Geotextiles and Geomembranes 28 (2010) 434–447

Contents lists available at ScienceDirect

Geotextiles and Geomembranes

journal homepage: www.elsevier.com/locate/geotexmem

Behaviour of footings on reinforced sand subjected to repeated loading – Comparing use of 3D and planar geotextile

S.N. Moghaddas Tafreshi [a,*], A.R. Dawson [b,1]

[a] Department of Civil Engineering, K.N. Toosi University of Technology, Valiasr St., Mirdamad Cr., Tehran, Iran
[b] Nottingham Transportation Engineering Centre, University of Nottingham, Nottingham, UK

A R T I C L E I N F O

Article history:
Received 24 May 2009
Received in revised form
17 November 2009
Accepted 3 December 2009
Available online 18 February 2010

Keywords:
Laboratory test
Repeated loads
Strip footing
3D and planar geotextile reinforcement
Footing settlement
Plastic shakedown

A B S T R A C T

This paper describes a series of laboratory model tests performed on strip footings supported on 3D and planar geotextile-reinforced sand beds under a combination of static and repeated loads. Footing settlement due to initial static applied load and up to 20,000 subsequent load repetitions was recorded, until its value becomes stable or failure occurred due to excessive settlement. The response under the first few cycles was found to be a significant behavioral characteristic of footings under repeated loads. The influence of various amplitudes of repeated load on foundations containing different numbers of planar geotextile layers and different heights of the 3D geotextile reinforcement were investigated. Most of the observed responses show plastic shakedown developing – that is a stable, resilient response is observed once incremental plastic strains under each load repetition have ceased to accumulate. The results show that the maximum footing settlement due to repeated loading is comparable for either planar- or 3D-reinforced sand and much improved over the settlement of unreinforced sand. The efficiency of reinforcement in reducing the maximum footing settlement was decreased by increasing the mass of reinforcement in the sand. On the whole, the results indicate that, for the same mass of geotextile material used in the tests, the 3D geotextile reinforcement system behaves more effectively than planar reinforcement as a retardant for the effects of dynamic loading. Thus, a specific improvement in footing settlement can be achieved using a lesser quantity of 3D geotextile material compared to planar geotextile.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

Machine foundations require the special attention of a foundation engineer. In addition to static loads due to the weight of machine and the foundation, loads acting on such foundations are often dynamic in nature due to the action of the moving parts of the machine. While these dynamic loads are generally small, as compared to the static load, they are applied repetitively over a very large number of loading cycles. Therefore it is necessary that the soil behaviour is elastic, or else deformation will increase with each cycle of loading until the unstable soil behaviour develops.

Research into the behaviour of unreinforced soil and shallow foundations were subjected to dynamic loads was initiated during the 1960s. Both theoretical and experimental studies of the dynamic bearing capacity of shallow foundations have been reported by several researchers to understand the load–settlement relationship of footings and also the relationship between footing settlement and the number of load cycles (Cunny and Sloan, 1961; Raymond and Komos, 1978; Das and Shin, 1996).

In recent decades, due to its economy, ease of construction and ability to improve the visual appearance, reinforced soil has been widely exploited in geotechnical engineering applications such as the construction of roads, railway embankments, stabilization of slopes, and improvement of soft ground and so on.

In the case of monotonic loads, the beneficial effects of the planar geosynthetic (Shin and Das, 2000; Dash et al., 2004. Yoon et al., 2004; Deb et al., 2005; Ghosh et al., 2005; Patra et al., 2005, 2006; Hufenus et al., 2006; El Sawwaf, 2007; Alamshahi and Hataf, 2009; Bathurst et al., 2009; Sharma et al., 2009) and 3D geosynthetic geocells (Rea and Mitchell, 1978; Mitchell et al., 1979; Shimizu and Inui, 1990; Cowland and Wong, 1993; Krishnaswamy et al., 2000; Dash et al., 2001a,b; Dash et al., 2003; Sitharam et al., 2005; Dash et al., 2007; Madhavi Latha and Rajagopal, 2007; Sireesh et al., 2009) have most often been studied in geotechnical applications.

* Corresponding author. Tel.: +982188779473; fax: +982188779476.
E-mail addresses: nas_moghaddas@kntu.ac.ir (S.N. Moghaddas Tafreshi), andrew.dawson@nottingham.ac.uk (A.R. Dawson).
[1] Tel.: +441159513902; fax: +441159513909.

0266-1144/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.geotexmem.2009.12.007

In the case of reinforced footings under repeated loads, only a few relevant studies have been found and these concentrated on planar-reinforced applications (Das and Shin, 1994; Raymond, 2002; Shin et al., 2002). Das and Maji (1994) and Das (1998) conducted laboratory model tests, observing settlement of surface-positioned, square foundations supported by a medium dense reinforced sand bed and subjected to repeated loading of low frequency. The tests results indicated that the geogrid reinforcement can act as a settlement retardant for dynamic loadings conditions on the foundations. Mogahaddas Tafreshi and Khalaj (2008) performed an experimental study to investigate the behaviour of pipes buried in geogrid reinforced sand when subjected to repeated loads. They reported that the use of geogrid reinforcement can significantly reduce the vertical diameter change of pipe and settlement of the soil surface.

The literature above indicates that there is a lack of studies into the behaviour of footings under repeated load when supported on reinforced soil. This is especially the case for 3D fabrications of planar geotextile (as opposed to 3D arrangements of geogrids). Both might be termed geocells, but the term 3D geotextile is used in this paper for the specific geotextile-based geocells that are studied.

In the research described here, and in order to develop a better understanding of the behaviour of footings under a combination of static and repeated loads supported on 3D and planar geotextile-reinforced sand beds with the same characteristics, a series of different laboratory, pilot-scale tests were performed. In these tests the settlement of a strip footing supported by reinforced relatively dense sand with either a three-dimensional (3D) geotextile or with planar geotextile reinforcement is evaluated.

The overall goal was to investigate the response of footings built on reinforced sand and unreinforced sand to repeated loading and also, particularly, to demonstrate the benefits of 3D geotextile and to compare its behaviour to that of an equivalent, reference unreinforced case as well as to a conventional planar geotextile arrangement. Both effectiveness and economy are of interest. Also, the effect of the height of the 3D geotextile reinforcement (or the number of planar geotextile layers) below the footing base, the ratio of repeated load intensity to applied static load (for details see Table 2) and the rapidity with which steady-state (plastic shakedown) conditions arise are investigated.

It should be noted that only one type of 3D and planar geotextile, one footing width, and one type of sand were used in laboratory tests. It is recognized that the results of this study may be somewhat different to full-scale foundation behaviour in the field, although the general trend is expected to be similar.

2. Laboratory model tests

The general arrangement of the laboratory test is shown in Fig. 1. A physical model test was conducted in a test bed comprising a loading system, testing tank, and data acquisition system.

The loading system includes a loading frame, a hydraulic actuator and a controlling unit. The loading frame consists of four stiff and heavy steel columns and a horizontal crosshead that supports the hydraulic actuator. The actuator may produce monotonic or repeated loads and has a maximum capacity of 10 kN, depending on the intensity of the input compressed oil. The repeated load with different amplitudes, different frequencies (up to 10 Hz) and an unlimited number of load cycles can be produced and controlled by the hydraulic jack and server control. The controlling unit consists of an electromechanical system, which can regulate the intensity of the compressed oil required to produce a repeated load with the desired amplitude and frequency.

The testing tank is designed as a rigid box, 750 mm in length, 375 mm in height, and 150 mm in width, encompassing the reinforced soil and model foundation (Figs. 1, 4 and 5). The back and side faces of the tank consist of smooth ply-wood sheets of 17.5 mm thickness, which are permanently fixed to channel sections. To allow the visual observations of the sand-reinforcement system, as well as photo scanning (if desired), the front face of the tank is made of a Plexiglas sheet, 15 mm in thickness. To prevent undesirable movement of the back and front sides of the tank (so as to maintain plane strain conditions) the rigidity of the tank has been guaranteed by using two stiff steel sections of U-100 on the back face, with two stiff wedged blocks and a metallic spreader beam to retain the front face of the tank relative to the steel columns of the loading system. According to some preliminary test results (not further reported here), under a maximum applied loading stress of 1000 kPa on the soil surface, the measured deflection of the back and front faces of the tank were very small demonstrating that they would be negligible at the stress levels applied in the main test programme. The side wall friction effects on the model test results were reduced by coating the inside of the front and back walls with petroleum jelly. Also during the tests, no differential settlement between the two ends of the footing (loading plate) was observed. Taking these observations together demonstrates that plane strain conditions were sensibly achieved.

The data acquisition system was developed in such a way that both load and settlement could be read and recorded automatically. An S-shape load cell with an accuracy of ±0.01% full-scale was also used and placed between the loading shaft and footing to precisely measure the pattern of applied load. A linear variable differential transducer (*LVDT*) with an accuracy of 0.01% of full range (75 mm) was placed on the footing model to provide the value of footing settlement during the loading. To ensure an accurate reading, all of the devices were calibrated prior to each series of tests.

Table 1
The engineering properties of the geotextile used in the tests.

Description	Value
Type of geotextile	Non-woven polymer
Type of polymer	100% polypropylene
Area weight (g/m^2)	190
Thickness under 2 kN/m^2 (mm)	0.57
Thickness under 200 kN/m^2 (mm)	0.47
Tensile strength (kN/m)	13.1
Strength at 5% (kN/m)	5.7

3. Materials

3.1. Sand

The soil used is a relatively-uniform silica sand with grain sizes between 0.85 and 2.18 mm and with a specific gravity, G_s, of 2.68. It has a Coefficient of uniformity, C_u, of 1.35, Coefficient of curvature, C_c, of 0.95, an effective grain size, D_{10}, of 1.2 mm, and mean grain size, D_{50}, of 1.53 which means that almost all the grains are between 1 and 2 mm in size. The maximum and minimum void ratio (e_{max} and e_{min}) of the sand was obtained as 0.82 and 0.54, respectively. According to the Unified Soil Classification System, the sand is classified as poorly graded sand with letter symbol *SP*. The angle of internal friction of sand obtained through drained triaxial compression tests on dry sand sample at a relative density of 72% was 37.5° (all tests being run on dry sand at this relative density).

3.2. Reinforcement

Geocells may consist of a cellular structure manufactured from flexible, semi-flexible or strong geosynthetics such as geotextile. In the researches reported by Bush et al. (1990), Krishnaswamy et al.

Download English Version:

https://daneshyari.com/en/article/274405

Download Persian Version:

https://daneshyari.com/article/274405

Daneshyari.com