



IMPROVEMENT OF SOIL USING GEOGRIDS TO RESIST ECCENTRIC LOADS.

Prof. Dr. Mosa J. Al-Mosawe

Civil Engineering Department, College of Engineering, University of Baghdad.

Dr.A'amal A. Al-Saidi

Civil Engineering Department, College of Engineering, University of Baghdad

Faris W. Jawad

Civil Engineering Department, College of Engineering, University of Baghdad.

ABSTRACT

This paper presents the results of experimental investigations to predict the bearing capacity of square footing on geogrid-reinforced loose sand by performing model tests. The effects of several parameters were studied in order to study the general behavior of improving the soil by using the geogrid. These parameters include the eccentricity value, depth of first layer of reinforcement, and vertical spacing of reinforcement layers. The results of the experimental work indicated that there was an optimum reinforcement embedment depth at which the bearing capacity was the highest when single-layer reinforcement was used. The increase of (z/B) (vertical spacing of reinforcement layer/width of footing) above 1.5 has no effect on the relative improvement for the soil and the relative improvement (%) of the reinforced soil can be predicated by using a simple equation .

الخاصة

يستعرض هذا البحث النتائج لدراسة مختبرية لتقدير قابلية التحمل لترربة رملية مفككة بعد تسليحها بال (geogrid) . و قد تمت دراسة تأثير بعض العوامل لغرض الحصول على التصرف العام للتربة المحسنة بال (geogrid) وتشمل هذه العوامل الانحراف المركزي ، عمق الطبقة الاولى من التسليح ، والمسافة العمودية بين طبقات التسليح . وقد بينت النتائج الى ان هنالك عمق امثل لطبقة التسليح الذي يعطي اعلى قابلية تحمل ، زيادة نسبة (Z/B) (المسافة العمودية لطبقة التسليح / عرض الاساس) اكثر من 1.5 ليس لها تأثير على نسبة التحسين للتربة ، كما تم الوصول الى معادلة بسيطة لايجاد نسبة التحسين للتربة المسلحة .

INTRODUCTION

The reinforced earth has been most widely applied with something in excess of one million square meters of wall facing benign erected to the end of end of 1978, Mickittrick and Darbin (1979). The soil particles in direct contact with the reinforcements tend to slide over them under the effect of the load. The sliding is reduced by the frictional resistance between the particles and the surface of the reinforcement. Consequently this resistance will produce a tensile force along the reinforcing element which will acts as a tie between the particles surrounding it. The soil particles which are in direct contact with the reinforcement are bounded to other particles by the interlocking action. The frictional resistance will be transferred through the reinforced mass (Vidal, 1969).

The present study was undertaken to investigate the bearing capacity of square footings on geogrid-reinforced sand. The parameters investigated include

- 1)- Eccentricity value (e)
- 2)- Depth Ratio of first layer (u/B), where u and B are depth of first reinforced layer and footing width, respectively.

The symbols of the geometric parameters used in this present paper are shown in Fig (1).

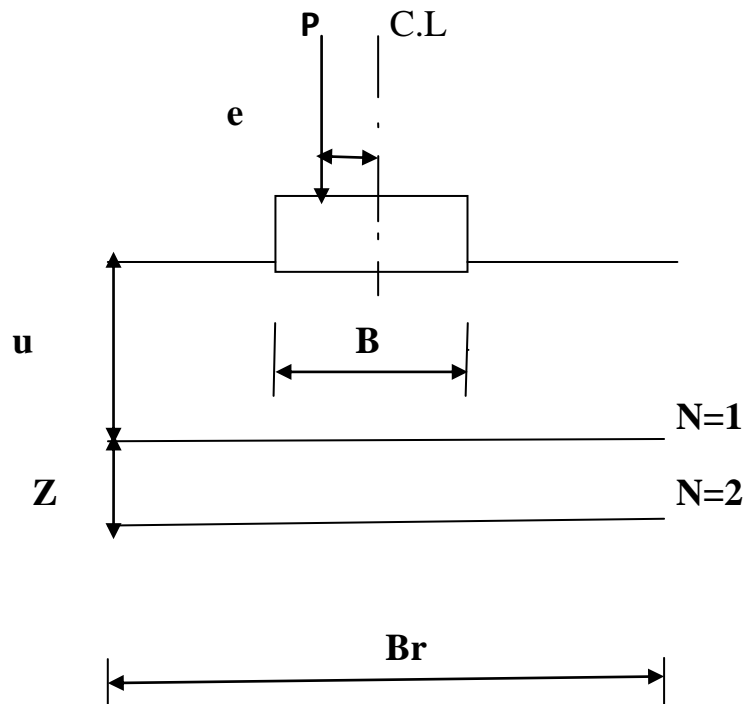


Figure (1) Geometric parameters of Reinforced Foundation.



EXPERIMENTAL TESTS AND TESTS PROCEDURE

A series of model loading tests were conducted inside steel box of 600 X 600mm in plane and 700mm in depth. The box was made of steel plate of 3mm thickness, stiffened with angle sections, as shown in Plate (1) . The internal faces of the box were covered with polyethylene sheets in order to reduce the slight friction which might be developed between the box surface and soil. Static vertical loads were applied using electrical hydraulic pump. Loads transferred from the pump to a hydraulic jack were carefully recorded by proving ring installed between the jack and the tested footing.

The footing was loaded at a constant loading rate to failure. The ultimate bearing capacity state was defined as the state at which either the load reached a maximum value where settlement continued without further increase in load or where there was an abrupt change in the load –settlement relationship. Settlement of the footing was measured using two dial gauges fixed in the middle and edge of footing.

The test footing was a square steel plate 60mm in plane and 5mm thick.



Plate (1) General View of Testing Equipment

SOIL PROPERTIES

Clean, oven-dried, uniform quartz sand (Kerbela sand) was used in the tests. The sand was placed in the test box at unit weight of approximately 15.2 kN/m^3 (relative density is 31%). Some properties of the sand are given in Table (1).

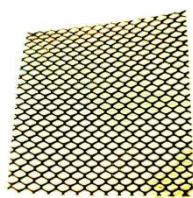
Table (1) Sand Properties.

Property	Values
Specific Gravity	$G_s = 2.63$
Void Ratio and Dry Unit Weight	$e_{\max} = 0.8, \gamma_{d\max} = 17.39 \text{ kN/m}^3$ $e_{\min} = 0.5, \gamma_{d\min} = 14.4 \text{ kN/m}^3$ $e_{\text{used}} = 0.74, \gamma_{d\text{used}} = 15.2 \text{ kN/m}^3$
Relative Density	$D_r = 31\%$
Angle of Internal Friction	$\phi = 29^\circ$

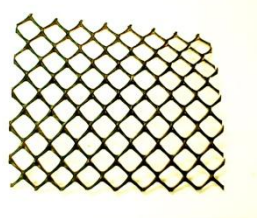
The value of (ϕ) was obtained from the result of triaxial test (UU.test) in accordance with ASTM(D2850-95).

REINFORCEMENT PROPERTIES.

The reinforcement used is polymer geomesh the general view for three types used in tests described, Plate (2). The dimensions of the geogrid samples used in this study are listed in Table (2). The physical and chemical properties for sample used were listed in Table (3). The technical properties for sample used were listed in Table (4).



Geogrid No.1



Geogrid No.2



Geogrid No.3

Plate (2) The Reinforcement Used.

Table (2) Dimensional properties for geogrids used. .(Latifia Geogrid)

Property	Unit	Data for geogrid No.1	Data for geogrid No.2	Data for geogrid No.3
Aperture Size	mm	6x10	55x55(±4)	39x39(±2)
Mass Per Unit Area	g/m ²	700	520(±%)	770(±40)
Roll Width	m	2.0	1.0	2.5
Roll Length	m	20	20	30
Roll Diameter	m	0.40	0.43	0.50
Cross Roll Weight	kg	28.0	10.4	57.75

Table (3) The physical, chemical and biological properties for geogrids used. .(Latifia Geogrid)

Property	Data for Geogrid No.1	Data for Geogrid No.2	Data for Geogrid No.3
Structure	Extruded Geogrid	Extruded Geogrid	Extruded Geogrid
Mesh Type	Diamond	Square	Diamond
Standard Color	Black	Black	Black
Polymer Type	HDPE	HDPE	HDPE
U.V Stabilized	Carbon Black	Carbon Black	Carbon Black
Chemical Resistance	Excellent	Excellent	Excellent
Biological Resistance	Excellent	Excellent	Excellent
Packaging	Rolls	Rolls	Rolls



Table (4) The technical properties for geogrid used.(Latifia Geogrid)

Property	Unit	Data for Geogrid No.1	Data for Geogrid No.2	Data for Geogrid No.3
Tensile Strength at 2% Strain	kN/m	5.1	2.3	4.3
Tensile Strength at 5% Strain	kN/m	9.1	4.0	7.7
Peak Tensile Strength	kN/m	16.0	7.1	13.5
Yield Point Elongation	%	20.0	20.0	20.0

VARIABLES STUDIED

Effect of Depth Ratio

The relative improvement for soil versus depth ratio for each value of eccentricity is shown in Fig (2). The optimum depth ratio ($u/B=0.75, 0.5, 0.25$) show the maximum rate of strength improvement is define $[(Pr/P) - 1]*100$ where Pr and P is the max load for reinforced and un reinforced sand for eccentricity values ($e= 0.05B, 0.135B, 0.22B$) respectively. It is noted that for depth ratios ($u/B=1.0$), improvement values decreased and approach a constant for eccentricity values ($e= 0.05B, 0.135B$ and $0.22B$). The relative improvement increases with decreased the values of eccentricity.

It should be pointed out that there is no general consensus regarding the effect of depth ratio on the relative improvement of the soil . Singh (1988), based on the study of square footing on sands reinforced with mild steel grids (also called "welded mesh"), indicated that the effect of depth ratio on the bearing capacity was independent of the number of

reinforcement layers and the optimum depth ratio was about 0.25. Selvadurai and Gnanendran, (1989) to improve the bearing capacity of footing located on slope fill using geogrids, showed that when ($u < B$), the failure path is penetrated below the reinforcement while when ($u > B$) the failure occurs at the soil geogrid interface (i.e. the failure path is limited in narrow zone) and the deep location of the geogrid layer at ($u > 2B$) does not lead to any improvement in either the carrying load or the stiffness of the footing

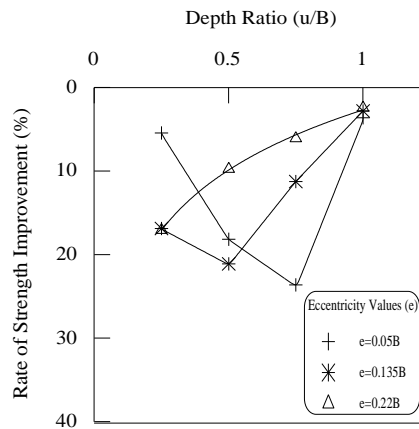


Figure. (2) Improvement versus Depth Ratio for Different Eccentricity Values, and $B_r / B = 3$.

The maximum improvement versus eccentricity values when depth ratio is optimum value ($u/B = 0.75, 0.5$ and 0.25) for eccentricity value ($e = 0.05B, 0.135B$ and $0.22B$) respectively is illustrated in Fig. (3). This figure shows the deterioration in strength with increasing eccentricity values.

The general equation for the relative improvement (%) for the soil can be expressed as follows:

$$q = 25.863 - 6.563e \quad \dots \dots \dots (1)$$

Where q = maximum rate of strength improvement (%)

e = eccentricity value (mm).

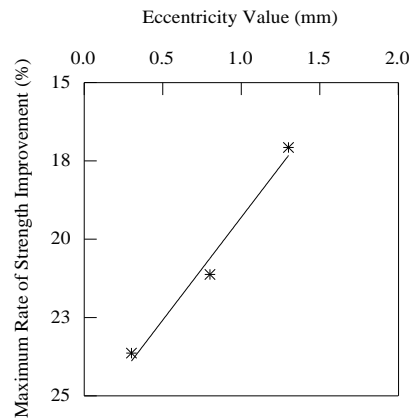


Figure (3) Maximum Improvement Versus Eccentricity Values for Optimum Depth Ratio and $Br/B=3$.

Effect of Vertical Spacing of Reinforcement Layers :

Figure (4) shows the relative improvement (%) versus vertical spacing ratio ($z/B=0.5, 0.75, 1.0$ and 1.5) for different eccentricity values ($e=0.05B, 0.135B$ and $0.22B$). This figure illustrated the maximum improvement for eccentricity values ($e=0.05B, 0.135B$ and $0.22B$) at $z/b=0.5$. It can be seen that the rate of strength improvement equals (0) for vertical spacing ratio ($z/B=1.5$) for different eccentricity values thus the increase of (z/B) above 1.5 has no effect on the relative improvement for the soil. Similar to these findings were found by Fukuda et. al., (1987) who tested concentric load applied on footing with polymer grid reinforcement showed that the optimum vertical spacing between reinforcement is $2/3B$. Guido et al (1987) indicated that the bearing capacity decreased with increasing vertical spacing ratio for Tensar SS1, SS and SS3 geogrid.

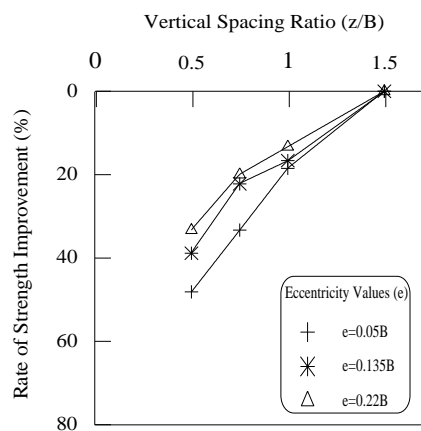


Figure (4) The Relative Improvement Versus Vertical Spacing Ratio for ($u/B=$ Optimum Value and $Br/B=3$)

The maximum relative improvement versus eccentricity values is shown in Fig. (5). This figure illustrates that the maximum rate of strength improvement decreased with increasing eccentricity values. For any value of eccentricity value and $(z/B)=0.5$, the relative improvement can be obtained according to the equation (2).

$$q = \exp(-0.368e) * 53.239 \dots\dots\dots (2)$$

where

q = maximum rate of strength improvement (%) .

e = eccentricity values (mm).

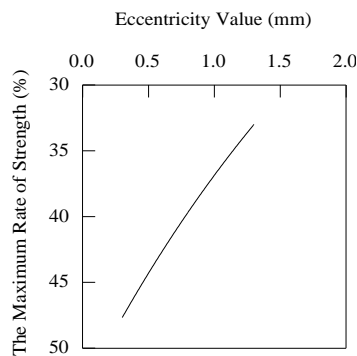


Figure (5) Maximum Rate of Strength Improvement Versus Eccentricity Values for $(z/B)=0.5$, u/B =Optimum Value, $N=2$, $B_r/B=3$).

CONCLUSIONS

- * For single-layer reinforced sand, there is an optimum depth ratio of the first layer at which the bearing capacity is the highest. The tests indicated that the optimum depth ratio of reinforcement of the first layer is equal to $(u/B=0.75, 0.5$ and $0.25)$ for eccentricity values $(e=0.05, 0.135$ and $0.22B)$, respectively.
- * The increase of (z/B) (vertical spacing of reinforcement layer/width of footing) above 1.5 has no effect on the relative improvement for the soil.
- * The relative improvement (%) of the reinforced sandy soil can be predicated by using a simple equation $(q=25.863 - 6.563e)$.
- * For any value of eccentricity value and $(z/B) =0.5$, the relative improvement can be obtained according to the equation $\{ q= \exp (-0.368e) * 53.239\}$.



REFERENCES

- Fukuda, N., Taki, M., and Sutoh, Y., 1987. Foundation Improvement by Polymer Grid reinforcement. Proceedings of the 8th Asian Regional Conference on Soil Mechanics and Foundation Engineering, pp. 365-368.
- Guido, V.A., Knueppel, J.D., and Sweeny, A.1987. Plate loading test on geogrid reinforced earthslabs. Proceedings Geosynthetics' 87 Conference, New Orleans. pp216-225
- Mckittrick, D. P. and Darbin, M., (1979); "World- Wide Development and Use of Reinforced Earth Structures", Ground Engineering, Vol. 12, No.2, p.p. 15-21.
- Selvadurai, A.P.S. and Gnanendran, C.T., 1989. An Experimental Study of a Footing Located on a Sloped Fill: Influence of a Soil Reinforcement Layer. *Canadian Geotechnical Journal*, Vol. 26, No. 3, pp. 467-473.
- Singh, H.R. 1988. Bearing capacity of reinforced soil beds. Ph.D. Thesis . Indian Institute of Science, Bangalore, India
- Vidal, H., (1969); "The Principle of Reinforced Earth", Highway Research Record, HRR-282, p.p. 1-16.