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Jet-grout column-reinforced soft soils incorporating multilayer geosynthetic-reinforced platforms

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Abstract

Geosynthetic-reinforced load transfer platforms are commonly used in constructions over column-reinforced soft soils and correspond to modifications of conventional granular load transfer platforms that utilise only the arching effect of the granular soil to transfer the loads onto the columns. Both a single geosynthetic layer and several geosynthetic layers can be used to reinforce the granular soil of a platform. Most of the studies published in the literature address the use of single geosynthetic-reinforced platforms, while there is a lack of studies on multilayer geosynthetic-reinforced platforms. In the present study, to help overcome that lack, a jet-grout column-reinforced soft soil foundation with a platform that incorporates five geosynthetic layers is analysed. A parametric study is also performed in order to analyse the influence of four key factors. A numerical code based on the finite element method is used, incorporating a fully coupled analysis and soil constitutive relations simulated by the p-q-θ critical state model. The study mainly shows that a larger number of geosynthetic layers within the platform brings about better geotechnical behaviour of the column-reinforced soft soil foundation in terms of the settlement and the load transfer onto the columns.

Keywords: Geosynthetics; Soft clay; Jet-grout columns; Multilayer geosynthetic-reinforced platform

1. Introduction

Construction over soft soils has rapidly increased worldwide during the last decades, mainly due to the increasing lack of suitable ground for infrastructures and other works, related to the rapid rise in population and associated developmental activities. Soft soil deposits have low bearing capacity as well as excessive settlement characteristics; this implies that geotechnical engineers face several challenges when designing works on such soils: (i) the low shear strength of the soft soils significantly limits the load magnitude that is possible to apply with adequate safety for short-term stability; (ii) the high deformability and low permeability of soft soils provoke high settlements that develop slowly as excess pore pressure dissipates (consolidation).

A variety of techniques can be used to overcome the above concerns. The techniques commonly used are: (i) reinforcement with geosynthetics (Rowe, 1984; Borges and Cardoso, 2001, 2002), (ii) total or partial replacement of the soft soils with granular materials, (iii) preloading to improve the soft soils, (iv) stage construction of the embankment, (v) the use of prefabricated vertical drains to accelerate ground consolidation (Borges, 2004; Shen et al., 2005), (vi) the use of light-weight materials for the embankment to alleviate stress in the subsurface soil and (vii) the application of pile/column-reinforced foundations.

The major advantage of the column-reinforced technique in soft soils is its rapid construction and very low settlement.

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Constructions of column-supported embankments have been reported in the bibliography. Reid and Buchanan (1984) mentioned that this technique, with concrete piles, was used to prevent differential settlements between an approach embankment, constructed over soft soil, and a bridge abutment, supported by long piles. A similar construction with soil-cement mixing columns was reported by Lin and Wong (1999).

For the different methods that involve column-supported constructions, a layer can be used to bridge over the soft soil area. Fig. 1 shows different types of load transfer platforms (LTP) for embankments on soft soil (Abdullah, 2006), namely, conventional unreinforced granular LTP, reinforced concrete (rigid) LTP, catenary LTP (one or two layers of geosynthetics), and beam LTP (three or more layers of geosynthetics, which form a flexible beam of reinforced soil).

Geosynthetic-reinforced LTPs are a modification of the conventional granular LTPs that utilise only the arching effect of the granular soil to transfer the loads onto the columns. The inclusion of geosynthetics is expected to improve the transfer of loads to the top of the columns. A single geosynthetic layer behaves as a tensioned membrane (catenary behaviour), while a multilayer system acts as a stiffened platform due to the interlocking of the reinforcements with the surrounding soil.

It should be noted that the column-reinforced technique in soft soils is used in practice not only for the foundations of embankments, but also for the foundations of other types of constructions, for example, concrete reservoirs, industrial buildings and other low buildings, founded through a concrete mat-slab on top of the LTP. A case history of an industrial building founded on a multilayer geosynthetic-reinforced platform over jet-grout column-reinforced soft soils was reported by Neves et al. (2004).

Most of the studies on geosynthetic-reinforced LTPs published in the literature correspond to the solution of the catenary LTP (one geosynthetic layer at the LTP base) when embankments are constructed (Liu et al., 2007; Blanc et al., 2014; Zhuang et al., 2014; Ariyarathne et al., 2013; Eskisar et al., 2012; Van Eekelen et al., 2012a, 2012b, 2013). However, for the solution of the beam LTP (three or more layers of geosynthetics), a lack of studies can be found in the literature, mainly when the construction is not an embankment, despite a few studies that have numerically analysed the solution with three layers of geosynthetics (Huang et al., 2005). In the present study, in order to help overcome this lack, the geotechnical behaviour of a jet-grout column-reinforced soft soil, with a load transfer platform incorporating five geosynthetic layers, is analysed, on which a concrete mat-slab is constructed as the foundation of a low building (Fig. 2). Therefore, this study involves two characteristics that are usually not presented in studies published in the literature: (i) the use of a multilayer geosynthetic-reinforced platform and (ii) the construction of a low building, not an embankment, on an LTP through a concrete mat-slab.

A numerical code based on the finite element method is used. A parametric study is also performed in order to analyse the influence of four factors: the number of geosynthetic layers, the column spacing pattern (secant or spaced columns in the longitudinal direction), the elastic modulus of the column and the tensile stiffness of the geosynthetics. Load transfer, settlement, excess pore pressure, effective stress, stress level and tension in the geosynthetics are analysed. An overall efficiency coefficient is also introduced which corresponds to the ratio of the sum of the loads applied in all columns to the total load applied on the top surface of the soft soil and the columns (base of the LTP).

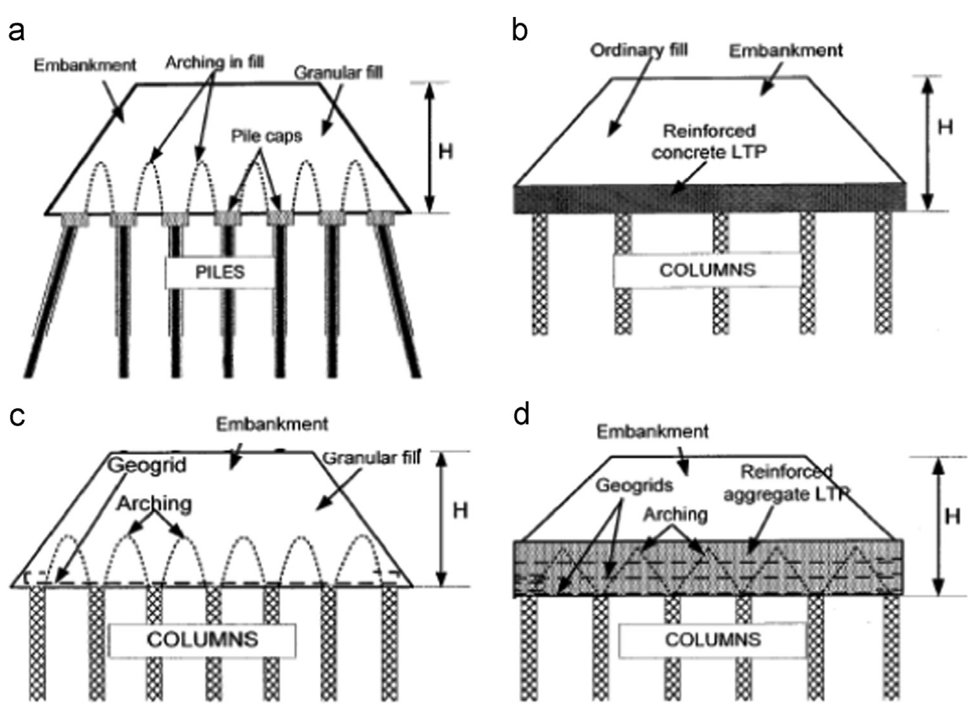

Fig. 1. Different types of load transfer platforms (LTPs) (Abdullah, 2006): (a) conventional unreinforced granular LTP, (b) reinforced concrete (rigid) LTP, (c) catenary LTP (one or two layers of geosynthetics) and (d) beam LTP (three or more layers of geosynthetics).