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Estimating the bearing capacity of single reinforced granular fill overlying clay

Gizem Misir[a,*], Mustafa Laman[b]

[a] Karamanoglu Mehmetbey University, Karaman, Turkey
[b] Liverpool University, England, United Kingdom

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ABSTRACT

This paper develops an empirical design approach for estimating the footing pressure and settlement behavior of a circular footing on a geogrid reinforced granular fill overlying a weak clay soil by regression analysis. A power model has been developed with a high coefficient of determination R^2 with 0.959, according to the 398 training data obtained from in-situ tests. The empirical formulation has been evaluated for the validity of the regression model with 220 data which were not used in the derivation of the formulation and the mean absolute percentage error values have been demonstrated that the predictions were obtained with less than 10% error, on average. Additionally, the validity of the developed formulation has been confirmed with different plate load test results from literature, with an acceptable convergence.

1. Introduction

Foundation engineering is one of the most common and mainly the first investigated subject of geotechnical engineering. In general, the design of the foundations depends on the superstructure and the soil parameters below the structure. Almost all of the main analytical theories that proposes the bearing capacity values in the literature assumes the soil profile infinite, isotropic and homogeneous. But, the real soil profiles may occur from with different type of soils with varied thicknesses. Soil properties and locations of the strong and weak soil layers according to each other are the most important parameters affecting the bearing capacity and failure mechanisms of this type of soil profiles. Investigation of the bearing capacity increment of the weak soils by a desired fill layers with and without an improvement material as geosynthetics are widely used by the researchers, especially with small and large-scale model tests. The first usage of the geosynthetic materials in a concept of reinforced earth has been entered to the literature by Vidal (1966). The practical and academical studies on these materials are still being carried out intensively by researchers. Several studies in the literature about the bearing capacity of reinforced layered soil, conducted in recent years, has been investigated by Dash et al. (2003), Som and Sahu (1999), Rethaliya and Verma (2009), Kolay et al. (2013), Hemalatha et al. (2014), Jayamohan and Shivashankar (2012), Das and Samadhiya (2016), Tripathi and Yadu (2014), Deb et al. (2005), Biswas et al. (2016), Ghosh and Dey (2009), Laman et al. (2009), Sireesh et al. (2016), Roy and Deb (2017a,b), Dutta and Mandal (2016), Kurapati et al. (2015), Sanoop and Patel (2017) and etc.

The geosynthetic reinforcement layer/layers are generally placed beneath the foundations to improve the settlement characteristics and to increase the load bearing capacity. With the developments in recent years, the geosynthetic materials can be produced to meet the needs in various purposes with different features such as woven geotextile, uniaxial/biaxial geogrid, nonwoven geotextile, geocell and etc. Infante et al., 2016 has investigated the shear strengths of the reinforced two different soil samples with four different geosynthetic materials as woven and nonwoven geotextiles, uniaxial and biaxial geogrids. And the results showed that, maximum improvement on the shear strength has been occurred under the usage of biaxial geogrid condition.

Haeri et al. (2000) has investigated the effect of geotextile reinforcement on the mechanical behavior of sand by laboratory triaxial compression test. They have used three different non-woven geotextile with seven different geotextile arrangements. And as a result of the experimental studies, the researchers have been concluded that, the obtained increment in the peak strength of the geotextile-reinforced sand has been impressed by the coefficient of friction between geotextile and sand. On the other hand, the stiffness of reinforced sand has been affected substantially from the load-elongation characteristics of the geotextile. Latha and Somwanshi (2009) have evaluated the performance of the square footings resting on geosynthetic reinforced sand by laboratory model tests and numerical studies. The researchers have

* Corresponding author.
E-mail addresses: gmisir@kmu.edu.tr (G. Misir), mlaman@performgeo.com (M. Laman).

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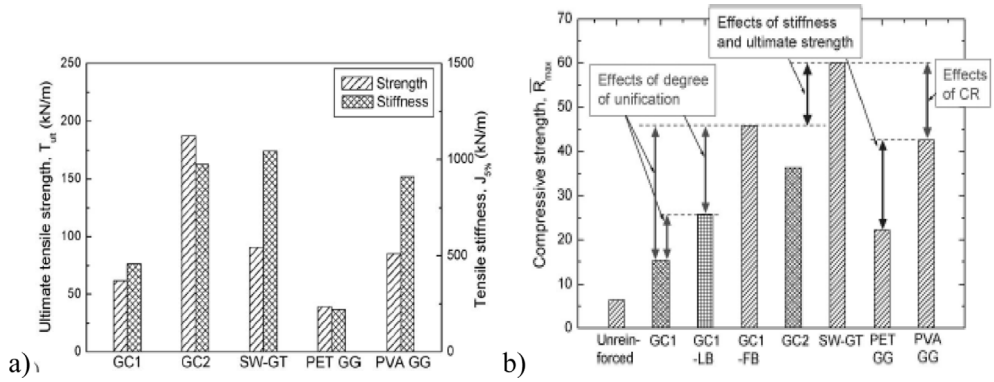

Fig. 1. a) Ultimate tensile strength and stiffness values of geosynthetic reinforcement types, b) Effects of various factors on reinforcing effects (Kongkitkul et al., 2007).

investigated the effect of the type and tensile strength of geosynthetic material (weak biaxial geogrid, strong biaxial geogrid, uniaxial geogrid and geonet), amount of reinforcement layout and configuration of geosynthetic layers below the footing on the bearing capacity improvement of the footing. According to the test and numerical results, the layout and the configuration of reinforcement play a vital role in bearing capacity improvement, rather than the tensile strength of the geosynthetic material. Kongkitkul et al. (2007) has investigated the geosynthetic reinforcement type effect by a series of drained plane strain compression (PSC) tests on large sand specimens. For this purpose, the authors have used different types of geosynthetics as, with a low and high strength non-woven geotextile (GC1 and GC2), weak and strong geogrid (PET GG and PVA GG), woven geotextile (SW-GT) and bonding technique effect on GC1 type of non-woven geotextile (GC1-LB and GCA-FB). The test results have been summarized in Fig. 1, the geocomposite system performance is affected from the geosynthetic stiffness, unifying effect and covering ratio.

Pinho-Lopes and Lopes (2014) have investigated the main factors by field installation trials and laboratory simulations, that effects the installation damage on the tensile properties of geosynthetic materials. The researchers have tested six type of geosynthetics as two woven geotextiles (GTX1 and GTX2), two woven geogrids (GGw1 and GGw2, one extruded geogrid (GGe) and one reinforcement geocomposite (GC). The results have been shown that, woven geotextiles (GTX1 and GTX2) have obtained more sensitive to installation damage. SEM results have indicated that, the installation damage induced in laboratory has shown more severe than induced in field trials. Also, increasing the compaction energy has caused more severe damage for geotextiles GTX1 and GTX2. Furthermore, installation damage has depended on the grain size, angularity and thickness of the fill material. Rosete et al. (2013) has evaluated the tensile and hydraulic properties of six different geosynthetics after mechanical damage and abrasion with laboratory tests. Results have shown that the effects of induced mechanical and abrasion damages essentially depend on the geosynthetic structure. The structures of the GGRw woven geogrid and the GCR1 and GCR2 reinforcement geocomposites have been more susceptible to induced damage compared with the other geosynthetics tested. Also, the strength losses for GTX1 and GTX2 geotextiles and for the GGRe extruded geogrid have obtained much lower than for the other geosynthetics studied. For the most affected materials, strength losses after abrasion (in isolation and combined with mechanical damage) have obtained higher than after the induced mechanical damage. Therefore, for commonly used geosynthetics, abrasion is the conditioning mechanism which most affects their tensile strength.

The recent studies have shown that, the geosynthetic layout plans and layer positions in the soil are the most important parameters that affect the system performance together with the geosynthetic material properties. (Tafreshi et al., 2015; Lovisa et al., 2010; Wu et al., 2016; Hegde and Sitharam, 2015b; Abu-Farsakh et al., 2016; Sireesh et al., 2016; Latha et al., 2013; Chen and Abu-Farsakh, 2015; Lal et al., 2017; Cicek et al., 2015; Roy and Deb, 2017a; Harikumar et al., 2016; Dutta and Mandal, 2016; Lavasan et al., 2017; Soleimanbeigi and Hataf, 2006; Cheng et al., 2017; Badakhshan and Noorzad, 2017; Oliaei and Kouzegaran, 2017).

Bera et al. (2005) has suggested a power model from multiple regression method for predicting the bearing capacity of square footing on reinforced pond ash. Biswas et al. (2015) has investigated the effect of subgrade clay soil strength underlying the sandy soil with a planar geogrid at the interface by laboratory model tests. Hegde and Sitharam (2015a) have carried out small scale model plate load tests to evaluate the effect of infill materials on the performance of the geocell on soft clay beds.

Mosallanezhad et al. (2016) has studied a new reinforced system created by adding cubic anchors to ordinary geogrids named as Grid-Anchor to increase the ultimate bearing capacity of square footing. The researchers were conducted 45 model and 15 field experiments to investigate the effect of Grid-Anchor. The results have shown that, 1.8 times increament have been obtained by using the Grid-Anchor system than ordinary geogrid reinforced system. Furthermore, the failure for the ordinary geogrid reinforced system has been occurred at the settlement of 9% of the foundation width, while the settlement ratio at the failure was observed as almost 13% for Grid-Anchor system. Rowe and Liu (2015) have investigated the performance of full-scale embankment constructed on soft soil with different improvement options as only pile support, with a single layer geotextile-reinforced platform and pile-support, with two-layers of geogrid-reinforced platform and pile-support by experimentally and numerically. 3 dimensional numerical analysis results were obtained inaccordance with the field data. The settlement at the subsoil surface has decreased 52% according to the unimproved section with the pile support only. Furthermore, the addition of single layer of geotextile reinforcement further has reduced the subsoil surface settlement to only, 31% of that for the unimproved section. The additional of two layer of geogrid reinforcement with pile support has reduced the subsoil surface settlement with a minor additional effect to 28% of that unimproved condition. Shivashankar and Jayaraj (2014) have studied the effects of reinforcement prestressing on the strength increment and settlement reduction of a reinforced granular bed overlying weak soil, through a series of laboratory model tests. Kazimierowicz (2007) has compared the beneficial effects to the bearing capacities of the two-layer reinforcements, with an analytical membrane action model presented by Burd (1995) and different experimental studies in literature. Hegde and Sitharam (2015c) have presented a new approach to modelling a square footing resting on the geocell reinforced soft clay using Finite difference package FLAC 3D. Numerical analysis have been carried out by three different material models as modified Cam-Clay, Mohr Coulomb and Linear Elastic to

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