Assessment of behavior of soil-geocell pullout capacity

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ABSTRACT: In this study, soil-geocell interface behavior was investigated from the laboratory pullout test. The pullout resistances acting along wall surfaces of geocells were determined under the different vertical loads. A large scale pullout test box (1500 mm long, 1000 mm wide and 700 mm high) were designed and built at geotechnical laboratory of Gazi University in order to determine interaction between cohesionless soil and the geocell. A total of twelve pullout tests were conducted under 10, 25 and 50 kPa of uniform loads. The soil used in this study was sand with specific gravity (G_s) of 2.74, the average particle size (D_{50}) of 1.6 mm, maximum and minimum void ratios were 0.87 and 0.60, correspondingly. The maximum and minimum dry unit weights of the sand were found to be 16.52 and 15.00 kN/m^3. The model pullout tests were performed at relative densities of 73 %. The internal friction angle of the sand at relative density of 73 % determined from direct shear tests was 43°. The distribution of pullout resistance along the length of geocells was determined from strain gauges placed on the wall surfaces of geocell. The experimental results showed that the mobilized pullout force increased with increasing normal stresses.

Keywords: geocell, pullout force, strain, displacement

1 INTRODUCTION

Behavior of soil–reinforcement interaction is very importance for a design and performance of any reinforced soil structures. The behavior of soil-reinforcement interaction depends on a nature, geometry of the reinforcement and the engineering properties of soil. The soil-reinforcement interaction behavior has been studied by many researchers using pullout and large direct shear test equipment (Ingold, 1983; Jewell et al., 1985; Koerner, 1986; Farrag et al., 1993; Bergado and Chai, 1994; Raju, 1995; Perkins and Cuelho, 1999; Palmeira, 2004; Moraci and Recalcati, 2005; Palmeira, 2009; Ezzein and Bathurst, 2014; Wang et al, 2016; Vangla and Latha Gali, 2016). Geocells materials as soil reinforcement have been extensively used for geotechnical engineering applications, such as; control of slopes, reinforcing slopes, protecting channel beds, improving bearing capacity of soft grounds and retaining structures. Geocells are made from high density polyethylene (HDPE) strips ultrasonically welded or new polymeric alloy (NPA) materials and have a honeycomb-like structure. Geocells are commonly exposed to tension force under structural loads. Unlike other geosynthetic materials (geogrid, geomembrane and geostrip), pullout behavior of geocells are still under consideration and studied by few researchers (Kiyota et al, 2009; Mohidin and Alfaro, 2011; Han et al, 2013; Manju and Latha, 2013; Han, 2014; Haussner at al, 2016) and there are not detailed studies that reveal the pullout behavior of geocells in soils. Therefore, the determination of the distribution of pullout resistances along the length of geocell is crucial as they are subjected to tension force in the soils. This paper investigates the behavior of soil-geocell interaction by using the large pullout test box developed for purpose of this study.

2 LABORATORY PULLOUT TESTS

2.1 *Test apparatus and instrumentations*

Laboratory pullout tests have been commonly being used for geogrid, geostrip and textile reinforcement (ASTMD-6706-01, 2001). However, laboratory pullout tests with geocell reinforcement are still under consideration. Geocell materials are three-dimensional configuration and consist of a series of interconnected cells. In this case, pullout tests for geocell to determine behavior of soil-geocell interaction is difficult due to 3D configuration of geocell and requirement of special test apparatus. Therefore, the large-scale pullout test box (1500 mm long, 1000 mm wide and 750 mm high) was designed and built at Gazi University. A schematic diagram and photo of the testing equipment used for the pullout tests are presented in Figure 1 and 2, respectively. A 10 mm thick steel plate with reaction steel bars was used to apply surcharge loading on the top of the box. A sleeve with 200 mm length was fixed to front wall to avoid front wall effects. The sides and bottom of box were made of 10 mm thick steel plates and there were slots in two sides of box to empty it easily. Two load cells are used to record normal force and pullout force during the tests. Displacements along the length of geocell are monitored using linear variable differential transformers (LVDTs). Also distributions of strains along the length of geocell are determined with help of large capacity of strain gauges. All instrumentations are connected to a computer through an electronic data logger in order to record the measurements.

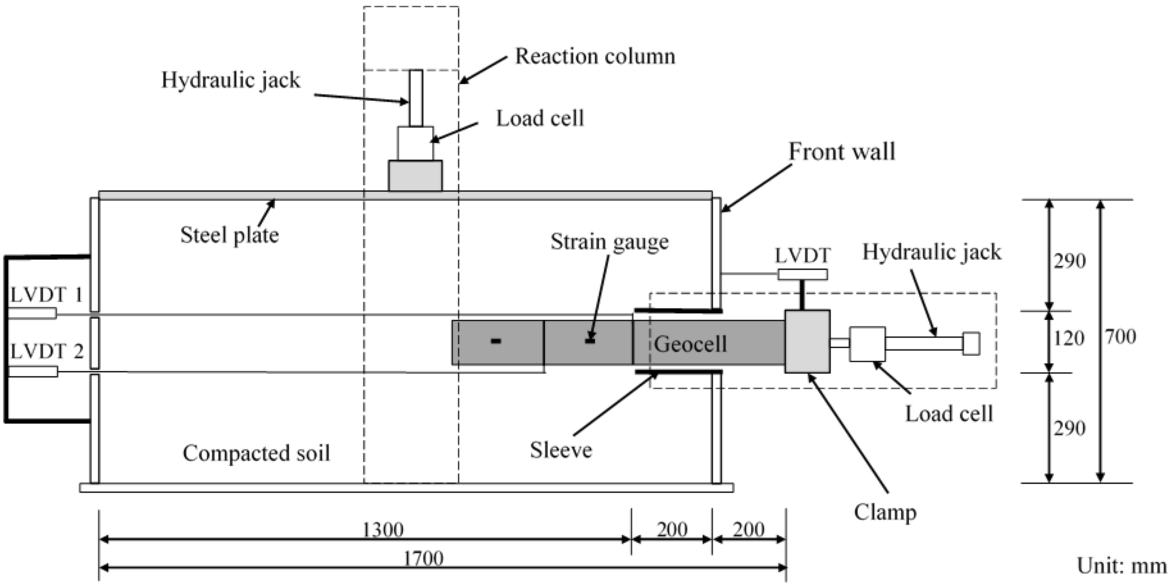


Figure 1. Schematic diagram of pullout test apparatus

Figure 2. Photograph of pullout test box

2.2 *Test procedure*

The granular soil was compacted in the pullout box by manual tamping. The compaction of the soil in the box made by divided into seven equal layers. Pre-determined 125 blows of tamper on top of each layers of soil surface have uniformly applied to have a uniform compaction at a relative density of 73 % approximately. The geocell specimen was placed into its positon at the middle of the test box. The strain gauges and four LVDTs were placed the surface of geocell along length before the geocell specimen was placed into its position in the test box. After placing the geocell specimen with instrumentations into middle of the box, the rest of the box was filled with soil at an approximately relative density of 73%. The clamping plates to grip geocell materials to be pulled were positioned front of sleeve and outer of box. Finally, the steel plate was placed on top layer of compacted soil and soil uniformly was loaded from hydraulic jack.

2.3 *Testing materials*

In this study, poorly graded fine sand was used. The sand has average particle size (D_{50}) of 1.6 mm; coefficient of gradation (C_c) of 1.1; and coefficient of uniformity (C_u) of 3.2. The maximum and minimum void ratios are 0.87 and 0.60, respectively. The maximum and minimum dry unit weights of the sand are found to be 16.52 and 15.00 kN/m^3. The particle size distribution curve of soil is shown in Figure 3. Internal friction angle at a relative density of 73 % from direct shear test was determined as 43 degrees.

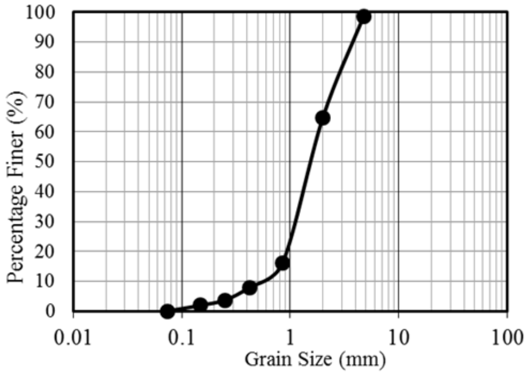
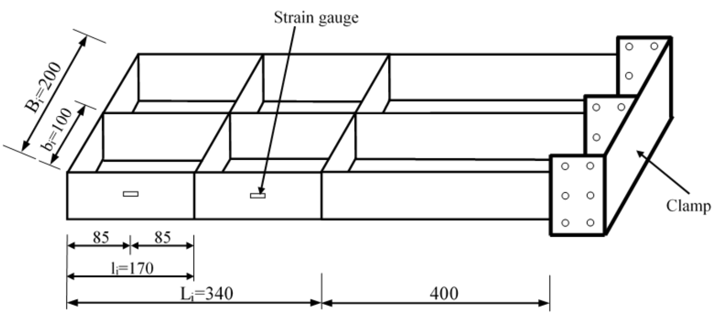


Figure 3. Particle size distribution of compacted soil

The geocell used in the experiment is perforated (Figure 4a and 4b). The rectangular cell pocket pattern was used in this study. The pocket dimensions of the geocell are 170 mm x 110. The properties of geocell are presented in Table 1.

a)



b)

Figure 4. a) The geocell specimen, b) the size of specimen for GC4 and position of the clamp

Table 1. Properties of geocell

Properties of Geocell	Values
Material	High Density Polyethylene (HDPE)
Pocket width (b_i)	100 mm
Pocket length (l_i)	170 mm
Pocket height (h)	100 mm
Density of polymer	0.965 g/cm^3
Thickness	1.5 mm
Tensile Strength– Perforated	20 kN/m
Junction Peeling Strength	20 kN/m

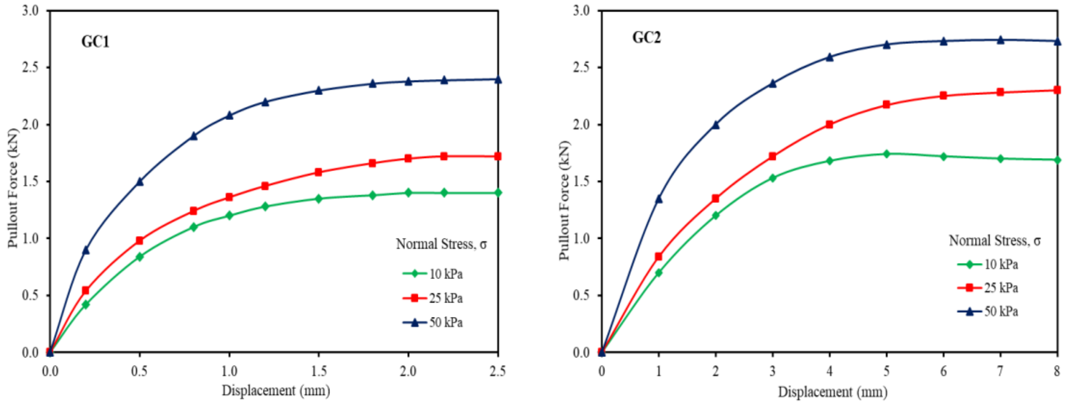
The study aims to investigate the behavior of pullout resistance of geocell reinforcement by conducting pullout tests. A series of pullout tests were conducted under 10, 25 and 50 kPa surcharge loading with the different geocell sizes. The experimental program used in this study is summarized in Table 2. Geocell reinforcement as named of GC1, GC2, GC3 and GC4 according to their sizes. In total 12 pullout tests were conducted in the laboratory.

Table 2. Experimental plan

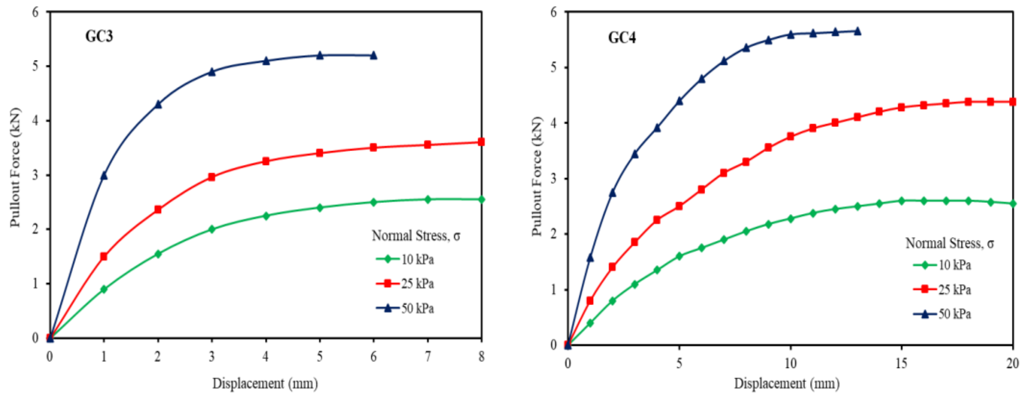
Geocell	Specimen width, B_i, (mm)	Specimen length, L_i, (mm)	Normal Stress (kPa)	Number of pockets in direction of geocell width	Number of pockets in direction of geocell length	Total of pocket numbers in geocell (S)
GC1	100	170	10	1	1	1
GC1	100	170	25	1	1	1
GC1	100	170	50	1	1	1
GC2	200	170	10	2	1	2
GC2	200	170	25	2	1	2
GC2	200	170	50	2	1	2
GC3	100	340	10	1	2	2
GC3	100	340	25	1	2	2
GC3	100	340	50	1	2	2
GC4	200	340	10	2	2	4
GC4	200	340	25	2	2	4
GC4	200	340	50	2	2	4

3 EXPERIMENTAL RESULTS

The pullout forces versus displacements measured at the front of wall which is attached to clamp, LVDT 1 and LVDT 2. The pullout forces versus displacements at the LVDT 1 (Figure 1) of geocell specimen are plotted in Figure 5 under the normal stresses of 10 kPa, 25 kPa and 50 kPa. It is determined that the pullout resistance increases with the increasing normal stresses as expected. The results of tests show that pullout behavior is strongly influenced by the applied normal stress and by the embedded geocell length.



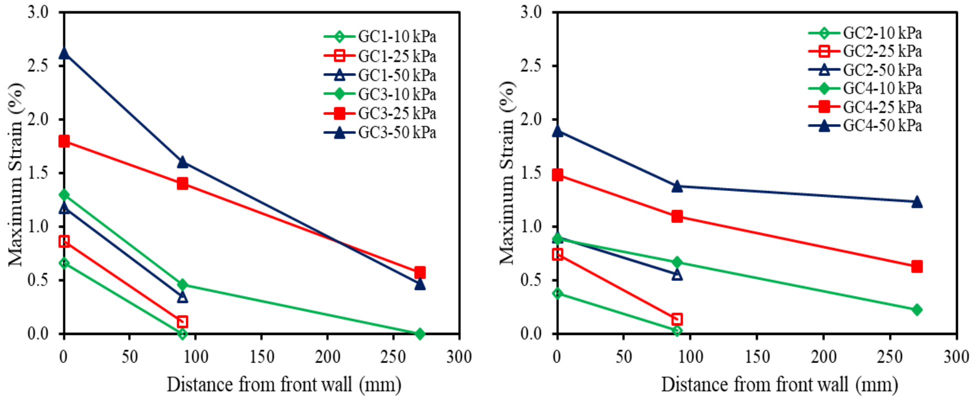
a) b)



c) d)

Figure 5. Pullout force-displacement curves of geocell at various pressures

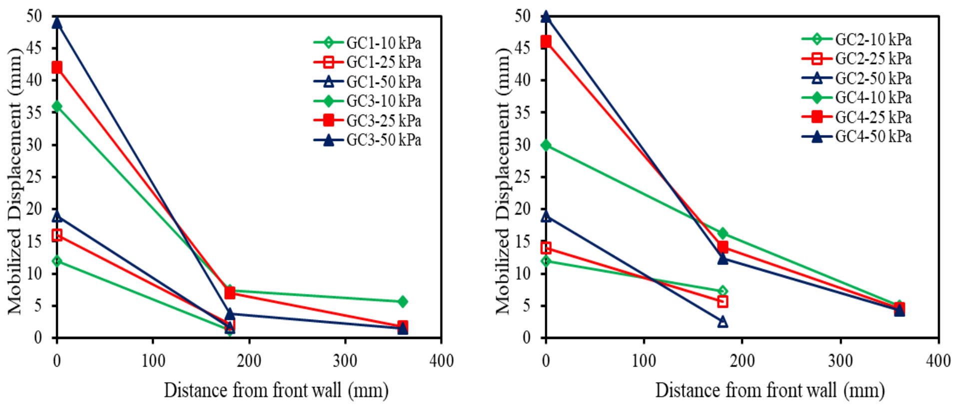
The pullout force generates strains along the length of geocell specimen. At the end of each tests, strains along the geocell specimen determined in this test program are shown in Figure 6. From Figure 6, it can be seen that the strain near the front wall in geocell specimen is significantly larger. Clearly, the mobilization of strains increases as the normal stresses increase. Besides that, the results show that the strains become higher when the width of geocell specimen become large (GC2 and GC4) because increasing the number of bearing member.



a) b)

Figure 6. Maximum strains versus distance from front wall along the specimen at various pressures

As for the mobilization of displacements along the length of geocell specimens, the results are shown in Figure 7. The results indicate that the mobilized displacement decreases with increasing normal stress. However, mobilized displacements at the front of wall are high due to absence of soil and confining pressure.



a) b)

Figure 7. Mobilized displacement versus distance from front wall along the specimen at various pressures

The effect of geocell specimen size on pullout force was investigated. For this, a comparison was made considering the effect of specimen length (L) and pocket number (S). The pullout force (P_F) versus $S*L$ under various stresses are given Table 3.

Table 3. The measured pullout forces

Geocell	Specimen length, *L*, (mm)	Total numbers of specimen pocket, *S*	*S*L* (m)	Normal stress (kPa)		
				10 kPa	25 kPa	50 kPa
				P_F (kN)	P_F (kN)	P_F (kN)
GC1	170	1	0.17	1.40	1.72	2.40
GC2	170	2	0.34	1.74	2.28	2.74
GC3	340	2	0.68	2.55	3.60	5.20
GC4	340	4	1.36	2.60	4.38	5.68

Pullout force against normal stress are plotted in Figure 8. The results illustrate that pullout forces increases as the vertical stresses increases. The peak pullout force increases with increase both in the length of geocell and length and pocket numbers of geocell.

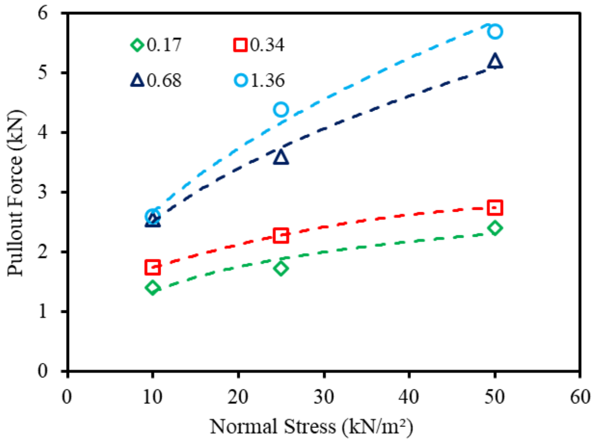


Figure 8. Peak pullout force versus normal stress at different values of S*L

4 CONCLUSIONS

Soil-geocell pullout behavior was investigated from large scale pullout tests. The results of pullout tests show that the pullout force increase with increasing the width and length of the geocell specimen because of both generating of bearing resistance and friction along the length of geocell. The mobilized displacements and strains are peak at the front face of geocell, however, they become minimal as moved from the front face of geocell.

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