Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-1459

Underpinning of foundations in collapsing soils

Reprise en sous oeuvre du fondations en sols â structure instable

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ABSTRACT
This paper presents an underpinning method with permanent fixation hydraulic pats. The function of this system is to preload the construction simultaneously on several points. It is necessary to drill holes in the shoes for installing bored piles as a basement.
The collapsing soil profile is described with laboratory and field tests results and the selected structures and places include: Primary school in Añelo City, Province of Neuquén, Argentina; Swimming pool and Supermarket in Rincón de los Sauces City, Province of Neuquén, Argentina; CPEM Nº 40 school in Neuquén City, Argentina.
Similar characteristics were found in the three working places. The soil profile is composed of fine siliceous sand, reddish, and loose to very loose compactness in 10/11 meters long. From hydrometrics and grain-size distribution tests, Cu is determined, and from pressure-void ratio curves the "collapsing relation" value with the Denisov´s relation is determined. There are microscopic photographs showing cementation with salts and their dissolution in the saturated soil. In one place we treated an inundation area, and we measured a settlement of 12 cm when the soil completed the saturation-collapse process.
Then, after a detailed study of the building, the Provincial Board of Education decided to repair it by underpinning. It was necessary to drill holes in the shoes, on several points, to install bored piles. This system allows preloading simultaneously on several points with equals deformations and the piles length was designed as a friction pile, to calculate the resistance by skin friction. A friction bored pile compressive load test, used as a basement to the underpinning system is attached together with photographs of collapsing field tests equipment, the general conditions of the buildings and the execution sequence of the underpinning method.

RÉSUMÉ
Cet article présente une méthode de soutien avec les tapotements hydrauliques de fixation permanente. La fonction de ce système est de précharger la construction simultanément sur plusieurs points. Il est nécessaire de forer des trous dans les chaussures pour installer les piles alésées comme sous-sol.
Le profil s´effondrant de sol est décrit avec le laboratoire et les résultats d`essais sur le terrain. Les structures et les endroits choisis incluent: École primaire dans la ville d`Añelo, Province de Neuquén, Argentine; Piscine et Supermarché en Rincón de los Sauces City, Province de Neuquén, Argentine; École de CPEM nº 40 dans la ville de Neuquén, Argentine.
Des caractéristiques semblables ont été trouvées dans les trois lieux de travail. Le profil de sol se compose de compacité très lâche siliceuse fine en 10 / 11 mètre de long. Á partir du hydrométrics et des essais granulométriques, le Cu est déterminé, et du rapport pression-vide courbe la valeur « de relation s`effondrante » avec la relation du Denisov est déterminé. Il a les photographies microscopiques montrant la cémentation avec des sels et leur dissolution dans le sol saturé. Dans un endroit nous avons traité un secteur d`inundation, et nous avons mesuré un règlement de 12 centimètres quand le sol a accompli saturation-effondrent processus.
Puis, après qu`une étude détaillée du bâtiment, le Conseil Provincial de L`éducation ait décidé de le réparer par le soutien. Il était nécessaire de forer des trous dans les chaussures, sur plusieurs points, pour installer les piles alésées. Ce système laisse précharger simultanément sur plusieurs points avec des déformations d´égales. La longueur de piles a été conçue comme pile de frottement, pour calculer la résistance par frottement de peau. Un frottement a alésé l`essai compressif de charge de pile, utilisé comme un sous-sol au système de soutien est attaché ainsi que des photographies d`équipement s`effondrant d`essais sur le terrain, les conditions générales des bâtiments et l`ordre d`exécution de la méthode de soutien.

1 INTRODUCTION

The damage caused to some school building structures alter a wetting process of collapsing soils in different cities in the Province of Neuquén is described with a typical case.
These soils have a macro porous structure in natural state, and the increase of the saturation grade develop a collapsing process.

The CPEM Nº 40 school case (Compagnucci JP, 2000) was constructed with a strip foundation and reinforcement under the columns of the multipurpose room.

The shoe foundation rested on a compacted one foot thick fill of granular soil, in accordance with the original soil report, wich recommended a rated pressure between 30 and 50 KPa.

After some time, differential settlements caused damage to the structure and there appeared traction diagonal fissures, shearing vertical fissures displacement areas, descent of walls, carpentry affected with deformation in frames, explosion on linings, cracked footpath and cavities on the floor.
These soils have a macro porous structure in natural state, and the increase of the saturation grade develop a collapsing process.

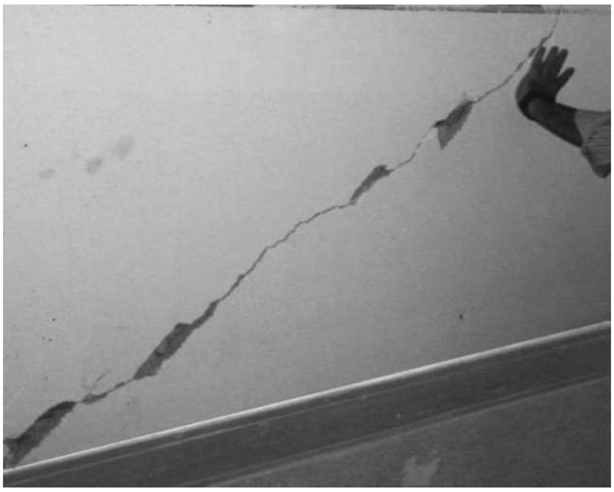

Figure 1. Traction diagonal fissure.

Figure 2. Cracked footpaths.

Figure 3. Explosion in sanitay linings.

2 SOIL PROFILE

The soil profile is composed of fine siliceous sand, reddish, and loose to very loose compactness in ten / eleven meters long.

The SPT tests resulted between two and six blows / feet, and the natural moisture contents resulted five to ten %. The minimum dry unit weight is 13,8 KN/m3 and the maximum is 15,2 KN/m3.

Relations and Laboratory tests:
From hydrometrics and graduations tests:
Uniformity Coefficient (Cu) = 5 / 6.
Loess fraction (0,01 to 0,05 mm) = 6 / 8%
From pressure void ratio curve:
Initial void ratio (eo) = 0,92.
Void ratio after press application (ep) = 0,88.
Void ratio with saturated soil (ew) = 0,63.
Denisov´s relations:
Rw = (ep – ew) / (1 + ep) = 0,133.
Rt = (eo – ew) / (1 + eo) = 0,151.
Collapsing relation value:
Rc = Rw * 100 / Rt = 88%.

In our example the loess fraction has a very low value, but the Cu is very near to the limit curves (Leoni et al., 1984).
Grain structure:
Cementation with salts and their dissolution in saturated soil.

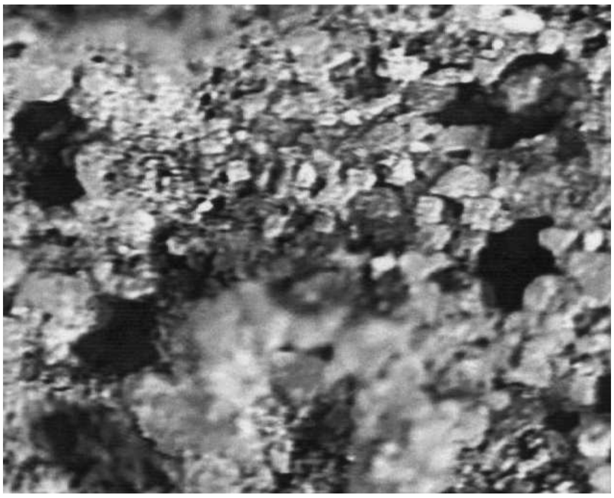

Figure 4. Microscopic photograph of granular structure with natural moisture.

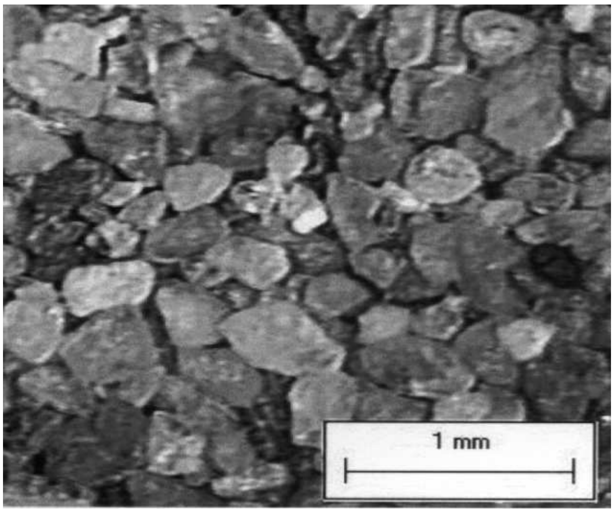

Figure 5. Microscopic photograph of granular structure after saturation process.

For Classification purposes, it World be a truly collapsing soil (Reginatto, 1970) with C< 0:
C = (Pfs – Po) / (Pfn – Po)

C = Collapsing coefficient.
Pfs = Flor pressure for a saturated soil.
Pfn = Flow pressure for a natural moisture soil.

Po = Vertical pressure by own weight.

2.1 *In situ collapsibility tests*

The basic equipment used is shown in attached by photographs (Terzariol and Abbona, 1997) it presents a few modifications that allow applying pressures of up to 100 KPa.

A program of fifteen tests was developed in Neuquén City, Rincón de los Sauces City and Añelo City, in the Province of Neuquén.

Table 1: In situ tests results (final settlement):

Nº	Sat. Pres.	Sat. Settlem.	Max.Pres,	Final Sett.
	(Kpa)	(mm)	(Kpa)	(mm)
1	17	2.5	74	5.2
2	17	2.92	74	5.7
3	45	3.9	74	6.4
4	45	Plate revolving	74	
5	45	5.2	74	7.2
6	74	Plate revolving	103	
7	74	6.8	103	8.4
8	74	7.25	103	9.8
9	103	Plate revolving	103	
10	103	10.6	103	10.6
11	74	6.3	103	8.7
12	74	6.9	103	9.4
13	103	Plate revolving	103	
14	103	11.3	103	11.3
15	103	9.8	103	9.8

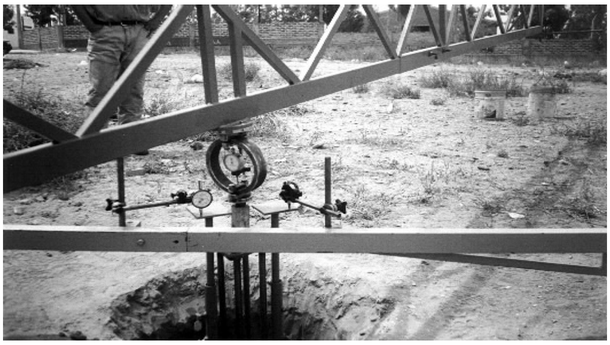

Figure 6. Equipment measurement system.

Fig. 7: Equipment general view.

2.2 *Laboratory Collapsing Tests*

Odometer tests were performed following one of the pressure increase and soil saturation sequences used in the field.
The moistening process was carried out with a 50 Kpa load and the undisturbed samples were taken in 10 of the 15 tested sites.

Two representative tests can be seen in Fig. 8 and 9:

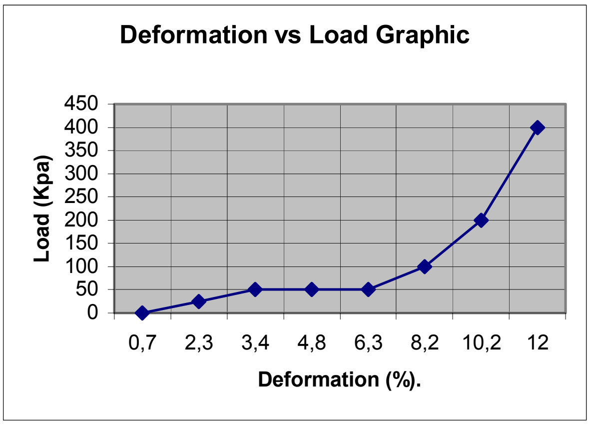

Figure 8. Odometer test nº 3

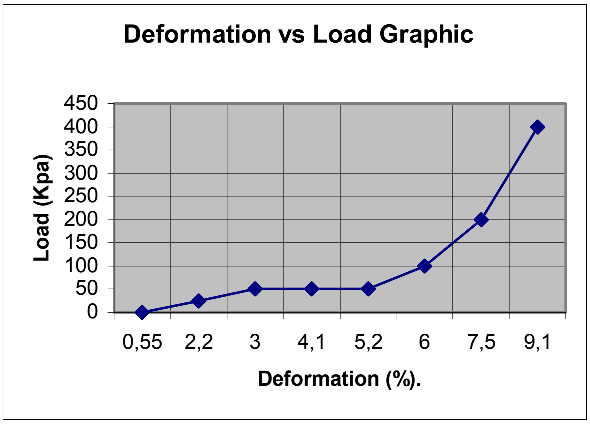

Figure 9. Odometer test nº 6.

2.3 *Inundation test*

According to Grigorian`s classification (Grigorian, 1984 / 1995) it would be a collapsing soil type II, which, apart from collapsing under external loads, they collapse under dead weight and exceed 5 cms.

In our cases, we treated an inundation typical area like example, and there, we measured a settlement of 12 cms when the soil completed a great percentage of the saturation collapse process, a few days later.

Fig. 10: Inundation test in process.

3 PILE FOUNDATION

With our soil profile a deep foundation was necessary to repair the building by underpinning and a pile length was designed to calculate the resistance by skin friction (like a friction pile).
To design a load test of a pile, the influence of the moisture regime of the soil was considered because in collapsible soils with lower moisture content in the soil, greater error to determine the ultimate resistance of a pile.

Our testing pile had a length of 10 m and a diameter of 30 cm. We tried with soil saturation for 48 hs but that time was not enough time because moisture measured parameters did not vary substantially compared with initial parameters and the necessary time was not compatible with the work´s terms.
The pile was cased in the upper 2,50 m and a plastic case was used in order to repeat the working conditions in terms of not providing resistance by friction on the first L quarter, the estimated penetration depth as a result of leaks.

The load settlement curve for compressive load test can be seen in the diagram. The test was done according to ASTM D standard 1143.

3.1 *Pile load test*

The failure load was 28 tns and for a service load of 10 tns (according to the project) the safety factor is 2.8.

The criteria to define the ultimate load was with the load at which there was a disproportionate increase of settlement in relation to the load growth and this load caused a gross settlement of 2% of the minimum pile width.

It is necessary not to forget the risk taken for not having enough time to perform the load test after a long saturation period, although the above mentioned precautions have been taken (plastic case).

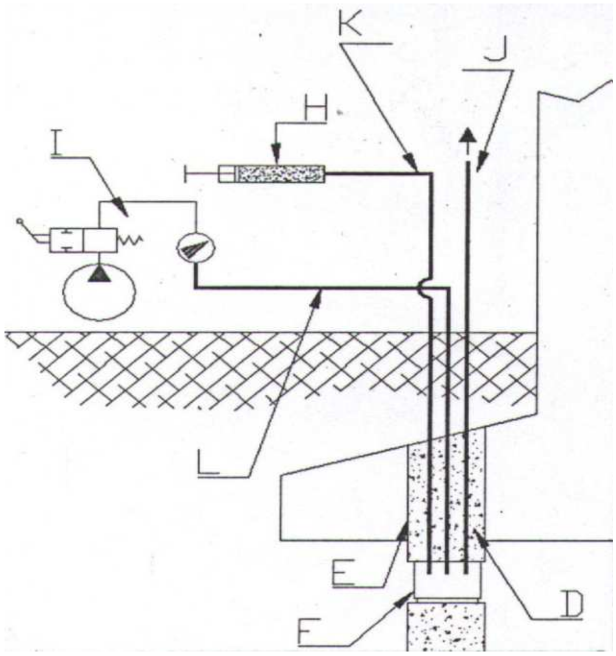

Figure 11. Underpinning scheme.
D = Concrete.
E = Binder between shoe and fill concrete.
F = Hydraulic pat with permanence for ever.
H = Grouting equipment.
I = Hydraulic equipment.
J = Training conduit.
K = Injection conduit.
L = Hydraulic equipment conduit.

4 UNDERPINNING SYSTEM

It is necessary to drill holes in the shoes on several points for installing bored piles. The piles heads are the basement for the underpinning system and the function of the permanent fixation hydraulic pats is to preload the building.

A grouting application was done inside the injection camera with enough fluidity to assure the load and strains permanence. This system allows preloading simultaneously on several points with equal deformations.

5 CONCLUSIONS

The fine sands and silty sands found in the study area can be defined as potential collapsing soils under a moisture process.
The necessary four factors to produce the collapse in a soil structure are complied with (Pereira and Fredlund, 2000).
Results variation shows the collapse association with shear local failures, rather than a mass soil failure.

The collapsing condition does not directly depend on relative density for the values found in our work. It is necessary to consider that any compacted soil on dry side with low density can develop a metastable structure.

High saturation grades measured on the odometer tests, higher than 85%, assure to eliminate the capillarity action because in low confinement pressures the capillary rise influences the collapsing process. It is possible to obtain these in situ tests with a great water entry.

The underpinning system with preload allowed to stop the deterioration process and to assure a structural good performance in the three working places, in three different cities in Neuquén Province, Argentine.

ACKNOWLEDGEMENTS

Thanks to: Lic. Félix Diaz of Compagnucci Diaz SRL., Lic. Luciano Di Nardo of South University and Mr. Vicente Chrestía of Toqui SA.

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