Contemporary Engineering Sciences, Vol. 6, 2013, no. 5, 213 - 223
HIKARI Ltd, www.m-hikari.com
http://dx.doi.org/10.12988/ces.2013.3529

Improving the Bearing Capacity of Brown Clay by Using Geogrid

Monther Abdelhadi

Department of Civil Engineering
AL-Ahliyya Amman University
Mabdelhadi@ammanu.edu.jo

Abstract

In this research a trial is made to investigate the efficiency and applicability of geogrid for a silty-sandy brown clay bearing capacity improvement. For this, a series of pull-out tests under different vertical loads followed by loading tests were performed using a brown clay sampled at Khalda, west of Amman, Jordan. Results showed that there is a noticeable increase in the bearing capacity when using either one layer or two layers of reinforcement. The size of the geogrid used was a square one with a dimension equals to 2B(B is the footing width) placed at a depth of B when used as a single layer and at B and 2B when two layers were used. The relationships between the pull-out stress of the two types of the geogrids used and the displacement under different normal stress have been analyzed and the load bearing capacity and settlement behavior at different depths of the geogrid were completely analyzed. Results showed that there is a noticeable increase in the bearing capacity of the brown clay due to the ineraction between the clay and geogrid.

Keywords: brown clay, pull-out test, interaction, settlement , geogrid, strength

Introduction

The western part of Amman, Jordan is awarded with 4 to 5 meters layer of a problematic brown clay that exhibits a wide range of plasticity and many engineering problems such as swelling and settlement (Nafeth et al ., 2006). Thus earth reinforcement technique become a necessity to solve this problem though this technique is not yet a popular one in the region due mainly to its high cost and the lack of experience in this field. This paper is believed to be the first trial trying to approach such problem by using geogrid as a reinforcing materials in Jordan. In this research two types of geogrids namely SS2 and SS40 with different dimensions were used with a maximum of two layers of reinforcement. The main role of the geogrid is to provide sufficient frictional force with the soil to constrain its lateral displacement at shear planes and so to decrease settlement and to increase the bearing capacity (Ochiai et al,1996). The pull-out test is used to characterize the stress transfer mechanism and to provide valuable information on the overall soil-reinforcement Interaction. The function of the geogrid inside the soil depends on the type of soil and on the intensity of the vertical stress imposed and also on the following mechanisms, a) soil to soil shear at the openings of the geogrid, b) soil bearing inside the opening of the geogrid and and c) soil to geogrid surface (Milligan et al., 1981) It was found out that reinforced earth increase the bearing capacity of soil and that the initial settlement could not be reduced until the full shear mobilization of geogrid and soil is achieved(Mitchell 1981) . However this research show that increasing the No. of geogrid layers is effective in reducing the settlement and increasing the bearing capacity of the brown clay.

General Review

Reinforced soil main advantage is to transfer the stress from the soil to the reinforcement at the contact planes. This interaction mechanism is mainly caused by a confinement at the dilating zone of soil around the reinforcement (Schlosser and Elias, 1978). Many studies concluded that the passive resistance depends on the grid geometry, density and particle size distribution of the soil (Sednei et al, 2007). Furthermore the stress redistribution inside reinforced soil depends on the shear strength of the soil as well as the tensile property of geogrid.

1. Materials

1.1 Brown Clay

A representative brown clay sample was sampled at Khalda town, west of Amman, Jordan. The main problems of this type of clay is known to engineers for its swelling, settlement and lack of shear resistance. Sand cone method used to determine the in-situ density of the sample. It is believed that the major components of this clay is quartz and smectites (nafeth et, al, 2006).The physical characteristics of this sample is shown in Table 1.

Table 1: Physical and chemical properties of Brown clay

Property	Value
Liquid limit (LL)	46.3
Plastic limit (PL)	23.5
Shrinkage limit(SL)	11.7
Plasticity index	22.8
Clay fraction %	56.6
Specific gravity	2.64
In-situ density g/cm3	1. 88

1.2 Geogrid

In this research two types of geogrid were used, namely SS2 amd SS40 both are made of Polypropylene. The Unit weight of geogrid SS2 is 0.29kg/m and 0.53kg/m for SS40. The only difference between the two types is that SS40 has a square openings while the SS2 has a rectangular openings. The modulus of elasticity is not the same even for the same geogrid because it depends on the direction of loading whether it is at the longitudinal or at the transverse direction. Table one shows the properties of the two types. Figure 1 also shows the detaile specification of SS40 geogrid.

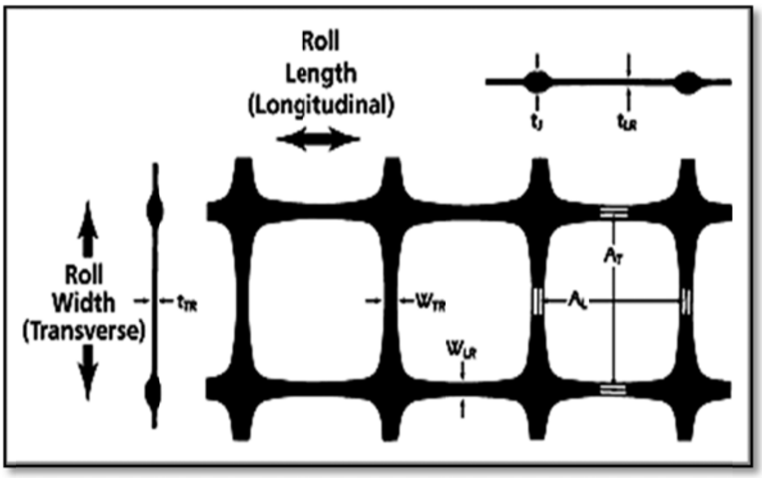

Fig. 1: Details of geogrid SS40

Table 2: Tensar geogrids physical properties

Geogrid type	**Unit weight (Kg/m^2)**	**Polymer**	**Direction**	**Tensile Strength (KN/m)**	**Weight (kg/m^2)**
SS2	0.29	Polypropylene	Longitudinal Direction	31.5	0.16
			Transverse Direction	17.5	
SS40	0.0.6	Polypropylene	Longitudinal Direction	40	0.16
			Transverse Direction	40	

2. Testing Procedure and Results

2.1 Pull-out test

For Practical use of geogrids as soil reinforcement material, efficiency of these geogrids must be checked and evaluated. This evaluation is not only concerned with the geogrids itself but also it is more associated with the soil geogrids interaction properties. One of the most sophisticated methods of understanding the soil- geogrid interaction properties is the pull-out test(Farraj et al, 1993). This test gives a quick prediction about the behavior of both soil and geogrids without consuming much time. Thus, the first step was to determine the failure mechanism of geogrid and soil by means of conducting a series of pullout tests. The schematic diagram of the pull-out testing apparatus is shown in Fig.2. As shown the dimension of the shear box is 60mm (length) × 400mm (width) × 200mm (depth).

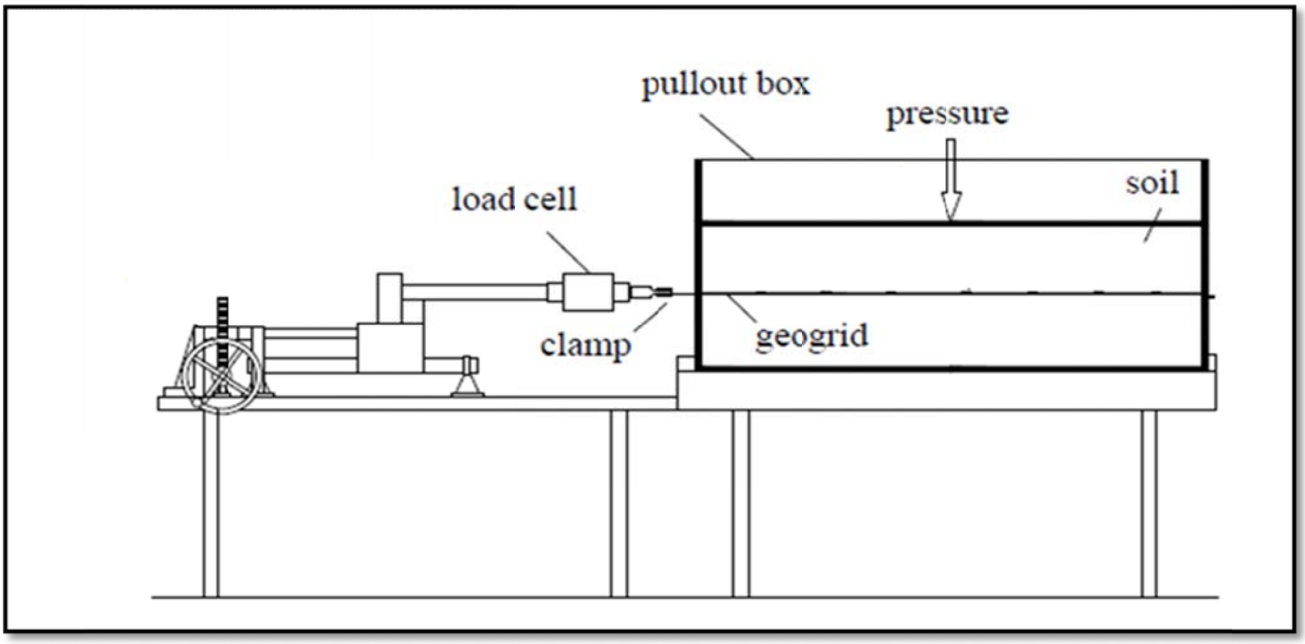

Fig.2: A schematic Diagram of the pullout testing Apparatus.

At each trial a 250mmx200mm piece of geogrid was laid horizontally over the lower compacted half of the box and then the upper half was filled and compacted with brown clay. Prior to the pull-out a normal load was applied using tiles at the top of the clay. The geogrid was pulled out at a constant displacement of 5mm and the pulling force was measured by a load cell placed between the pulling motor and the geogrid . The interaction resistance which is composed mainly of two components; (a) The frictional resistance caused by longitudinal members and (b) The bearing resistance by the transverse members (Alfaro et al,1995). Results of these tests are shown in Figures 3 and 4 . It indicates that the geogrids mobilize more friction between the fabric and the clay than the clay itself at any normal stress. All the shown stresses were obtained by dividing the pull out force by twice the geogrid area because two shear planes are involved in the pullout process. With these results one can conclude that the bearing capacity of geogrid reinforced clay must increase since the friction between geogrid and clay plays an important role in increasing the bearing capacity of clay. Comparing the pull-out resistance of the two types of geogrids it clearly shows that geogrid SS40 shows more resistance at all levels of vertical stresses. Fig. 5 Shows the complete set up of the pull-out test.

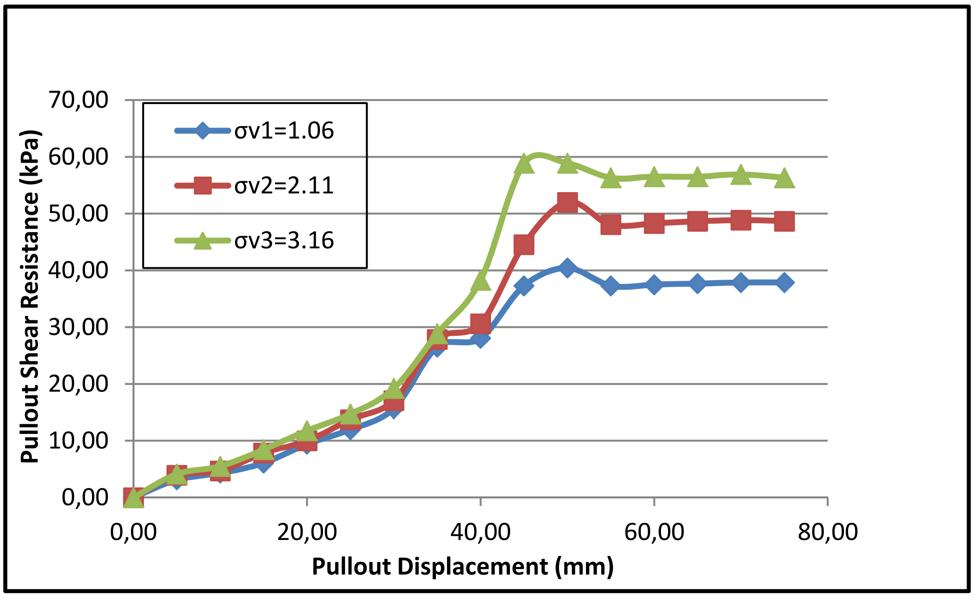

Fig.3: Pull-out test resistance of brown clay using SS40 Geogrid

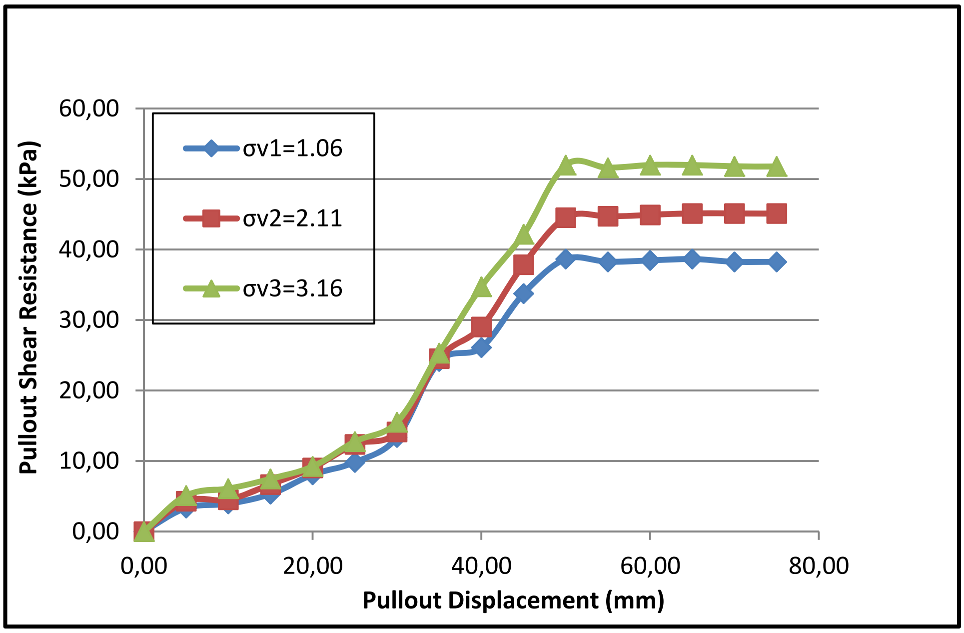

Fig.4: Pull-out test resistance of brown clay using SS2 Geogrid.

Fig.5: Pull-out test set up.

2.2 Load- Settlement test

The reinforced soil technique is based mainly on the friction mobilization between soil and reinforcement which restrain the soil against lateral movement and or deformation (Jewell, 1984). Usually soil beneath any footing moves downward causing radial shear zones which finally will push the soil upward. Thus placing the geogrid horizontally under the footing will restrain the lateral movement and increasing the bearing capacity of the soil(Huang and Tatsuka, 1988). A concrete made footing measured to be 100mmx100mmx100mm was used together with a steel square box made of hard steel with a thickness of 5mm. The clay was compacted inside the box at density of $14kN/m^3$ until the depth required for the location of the geogrid is attained. Accordingly, the following cases were studied:

Case 1 without any reinforcement.

Case 2 one layer of geogrid was placed at a depth equal to the width of the footing.

Case 3 Two layers of geogrid were placed at a depth of B and 2B respectively.The load was imposed at each trial by using a hand operated jack with the load cell attached between the base of the jack and the top of the concrete footing as shown at photo 1. The load was applied while allowing the rotation of the footing and the corresponding settlements were measured. Figures 5 and 6 show the complete results of all cases using both types of geogrid. The ultimate bearing capacity at each trial was determined by taking the load at 30mm settlement. As shown these figures the maximum load was taken at 30mm settlement at each case. I t is clear that geogrid SS40 is more effective in load bearing capacity because its openings are square in shape which means that both longitudinal and transverse members are working in similar manner while in case of SS2 the transverse members are not of the same efficiency compared with the longitudinal one. Table 1 summerize the changes of the bearing capacity ratio of the all cases.

Photo1: Load settlement test set up

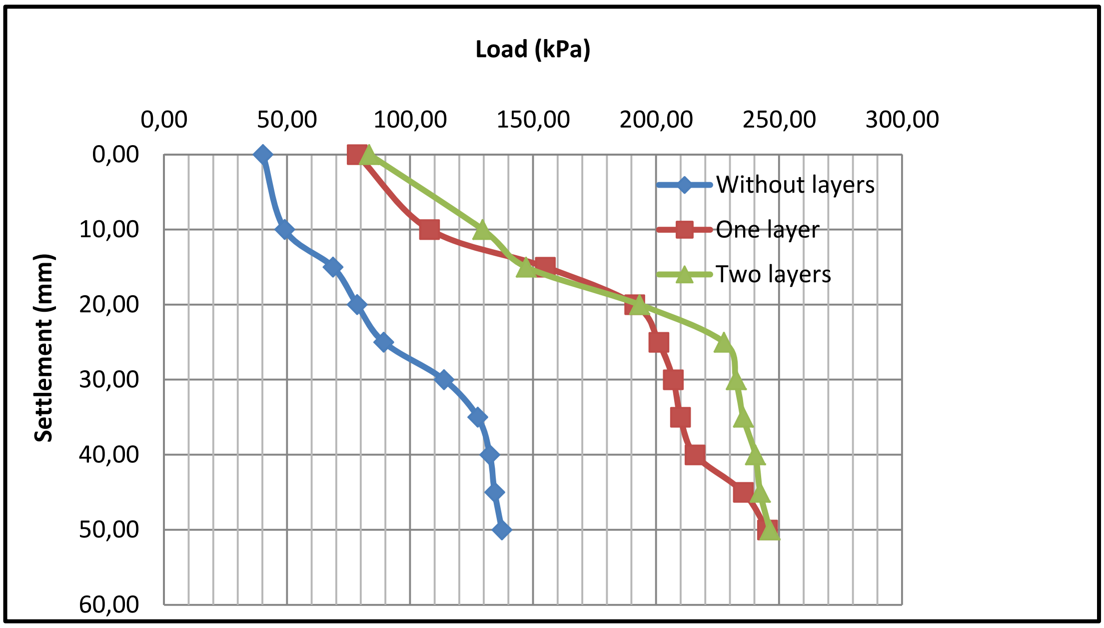

Fig.6: Load- Settlement of clay reinforced with geogrid SS40

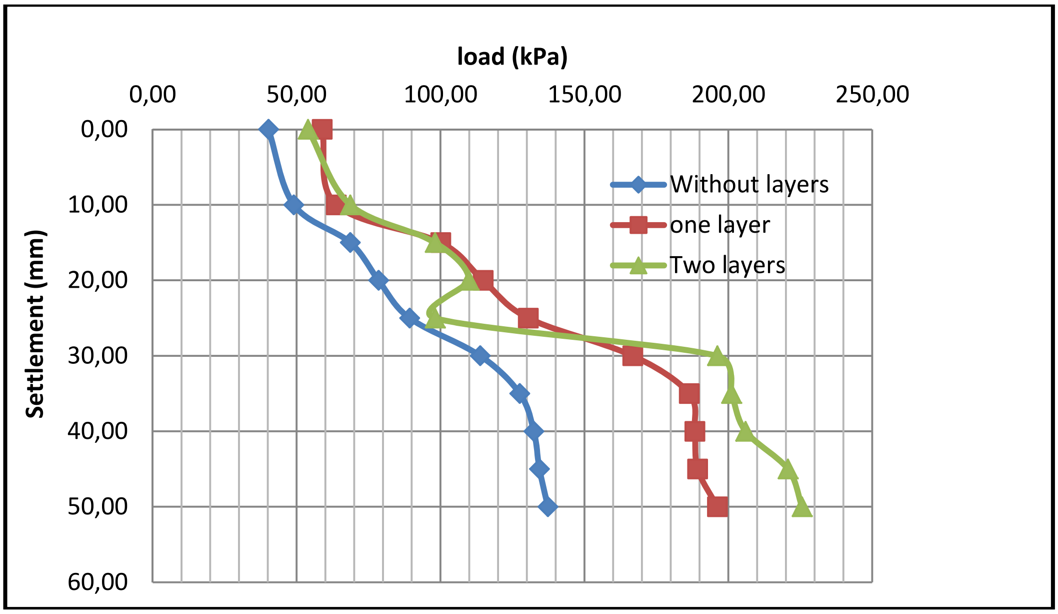

Fig.7: Load- Settlement of clay reinforced with geogrid SS2

Table 3 Bearing Capacity Ratio.

Type of Reinforcement	Bearing capacity (kPa)	Bearing Capacity Ratio
Without Reinforcement	113.80	________
One Layer (SS40)	166.77	1.68
Two Layer (SS40)	196.20	2
One Layer (SS2)	191.30	1.47
Two Layer (SS2)	227.59	1.72

3. Conclusions

The role of geogrid to the overall pullout behavior and resistance were studied. Results of this study clearly show that both types of geogrid are efficient in increasing the bearing capacity of the silty-sandy brown clay either by using one or two layers. Results also show that the dimensions of the opening plays an important role in the overall behavior of the geogrid reinforced soil since it so important to lay the geogrid either in the longitudinal or transverse direction. Strain and elongation of the nodes of the geogrid was not measured due to the lack of facilities and equipment.

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Received: May 23, 2013