Evaluation The Behaviour of Reinforced Loose Sand under Inclined Loading

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Abstract:

This paper presents the results of laboratory models test on the behaviour of a model footing resting on loose sand reinforced by geogrids under inclined load.

Several parameters were studied in order to find the general behaviour of improvement in the soil by using the geogrid. These parameters includes depth of the reinforcement layer , vertical spacing of reinforcement layers and the angle of inclination of load.The results show that the optimum ratio of reinforcement for the first layer is (0.5) . The increase of such ratio between vertical spacing layer and footing width above 1 has no effect on soil improvement and an apparent increase is observed in the load carrying capacity for treated soil (200%,170%,156%) for inclined load (25^o , 45^o, 65^o),respectively.

الخلاصة:

يستعرض هذا البحث النتائج لدراسة مختبرية لمعرفة تأثير تسليح التربة بالمشبك على تصرف نموذج لاساس جالس على تربة رملية مفككة معرض لحمل مائل.لدراسة السلوك العام ومدى تحسين التربة بواسطة المشبك تمت دراسة تاثير كل من عمق طبقة التسليح والمسافة العمودية بين طبقات التسليح وزاوية ميلان التحميل.وقد بينت النتائج ان العمق الامثل لطبقة التسليح(0.5),ان زيادة نسبة(المسافةالعموديةلطبقة التسليح/عرض الاساس)اكثر من 1 ليس لها تاثيرعلى تحسين التربة,كما لوحظ زيادة قابلية التحمل للتربة المعالجة(156%,170%,200%) لزاوية تحميل (25^o , 45^o, 65^o) وعلى التوالي.

1-Introduction

Reinforced soil is becoming a very important technology and useful method in the construction of structures such as retaining walls, embankments over soft soil, steep slopes, and various other structures.

The use of geogrid layers could be particularly convenient when the mechanical characteristics of the soil beneath a foundation would suggest the designer in adopting alternative solution ,e.g .a deep foundation.

The use of geogrids for soil reinforcement has increased greatly, primarily because geogrids are dimensionally stable and combine features such as high tensile modulous (low strain and high load), open grid structure, positive shear connection characteristics, light weight, and long service life. The open structure provides enhanced soil reinforcement interaction.

Schimizu and Inui (1990) carried out load tests on a single six_sided cell of geotextile wall buried in the subsurface of the soft ground. Khing et al. (1993) investigated the laboratory_model test results for the bearing capacity of a strip foundation supported by a sand layer reinforced with layer of geogrid. Das and Omar (1994) presented the ultimate bearing capacity of surface strip foundations on geogrid_reinforced sand and unreinforced sand. Mandal and Manjunath (1995) used geogrid and bamboo sticks as vertical reinforcement elements and studied their effect on the bearing capacity of a strip footing. Dash et.al. (2001) investigated the use of vertical reinforcement along with horizontal reinforcement. The reinforcement consisted of a series of interlocking cells, constructed from polymer grides, which contain and confine the soil within its pockets.

Shin et.al. (2002) , Patra et. al., (2005) provided the results of a limited number of a laboratory model studies for the ultimate bearing capacity of a strip foundations with (D_f /B) (where D_f depth of foundation / B width of foundation) greater than zero under eccentric load.

Cindric et.al., (2006) presented a new measuring technique for detection of soil-grid interaction . It is based on measurement of wave velocities in soil.

Most of the previous studies concentrated on using geogrid as reinforcement to the soil under footings subjected to concentric or eccentric load and studied the effect on the soil bearing capacity.

Study of bearing capacity of footing under inclined load has been carried out by many researchers in the past but without reinforcement (Meyerhof ,1953 ;Meyerhof ,1963;Meyerhof ,1965; Prakash and Saran , 1971; Prakash and Saran, 1977).

This laboratory-testing program attempts to provide the general behaviour of square footing resting on reinforced losse sand under inclined load.

2-Laboratory Model Tests

2-1 Model Test Tank

Model tests were conducted in a test tank , having dimensions of 600*600 mm in plan and 700 mm deep , made of steel plate of 3 mm thickness (as shown in Plate 1) .

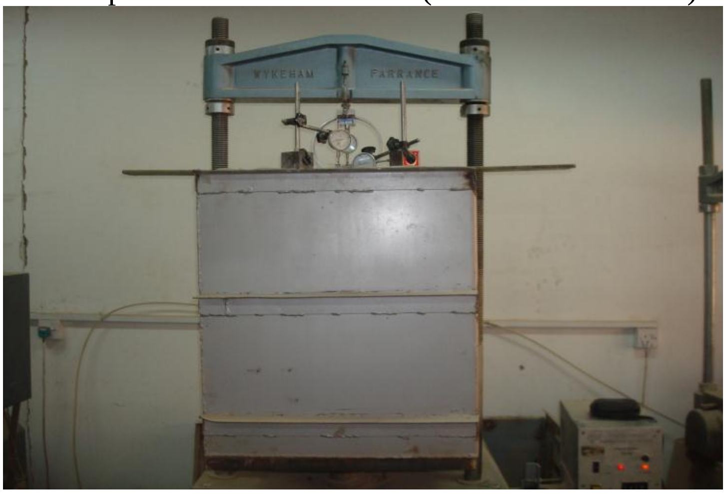


Plate (1) Model Test Tank

2-2 Footing

The test footing was a square steel plate 60 mm in plan and 5 mm thick. The load transferred to the footing was measured by proving of 3 kN capacity proving ring ,while the vertical deflection and horizontal displacement of the footing was measured using two dial gauges (0.01 mm/ division) as shown in Plate(2). The size of the footing was decided by the size of the model test tank and the zone of influence.

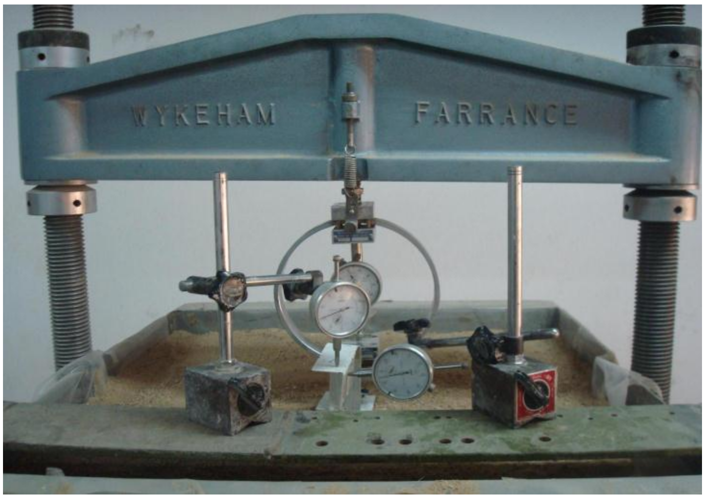


Plate (2) Arrangement of The Proving Ring and Dial Gauges during Loading Tests.

3-Test Material

3-1 Sand Properties

The sand used in this study, is poorly graded sand passing sieve No.4. In order to remove as much dust as possible the sand was washed with running water.

The test was performed with loose sand corresponding to a dry unit weight of approximately 15.2 kN/m^3 the maximum and minimum dry unit weights of the sand are determined according to the ASTM (D4253-00) and ASTM(D4254-00), respectively.

The results of maximum and minimum dry unit weight of sand are 17.4 kN/m^3 and 14.4kN/m3 respectively. The specific gravity test is performed according to the British standard B.S. (1377: 1975). The specific gravity of the used sand is 2.63. The grain size was analyzed according to the ASTM (D422-63) , the grain size distribution curve was shown in Figure (1).The sand is classified according to the unified classification as poorly graded sand with a coefficient of uniformity (C_u) = 1.57 and coefficient of curvature (C_C) = 1.0.

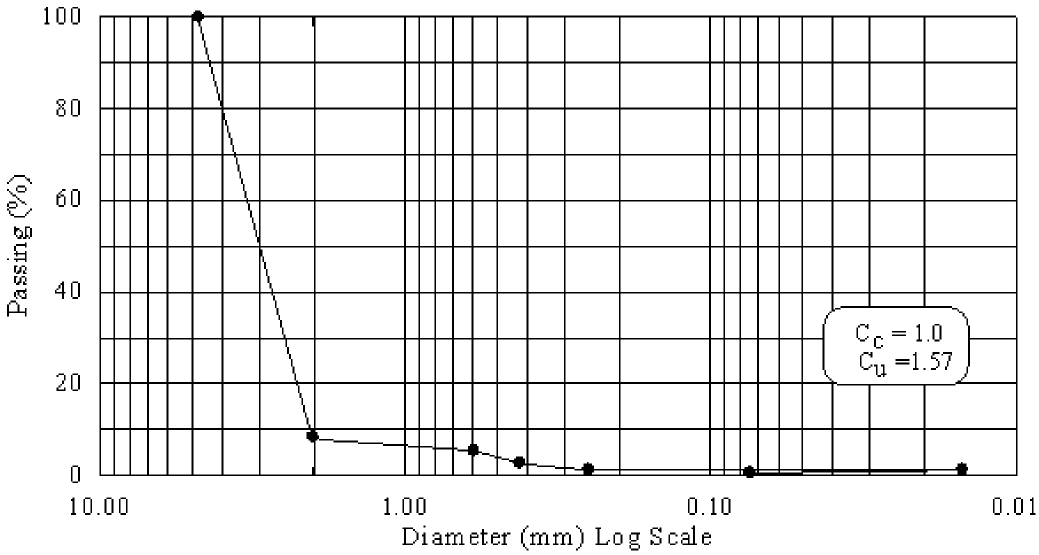


Figure (1) Grain Size Distribution Curve for The Tested Sand(ASTM) Standard.

Laboratory tests were carried out on the sand to get some other properties and their values are listed in Table (1).

Table (1) Sand properties.

Specific Gravity	***G_s = 2.63***
Void Ratio and Dry unit weight	e_{max} = 0.8, d_{max} = 17.4KN/m^3 e_{min} = 0.5, d_{min} = 14.4KN/m^3 e_{used} = 0.74, d_{used} = 15.20KN/m^3
Relative Density	D_r = 31%
Angle of Internal Friction	Ø = 29^o

3-2 Geogrid

A geogrid is defined as a geosynthetic material consisting a connected parallel sets of tensile ribs with apertures of sufficient size to allow strike through of surrounding soil , stone, or other geotechnical material (Koerner,1998).

The dimensional properties of the geogrid sample used in this study were listed in Table (2).

Table (2) Dimensional Properties for Samples as Supplied by The Manufacturer.

Property	***Unit***	***Data for sample Used***
Aperture Size	mm	6×10
Mass per unit area	g/m^2	700
Roll Width	m	2.0
Roll Length	m	20
Roll Diameter	m	0.40
Gross roll weight	kg	28.0

The physical , chemical properties for sample used as supplied by the manufacturer. were listed in Table (3)

Table (3)Physical and Chemical Properties for Sample Used.

Property	***Data for sample used***
Structure	Extruded Geogrid
Mesh type	Diamond
Standard Color	Black
Polymer Type	HDPE
U.V Stabilizer	Carbon Black
Chemical resistance	Excellent
Biological resistance	Excellent
Packaging	Rolls

The technical properties for sample used as supplied by the manufacturer were listed in Table (4).

Table (4) The Technical Properties for Model Sample Used.

Property	***Unit***	***Data for sample used***
Tensile Strength at 2% Strain	kN/m^2	5.1
Tensile Strength at 5% Strain	kN/m^2	9.1
Peak Tensile Strength	kN/m^2	16.0
Yield Point Elongation	%	20.0

4-Experimental Setup and Test Program

The footing was placed in position and the load was applied to it through the proving ring . The load was applied until failure occurred. The test program consisted of carrying out of series of tests on square footing to study the general behaviour of reinforced soil by geogrid under inclined loading.

The details of the testing program are shown in Table (5).

Table (5) The Testing Program.

Variables Studied	*Soil Condition*	*(u/B)*	*(z/B)*	*Load Inclination*
1-Depth Ratio	*unreinforced*	-	-	25°
	reinforced	*0.25*	-	25°
	reinforced	*0.5*	-	25°
	reinforced	*0.75*	-	25°
	reinforced	*1.0*	-	25°
2-Verticl Spacing Ratio	*unreinforced*	-	-	25°
	reinforced	*0.5*	*0.5*	25°
	reinforced	*0.5*	*0.75*	25°
	reinforced	*0.5*	*1.0*	25°
	reinforced	*0.5*	*1.5*	25°
3-Inclination Load	*unreinforced*	-	-	25°
	reinforced	*0.5*	*1.0*	25°
	unreinforced	-	-	45°
	reinforced	*0.5*	*1.0*	45°
	unreinforced	-	-	65°
	reinforced	*0.5*	*1.0*	65°

Note: u= Depth of the reinforced layer.
B= Footing width.
Z= Vertical spacing between reinforced layers.

5-Results and Discussion

5-1 Variables Studied

a. Depth Ratio

Depth ratio (u/B), is the depth of the geogrid layer compared to the footing width.
Figure (2) shows the load –settlement relations for the footing of different depth ratio(u/B) (0,0.25,0.5,0.75,1).

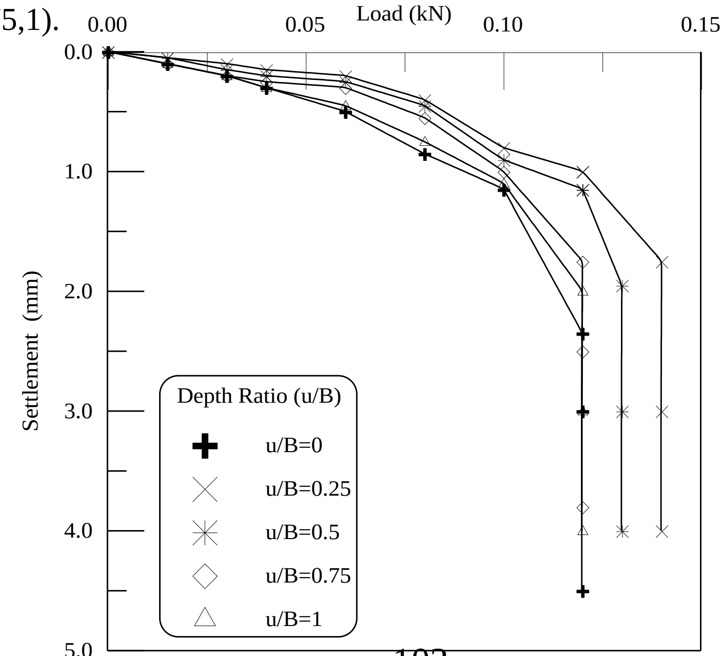


Figure (2) The Relation between Load-Settlement for Different Depth Ratio.

The test results show that the bearing capacity of reinforced soil increases as the depth ratio decreases.

Higher values of (u/B) (greater than 0.5) gives the same bearing capacity ,i.e, the effect of the geogrid diminishes with increase of the geogrid layer depth with respect to footing width (as shown in Figure (2)).

The improvement due to the reinforced the soil can be determined by using the ratio between the ultimate bearing capacity of treated soil to that of untreated soil,(F)

$$F = \frac{q_{ult} \text{ for treated soil}}{q_{ult} \text{ for untreated soil}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Figure (3) shows that the improvement factor (F) computed using Eq.(1) as a function of the (u/B) ratio.

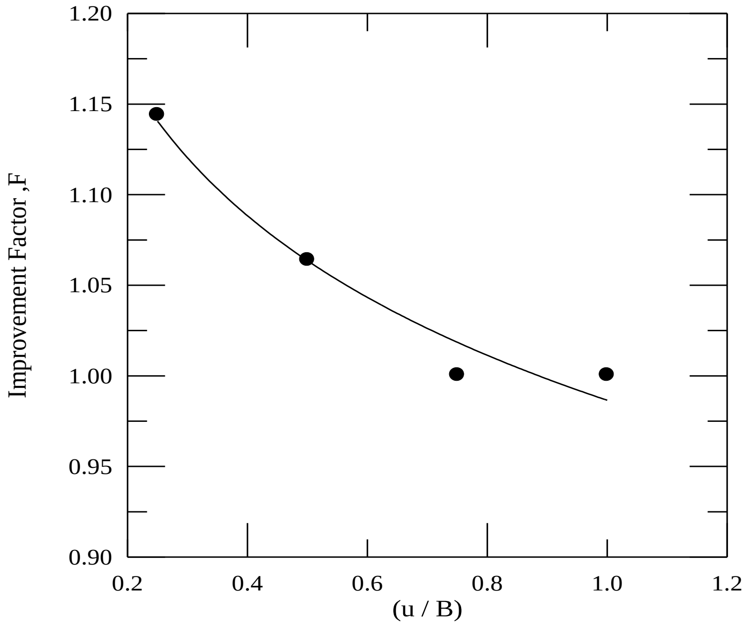


Figure (3) The Relation between The Improvement Factor and (u/B) Ratio.

The general equation for the improvement factor and depth ratio can be expressed as follows:

$$F = -0.111*\log(u/B)+0.99 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

b- Effect of Vertical Spacing between Geogrid Layer

Figure (4) presents the load-settlement relation for untreated and a number of treated soil with (z/B) (vertical spacing between geogrid layers / footing width) (0.5,0.75,1,1.5). The test results show that the load carrying capacity of reinforced soil increases as the (z/B) decreases.The increase of (z/B) above 1.0 has no effect on the load carrying capacity for the treated soil.

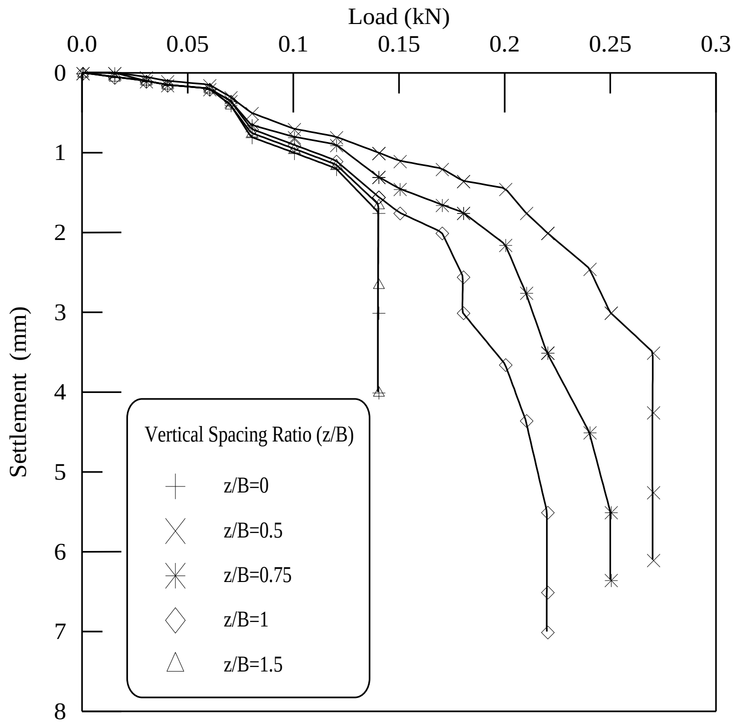


Figure (4) The Relation between Load-Settlement for Different (z/B) Ratio.

Figure (5) shows the variation of the load reduction factor , r (r =(1-Puu/Put)*100,where Puu and Put are the ultimate loads for untreated and treated soils,respectively) with the (z/B) ratio. The figure shows that the load reduction factor decreases when the (z/B) ratio increases. The load reduction factor, r , decreased to about (50 %) when the (z/B) increase from (0.5 to 1.5)

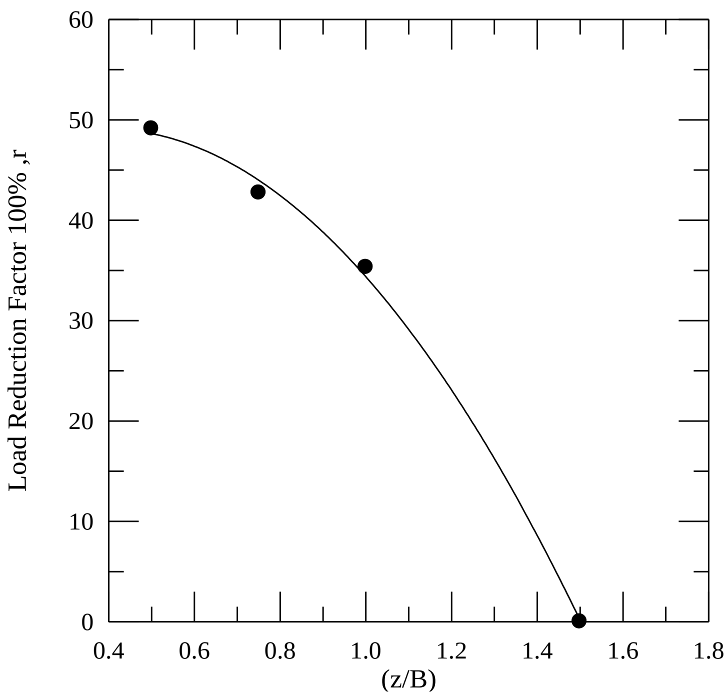
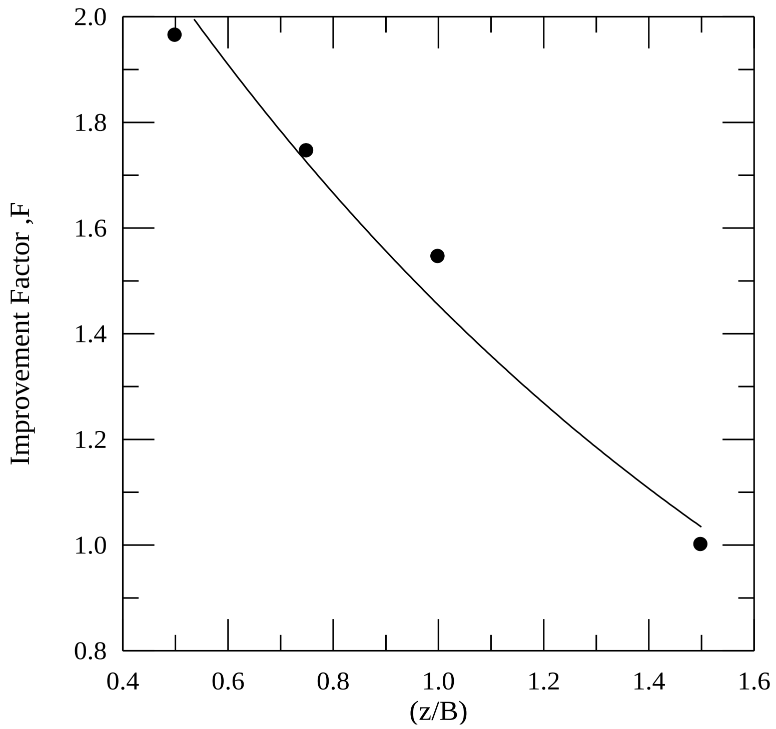


Figure (5) The Relation between Load Reduction Factor and (z/B)Ratio.

Figure (6) illustrates the improvement factor(F) computed using Eq.(1) as a function of the (z/B) ratio.



Figure(6) The Relation between Improvement Factor and (z/B) Ratio.

The general equation for improvement factor and (z/B) ratio can be expressed as follows:

F = exp (-0.68(z/B))*2.87……………………………………(3)

C- Inclined Loading.

Inclined load was applied to the footing for the untreated and treated soil. The ratio of (u/B)=0.5,(z/B)=1 and load inclination is 25^o, 45^o and 65^o. Ultimate bearing capacity has been found out from the load-settlement curve. Vertical Settlement and horizontal displacement of the footing were recorded by dial gauges. It was observed that as the load inclination increase, there was a reduction in the ultimate load carrying capacity. This ultimate load was found to show a remarkable improvement with reinforced soil. The Horizontal displacement of the footing also increased with the increase in load inclination. The results are presented in Table (6) .

Table (6) The Results of The Inclined Loading Factor.

Degree	*Load,kN*	*Vertical Set.,mm*	*Horizontal Disp.,mm*	*Soil condition*	*F*	*Load Reduction Factor,100%,r*
25^o	0.23	5.7	5.2	Untreated	_	____________
25^o	0.45	3.7	4.9	Treated	2.0	50%
45^o	0.17	4.7	6.0	Untreated	_	____________
45^o	0.29	3.2	5.3	Treated	1.7	41%
65^o	0.115	4.0	6.3	Untreated	_	____________
65^o	0.18	3.0	5.5	Treated	1.56	36%

The decrease in load carrying capacity is about (50% and 60%) when the load inclination increased from 25o to 65^o for untreated and treated soil, respectively. Vertical settlement, horizontal displacement, improvement factor and load reduction factor also showed a reduction due to reinforcement of soil.

Apparent increase is observed in the load carrying capacity for treated soil (200%,170%,156%) for inclination load (25^o, 45^o, 65^o), respectively.

6-Conclusion

- The optimum depth ratio for reinforcement is equal to (0.5) .
- The increase of (z/B)(vertical spacing of reinforcement layer /footing width) above 1 has no effect on the relative improvement of the soil.
- The decrease in load carrying capacity is (50% and 60%) when the load inclination increase from 25 ^{o} to 65^o for untreated and treated soil, respectively.
- Apparent increase is observed in the load carrying capacity for treated soil (200%,170%,156%) for inclination load (25^o, 45^o, 65^o), respectively.

7-References

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