Laboratory study of geotextile encased sand columns

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ABSTRACT: Several technical solutions are available for the construction of embankments on soft soils. One of them is to use piles or columns that transfer the loads of the embankments to stronger soil layers in the foundation, which both stabilize the embankment and reduce significantly its settlements. These piles can be made of concrete or good quality granular materials, such as sands or gravels. The latter may present a lower load capacity if the foundation soil is soft and cannot provide sufficient lateral confinement along the column length. Strong and stiff geosynthetic layers can be used to encase granular columns and to provide lateral restraint, increasing column load capacity. The present paper presents a laboratory study on the use of geotextile to encase columns made of sand. A large scale laboratory apparatus was commissioned and allows testing of columns with up to 30 cm diameter, 45 cm high and confining pressures up to 400 kPa. In order to measure the horizontal (radial) strains inside the specimen, a special strain-gauge was designed. Low confining pressures were applied to simulate column confinement by a very soft soil. Tests with and without geosynthetics showed that the presence of the geosynthetic casing increases markedly the load capacity of the column. It was also observed that the solution of geosynthetic encased granular or improved columns may be a very cost-effective solution for the stabilization of embankments on soft or collapsible soils in comparison with the use of conventional concrete piles.

1 INTRODUCTION

The use of geosynthetics in geotechnical engineering has increased markedly in the last decades. There are several types of geosynthetic materials available an applications in geotechnical and geoenvironmental engineering. Regarding embankments on soft soils, geosynthetics can be used as basal reinforcement and to accelerate soft soil consolidation by means of horizontal drainage blankets or vertical drains.

A traditional solution for the stabilization of embankments on soft soils is the use of pile foundation. Concrete or granular piles can be employed. Despite the larger load capacity, concrete piles are usually more expensive than granular ones. On the other hand, granular columns can be significanly less expensive than concrete ones and may also have the beneficial effect of dissipating pore pressures (if any) generated in soft saturated soils during embankment construction. However, low lateral confinement from the soft soil along the column upper part can reduce or compromise granular columns performance, due to column bulging and reduction of load capacity, which will be detrimental to the embankment. Geosynthetic encasement can be used to avoid or minimise excessive lateral deformation of granular columns. Strong and stiff woven geotextiles can encase sand columns, increasing lateral confinement and avoid excessive bulging. This type of application was successfully used works such as the expansion of an industrial plant (Raithel *et al.* 2002) and road construction (de Melo *et al*. 2008), for instance. Al Joulani (1995) showed that the presence of a geogrid encasing gravel columns increased their load capacity markedly. Ayadat & Hanna (2005) also reported the beneficial effect of granular columns encasing with geotextile in small scale tests with a collapsible soil confining the column.

The city of Brasilia has a collapsible, porous clay, which can present significant volumetric strains when moistened or under changes of stress level. Figure 1 shows the differential settlement (~ 0.7m) between an abutment and a bridge in the city due to foundation structural collapse of the foundation soil.

So, when vertical settlements of buildings or embankments must be limited usually concrete piles are used, which brings substantial cost increases to the project. The validation of the use of granular columns in such problems can bring important cost savings for projects involving embankment construction.

Figure 1. Excessive abutment settlement due to foundation soil structural collapse.

This paper presents and discusses results of large scale tests on granular columns with and without geosynthetic encasing, which are part of a research programme on the use of geosynthetic encased granular columns for the stabilisation of embankments on collapsible soils.

2 METHODOLOGY

A large triaxial test device was developes for the experiments carried out in the research programme (Araujo, 2009). Figure 1 shows the equipment used and Figure 2 presents a view Figures 2 and 3 show the equipment used in the tests. A confinement pressure (up to 400kPa) can be applied to the specimen. Granular column specimens up to 0.3m in diameter and 0.45m high can be tested. Dupas et al. (1986) showed that the specimen size can influence the values of Poisson coefficient and Young modulus obtained. Vertical load, vertical displacements of the specimen top and horizontal deformations of the specimen were measured during the tests. For the latter, a horizontal strain gauge specially developed for the experiments, was positioned oriented along the horizontal direction at specimen mid height for the measurement of radial strains during the tests.

The sand rain technique was used for the preparation of the granular column specimens. This technique allowed a dense and uniform sample to be obtained. Other aspects of specimen preparation were similar to those used for the preparation of specimens of cohesionless soils in conventional triaxial tests. All tests were carried out on dry specimens. Table 1 shows proprieties of granular material.

Table 1. Properties of the granular materials used in the columns.

Property	Sand
D_{10} (mm)$^{(1)}$	0.25
D_{50} (mm)	0.39
D_{85} (mm)	1.00
Coefficient of uniformity	2.84
Friction angle (degrees)$^{(2)}$	43

Notes: (1) D_{10}, D_{50} and D_{85} = diameters for which 10%, 50% and 85% of the remaining soil particles diameters are smaller than those values, respectively;

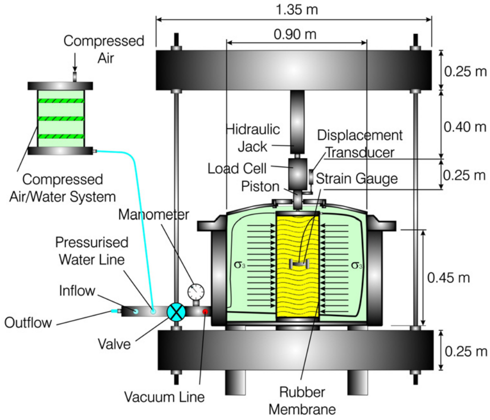

Figure 2. Characteristics of the triaxial apparatus used in the tests.

Figure 3. View of the equipment during a test.

A woven geotextile, made of polyester, was used to encase the granular columns. The woven geotextile had a tensile stiffness of 2000kN/m, maximum tensile strain of 10% and tensile strength equal to 200 kN/m.

The confining pressures used in the tests were equal to 30kPa, 60kPa and 120kPa for tests with and without geotextile casing. A data acquisition system connected to a microcomputer allowed for the automatic data acquisition of the signals from the instrumentation.

Additional information on the apparatus, materials and testing methodology are presented by Araujo (2009). A rigid steel plate distributed the vertical load along the specimen top. Ports in this plate allowed the application of vacuum for the placement of the enveloping rubber membrane (Figure 4). The correction for the strength of rubber membrane was made.

Figure 4. Granular specimen just before test.

3 RESULTS

Figure 5 shows stress-strain curves obtained for the conventional granular column (no casing) for confining stresses ranging from 30kPa to 120kPa. These results show a consistent increase of the maximum deviatoric stress with confining stress, yielding to a friction angle of the granular material under triaxial conditions of 43^0.

Figure 6 shows the horizontal strains measured in the conventional granular column specimen for the confining stresses reported above. These results show that the Poisson coefficient of the granular material increased with the confining stress. This behaviour is consistent with the results of triaxial tests reported by Fawaz *et al.* (2002).

The results of stress-strain curves obtained for the granular columns encased by the woven geotextile are presented in Figure 7. It can be seen that tensile failure of the geotextile casing was not reached for the stress levels used. In addition, the shape of the stress-strain curves shows that the behaviour of the columns in terms of mobilised stresses and strains is controlled by the geotextile casing.

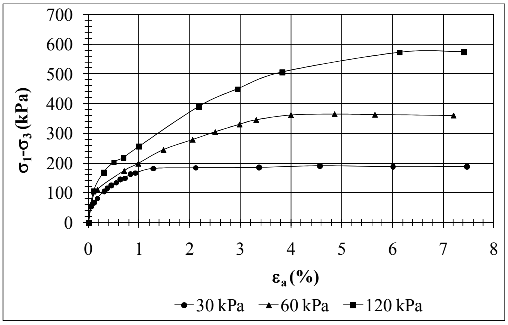

Figure 5. Stress-strain curves for tests with granular columns without casing.

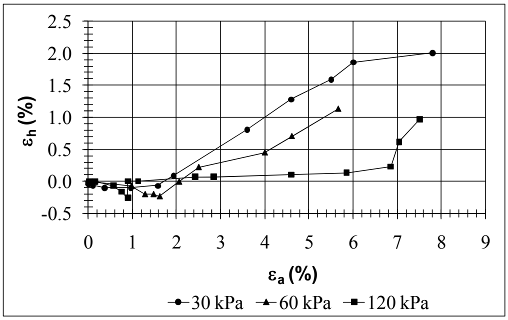

Figure 6. Horizontal strain versus vertical strain obtained for granular columns without casing.

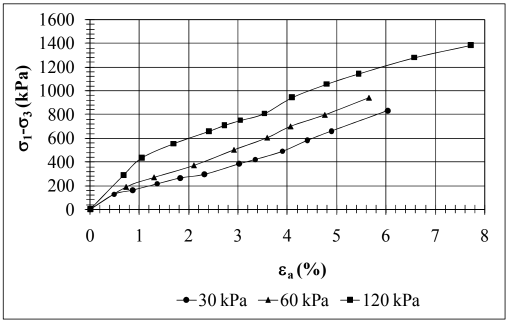

Figure 7. Stress-strain curves for tests with geotextile encased granular columns.

Figure 8 depicts the variation of granular column horizontal strain versus vertical strain for the tests with geotextile casing. A distinct behaviour can also be notice with respect to the results obtained for the columns without casing. Much lower horizontal strains are observed for a given vertical strain due to the influence of the lateral confinement provided by the geotextile casing.

The results in Figures 7 and 8 show that the presence of the geotextile casing can provide a significant increase on the load capacity of the column and substantial reduction of its lateral deformation. The values for 120 kPa for encased granular columns are missing because of some damage to the strain gauge.

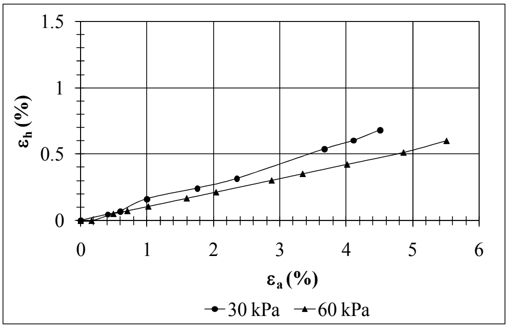

Figure 8. Column horizontal strain versus vertical strain for tests on geotextile encased granular columns.

4 CONCLUSIONS

This paper presented results of large scale triaxial tests carried out on specimens of granular columns with and without geotextile casing. The main conclusions obtained are summarised below.

- The presence of the geotextile casing caused a substantial increase on the load capacity of the granular column.
- The stress-strain behaviour of the encased column is basically controlled by the geotextile casing.
- The presence of the geotextile casing reduced significantly the horizontal (radial) deformations of the column.
- As in the case of embankments constructed on soft saturated soils, the results obtained suggest that geotextile encased granular columns can also be efficient for the reduction of settlements of embankments on collapsible soils.

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