Effect of Repeated Loading on Footing Resting on Geogrid Reinforced Clay Sand Medium

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***Abstract*— The foundations resting on clayey soil is subjected to excessive settlement under repeated loading. Mainly, the traffic movements contributes to repeated loads. This paper presents model plate load test on footing subjected to repeated loading condition. Repeated load tests were performed with different load levels to simulate the frequent changes in incoming loads. The foundation medium considered in this study involves sand layer overlying a clay layer. Tests were performed on a square footing (10cmx10cm) resting on both the reinforced and unreinforced foundation medium. Geogrids were used as reinforcement material. The parameters that were considered involves, 2.5cm thickness of sand layer over clay layer and the position of geogrid in the sand layer. From the test results it was found that, with the addition of sand layer over clay layer, the deformation occurring on the clay layer decreases. The inclusion of geogrid in the sand layer reduces the thickness of sand layer over clay layer. The load intensity of reinforced soil layer with one layer of geogrid increases by 19% with respect to unreinforced condition for H/B= 0.25(where; H= thickness of sand layer and B= width of plate).**

Keywords—repeated loading, geogrid, clay-sand medium

I. INTRODUCTION

In many engineering applications, granular soil layer with reinforcements are placed on soft foundation soil to enhance the load carrying capacity and also to reduce the settlement. The commonly used granular fill material is river sand. Numerous studies have been conducted to determine the load settlement characteristics of reinforced sand layer over clay layer (Giroud and Noiray 1981; Love et al 1987; Madhav and Poorooshasb 1988; Bourdeau 1989) Model studies were also conducted to determine the bearing capacity of rectangular footings resting on sand layer over weak soil with reinforcements at the interface(S. Saha Roy and K. Deb 2016) Pokharel, S, K., et.al(2018) have investigated the performance of geocell-reinforced bases under repeated loading. In this study, single and multiple geocell-reinforced granular bases with three types of infill materials (Kansas River sand, quarry waste, and AB-3 aggregate) were tested and compared with the unreinforced bases under repeated loading. Geosynthetic reinforcement has wide range of applications, this includes; reinforcing sub base or sub soil. It is also used to increase the load carrying capacity of foundation, reducing settlement in foundation soil, reducing the thickness of pavement layers, increasing the service life of pavements, reducing operational and maintenance costs. The reinforcements includes metallic strips, geotextiles, geogrids, geocells e.t.c. Several model and experimental studies were conducted to prove the beneficial effects of geosynthetics in improving the bearing capacity of foundation soil, slope stabilization applications. The improvement of soil using using geosynthetics may depend on several factors. This includes; size of reinforcement material, its position, number of layers of reinforcement, interface friction between reinforcement and soil. In countries like India, it is very essential to carry out research relating to the applications of geosynthetics. For improving the perfomance of shallow foundations, geosynthetics has been in effective from the past few decades. Of all the geosynthetic materials available, geogrid is found to be very cost effective in reinforcing foundation soil.. The beneficial effect of a geosynthetic inclusion is largely depends on the form in which it is used as reinforcement. For example, the same geosynthetic material, when used in planar layers or geocells or discrete fibers comprising exactly the same quantity of materials, will give different strength improvements in different forms. This difference in strengths achieved is mainly due to the different mechanism of failure in soil reinforced with geosynthetics in different forms.

So far, most of the studies have been focused on the behaviour of geogrid reinforced foundation soil under static loading. In this study the repeated loading coming on the footings are proposed to analyse. Repeated loadings are mainly occurring on structures such as oil storage tanks and ship repair tracks. The traffic loading and train movements also contribute to the repeated loading on the foundation medium. Here clay and sand are used as foundation medium. The major portion of foundation medium is clay. Since clay is very weak in supporting the loads, the need for soil reinforcement arises. Therefore geogrid is going to be used as reinforcing material in clay sand interface. The effect of repeated loading on both the reinforced and unreinforced foundation medium is going to analyze in this study.

II. MATERIALS

The test material involves clay and sand. Major portion of the foundation medium involves clay. For reinforcing the foundation medium, geogrid was used.

A. Clay

The soil used in this study is soft clay. The sample was collected from Edathua, Alappuzha district, from a depth of 3m from a construction site. The sample was black coloured with a glowing texture. An air tight container was taken and the sample was stored in it to determine the initial moisture content. The soil sample was collected and stored near the laboratory premises. The initial test conducted involves, initial moisture content, specific gravity, consistency limit and grain size analysis. It is shown in table 1

Fig. 1: Clay sample

TABLE I. PROPERTIES OF CLAY

Sl No	Property	Value
1	Initial moisture content	90.4%
2	Specific gravity	2.6
3	Liquid limit	105%
4	Plastic limit	38%
5	Plasticity index	67%
6	Optimum moisture content	29%
7	Dry density	1.235g/cc
8	Percentage of gravel	1%
9	Percentage of sand	9.9%
10	Percentage of silt	43.1%
11	Percentage of clay	46%
12	Soil classification	CH
13	UCC value	3.869kN/m^2

B. Sand

The sand was collected from Pathanamthitta district, has grain size between 1mm and 2mm. The specific gravity is found to be 2.68. The uniformity coefficient Cu is 4, coefficient of curvature is 1, and effective grain size is. According to the Indian Standard Soil Classification System the sand is found to be well graded. The particle size distribution curve is shown in fig 2.

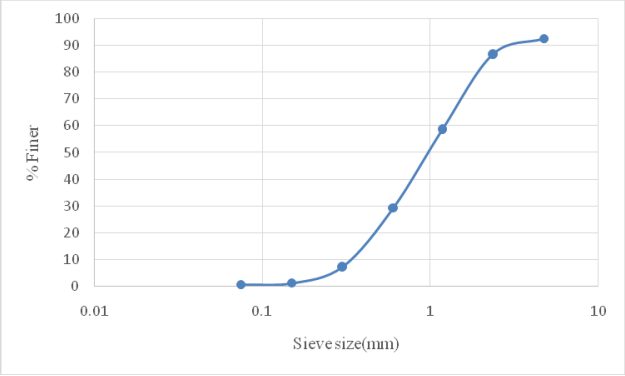

Fig 2: Particle size distribution curve of sand

C. Reinforcement

Biaxial geogrid was used as reinforcement material. It was collected from Ernakulam. It has an aperture size of 2cmx2cm

Fig. 3: Biaxial geogrid

II EXPERIMENTAL SET-UP

The repeated load test is conducted in a testing tank with loading frame. It is shown in fig 3. The tank is made of made of mild steel sheet of 4mm thickness. The tank is 60cm in length, 60cm in width and 80cm in height. The size of the tank is fixed so as to eliminate the boundary effects. The lateral dimensions of the tank is taken as five times the size of footing plate. The reaction frame attached to the testing tank is used for loading. Mild steel plate of 1cm thickness is used as footing plate. The size of the plate used for the study is 10cmx10cm. The loading was given by means of a loading handle. It is shown in fig 4.

Fig. 4: Testing tank with loading arrangement

Fig 5: Loading handle

A . Preparation of tank and testing procedure

The clay has filled in the tank, taking into account of the actual site conditions. The side walls of the tank has made frictionless. The top soil layer of varying thickness is considered in this study. The clay has filled in the tank in three equal layers so as to attain the field density. In case of two layered foundation medium, firstly the clay layer is prepared and then the granular soil layer

is placed over it. The sand layer is placed over the soft clay so as to attain a bulk density of 16kN/m^3. After filling the tank, the top surface is leveled and the test plate has placed on the surface and the loading was given. The loading, unloading and reloading was applied using loading handle, to stimulate the repeated loading coming on the foundations. The applied load is measured by means of a proving ring(of capacity 2.5kN). The test has to be conducted for both the reinforced and unreinforced condition. The cycles of loading and unloading has to be repeated till the displacement of the model plate is negligible. Two dial gauges has attached to the model plate to measure the displacements. The test has to repeated with inclusion of geogrid layer and by varying the top soil layer thickness.

B. Placement of geogrid

For the reinforced condition, only one layer of geogrid was used and the position of geogrid is changed. For one of the trials, geogrid is placed at the interface of sand and clay. While for the other trial, geogrid is placed at 0.15B(B-width of footing) from the bottom of footing plate. The size of the geogrid is taken so as to have an offset of 5mm from each side of the footing.

III RESULTS AND DISCUSSIONS

Repeated plate load tests were conducted on footing plate of 10cm x 10cm. Firstly, repeated loading was performed on clay alone. Then the effect of sand layer over clay is considered. For this, H/B= 0.25 (H-thickness of sand layer, B- width of footing) is considered in the study. Unreinforced and reinforced sand layer is placed over clay layer. tests were conducted on .

From the model tests it was found that, the settlement for clay alone is very large. The clay layer undergoes larger settlement with smaller values of load intensity. With the addition of sand layer over clay layer, the settlement occurring decreases. The load intensity that can be applied on the foundation soil increases with addition of sand layer over clay layer. Also the load intensity that can be applied on the foundation soil increased with the inclusion of reinforcement in sand layer.

The settlement for H/B=0.25, (with geogrid at interface), shows a 19% reduction with respect to unreinforced condition. While the settlement for H/B=0.25 (with geogrid at 0.15B), shows a 43.63% reduction with respect to unreinforced condition.The most noticeable effect in decrease in settlement is found in sand layer with two layers of geogrid .The load carrying capacity of reinforced soil layer (one layer of geogrid) increases by 19% with respect to unreinforced condition.While the load carrying capacity of reinforced soil layer (two layers of geogrid) increases by 74% wrt to unreinforced condition

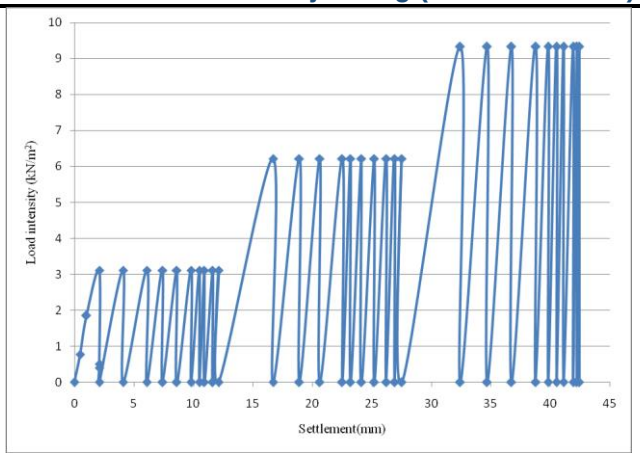

Fig. 6: Repeated loading on clay

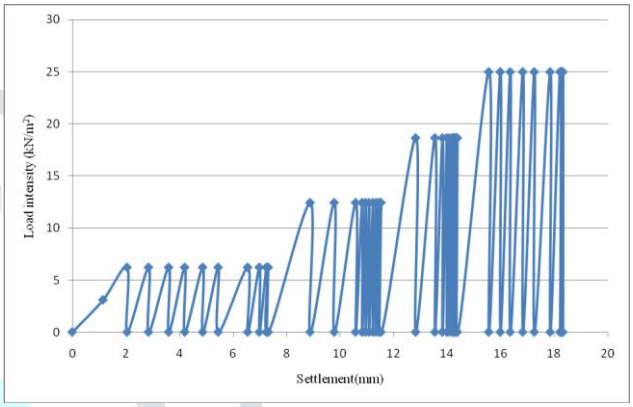

Fig. 7: Repeated loading on sand layer over clay layer(H/B=0.25, unreiforced)

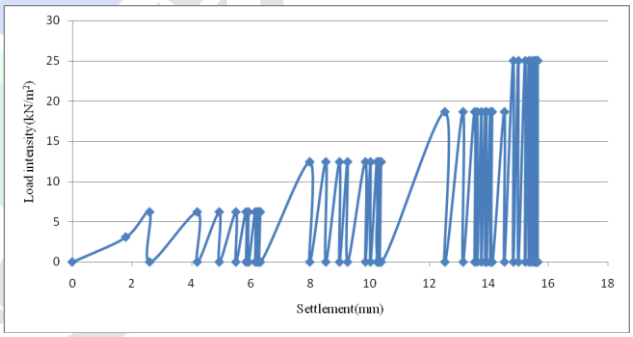

Fig.8 : Repeated loading on sand layer over clay layer(H/B=0.25, geogrid at interface)

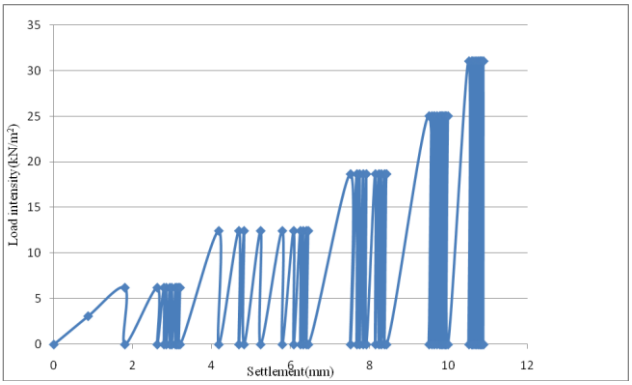

Fig. 9: Repeated loading on sand layer over clay layer(H/B=0.25, geogrid at 0.15B)

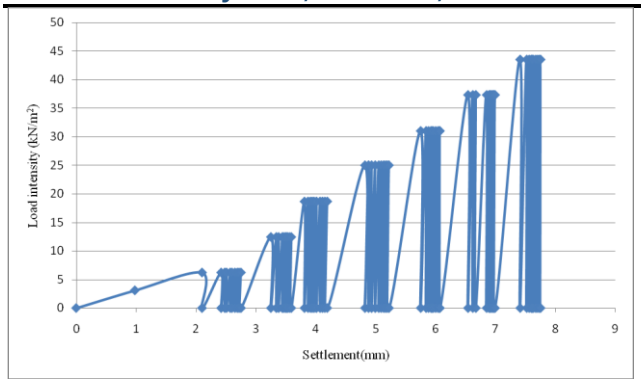

Fig. 10: Repeated loading on sand layer over clay layer(H/B=0.25, geogrid at interface and at 0.15B)

TABLE II. TEST RESULTS

H/B	Reinforced/ Unreinforced	Position of geogrid	Load intensity (kN/m^2)	Settlement(mm)
0	-	-	9.328	42.42
0.25	Unreinforced		25	19.32
0.25	Reinforced	Interface	25	15.64
0.25	Reinforced	0.15B	31	10.89
0.25	Reinforced	Interface, 0.15B	43.5	7.75

IV CONCLUSIONS

From the model test it was found that, when sand layer is provided over clay layer, the deformation occurring on the clay layer considerably decreases. This is because the load intensity coming on the clay layer is reduced. The load intensity that can be applied on the foundation soil increases when reinforced sand layer is placed over clay .When number of layers of reinforcement increases the settlement of footing decreases. Also, it was found that the settlement of footing is minimum when geogrid is placed at 0.15B.

REFERENCES

[1] Lekshmi Suku, and Sudheer S. Prabhu "Effect of geogrid-reinforcement in granular bases under repeated loading" Journal of geoextiles and geomembranes , pp 1-13, April 2017

[2] G.H Tavakoli Mehrjardi, M. and Khazaei(2017) "Scale effect on the behaviour of geogrid-reinforced soil under repeated loads" Journal of geoextiles and geomembranes pp 603-615

[3] Mostafa A and E.L Sawwaf "Behavior of strip footing on geogrid reinforced sand over a soft clay slope". Journal of Geotexties and Geomembranes, vol 25, pp 50-60, September 2007

[4] H.A. Alawaji "Settlement and bearing capacity of geogrid-reinforced sand over collapsible soil." Journal of Geotextiles and Geomembranes, vol 19, pp 75-88, December 2001

[5] Qiming Chenn, and MuradbAbu Farsakh" Ultimate bearing capacity analysis of strip footings on reinforced soil foundation ". Journal of Soils and Foundatins , vol 55, pp 74-85 , January 2015

[6] S.N. Moghaddas Tafreshia, P. Sharifi, A.R. Dawson "Performance of circular footings on sand by use of multiple-geocell or -planar geotextile reinforcing layer"Journal of Soils and Foundations, vol 56, pp 984-997 , December 2016

[7] Elif Ciceka, Erol Guler and Temel Yetimoglu "Effect of reinforcement length for different geosynthetic reinforcements on strip footing on sand soil " Journal of Soils and Foundations , vol 55, pp 661-677, July 2015

[8] R. Sridhar and M. T. Prathap Kumar "Effect of number of layers on coir geotextile reinforced sand under cyclic loading" International Journal of Geo Engineering , vol 9, pp 1-14 , June 2018

[9] B.M. Das, E.C. Shin and M.T Omar "The bearing capacity of surface strip foundations on geogrid-reinforced sand clay- a comparative study " Journal of Geotechnical and Geological Engineering , vol 12, pp 1-14, July 1994

[10] Mostafa El Sawwaf "Experimental and Numerical Study of Eccentrically Loaded Strip Footings Resting on Reinforced Sand"Journal of Geotechnical and Geoenvironmental Engineering, vol 135, pp 1509-1518, October 2009

[11] S.N. Moghaddas and Tafreshi"Behaviour of footings on reinforced sand subjected to repeated loading – Comparing use of 3D and planar geotextile " Journal of Geotextiles and Gemembranes, vol 28, pp 434-447, February 2010

[12] Subinay Saha Roy and Kousik Deb "Bearing Capacity of Rectangular Footings on Multilayer Geosynthetic-Reinforced Granular Fill over Soft Soil" International Journal of Geomechanics pp 1-17, May 2017

[13] Shivashankar, R., and Jayaraj, J."Effects of prestressing the reinforcement on the behaviour of reinforced granular beds overlying weak soil." Journal of geotextiles and geomembranes, vol 42, pp 69-75, April 2014

[14] Abu-Farsakh, M., Chen, Q., and Sharma, R. "An experimental evaluation of the behaviour of footings on geosynthetic-reinforced sand." Journal of soils and foundation, vol 53, pp 335-348, March 2013

[15] Ghosh, C., and Madhav, M. R. (1994). "Reinforced granular fill-soft soil system: Membrane effect." Journal of geotextiles and geomembranes, vol 13, pp 743-759, February 1994