Geosynthetic Encased Columns in a Tropical Collapsible Porous Clay

Colonnes renforcée avec Géosynthétiques et argileux tropical poreux effondrable

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ABSTRACT

Embakments constructed on soft soils can have their performance compromised because of settlements due to consolidation or colapse of the soft foundation soils. The same can happen in case of embankments on collapsible soils. One way to avoid or minimise this type of problem is by using granular columns underneath the embankment. This paper presents the results of field loading tests on granular (sand) columns. The results obtained from tests on conventional and on geotextile encased columns are presented and discussed. A significant increase on column bearing capacity was achieved due to column geotextile encasing and the experiments showed the potential of the use of this type of solution to stabilise embankments on collapsible soils.

RÉSUMÉ

Parfois, les remblais construits sur sols mous ont une performance réduite en raison des déplacement dus à la consolidation ou à l'effondrement de sa fondation. Une façon de réduire ce genre de problème consiste à utiliser des pieux dans la base du remblai et le sable est un matériel qui peut être employé pour les remplir. Ce article présente les résultats des essais de chargement de champ sur les colonnes granulaires de fondation, où la matière de remplissage est du sable. Les résultats expérimentaux des cas renforcés contre des cas non renforcés sont comparés et discutés. Les résultats obtenus sont montrés en termes de courbes charge-déplacement, déformations mesurées en fonction de la profondeur, et portance des colonnes. Ils permettent une bonne perception de l'utilisation pratique de tels systèmes de renforcement dans plusieurs cas de remblais fondés sur un matériau argileux tropical et effondrable.

Keywords: Geosynthetics, Encased Columns, Load Tests, Bearing Capacity.

1 INTRODUCTION

In some areas around the world, geotechnical engineers have to face constructions on collapsive soils. This kind of soil is common in several parts of the city of Brasilia, the capital city of Brazil and presents structure breakdown phenomenon related to loading and/or increase of moisture content. These conditions can yield to excessive vertical displacements, usually associated with low bearing capacity.

There are different ways to accelerate embankment settlements, but sometimes the time required for that can be very long, regarding construction schedule constraints. The use of granular columns under the embankment increases its bearing capacity and reduces vertical displacements and this solution has been used for a long time when the embankment foundation soil is soft.

Some works can be found in the literature, regarding the use of encased granular columns to stabilise embankments on soft soils. Raithel et al. (2002) describe the construction of a dyke to protect the extension of the facilities of the Airbus 380 factory, in Hamburg, Germany. In this case, sand columns were encased by strong and stiff woven geotextile. The performance of the pile dyke was excellent.

Another application of piled embankments is in bridge abutments on soft ground. Horizontal displacements of the soft soil due to the abutment construction can cause damages to the bridge foundations.

The lack of confinement of a granular column can cause bulging of the column, particular along its upper part. These excessive lateral deformations of the column can increase embankment settlement and reduce the bearing capacity of the column (Chummar, 2000). The use of a stiff and strong geotextile to encase the column can avoid or reduce significantly such deformations, also yielding to bearing capacity increases.

This paper presents the results of field loading tests on sand columns with and without geotextile casing. The columns were constructed crossing a collapsible soil layer commonly found in the city of Brasilia, and one of the objectives of the study was to investigate the potential of such foundation solution for the stabilisation of embankments on that type of soil in the city.

2 METHODOLOGY

This study was carried out in the Experimental Foundations Research Site of the University of Brasilia, where a large amount of data on the local soil (Brasilia's collapsible porous clay) is available (Cunha *et al.*, 1999). The columns were eight meters long and had a diameter of 0.4m. The columns ends rested on a strong soil layer. In all cases, strains were measured along the column length aiming to verify the influence of the presence of the geotextile casing.

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2.1 Construction of the granular columns

Sand pluviation was used to prepare the columns. Figure 1 shows the execution of one of the columns tested. It is important to point out that this is not the traditional procedure used in real works. However, it was employed in this research work to avoid damages to the instrumentation inside the column, that otherwise would occur in case conventional compaction techniques were adopted. The granular material used was a medium sand with D_{50} = 0.39 and C_u = 5.2. The sand unit weight reached under these conditions was equal to 14.8 kN/m^3.

Figure 1. Pluviation technique used.

2.2 Instrumentation

Strain gauges were positioned at depths equal to 1.0 m, 2.5m, 4.5 m and 6.5 m from the column top. At both 1.0 and 4.5 m depths, horizontal strain gauges were also installed. The strain gauges consisted of electric strain gauges anchored to epoxy disks at its ends. Figure 2 shows the locations of the strain gauges along the pile length.

To maintain the strain gauges aligned with the vertical or the horizontal direction and to protect them from damage during installation, freezing of a certain amount of sand containing the strain gauge was carried out in the laboratory, prior to gauge installation in the column. Figure 3 shows a detail of this procedure. The soil containing the strain gauge was frozen inside a steel mould. Firstly the mould was half filled with sand. Then, the strain gauge was positioned and the sand was poured to fill entirely the mould with the same soil density expected in the field. The sand mass was saturated and taken to a freezer. The installation of the strain gauges in the columns was done with the help of cables, as illustrated in Figure 4.

A polyester woven geotextile was used to encase the sand columns. The nominal diameter of the geotextile casing was equal to 0.40 m .The geotextile casing was manufactured without seams to avoid weak regions along its length. The tensile strength and stiffness of the geotextile were equal to 200 kN/m and 2000 kN/m respectively.

The instrumentation of the loading tests consisted of three LVDT's to measure column top displacements, six strain gauges along the column length and a load cell to measure the loads transmitted to the columns top. A data acquisition system (Spider 8) was used to acquire the readings from the instruments.

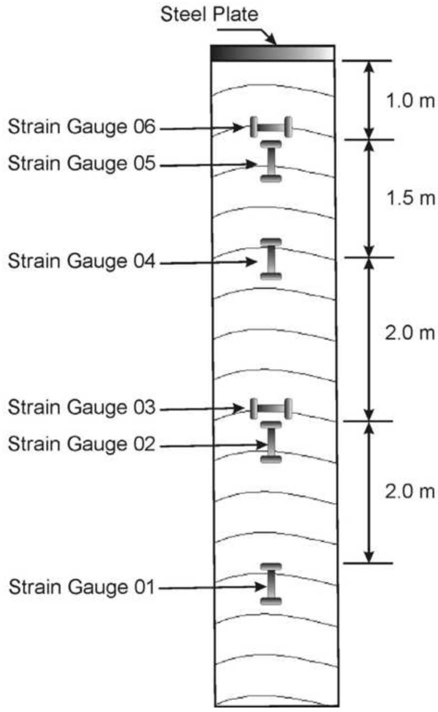

Figure 2. Locations of the strain gauges.

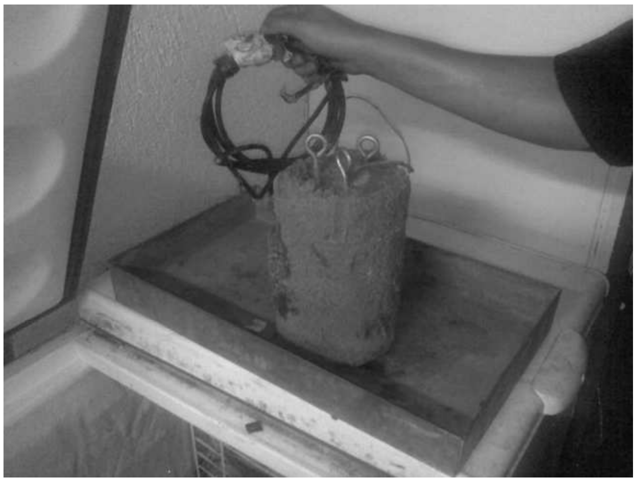

Figure 3. Frozen soil mass containing the strain gauge..

The methodology employed in the loading tests followed the procedure established in the Brazilian standard NBR 12131, for pile loading tests.

3 RESULTS OBTAINED

Figure 5 shows some results obtained in terms of loads vs. displacements for conventional and encased columns. It was observed that the encased column presented an initial vertical displacement greater than that of the conventional column (Fig. 5). This was due to the initial stretching and lateral deformation of the geotextile of the encased column so as to comply with the ground hole internal shape. This accommodation was a consequence of the hole not having uniform diameter along its length.

The method developed by Decourt (1996) was employed to obtain the bearing capacity of the column. The bearing capacity of a pile is obtained from a plot of pile load *versus* loading/settlement index (stiffness).

Figure 4. Placement of a strain gauge in the column.

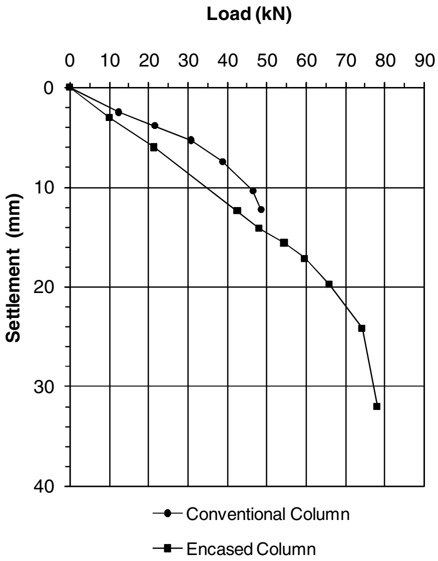

Figure 5. Load-Settlement curves for conventional and encased sand columns.

The pile bearing capacity is assumed as the load for which the stiffness is equal to zero. More details on this method are reported by Decourt (1996). Figures 6 and 7 illustrate the use of the method for the tests on the conventional and on the encased sand columns. For the conventional column the bearing capacity obtained was equal to 53 kN, whereas the encased column presented a bearing capacity of 96 kN (81% increase). These results show the significant increase on the column bearing capacity caused by geotextile encasing.

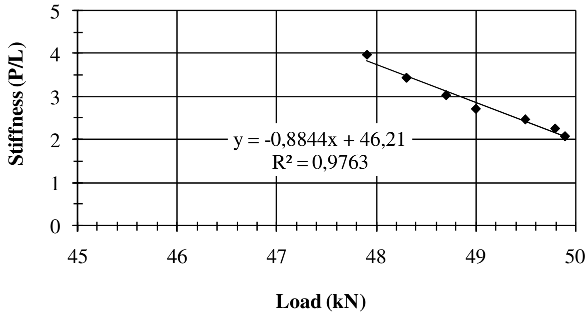

Figure 6. Load-Stiffness curve for the conventional column.

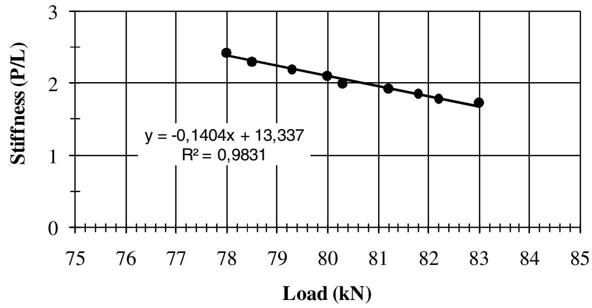

Figure 7. Load-Stiffness curve for the encased column.

Figure 8 shows low strain levels close to the bottom end of the conventional column (strain gauge 1). In the central part of the conventional column, strain gauge 3 indicated a small lateral deformation for loads higher than 40 kN (Fig. 8). For the encased column (Fig. 9), strain gauges 5 and 6, positioned close to the column top, indicated greater compressive and tensile strain values, respectively, associated with the higher loads supported by this column in comparison to the conventional one and the lateral stretching of the geotextile casing, as commented above.

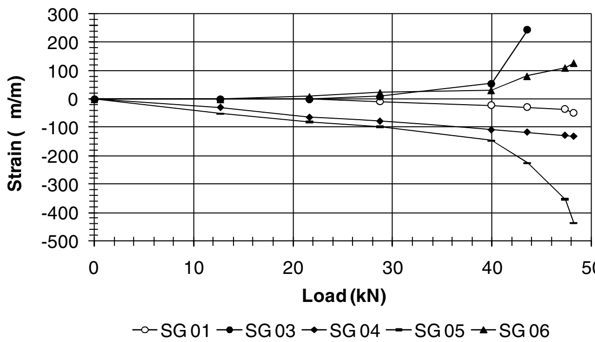

Figure 8. Strains along the length for the conventional column.

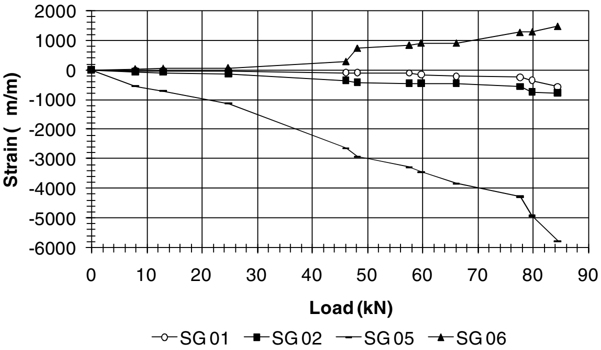

Figure 9. Strains along the length for the encased column.

The strain measurements show that there was greater load transference from the top of the column to its tip in the test with the encased column.

Figure 10 presents the top 0.90m of the encased column after exhumation, which shows larger diameters of the column close to its top, as commented above.

Figure 10. View of the exhumed top portion of the encased column.

4 CONCLUSIONS

This paper presented the behaviour of two sand columns during loading tests. One of the columns was encased by a woven geotextile and the other was constructed without any casing, as it is conventionally done. These columns were installed in a porous collapsible clay. The main conclusions obtained are as follows:

- ✓ The loading tests showed that the presence of a geotextile layer encasing the sand column can significantly increase its the bearing capacity. The vertical displacements at the top of the encased column were larger than those of the conventional one for loads up to 50 kN, mainly because of gaps between the encased column and the internal hole surface due to the non-uniformity of hole diameter through depth. However, the magnitude (< 10mm) of these displacements can be considered very small for routine embankment constructions. Besides, most of these displacements will occur during embankment lifting, if no further surcharge is expected on the embankment top.
- ✓ The results obtained show the potential for the use of geotextile encased sand columns for the stabilisation of embankments constructed on collapsible soils.

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