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HYDRAULIC CONDUCTIVITY IN LOESSIC STABILIZED SOIL

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ABSTRACT

The loessic soils are the main geological storage available as a building material in Cordoba, Argentina. Infiltration tests were done using remoulded samples and a flexible wall permeameter. Water content, dry unit weight, and percentages of ionic stabilizer and bentonite have been studied. Experiment results were compared between mixtures with different percentages of additives. The results show the reduction of hydraulic properties of local soils to improve geotechnical structures.

Keywords: Silty Clay, Infiltration Test, Flexible Wall Permeameter, Falling Head Method

INTRODUCTION

The loess soils have particles from 10 to 50 microns. In Argentina, covering a wide area and are naturally macroporous [1]. The increment in water content cause a dissolution of soluble salts and this reduce the shear strength [2]. In Córdoba city, usually geotechnical properties of loessic soils are modified by compaction or with chemical stabilizers [3]. Addition of sodium bentonite in soil has shown improvement of hydraulic properties [4]. During last year, artificial products have appeared in market, to reduce absorption capacity of loessic soils. In this paper, analyzes and compares the improvement in the hydraulic and mechanical properties of loess by incorporation of bentonite and base polymeric chemical stabilizer. Coefficient of permeability, absorption capacity and stress strain curves are show in this work.

MATERIALS

Loessic soil - Bentonite

The soil used was obtained from boreholes at 1m depth, in Ciudad Universitaria, Córdoba. Sodium bentonite was used, provided by Minarmco SA deposits from Pellegrini Lake, Black River, located at north of Patagonia. Composed of 92% of motmorillonita, and lower percentages of quartz, gibbsite, feldspar, calcite and zeolites. It has a high sodium content product as a result of the presence of soluble salts and cations retained in the thickness of the diffuse double layer. The magnesium comes from octahedral positions of the clay structure, from soluble salts and exchangeable cations. Generally show high proportions of iron between 4% and 6%. It has a high cation exchange capacity, which varies between 76 and 97 meq/100g. The exchangeable ions are Na^+, Ca^{++}, Mg^{++} and K^+, with a predominance of sodium cations, hence its classification [5]. It has high plasticity and high swelling capacity. Table 1 presents the principals geotechnical properties of the soils used in this work.

Base Polymeric Ionic Stabilizer (BPIS)

BPIS is a viscous liquid, colorless, without odor, miscible in water. It has a ph (13-14) and density is 1.05 gr/cm^3. BPIS are composed of a biodegradable polymer, mineral salts and cationic surfactant (potassium polyacrylate, potassium hydroxide and Belzanconio chloride). The ionic stabilizer is an argentinian additive provided by Polydem Argentina SA, and it called Poly-Ses 028. The percentages of chemical composition are reserved by industrial protection. The chemical process of soil stabilization is produced by neutralization of the electrochemical activity of the clay particles (with negative electric charge) thus avoiding the adsorption of positive cations from water molecules, and so promote the attraction between particles ground, reducing the empty spaces and consequently increasing the density of the structure. The manufacturer ensures that the stabilizer BPIS modifies the surface tension of water on granular bodies and increases the contact angle of the water present in the interstices of the soil.

METHODS

Soil/Bentonite and Soil/ BPIS mixtures

The materials were collected on trays at 20°C during 24hs. Soil passing sieve 100 was used. Soil has been drying at 105 °C during 24 hs. The loessic soil comparison specimen was dry unit weight γ_d (kN/m^3) = 12.4, initial water content ω_{ini} (%) = 18.1.

Two groups of soil were selected, (a) loess and bentonite in dry weight in percentages SB1 = 3%, SB2 = 6% and SB3 = 9%, the ω_{ini} (%) = 18.2, 18.2, 19.6, the γ_d =12.8, 12.5, 12.7 respectively, and (b) loessic soil and BPIS with SE1 = 0.5 ‰, SE2 = 1.0 ‰ and SE3 = 1.5 ‰ incorporated in water. The ω_{ini} (%) in static compaction was 18.5 16.3 17.7, and γ_d (kN/m^3) 13.6, 13.7, 13.3 respectively. The specimens were 0.07m in diameter and 0.14m in high. Static compaction method was used to prepare samples, in cylindrical molds. The specimen test was built and compacted in three layers of equal thickness. Extraction of samples was performed using a hydraulic jack. In order to conserve water content, plastic bags were used.

Table 1 Materials properties

Properties	Loess	Bentonite
γ_d (kN/m^3)	12.2-14.5	--
γ (kN/m^3)	14.9-16.8	---
LL (%)	20.8-32.2	301
IP (%)	0-8	231
Gs	2.68	2.71
Ps 200 (%)	96	100
Clay content< 0,002 mm (%)	4	85
SUCS	CL-ML	CH
Ss (m^2 /g)	1	731(*)
Ph	> 8	7-7.5
Sc (%)	0.38	< 0.1

Note: γ = natural unit weight, *LL* = Liquid limit, *IP* = Plasticity index, *Gs* = Specific gravity, *Ps* = passing sieve, *Ss* = Specific surface, *Sc* = salt content. (*) [12]

Infiltration test

A flexible wall permeameter was used to evaluate hydraulic properties of samples. Variable-head permeability test was conducted [6].

Loess-bentonite samples were infiltrated in unsaturated and saturated condition. At the ends of each sample, filter paper and porous stones were used. Porous stones were saturated during 24 hours. During infiltration tests, the gradient was 10 [6]. Pressures for the camera, upper and lower head were taken as 117 kPa, 114 kPa and 100 kPa respectively. Deaerated water was used as permeant fluid.

In unsatured condition, the infiltration rate (I_r) is adopted (Eq. (1)).

$$I_r = \frac{\Delta V(t)}{\Delta t\ A} \tag{1}$$

Where ΔV: volume infiltrate during time Δt, A: cross section specimen area. Under saturated condition the permeability parameter k is obtained with Eq. (2).

$$k = \frac{a\ L}{A\ \Delta t} Ln\left(\frac{PB_1 + \frac{V_{u(t_1)} - V_{l(t_1)}}{a}}{PB_2 + \frac{V_{u(t_2)} - V_{l(t_2)}}{a}} \right) \tag{2}$$

Where a: area of burette, L: length of sample, A: area of sample, Δt: lapsed time, PBi: bias pressure, $Vu(ti)$: volume reading of upper burette at time i, $Vl(ti)$: volume reading of lower burette at time i. The saturation level was calculated as $B = [(u_2-u_1)/(\sigma_2-\sigma_1)]$. Where $u_2 - u_1$: increase in pore pressure, $\sigma_2 - \sigma_1$: increase in cell pressure. We consider that, B at 98% is saturation condition [7]. At the end of experiment, the water content was established in each sample.

Unconfined compression (UC)

For UC test a mechanical press was used instrumented with a load cell with a capacity of 50kN and a digital comparator for recording displacements with a precision of 0.001 mm, to a constant deformation rate of 2.4 mm/min. UC tests is used to evaluate the stress–strain characteristics and the stiffness properties of the Soil-Additive-Mixture. Secant modulus at 1% of axial strain was defined.

Capillary rise

To set the speed of capillary rise was used a metal container with the addition of distilled water. The specimens were placed on metal cylinders with 0.03 m height and slotted base. It was measured the rise of moisture in function of time.

RESULTS DISCUSSION

Infiltration test

The results of infiltration tests were ω (3%)= 34.6 %, ω (6%)= 26.4 %, ω (9%)= 34.7 %, ω (0.5 ‰)= 29.2 %, ω (1 ‰)= 29.7 % , ω (1.5 ‰)= 37.8 % and ω (soil)= 29.5%.

Incorporating clay to the silty soil produces a decrease in the infiltration and also on the permeability coefficient [8]-[10]. No records of permeability tests results were found on remoulded samples with densities near a value 13 kN/m^2. Figure 2 shows the response under infiltration conditions for stage was done. In unsaturated conditions, uncontrolled suction level, it has been pretending to simulate field conditions. In unsaturated conditions, non controlled suction level, we have tried to simulate field conditions.

Under saturation condition decreasing permeability coefficients with increasing percentage of bentonite is observed. The minimum value of permeability was obtained for samples with addition of 9% of bentonite.

The permeability parameter magnitudes were,

$k_{SB1} = 1.36 \times 10^{-6}$ m/s, $k_{SB2} = 1.22 \times 10^{-6}$ m/s, $k_{SB3} = 8.03 \times 10^{-7}$ m/s.

One possible explanation for this behavior is a high exchange capacity cation of sodium bentonite, provided by the presence of sodium ions Na^+, providing attraction in the water particles, increasing the thickness of the diffuse double layer. Swelling of the ions Na^+ also occurs, develop their full potential and affect the hydraulic conductivity. This behavior is accentuated with increasing bentonite

In Figure 2, is shown the hydraulic behavior of the specimens with the addition of stabilizer. It was observed a lower volume of fluid filtered with increases the contained of stabilizer in the blends.

Values being lower permeability, so the lowest permeability value is recorded for samples with 1.5 ‰ stabilizer. The value obtained was $k = 3.98 \times 10^{-6}$ m/s.

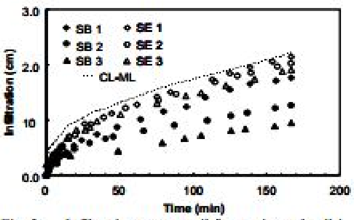

Fig. 2 Infiltration test on soil /bentonite and soil / BPIS samples

Unconfined compression (UC)

The results of unconfined compression are shown on Fig. 4. The graphic shows that stiffness increase with bentonite content.

The increase of bentonite content causes an increase of the stiffness four times. The values obtained were $Es_{SB1} = 19.7$ kN/m^2, $Es_{SB2} = 25.6$ kN/ m^2, $Es_{SB3} = 41.8$ kN/ m^2.

There is no significant change in stiffness properties in soil-EIBP samples. The increment was once more and a half. The values obtained were $Es_{SE1} = 11.6$ kN/m^2, $Es_{SE2} = 16.6$ kN/m^2, $Es_{SE3} = 16.8$ kN/m^2 and $Es_{SOIL} = 10.1$kN/m^2.

Higher compression resistance is achieved in samples with bentonite than BPIS samples. The value obtained was 36.95 kN/m^2.

Capillary rise

Figure 4 shows the progress of hydration in the soil-bentonite specimens for capillary rise testing. The velocity of capillary rise increases with the amount of bentonite. Note that no significant difference was observed in samples with 3% and 6%.

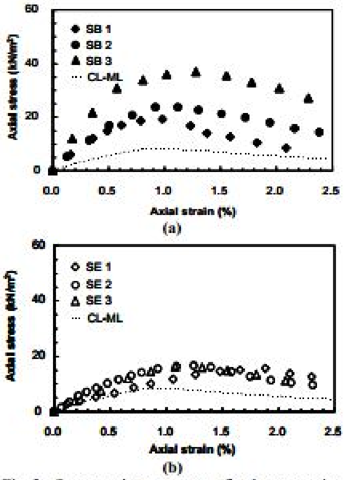

Fig. 3 Stress-strain curves unconfined compression test. (a) Soil/Bentonite. (b) Soil/BPIS

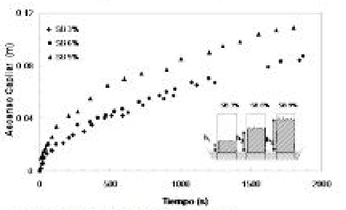

Fig. 4 Capillary rise. Soil/Bentonite

Figure 5 presents the results of the mixtures with ionic stabilizer. The results indicate that the speed of capillary rise decreases with increasing stabilizer content.

An explanation of the phenomenon is the reduction of the electrostatic potential of the soil particles, precluding its adsorption capacity. Thus, negative charges present in the soil are neutralized, and prevent the absorption of positive charge present in the water molecules, producing an attraction between the solid particles, a rearrangement of the granular bodies and reduction of voids. Consequently, it produces a decrease of the film layer present in the soil particles [11].

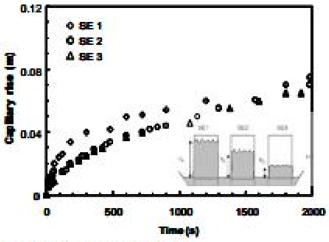

Fig. 5 Capillary rice. Soil/BPIS

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CONCLUSION

This paper has presented a study on mixtures of loess soil, bentonite and materials and revised the importance of interparticle interactions and their influence on the mechanical and hydraulically performance of the material. Water content, unit weight, and percentage of stabilizer have been studied. For low unit weights (γ_d = 13kN/m^3) have been identified the main results as follows:

Hydraulic properties: (a) in unsaturated state, the infiltration volume decreases with increasing content of bentonite. (b) Soil / PBIS shows no reduction in volume infiltration compared to loess soil in the dosage used. In saturated condition, the behavior tendencies are similar to unsaturated conditions.

Unconfined compression: (a) It has been identified that the addition of bentonite increases the compressive strength by 400%. (b) Unconfined compression test shows no increase of resistance with PBIS addition.

Capillary rise: (a) the capillary rise increase with the content of bentonite. (b) The capillary rise decreases with increase of EIBP content.

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