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PREDICTION OF INFILTRATION ON SMALL SCALE FIELD TESTS PERFORMANCE IN COMPACTED LOESSIC SOIL

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ABSTRACT: Silty loess soils are widely spread on Córdoba city, Argentina. The ability to use this soil improved by compaction on embankments it is of interest to different types of local constructions, with purpose of reducing settlements and infiltration. This work research the water infiltration through compacted silty soils from Córdoba by small scale field test. Four small test embankments were constructed on natural soil with different compaction conditions using local silty soils. The site was characterized by typical geotechnical laboratory and field tests. The infiltration tests were performed using double ring infiltrometers for a time period around of 2 months. Results were used to field permeability estimated (kf) and these were compared with laboratory results (kl). Conclusions regarding the behavior observed in the field are presented.

Keywords: Embankment Test, Double Ring Infiltrometers, Site Investigation, Córdoba Soil

1. INTRODUCTION

Compacted soils are frequently used for different engineering project. Soils excavated from nearest works may be utilized for embankment construction. This is an economic and sustainable alternative, but data are needed to characterize the mechanical and hydraulic performance of the material. Lagoons and other waterworks, require barrier systems generally include layers of compacted soil. In these cases it is of interest to determine the infiltration of water. Permeability tests are generally performed on samples in laboratory compaction molds, or undisturbed samples. However, these tests do not take into account possible effects of scale which can be noticed through large-scale laboratory [1] or field test [2], [3], [4]. The study presented in [5] explores, by laboratory and field test, the possibility uses of silty soil as landfill liner material. A test pad was constructed in field using different soil composition and different compaction effort. Sealed double ring infiltrometers were employed to hydraulic conductivity determination. Differences between the results of hydraulic conductivity obtained from laboratory and field were found. Laboratory values were lower [5].

This work research the field water infiltration through compacted silty soils from Córdoba [6], [7], [8]. Four small test embankments were constructed on natural soil with different compaction conditions using local silty soils. The site was characterized by typical geotechnical laboratory and field tests. The infiltration tests were performed using double ring infiltrometers. The results show the effect of scale compared with previous laboratory data on these soils, and the effect on field compaction conditions.

2. MATERIAL AND METHOD

Soil used in laboratory and field experiments was a silty loess from Cordoba. The Table 1 reports principal properties.

Table 1 Properties of liner soil

Properties	Unit	Value
Liquid limit	%	26.7
Plasticity index	%	4.3
Fines (<0.074mm)	%	97
Fraction <0.002mm	%	5
Specific gravity		2.67
Class (ASTM D2487)		ML
Max dry unit weight	kN/m^3	16.8
Optimal water content	%	19

Note: max dry unit weight and optimal water content are for Standard Proctor (ASTM D698).

For field infiltration test a small probe fills was constructed in the Universidad Tecnológica Nacional campus located on City Southern Cordoba City. The selected site was gated. The position of each cell was set and then excavations were undertaken (Fig. 1). For the excavation, a dimension plan of 1 m by 1 m was adopted and 0.55 m in thickness.

Soils excavations were scrapped because these contained many roots. Silty local materials were used, in depths of 3-5 m, in order to avoid impurities (Table 1), and prepared carefully to remove clods and mix well with added water. The construction of the cells was performed under controlled compacted soil layers. Each layer was compacted by dynamic impacts. The compaction condition was controlled by the number of blows applied. Control tests as DCP (dynamic cone penetrometer) and in place unit weight were performed (Fig. 2).

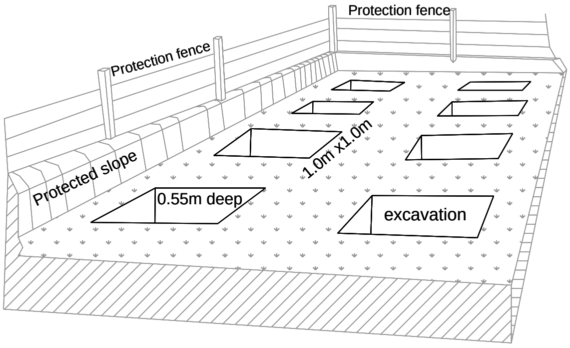

Fig. 1 Design of cells construction

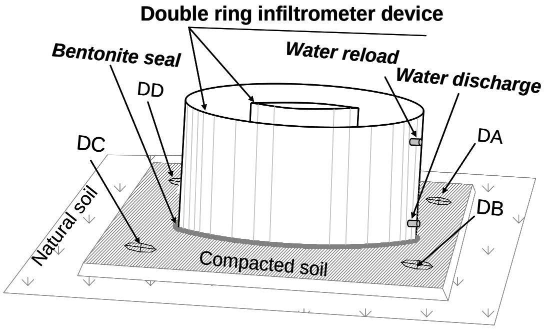

Fig. 2 Sketch of cell

Mean value of dry unit weight in place were 13.3 kN/m^3 (Cell 1), 15.8 kN/m^3 (Cell 2), 14.5 kN/m^3 (Cell 3), 15.2 kN/m^3 (Cell 4). Relating to Standard Proctor the relative compaction were 79% (Cell 1), 94% (Cell 2), 86% (Cell 3), 90% (Cell 4). These values can be easily achieved in construction practice.

The Fig. 3 shows the curve of loessic soil compaction sample. The dots indicate the dispersion of the results obtained during the construction process. Note that in some situations the dry unit weights overlap despite having made a highly controlled compaction.

Figure 4 shows DCP test results. Generally, a first surface layer of 5 cm with relatively low compaction is observed, then the embankment with a thickness of approximately 50 cm, followed by a layer of compacted natural soil to 65 or 70 cm deep. Finally, natural soil not affected by compaction, with a DCP index of 30 mm/blow is detected.

In the local practice, it is frequently characterized the compactness of the soil through the Dynamic Probe Super Heavy (DPSH).

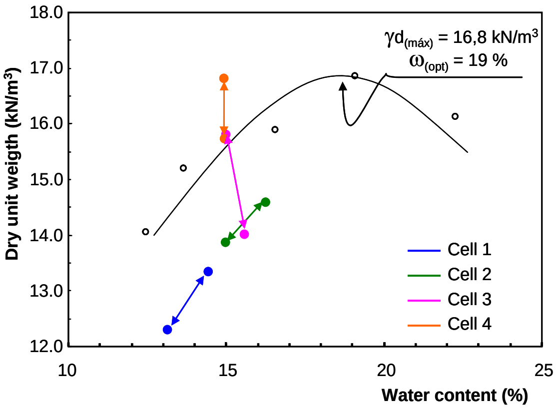

Fig. 3 Variability of results for cell construction

That is why has been established a specific energy factor between light penetration tests made (E_{LP}) and super heavy test (E_{SHP}). The specific energy is defined as energy applied divided by the projected area of penetration cone.

$$\xi = \frac{E_{LP}}{E_{SHP}} \qquad (1)$$

Where ξ: specific energy factor. Applying the specific energy factor, and by adopting the mean value for the distance of 20 cm (N_{DPSH}), the cells are characterized by Fig. 5.

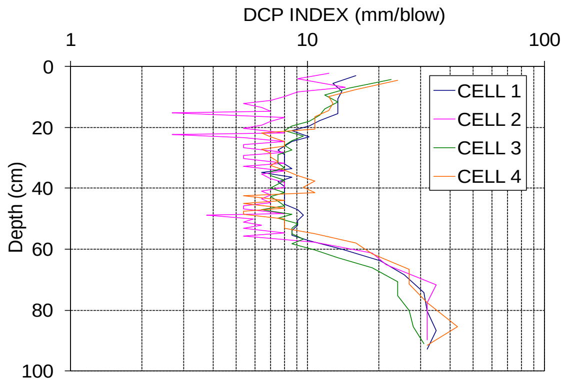

Fig. 4 DCP test results

The infiltration tests were performed using double ring infiltrometer. Inner ring of 30 cm diameter and outer ring of 60 cm were used. The water level was preserved approximately constant with a height of 5 cm. During the test progress, a waterproof cover was installed on each cell to prevent from rain event (Fig. 6).

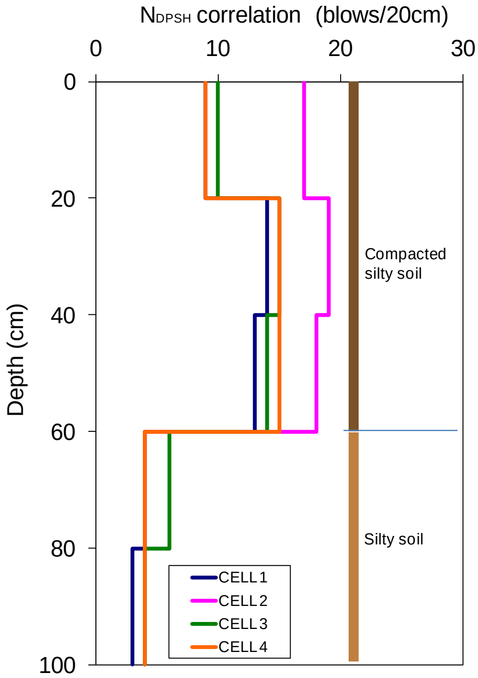

Fig. 5 DPSH correlation

Additionally, a container for controlling evaporation occurred during the test was used. This determination not intended to provide weather information, it was made only for the purpose of correcting the volume of water infiltrated into the ring.

Fig. 6 Test in progress

Infiltration tests were conducted at the site on the natural soil without compacting, in order to assess the influence of compaction. For this, the rings were installed on a prepared surface where it was removed coverage of grass and roots.

3. RESULTS AND ANALYSIS

Measurements of water infiltration into the natural silty soil are shown in Fig. 7. To analyze the results the infiltration rate (I_r) is adopted. Eq. (1) presents the formulation for field infiltration rate calculation.

$$I_r = \frac{\Delta V(t)}{\Delta t \cdot A} \qquad (2)$$

Where ΔV: volume infiltrate during time Δt, A: inner ring area.

For natural silty soil the *Ir* results 2×10^{-6} m/s. This value characterizes the material located beneath the cells with compacted soil.

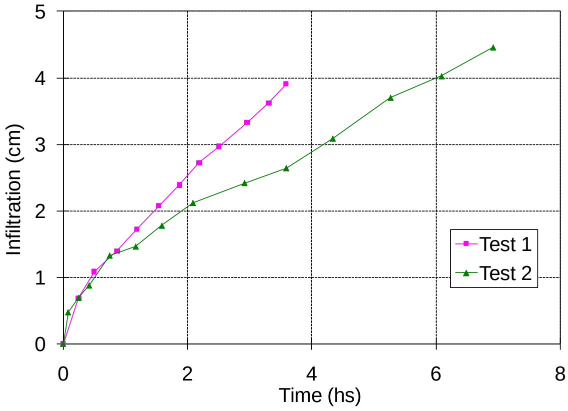

Fig. 7 Field infiltration test on natural silty soil.

In the case of the compacted soil a correction was made for the infiltrate water, due the long test duration, and consequently the evaporation effect. Fig. 8 shows results of evaporation control test. In simplified form, a constant correction factor of 5.2 mm/day was adopted.

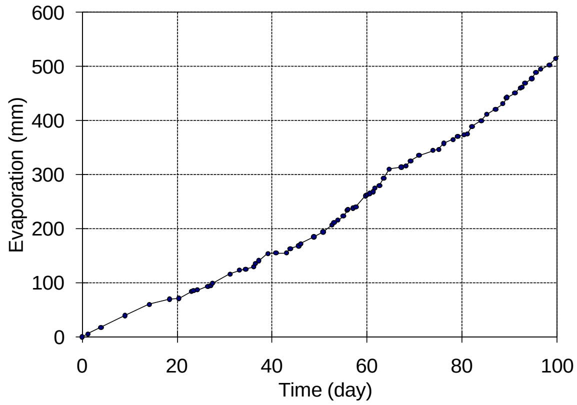

Fig. 8 Evaporation control test.

Fig. 9 shows corrected results of field infiltration test from cells. For compacted silty soil the *Ir* results 2.0×10^{-7} m/s (Cell 1), 9.8×10^{-8} m/s (Cell 2), 2.4×10^{-7} m/s (Cell 3), 1.7×10^{-7} m/s (Cell 4).

The comparison of results is performed by a factor relating infiltration rate of two cases (Eq. 2). Thus, η results 2.4 for cells 2 and 1. Comparing natural silty soil relative to the improvement by compaction, values for η between 8 to 20.

Concerning results of laboratory tests on samples compacted under similar conditions can be observed that in field values are similar without a clear scale effect.

$$\eta = \frac{I_{r1}}{I_{r2}} \qquad (3)$$

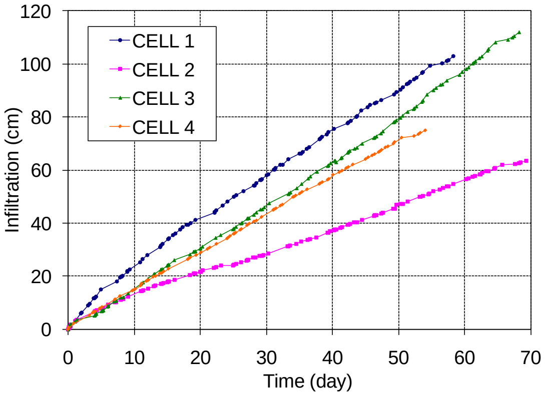

Fig. 9 Field infiltration test on compacted silty soil.

The prediction of infiltration for different states of compaction on the dry unit weight, has been one of the most important issues that face construction supervisors.

Having a simple equation approach is useful. A linearization of the figures shown in Figure 9 is shown in equation (4).

$$I_r = f(\gamma_d, T) = \alpha_{(\gamma_d)}\ T \qquad (4)$$

Where γ_d = dry unit weight, T = time in days, $\alpha(\gamma_d)$ slope of linear function as a function of γ_d.

The initial condition are;

t = 0 for Ir = 0;

$$\frac{\partial Ir(\gamma_d, 0)}{\partial T} = \alpha \qquad (5)$$

The numerical approximation is

$$\gamma_d = -2{,}65 \frac{\partial Ir}{\partial T} + 18{,}6 \qquad (6)$$

Finally, infiltration (Ir) is obtained by equation 7.

$$I_{r(cm)} = 0{,}38\ \gamma_{d(kN/m^3)}\ T_{(days)} + 7\ T_{(days)} \qquad (7)$$

Figure 10 shows the trend for different magnitudes infiltration dry unit weight. Fig. 10 can be used as a reference in estimating expected infiltration rate for different degrees of compaction

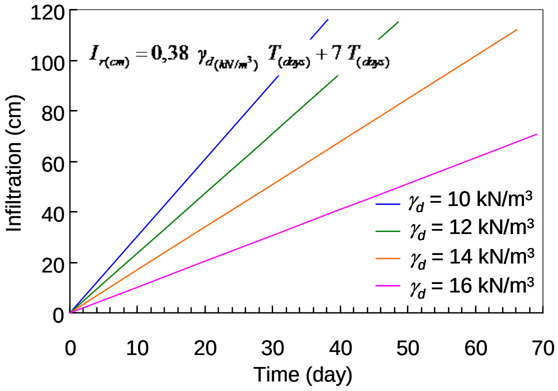

Fig. 10 Field infiltration predictions

4. CONCLUSION

In this paper, an experimental study of field infiltration tests on small silty soil compacted embankments is presented. The embankments were prepared under controlled compaction conditions. Cells were protected from the rain and the effect of water evaporation was contemplated due to the long test duration.

Compaction provides improved hydraulic performance, considerably reducing the rate of infiltration respect the natural soil. The condition of compaction affected the results. The greater relative compaction (Cell 2) determined the lowest cumulative infiltration, while the cell with lower relative compaction (Cell 1) presented the highest cumulative infiltration. Field results were similar to available laboratory compaction by similar conditions.

Despite soil compaction, the infiltration rate may be high for many project.

It could increase the relative compaction or incorporate some added material in order to attempt to reduce the infiltration rate. However, this work is one of the few local experiences with field infiltration tests on compacted silty soil. So, more embankments tests are needed in order to reach conclusions of general behavior.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] Shackelford CD and Javed F, “Large-scale laboratory permeability testing of a compacted clay soil”, Geotehnical Testing J., Vol. 14, No. 2, June 1991, pp. 171–179.

[2] Stewart JP and Nolan TW, “Infiltration testing for hydraulic conductivity of soil liners”, Geotehnical Testing J., Vol. 10, No. 2, June 1987, pp. 41–50.

[3] Sai JO and Anderson DC, “Field hydraulic conductivity tests for compacted soil liners”, Geotehnical Testing J., Vol. 13, No. 3, September 1990, pp. 215–225.

[4]Benson CH, Daniel DE and Boutwell GP, “Field performance of compacted clay liners”, J. of Geotechnical and Geoenvironmental Engineering, Vol. 125, No. 5, May 1999, pp. 390–403.

[5] Bozbey I and Guler E, “Laboratory and field testing for utilization of an excavated soil as landfill liner material”, Waste Management, Vol. 26, 2006, pp. 1277–1286.

[6] Arrúa P, Aiassa G., Eberhardt M and Alercia Biga C, “Behavior of collapsible loessic soil after interparticle cementation”, International J. of GEOMATE, Vol. 1, November-December 2011, pp. 130–135.

[7] Aiassa G. and Arrúa P, “Desempeño de barreras sanitarias simples de suelo loéssico compactado”, Revista Tecnología y Ciencia, Año 8, Noviembre 2009, pp. 26–40.

[8] Aiassa G, Zeballos M, Arrúa P and Terzariol R, “Infiltración en suelos limosos compactados”, XIX Congreso Argentino de Mecánica de Suelos e Ingeniería Geotécnica, Octubre 2008, La Plata, Argentina.

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