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Large scale field tests on geogrid-reinforced granular fill underlain by clay soil

Ahmet Demir[a], Mustafa Laman[b,*], Abdulazim Yildiz[b], Murat Ornek[c]

[a] Osmaniye Korkut Ata University, Civil Engineering Department, 80000 Osmaniye, Turkey
[b] Cukurova University, Civil Engineering Department, 01330 Balcali, Adana, Turkey
[c] Mustafa Kemal University, Civil Engineering Department, 31200 Iskenderun, Hatay, Turkey

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ABSTRACT

This study aims at experimentally explaining the potential benefits of geogrid reinforced soil footings using large scale field tests. A total of 16 field tests were carried out to evaluate the effects of replacing natural clay soil with stiffer granular fill layer and single-multiple layers of geogrid reinforcement placed into granular fill below circular footings. The large scale field tests were performed using different size of the circular footing diameters which have 0.30, 0.45, 0.60 and 0.90 m. The results of testing program are presented in terms of subgrade modulus and bearing capacity. These values were calculated for each test at settlements of 10, 20 and 30 mm. Based on the test results, it is shown that the use of granular fill and geogrid for reinforced soil footings (RSF) have considerable effects on the subgrade modulus and bearing capacity. Finally, the field test results are compared to the analytical methods proposed by different researchers including the statistical correlations.

1. Introduction

In many cases of construction, shallow foundations are built on top of existing cohesive soils, resulting in low bearing capacity and/or excessive settlement problems. An economical treatment method is the use of reinforced soil foundation (RSF). This can be done by either reinforcing cohesive soil directly or replacing the poor soils with stronger granular fill, in combination with geosynthetics. In this technique, one or more layers of a geosynthetic reinforcement and controlled fill material are placed beneath the footing to create a composite material with improved performance characteristics. This technique is commonly used for unpaved roads, embankments, and large stabilized areas such as car parks or working platforms for oil drilling (Giroud and Noiray, 1981; Giroud et al., 1984; Rowe and Soderman, 1986; Love et al., 1987; Fannin and Sigurdsson, 1996; Miura et al., 1990; Ling and Liu, 2001; Rowe and Li, 2005; Hufenus et al., 2006). In comparison with other applications of geosynthetic-reinforced soil, relatively less emphasis has been placed on reinforced soil foundations. There have been some studies of shallow foundations on reinforced soil systems, most of them concentrating on sandy soil (Adams and Collin, 1997; Gabr and Hart, 2000; Fonseca, 2001; DeMerchant et al., 2002; Fukushima et al., 2003; Latha and Somwanshi, 2009).

Analytical models have been proposed for calculation of the bearing capacity of a compacted sand or gravel layer on soft clay (Chen and Davidson, 1973; Hanna and Meyerhof, 1980; Love et al., 1987; Florkiewicz, 1989; Michalowski and Shi, 1995; Lyons and Fannin, 2006; Sharma et al., 2009).

However, a limited number of experimental studies are available at the present time relating to the bearing capacity of shallow foundations on reinforced granular material of limited thickness overlying soft clay (Love et al., 1987; King et al., 1993; Ornek, 2009; Consoli et al., 2009; Mohamed, 2010). Love et al. (1987) studied the effectiveness of geogrid reinforcement, placed at the base of a layer of granular fill on the surface of clay by small-scale model tests in the laboratory. In the tests, only one geogrid layer was used at the interface between granular fill and clay soil. They showed that performance of reinforcement systems to be excellent even at small deformations, due to the significant change in the pattern of shear forces acting on the surface of the clay. King et al. (1993) carried out some laboratory model tests to evaluate the improvement of ultimate bearing capacity of shallow strip foundation supported by

* Corresponding author. Tel./fax: +90 322 338 6702.
E-mail addresses: ahmetdemir@osmaniye.edu.tr (A. Demir), mlaman@adanabtu.edu.tr (M. Laman), azim@cukurova.edu.tr (A. Yildiz), mornek@mku.edu.tr (M. Ornek).

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a strong sand layer underlain by weak clay with a layer of geogrid at the sand–clay interface. Based on the model test results, they showed that the maximum benefit in increasing the ultimate bearing capacity by inclusion a layer of geogrid at the sand–clay interface is obtained at $H/B = 0.67$ (H, the thickness of sand layer; B, the size of strip footing) and the optimum width of the geogrid layer for improvement of ultimate bearing capacity is 6.0B. However, this topic is still being researched and there is no an accepted design technique in the practice. This study aims to be given an attention and it can be an alternative improvement method for shallow spread footings with low load capacity. It is necessary for engineers to understand more fully their behavior in order to carry out safe and economical design and construction. This paper relates to some recent field test results which were conducted to determine the bearing capacity and settlement behavior of a circular footing supported by a reinforced stiffer granular layer of limited thickness over soft clay. Subgrade modulus was also defined to evaluate improvement performance of geogrid reinforced system.

2. Field testing program

It is sometimes difficult to accurately model the full scale behavior of reinforced soil using small scale laboratory test due to the scale effect (Abu-Farsakh et al., 2008). Main reason for performing the tests in field is to indicate properly how the bearing capacity and subgrade modulus is affected by footing size in unreinforced and granular fill with and without geogrid reinforcement. The field testing program was carried out in the Adana Metropolitan Municipality's (AMM) Water Treatment Facility Center (WTFC) located in west part of Adana, Turkey. A total of 24 reaction piles were constructed in WTFC test area for large scale field tests. The locations of the piles in test area are shown in Fig. 1. Each plate load test was conducted in field test pit measuring 2.8 m × 2.8 m in plan, and 2.0 m in depth as seen in Fig. 1. Four different model rigid footings fabricated from mild steel was used for all load tests. The diameters of the footings are 0.30, 0.45, 0.60 and 0.90 m. All the footings have 0.03 m of thickness. The footings were loaded using a hydraulic jack against a reaction frame. A total of 16 field tests were performed on unreinforced clay soil, granular fill reinforced clay soil and geogrid reinforced granular fill over clay soil, respectively.

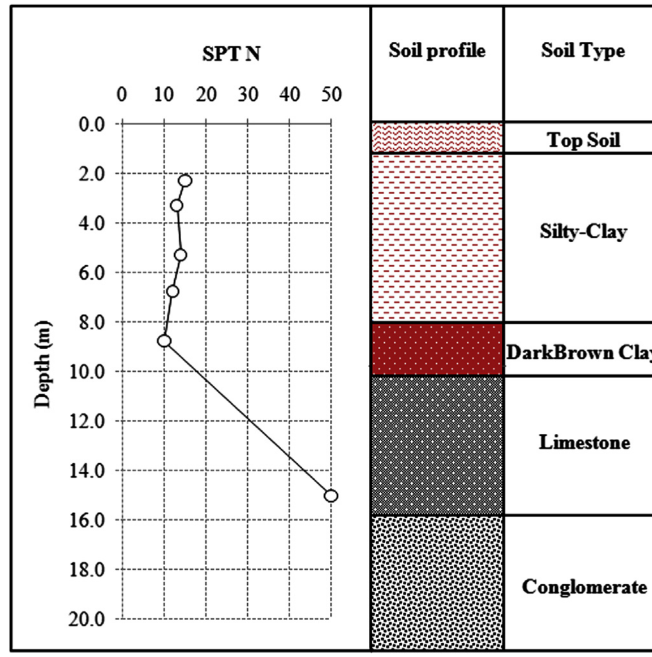

Fig. 2. Average SPT(N) values measured from borehole drillings.

3. Material properties

3.1. Site characterization

The soil conditions at the experimental test site (WTFC) were determined from a geotechnical site investigation comprised of both in-situ and laboratory tests (Laman et al., 2012). To define the soil profile of test site, two test pit excavations and four borehole drillings were performed. Ground water level was observed as 2.2 m from in the field. The general layout plan of the test area

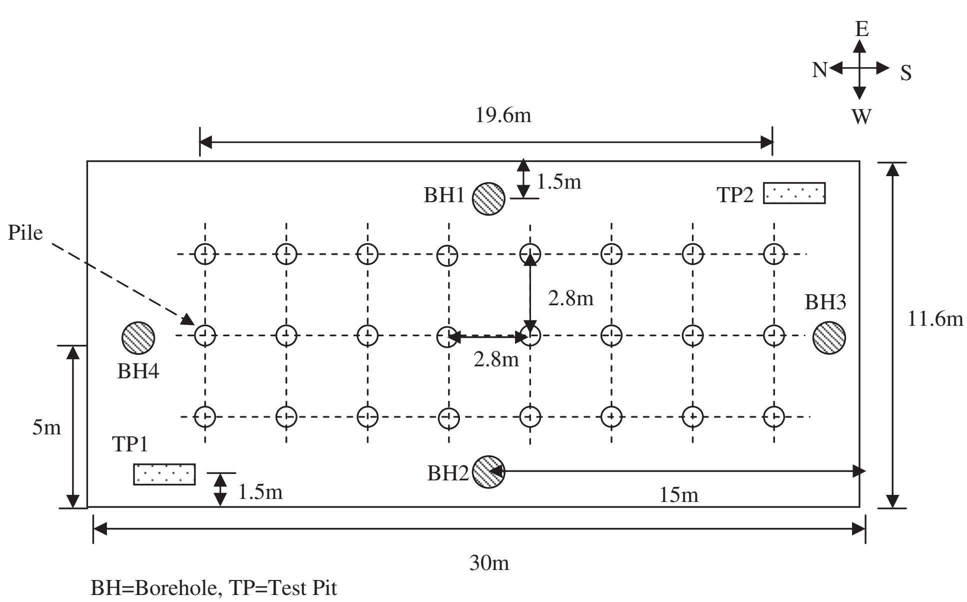

Fig. 1. Plan view showing piles, borings and test pits.