.35	6.35
S+PN15%+PL10%	29.22	22.885	6.335

6.2. Modified Proctor

The maximum dry density of the soil and the optimum moisture content were determined. According to Figure 1, it is observed from the compaction curves that when the percentage of natural pozzolana increases the dry density decreases and the optimum humidity content increases.

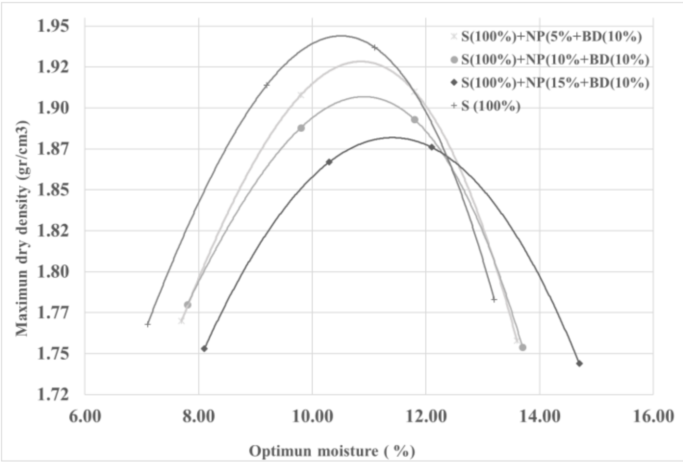

Figure 1: Compaction curves.

6.3. Shear Strength

The samples tested were prepared with the optimum humidity of the Modified Proctor, were cured for seven days in an airtight container, Table 4 presents the strength parameters obtained for the clayey soil and mixtures. The mixture S + PN5% + PL10% has the highest cohesion value (1.15 kg/cm2) with respect to the clayey soil and the other mixtures. Although the friction angle of S + PN5% + PL10% decreases with respect to the clayey soil, the shear strength is higher for the confinement levels analyzed. The higher the level of confinement, the shear strength of the clayey soil and the mixture with greater cohesion are closer, establishing a clear influence of the confinement efforts on the shear strength of the clayey soil improved with the natural pozzolana and the brick dust.

Table 4. Friction angle and cohesion

Description	Internal friction angle (Φ)	Cohesion (c´) kg/cm^2
S100%	31.5	0.51
S+PN5%+PL10%	22.2	1.15
S+PN10%+PL10%	26.7	0.92
S+PN15%+PL10%	31	0.69

6.3.1. Dilatant behavior

In the graphs of Figures 2, 3, 4 and 5 show the behavior of the shear effort and of the dilatation with respect to the horizontal displacement during the direct cutting test performed on the clayey soil and the mixtures S + PN5% + PL10%, S + PN10% + PL10% and S + PN15% + PL10%, respectively. In all specimens, a contractive behavior can be seen in the initial part of the test, together with an increase in the shear effort necessary to achieve horizontal displacement at constant speed. The contractive behavior changes towards a dilating behavior before reaching 1 mm of horizontal displacement, this for confinement efforts 0.5 and 1.0 kg / cm2. On the other hand, for the 2.0 kg / cm2 confinement effort, the dilating behavior occurs after 1 mm of horizontal displacement. The growth ratio, of the shear strength, decreases when the 2 mm horizontal displacement is reached coinciding with a purely dilating behavior. All the mixtures have a greater shear strength than the clayey soil, with the difference that the level of dilatation of the sample S + PN5% + PL10% is lower than that of the other mixtures, may be the explanation that it reaches greater shear strength.

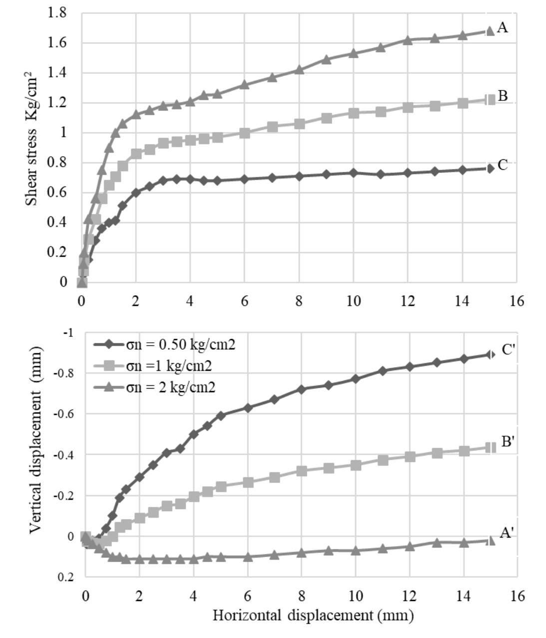

Figure 2. Results of shear stress for clayey soil (S100%)

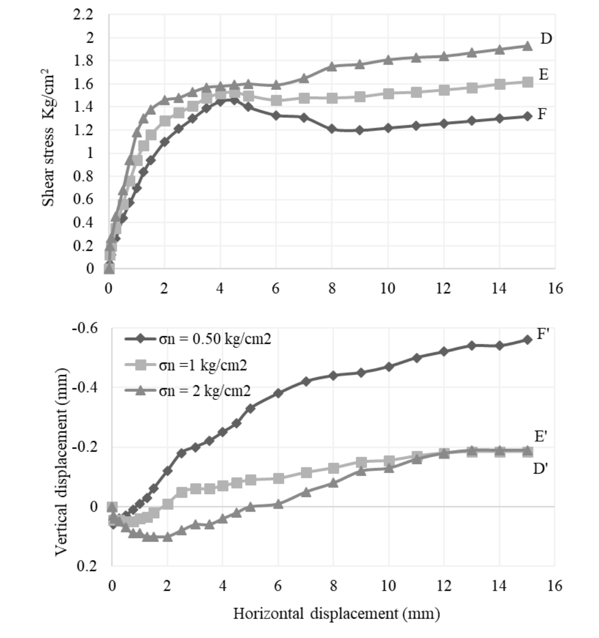

Figure 3. Results of shear stress for (S+NP5%+BD10%)

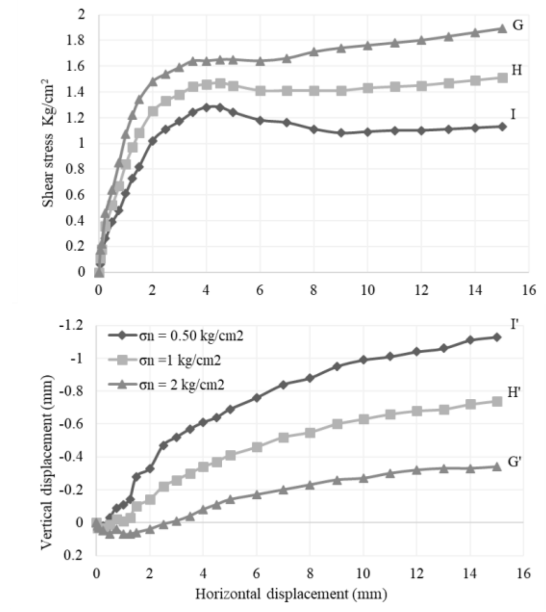

Figure 4. Results of shear stress for (S+NP10%+BD10%)

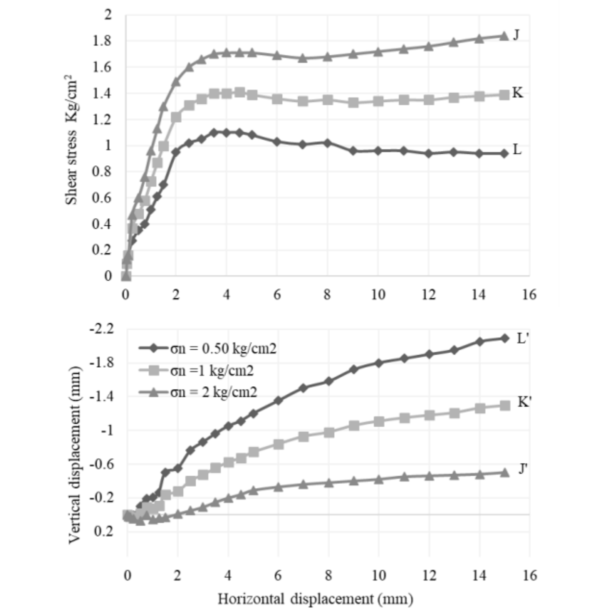

Figure 5. Results of shear stress for (S+NP15%+BD10%)

6.3.2. Cohesion and friction angle

Figures 6 and 7 confirm the variation of resistance parameters as a function of horizontal displacement level. Both the cohesion and the friction angle have a constant value trend after 8 mm of displacement, coinciding with a constant dilatation ratio.

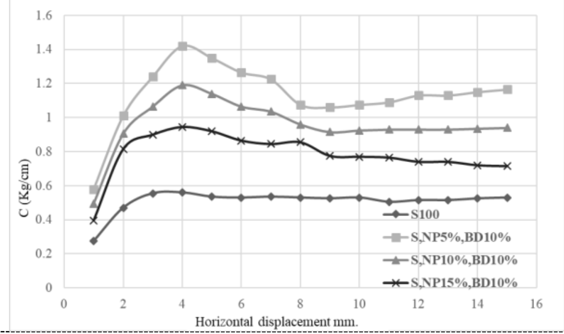

Figure 6. Cohesion variation at every 1 mm of horizontal displacement.

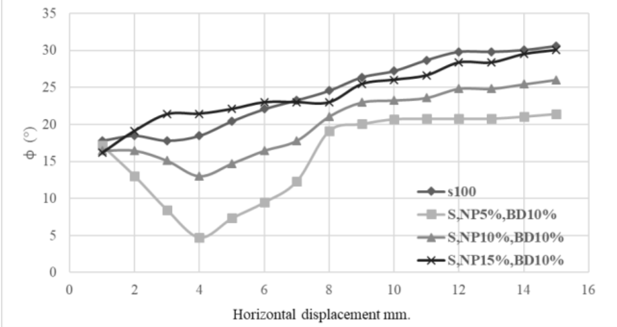

Figure 7. Variation of friction angle at every 1mm of horizontal displacement.

7. Conclusions

- The maximum dry density of the soil decreases with the increase of the natural pozzolana content. The lowest dry density was 1.88g / cm3 with the addition S + PN15% + PL10%.
- All mixtures have greater shear strength than clayey soil, being that for confinement levels greater than 2.0 kg / cm2, the difference decreases.
- The sample called S + PN5% + PL10% shows the best performance compared to clayey soil and the other mixtures. This sample also dilates less than the samples S + PN10% + PL10% and S + PN15% + PL10%, this may be the reason for reaching higher values of shear strength.
- The cohesion and friction angle vary depending on the level of horizontal displacement, being that for 4 mm these resistance parameters reach maximum and minimum values, respectively.
- Cohesion and friction angle have a tendency not to vary from 8 mm of horizontal displacement, coinciding with a constant dilatation ratio.

8. References

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