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Geotextile encased columns (GEC) used as pressure-relief system. Instrumented bridge abutment case study on soft soil

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ABSTRACT

Geosynthetic Encased Sand Columns (GEC) have been frequently adopted in geo-engineering practice to improve bearing capacity, reduce settlements and accelerate consolidation in saturated soft cohesive ground (e.g. Alexiew et al, 2005; Alexiew et al., 2012; Raithel et al, 2005). The present paper extends these early views by introducing the use of columns to reduce the magnitude of horizontal earth pressures acting on structures adjacent to compaction fills. The monitoring program of a full-scale bridge abutment on soft soil supported by GECs and geogrid reinforced system is described, where field performance is monitored with pressure cells, electrical piezometers, inclinometers and settlement plates. Analytical and numerical analyses have been performed to help on interpreting experimental measurements. The collected database is interpreted to demonstrate that GEC can reduce by up to 50% the horizontal earth pressure over bridge border foundation piles when compared to values predicted for unreinforced ground and demonstrate that the work conformed to acceptable limits of behavior.

1. Introduction

Sand columns have been systematically used in engineering practice as a ground improvement technique designed to transfer superficial applied loads to substratum of higher bearing capacity (e.g Gniel and Bouazza, 2010; Castro and Sagaseta, 2011; Alexiew et al., 2012; Keyhosropur et al., 2011; Hosseinpour et al., 2014). In very soft soils, the lateral confinement offered by the surrounding ground to the columns may not be sufficient to guarantee the necessary support and, consequently, the columns are encased by geosynthetics (in this case they are referred as Geosynthetic Encased Columns, GEC). The encasement increases the strength and stiffness of the sand column, providing higher load carrying capacities under lower settlements as extensively demonstrated by both experimental and numerical studies (Madhav et al., 1994; Raithel and Henne, 2000; Malarvizhi and Ilamparuthi, 2004; Alexiew et al., 2005; Raithel et al., 2005; Murugesan and Rajagopal, 2006; Gniel and Bouazza, 2010; Najjar et al., 2010). In addition to improving the overall mechanical properties of the stratum, columns work as vertical drains, thus reducing the consolidation time of clay deposits under loading.

Although the technique is now well established, no research has been undertaken on the use of encasement columns regarding the induced horizontal earth pressure acting on pile foundations embedded in soft soils. This is a common occurrence during fill and embankment elevation close to piled structures such as bridges, storage tanks and retaining walls. This paper aims at providing some insights on this topic by discussing the interaction of a bridge abutment and an 8 m high road embankment constructed on soft soil where one of the concerns was the potential increase in horizontal pressure to overload the previously constructed bridge piles.

2. Case study

For a new high traffic road project in the State of Rio Grande do Sul, southern Brazil, a solution was conceived to protect existing bridge foundations constructed prior to an 8 m elevation embankment. A view of the bridge abutment with the equipment used to construct the sand columns is shown in Fig. 1 and more

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Fig. 1. Sand column equipment.

detailed information of the project is reported by Schnaid et al. (2014).

A comprehensive site investigation program was carried out to evaluate conditions of the site comprising SPTs, CPTs, Vane and 4″ Shelby undisturbed soil sampling for triaxial and oedometer tests. A CPTU profile representative of the area is shown in Fig. 2, revealing a sedimentary deposit with a 6 m–8 m soft clay layer overlain dense sand. Near the surface there is an over-consolidated crust within the depth affected by seasonal variations of the water table. The hydrostatic pore-pressure is in accordance with the regional water level (near the surface), without artesianism indication.

The undrained shear strength s_u obtained from piezocone resistance (Schnaid, 2009), dissipation tests (Mantaras et al., 2015) and SPT energy measurements (Odebrecht et al., 2005) ranges typically from 10 to 15 kPa. A CPTU bearing factor value of Nkt = 15 provided the best fit with vane strength data. The value is consistent with clay deposits in the Brazilian coast (Schnaid, 2009) and with a recent study of 11 soft clay deposits (Low et al., 2010) which showed an average CPTU factor Nkt = 13 for reference with vane tests. The characteristic strength values measured in the soft clay yield normalized undrained strength ratios (s_u/σ'_{v0}) of about 1.0 near the surface, reducing gradually to 0.3 at 5 m depth, indicating a lightly overconsolidated profile according to the concepts of critical state soil mechanics (e.g., Wroth, 1984; Wroth and Houlsby, 1985) or normalized strength (e.g. Ladd and Foott, 1974; Ladd et al., 1977).

Given the presence of a soft clay deposit and the proximity of a thick embankment fill close to a bridge, a design solution has been conceived based on the installation of a Geogrid Reinforcement combined to 4 rows of Geosynthetic Encased Columns next to the bridge in addition to 2 rows outside the bridge edge, as illustrated by the cross-section of the construction site in Fig. 3. Sand columns 800 mm in diameter and 2.4 m spacing in a triangular grid were placed in the clay underneath the embankment, corresponding to an area replacement ratio of 0.1. The columns were installed up to

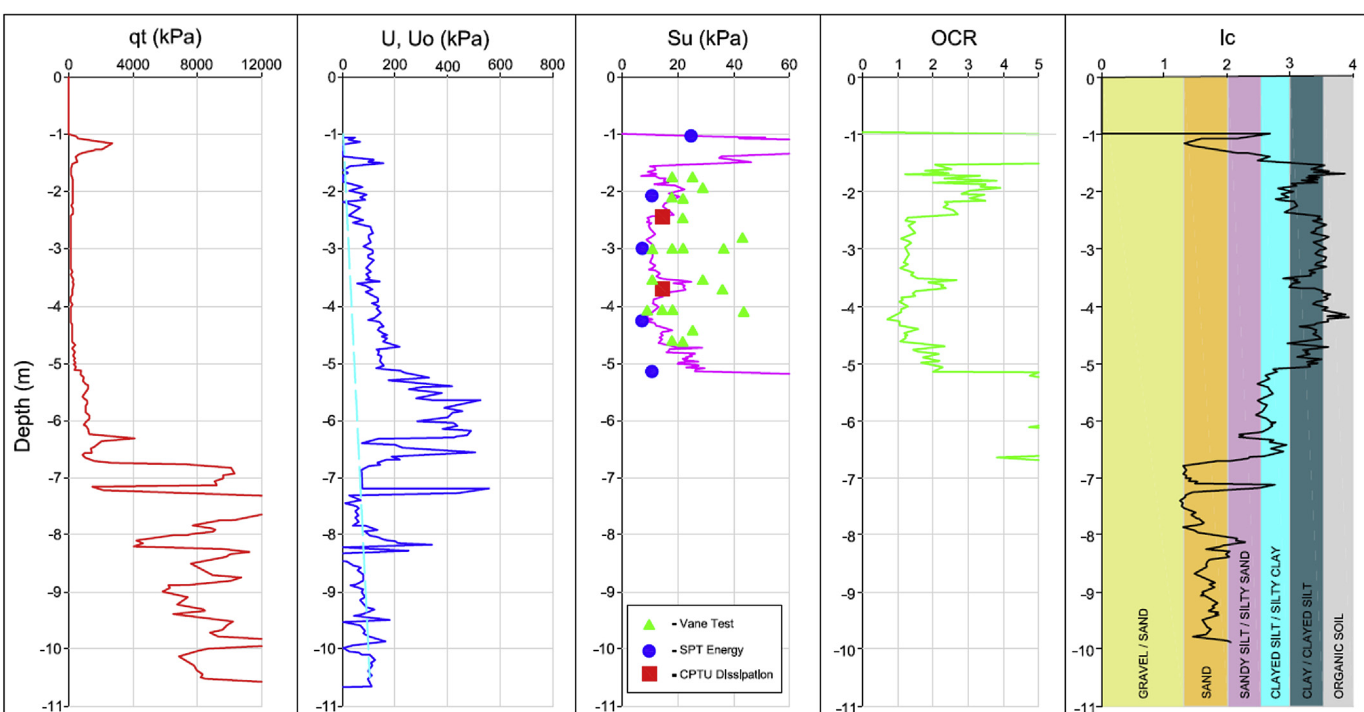

Fig. 2. Typical CPTU profile.