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Geosynthetic-encased stone columns: Analytical calculation model

Boštjan Pulko*, Bojan Majes [1], Janko Logar [2]

University of Ljubljana, Faculty of Civil and Geodetic Engineering, Jamova 2, 1000 Ljubljana, Slovenia

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ABSTRACT

This paper presents a newly developed design method for non-encased and encased stone columns. The developed analytical closed-form solution is based on previous solutions, initially developed for non-encased columns and for non-dilating rigid-plastic column material. In the present method, the initial stresses in the soil/column are taken into account, with the column considered as an elasto-plastic material with constant dilatancy, the soil as an elastic material and the geosynthetic encasement as a linear-elastic material. To check the validity of the assumptions and the ability of the method to give reasonable predictions of settlements, stresses and encasement forces, comparative elasto-plastic finite element analyses have been performed. The agreement between the two methods is very good, which was the reason that the new method was used to generate a parametric study in order to investigate various parameters, such as soil/column parameters, replacement ratio, load level and geosynthetic encasement stiffness on the behaviour of the improved ground. The results of this study show the influence of key parameters and provide a basis for the rational predictions of settlement response for various encasement stiffnesses, column arrangements and load levels. The practical use of the method is illustrated through the design chart, which enables preliminary selection of column spacing and encasement stiffness to achieve the desired settlement reduction for the selected set of the soil/column parameters.

1. Introduction

Stone columns or granular piles are frequently used to stabilize soft clays and silts and loose silty sands with large amount of fines. For low-rise buildings, highway facilities, storage tanks, embankments, bridge abutments and other structures that can tolerate some settlements stone columns are one of the most frequently used methods of support due to their low cost, effectiveness and ease of installation. The beneficial effects of stone columns are increased stiffness, reduced settlements, increased time rate of settlements, increased shear strength and reduction of the liquefaction potential of soft ground (Barksdale and Bachus, 1983). As the construction and use of the conventional stone columns in very soft soil with low undrained shear strength are almost impossible due to insufficient lateral support of the soil, the problem can be solved by encasing the column material in geosynthetics. The foundation system initially introduced as geotextile encased columns (GECs) has been adopted successfully and is well established in engineering practice (Raithel and Kempfert, 2000; Raithel et al., 2002). Similar concepts based on geogrid encasement as a more robust and perhaps stiffer alternative to geotextile have more recently been introduced and investigated (Sivakumar et al., 2004; Malarvizhi and Ilamparuthi, 2007; Murugesan and Rajagopal, 2006, 2007, 2010; Yoo and Kim, 2009; Araujo et al., 2009; Gniel and Bouazza, 2009, 2010) to demonstrate the effectiveness of geosynthetic encasement and to improve design methods.

The available methods for the design of foundations resting on soft soil stabilized by a large number of end-bearing stone-columns can be classified as either approximate methods with important simplifying assumptions or sophisticated methods based on complex modelling using finite element method or homogenization techniques. Most of approximate analytical solutions assume infinitely wide, loaded area with end-bearing stone columns having constant diameter and spacing, where the stone column and the surrounding soil are treated in axial symmetric conditions. This approach is commonly known as a unit cell concept (Priebe, 1976; Aboshi et al., 1979) and has been adopted by several researchers for the analysis of traditional and encased stone columns.

A number of methods are available for the analysis of traditional non-encased stone columns. First suggestions were based on elastic

* Corresponding author. Tel.: +386 1 4768523; fax: +386 1 4250681.
E-mail addresses: bostjan.pulko@fgg.uni-lj.si (B. Pulko), bojan.majes@fgg.uni-lj.si (B. Majes), janko.logar@fgg.uni-lj.si (J. Logar).
[1] Tel.: +386 1 4768522; fax: +386 1 4250681.
[2] Tel.: +386 1 4768526; fax: +386 1 4250681.

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