Effective Width of Geocell under Strip Footing

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ABSTRACT: Structures (road, dam, building etc.) sit on top of soils that should have enough bearing capacity with minimum settlement under structural loads. Bearing capacities of weak soils have been increased with soil improvement methods including grouting methods and geosynthetic materials. In this study, a geocell material was used in order to increase bearing capacity of a medium dense under a strip footing meanwhile effective width of geocell was determined. It is determined that the effective width of geocell under the strip footing is about eight times of the width of strip footing. In addition to that, an increase in bearing capacity of the medium dense sand with geocell reinforcement was three times more than that of the sand without geocell reinforcement.

Keywords: geocell, effective width, bearing capacity

1 INTRODUCTION

Soil improvement methods including cement injection, jet grouting and chemical grouting have been used both to increase the bearing capacity of weak soils and to decrease the settlement of foundations under structural loads. Over the past few decades, polymer based materials such as geosynthetic reinforcements to increase the bearing capacity of soil have increasingly being used. Geosynthetic reinforcement may provide easier installations, more economical solutions, and longer lifetime than other types of bearing capacity improvement techniques (Koerner, 2005).

In the form of a 3D-honeycomb structure, which is named as geocell and made with polyethylene (HDPE), polyester or another polymer material, is one of materials among geosythetic reinforcements. Geocell provides direct confinement to arrest the lateral spreading of the infill soil and creating relatively stiff bed that redistributes the footing pressure over wider area while enhancing the load carrying capacity and reducing the settlement.

Researches (Guido and Christou, 1988; Yoon et al.,2008; Wesseloo et al.,2009; Gurbuz and Mertol, 2012) provided plenty of useful information on the effectiveness of the geocell reinforced soils under different loading conditions. The aim of this study was to both investigate the effective width of the geocell and determine increase in bearing capacity of the sand under a strip footing sitting on a medium dense sand.

2 MATERIAL AND EXPERIMENTAL

2.1 *Material*

The soil used in this study was relatively uniform sand with a grain size distribution varying from 0.075 to 2 mm and a specific gravity (G_s) of 2.60. The physical properties of sand used in the study are presented in Table 1.

Table 1. The physical properties of sand used in the study

Description	Value
Effective grain size, D_{10} (mm)	0.18
D_{30} (mm)	0.35
D_{60} (mm)	0.44
Medium grain size, D_{50} (mm)	0.40
Specific gravity, G_s	2.60
Coefficient of uniformity, C_u	1.55
Coefficient of curvature, C_c	2.44
Maximum void ratio, e_{max}	0.85
Minimum void ratio, e_{min}	0.47
Internal friction angle , ϕ (degree), at 45 % relative density (D_r)	29

Geocell used in this study was produced from high density polyethylene (HDPE) welded to form a 3D-honeycomb structure as shown in Figure 1. Geocell height of 150 mm was used in this study. The properties of the geocell used in this study are listed in Table 2.

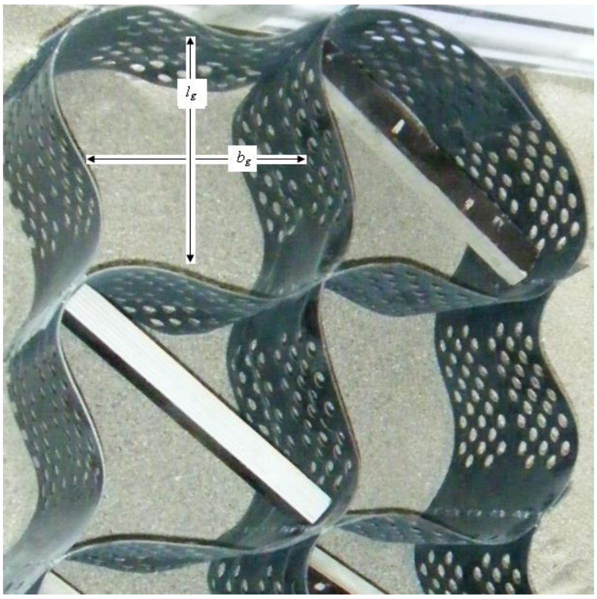

Figure 1: Assembled 3-D honeycomb cells produced from high density polyethylene

Table 2. The properties of 3-D honeycomb cells used in the study

Material type	polyethylene
Cell height, H (mm)	150
Width of one cell pocket, b_g (mm)	287
Length of one cell pocket, l_g (mm)	320
Density per m^2	21.7
Nominal area (cm^2)	460
Tensile strength at 5 % (kN)	3.66

2.2 *Test characterization*

The sand raining technique was used to deposit sand into the test tank. The height of sand raining to achieve a uniform relative soil density of 45 was determined by performing a series of trial tests with different heights of raining. Sand was rained from the pre-calibrated height to the predetermined depth of the geocell layers in the test tank and then raining was temporally ceased. After the geocells were placed on the leveled surface of the sand, the sand raining was released up to the footing level. Thereafter, the test tank was lifted into loading frame on which the spreader beam used as a strip footing was mounted as shown in Figure 2.

Figure 2. Test tank used in this study

Four linear variable displacement transducers (LVDT) were located on the footing, two at the midpoint of both sides of the footing and two at the ends of the footing. A load cell was placed on the loading system to measure applied static load. The static load was applied using the hydraulic jack at a rate of 1 kPa per second until the failure was obtained. The data obtained from the load cell and the LVDT's were recorded using a data acquisition system at every 0.1 sec intervals.

The geometry of geocell reinforced foundation system used in this study is presented in Fig. 3. The details of the test scheme are listed in Table 3. Test series A was conducted on unreinforced sand to quantify the improvements due to geocell reinforcement. Test series B to determine the effective width of geocell (B_g) were performed by varying the width of the geocell and keeping the height of the geocell (H) and the depth to the top of the geocell layer below the footing (u) constant. The tests described in Table 3 were repeated at least three times to both examine reliability of the test results and verify the consistency of test data.

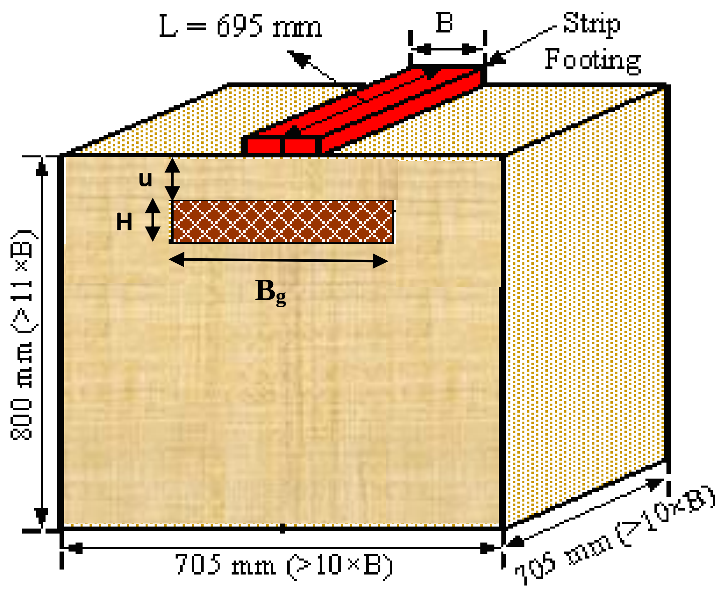

Figure 3: Geometry of the geocell reinforced foundation system.

Table 3. Tests series performed in the study

Test Series	Type of test	H/B	B_g/B	u/B	Remarks
A	Unreinforced	-	-	-	To quantify the improvements due to geocell reinforcement
B	Geocell reinforced	2.142	4.1 8.2 12.3	0.1	To reach at the optimum value of B_g /B

3. RESULT and DISCUSSION

The effectiveness of geocell reinforcement in this study was evaluated using the bearing capacity improvement ratio at ultimate ($BCIR_{ult}$) which specify the increase in the bearing pressure at failure:

$$BCIR_{ult} = \frac{q_{g-ult}}{q_{un-ult}} \quad \text{at ultimate} \qquad (1)$$

where $q_{un\text{-}ult}$ and $q_{g\text{-}ult}$ are the ultimate bearing capacity of unreinforced sand and geocell reinforced sand at failure, respectively.

Test series B conducted on different size of geocell (B_g/B) varying from 4.1 to 12.3 to determine the effective width ratio of B_g/B that would have no influence on values of bearing pressure versus footing settlement of geocell reinforced sand are plotted in Figure 4. Ultimate bearing pressures of unreinforced and reinforced cases at failure are listed in Table 4. The enhancement in bearing capacity ratio at failure increases as the width of the geocell becomes about eight times the width of the foundation, which was consist with a finding by Gurbuz and Mertol (2012). The result of the ratio of B_g/B of this study is different from those at B_g/B = 4.2 of Moghaddas Tafreshi and Dawson (2010a and 2010b), Sireesh et al (2009), Bg/B = 2.5 of Guido and Christou (2010b) and Bg/B = 2.17 of Yoon et al (2008). Different ratio of B_g/B might be due to the stiffness of reinforcement of materials and properties of soils used in the studies.

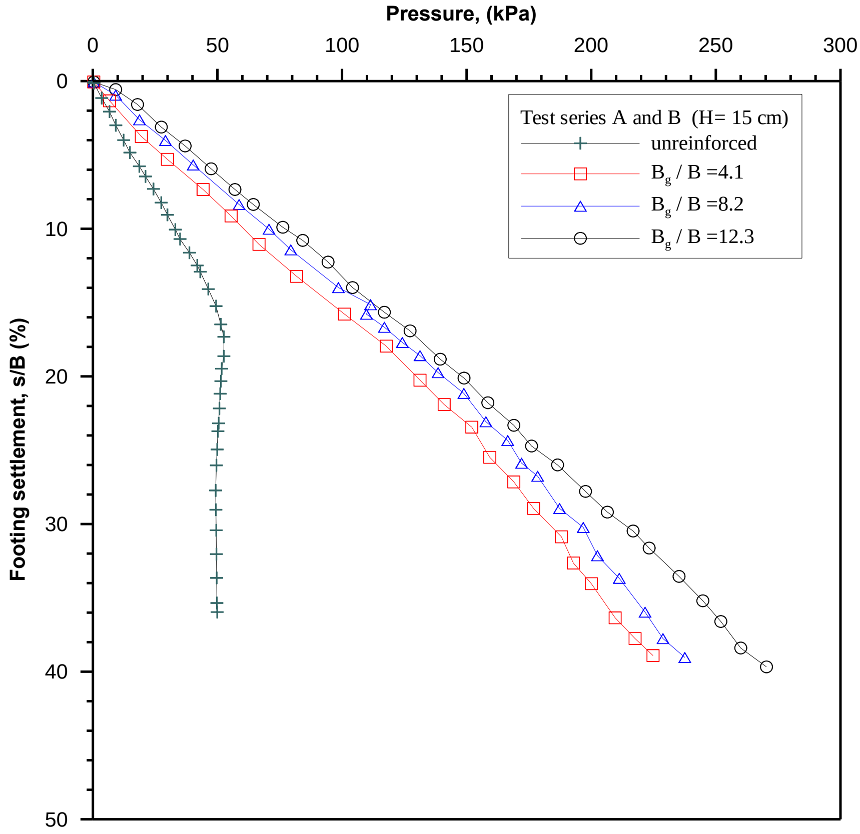

Figure 4: The effect of width of geocell layer on the bearing pressure – settlement relationship.

Table 4. Values of ultimate bearing pressure and footing settlement at failure for unreinforced and geocell reinforced sand (B_g/B =4.1, 8.2 and 12.3).

B_g/B	Ultimate bearing pressure at failure (kPa)	Footing settlement (*s/B*) at failure
Unreinforced case	52.2	17.5
4.1	158.0	24.0
8.2	170.0	22.2
12.3	170.0	22.2

Ratio ($BCIR_{ult}$) of ultimate bearing pressures of unreinforced and reinforced cases at failure versus B_g/B are plotted in Figure 5. It is determined that increase in bearing capacity with geocell having B_g/B of 8.2 reaches its maximum value. In other words, increase in the bearing capacity of the medium dense with geocell is about three times more than that of the soil without geocell reinforcement as B_g/B is 8.2.

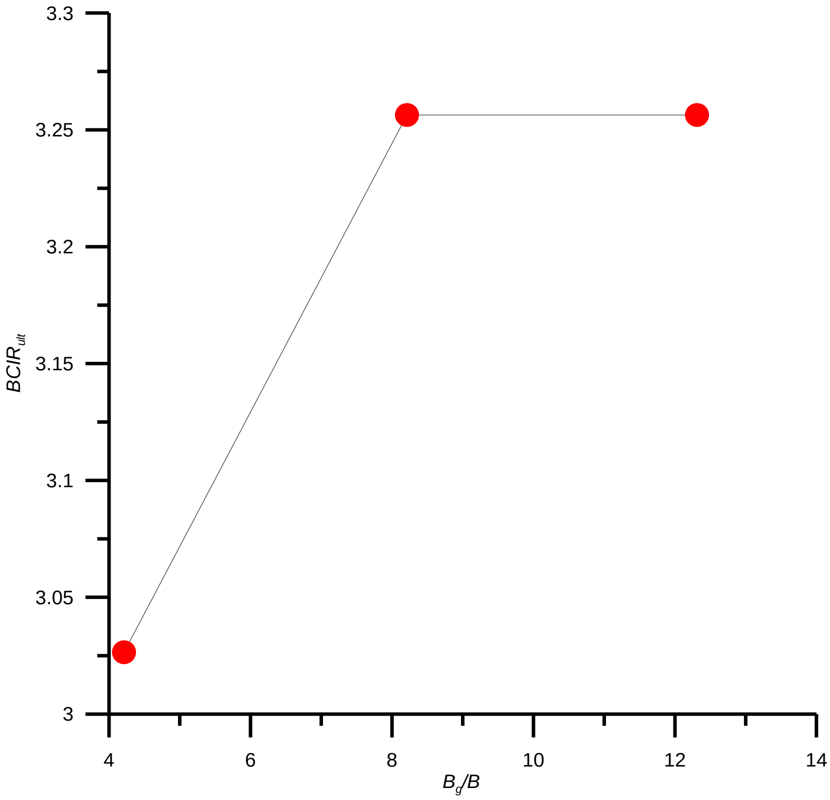

Figure 5: Increase in bearing capacity of the medium dense sand with geocell reinforcement versus B_g/B.

4. CONCLUSION

A series of laboratory tests were performed to both study the behavior of medium-dense sandy soil reinforced with geocell produced from high density polyethylene as compared to unreinforced soil and determine the effective width of geocell under the strip footing. From the comparison, the width ratio of geocell to foundation (B_g/B) that do not affect the bearing capacity of geocell-reinforced sand is determined about 8.2 that is similar to the ones by Gurbuz and Mertol (2012). Additionally, an increase in the bearing capacity of the medium dense with geocell reinforcement is about three times more than that of the soil without geocell reinforcement at B_g/B of 8.2.

It should be noted that only one type of foundation, one geocell type and one type of sand were used in this study; therefore, the results obtained from this study may be different than those of full-scale tests in field.

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