Effective Length of Geogrid Reinforcement Layers under Circular Footing Resting on Sand

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ABSTRACT
This investigation aims at finding the effective length of geogrid reinforcement layers under circular footing. For this purpose xperimental models were used. The effect of relative density of the sand and the depth of the footing on the effective length of geogrid reinforcement layer was studied. Also the effect of the change in the length of reinforcement layers on the ultimate bearing capacity was investigated. The results show that the length of reinforcement layers to diameter ratio of circular footing increased with decreasing relative density of the sand and is not affected by the change of the depth to diameter ratio of circular footing.
Keywords: Bearing capacity, Circular footing, Geogrid, Length of reinforcement, Reinforced sand

INTRODUCTION
Circular foundation is that type of shallow foundation, which has been used in many structures such as (tank, chimneys ,towers …etc.).

Reinforcement of soil has become a widely used and cost-effective technique only over the last 30 years. Reinforcement of soil is the technique where tensile elements are installed in the soil to enhance stability and control deformation. The major usefulness of reinforcement of soil is: The put of reinforcement in soil increases the shear strength of the soil thereby enhancing its structural capability. The use of reinforcement helps the use of weak soils to be used as structural components. Construction time is become less when reinforced soil techniques are used.[1,2,3,4,5,6]

The concept of effective length of soil reinforcement layer descends from the fact that only the part of reinforcement which lies within the shear zone under the footing will have its tensile resistance effectively improved. Some additional length after the shear zone is used as anchorage to provide pull-out strength to the reinforcement. Therefore, the effective length of soil reinforcement is the sum of shear zone width and anchorage zones on both sides. Any additional reinforcement width beyond this effective value will be ineffective, and therefore will not result in any additional enhancement in the bearing capacity of the footing. Lee et al.,(1999)[7] suggested that the effective length of the reinforcement is 5–6 times the footing width for a strip footing. The effective value of b/B for surface foundation condition for deriving the maximum benefit from reinforcement can vary from 6 to 8 for the width of strip foundations. [8, 9, 10, 11, 12]

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Bera et al. (2005) [13] concluded an effective reinforcement width of 5–7 times the width of square footing on reinforced pond as depend on a regression sample.
In this research, small experimental models were used to investigate the effective length of geogrid reinforcement layers under circular footing resting on sand for different relative densities of sand and for different depth to diameter ratios of circular footing.

Laboratory Model Test

The tests were conducted in a rigid steel box of square cross section area of 900 ×900 mm and 600 mm height placed over 1100 × 1100 steel base. The test footing was a circular model footing with diameter 120mm. The model footing was made of three layer of plastic glass each one 10mm thickness. The load was applied by means of mechanical arrangement technique. The proving ring attached to a cylindrical steel toothed shaft device which transfer load to the model footing. The vertical displacement of the footing was measured using electronic dial gage. In order to achieve required relative density (60% and 80%) , an electrical vibrator has been used. The time of vibration need to obtain the required relative density was computed earlier by performing series of trails. The time of vibration required to achieve 80% relative density was 65 sec. approximately, while for 60% relative density it was 35 sec. As shown in plate (1). While figure (1) shows the testing scheme.[14]

The geogrid was cut to form square sheets with different (LR/Dc) ratios. Two layers of geogrid reinforcement were used under circular footing with u/Dc equal to (0.25) and h/Dc equal to (0.35),(where (u) is the depth of the topmost layer of reinforcement and (h) is the vertical distance between constitutive reinforcement layers), these ratios have been taken from Al-Shindah (2011)[15]. Then after preparing the sand / sand-geogrid combination, the footing was situated at the center of the box. Continuous reading was recorded at constant load intervals up to failure. The failure condition was considered when the settlement increased rapidly with little increasing or constant value of load.

Test Material Properties

Sand Properties

In this study, **the** sand used has a properties show in Table (1). The sand was poorly graded sand passing sieve No.4.

Plate (1) The box and loading system

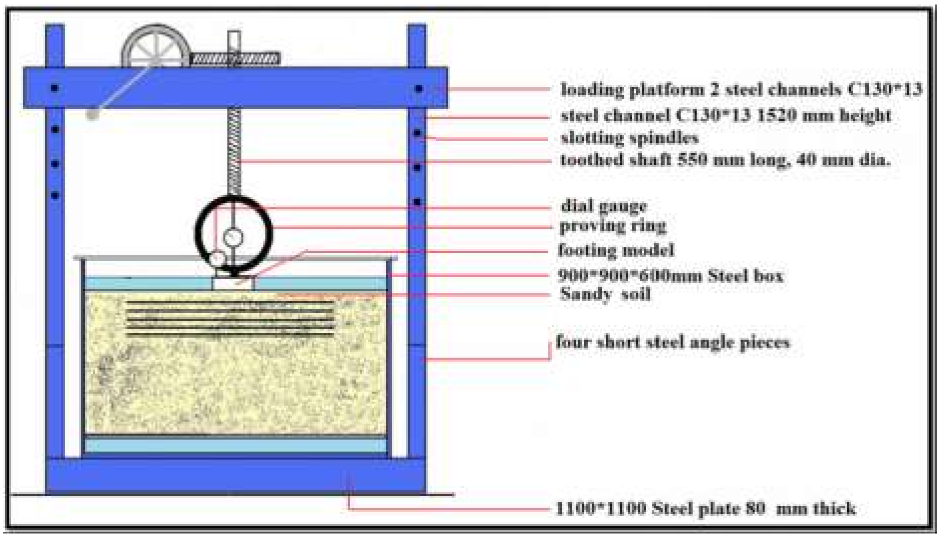


Figure (1) The testing scheme.

Table 1 Properties of sand

Property	value	Specification
Specific gravity	2.588	ASTM D-854
Maximum dry unit weight (kN/m³)	18	ASTM D-1557
Minimum dry unit weight (kN/m³)	15.57	ASTM D-4254
γ_d for relative density 60% (kN/m³)	16.94	-
γ_d for relative density 80% (kN/m³)	17.45	-
Effective grain size D_{10} (mm)	0.24	ASTM D-421
D_{60} (mm)	0.46	ASTM D-421
D_{30} (mm)	0.31	ASTM D-421
Coefficient of uniformity C_u	1.91	ASTM D-421
Coefficient of curvature C_c	0.87	ASTM D-421
c (kPa)	0	ASTM D-3080
For relative density 60% ϕ (degree)	34	ASTM D-3080
For relative density 80% ϕ (degree)	38.5	ASTM D-3080

Geogrid Properties

One type of geogrid was used TriAx TX140 Geogrid manufactured from punched polypropylene sheets, which were then oriented in three substantially equilateral directions so that the resulting ribs shall have a high degree of molecular orientation, that continues at least in part through the mass of the integral node. Table (2) lists the properties of the geogrid.

Table (2). Geogrid properties (product specification)

Index Proprties	Longitudinal	Digonal	Transverse	General
- **Rib pitch ,mm**	40	40	-	Rectangular
- **Mid-rib depth,mm**	-	1.2	1.2	Triangular
- **Mid-rib width, mm**	-	1.1	1.1	
- **Rib shape**				
- **Aperture Shape**				
Structure Integrity				
- **Junction effective , %**				93
- **Aperture stability ,kg-cm/ @5 kg-cm**				3.0
- **Radial stiffiness at law strain ,kN/m@ 0.5%strain**				22.5
Durability				
- **Resistance to chamical degradation**				100%
- **Resistance to ultra-violet light and weathering**				100%

Test Program

A number of 48 tests were conducted to find the effective length of geogrid reinforcement under circular footing. The effect of depth ratio of footing embedment (D_f/Dc) and relative density of sand (RD%) on the effective length of geogrid reinforcement layers were also investigated.

The term bearing capacity ratio (BCR) is used to express the effect of soil reinforcement on the bearing capacity as shown in figure (2) and it can be written as:

$$BCR = \frac{q_{uR}}{q_u} \quad \text{.... (1)}$$

Where :-

q_u:-Ultimate bearing capacity of sand under circular footing without reinforcement.

q_{uR}:- Ultimate bearing capacity of sand under circular footing with reinforcement .

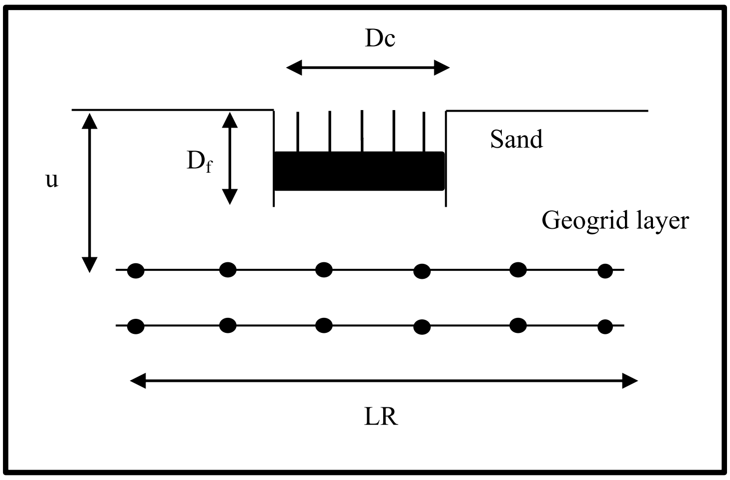


Figure (2) Parameters of circular footing on sand reinforcement

The parameters (length to geogrid reinforcement layer ratio *LR/Dc*, depth ratio of footing embedment D_f/Dc and relative density of sand (RD%) varied from one test to another as shown in the flow chart of the testing program in Figure (3).

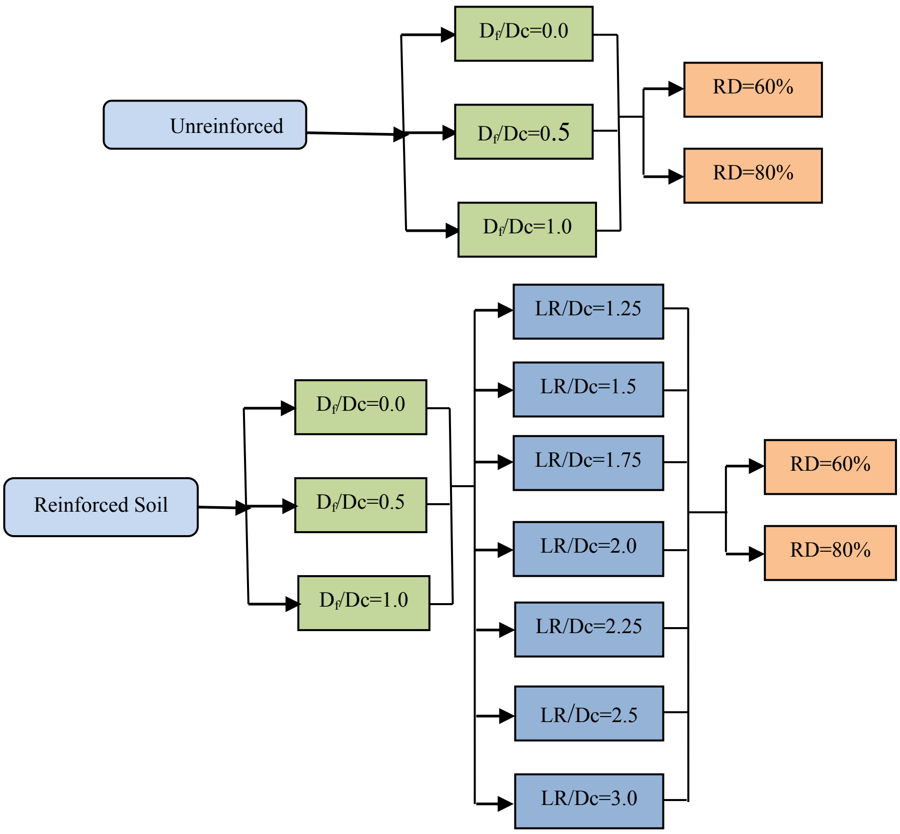


Fig.(3) Testing Program

Results and Discussions

The results of the tests conducted in this research are presented here. Each test was repeated at least three times to ensure repeatability of the results. Six tests were done for unreinforced sand (LR/Dc=0) in order to compare them with the results of tests conducted on reinforced sand.

Figures (4) to (9) show the ultimate bearing pressure-settlement curves for circular footing on reinforced and unreinforced sand with different length of reinforcement layers ratio (LR/Dc) and for different depth ratio of footing (D_f/Dc) with two relative density 60% and 80%. It is noticed that the ultimate bearing pressure (q_u) increase with increasing the length of reinforcement ratio (LR/Dc) for any values of depth ratio (D_f/Dc) and relative density (RD%). In addition; it is noticed that there is a limit of reinforcement length ratio (LR/Dc) after which there is little or no increases in ultimate bearing pressure (q_u). Table (3) show the values of ultimate bearing capacity (q_u) for different cases tested in this research.

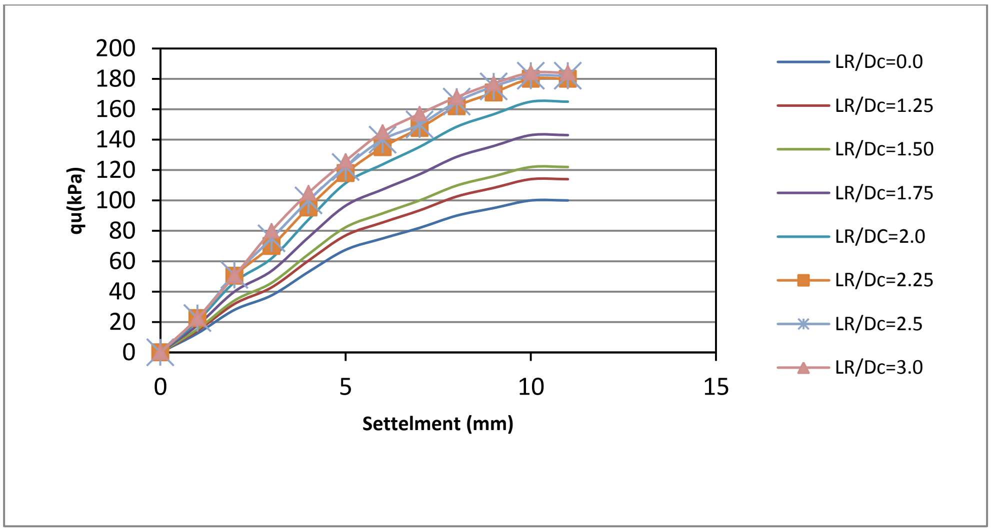


Figure (4): Ultimate bearing pressure – settlement curves for D_f/Dc=0.0, RD=60%

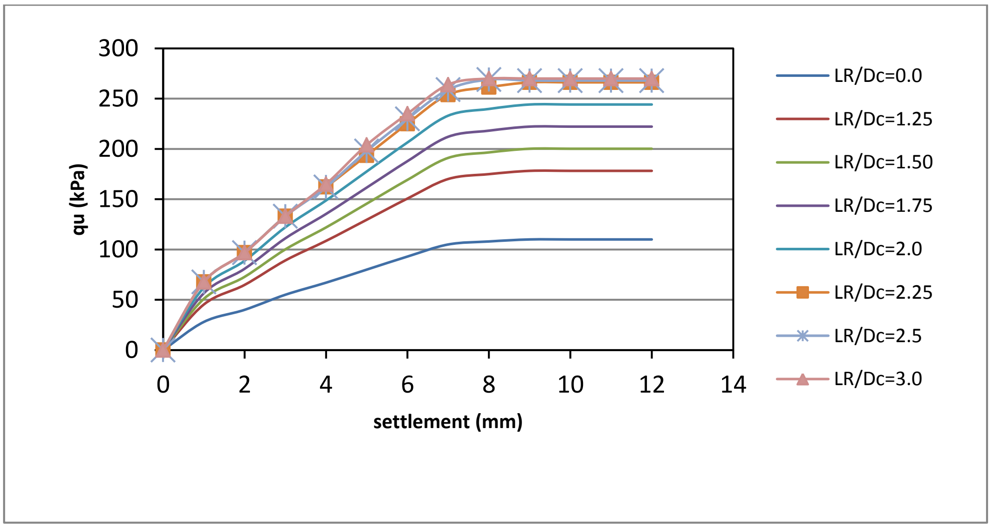


Figure (5): Ultimate bearing pressure – settlement curves for D_f/Dc=0.5, RD=60%

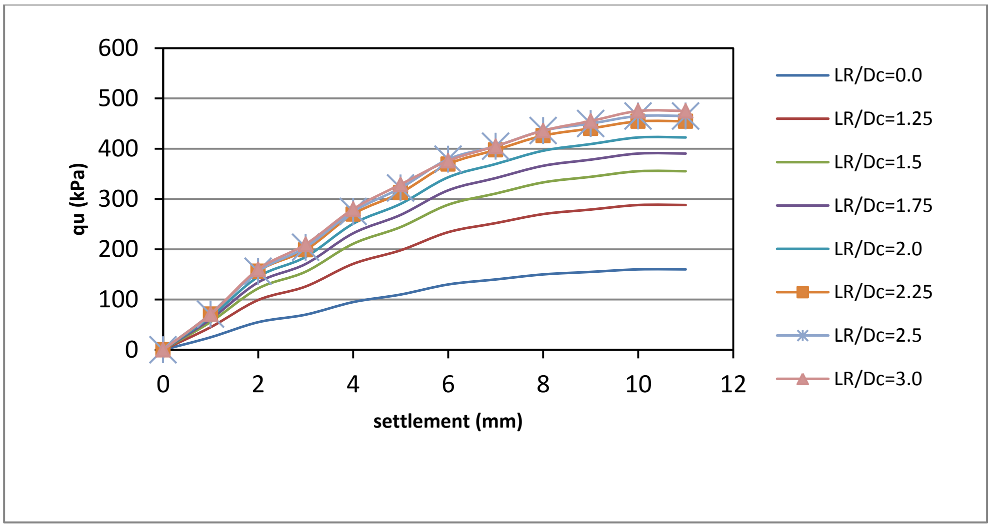


Figure (6): Ultimate bearing pressure – settlement curves for $D_f/Dc=1.0$, RD=60%

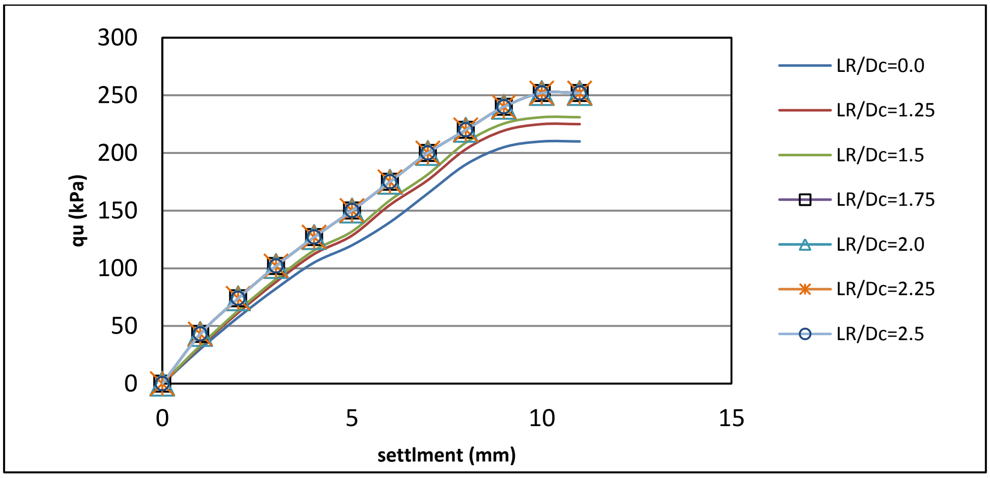


Figure (7): Ultimate bearing pressure – settlement curves for $D_f/Dc=0.0$, RD=80%

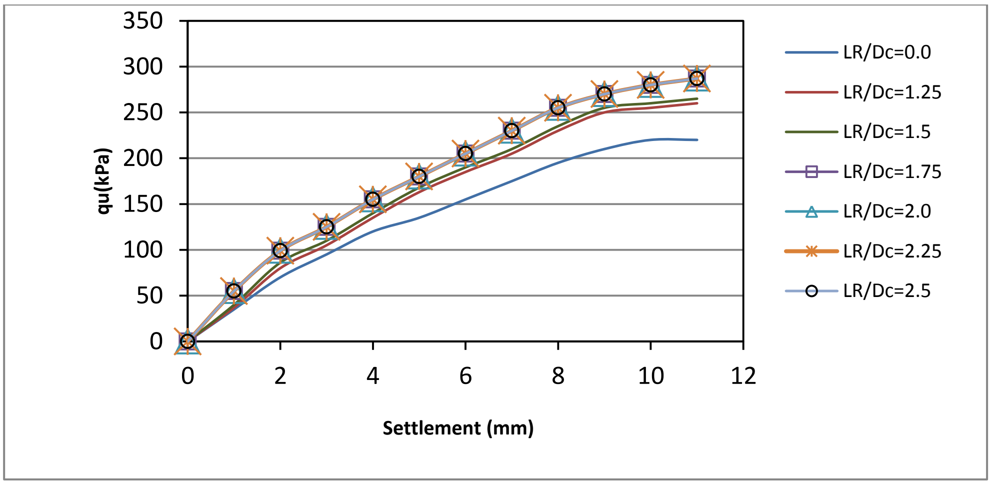


Figure (8): Ultimate bearing pressure – settlement curves for D_f/Dc=0.5, RD=80%

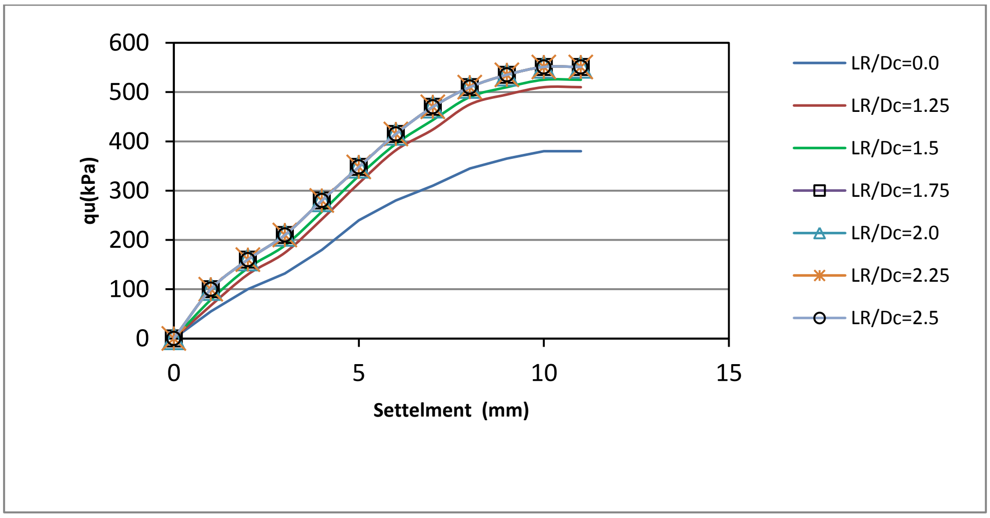


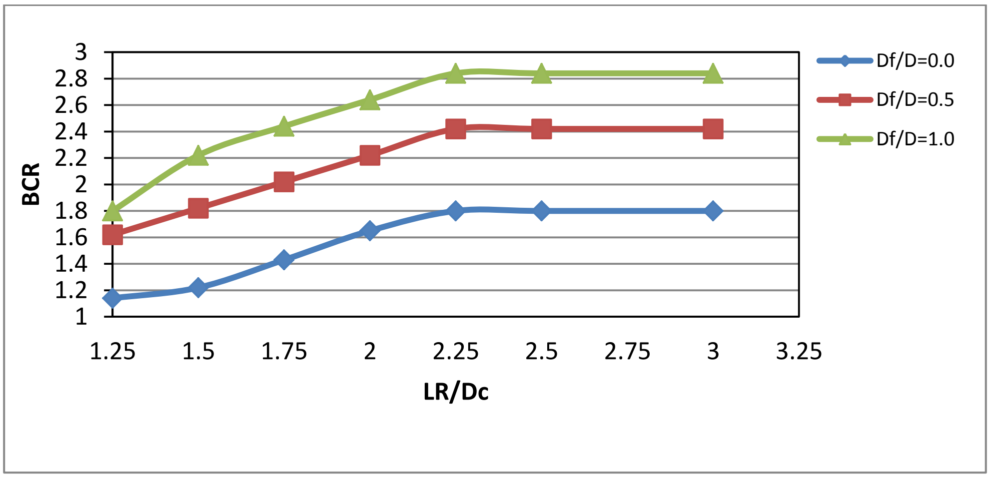
Figure (9): Ultimate bearing pressure – settlement curves for D_f/Dc=1.0, RD=80%

Table(3): Ultimate bearing capacity ($q_{u.}$)(kN/m^2) for different cases tested

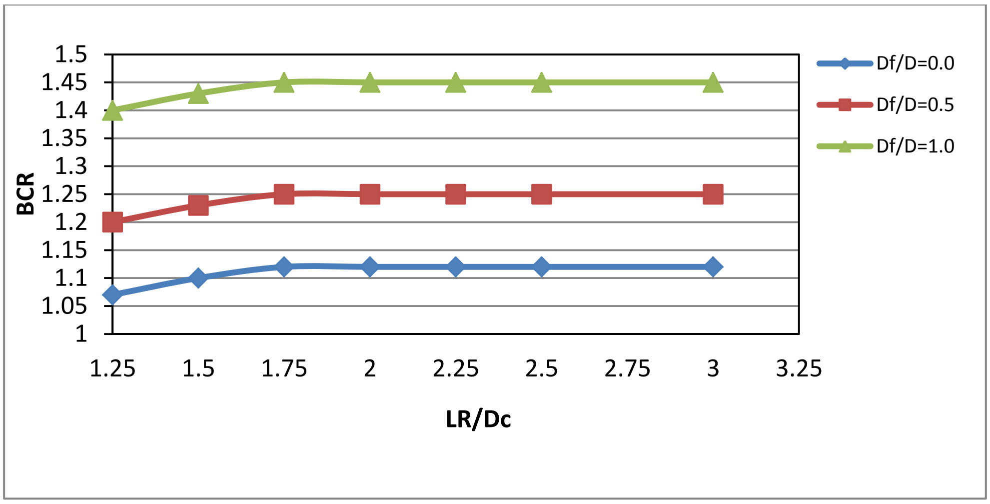
RD =60%								
LR/Dc D_f/Dc	0.0	1.25	1.50	1.75	2.0	2.25	2.50	3.0
0.0	100	114	122	143	165	180	180	180
0.5	110	178	200	222	244	266	266	266
1.0	160	288	355	390	422	454	454	454
RD=80%								
0.0	210	225	231	252	252	252	252	252
0.5	220	276	270	275	275	275	275	275
1.5	380	510	525	551	551	551	551	551

Figures (10and 11) show the relationship between bearing capacity ratio (BCR) and reinforcement length ratio (LR/Dc) for different depth ratio of footing (D_f/Dc) with two relative densities 60% and 80%. It can be seen that the bearing capacity ratio (BCR) increase with increasing reinforcement length ratio (LR/Dc) up to a certain value, after this value of (LR/Dc) the (BCR) not change (i.e. approximately remain constant).

The length of reinforcement ratio (LR/Dc) at which bearing capacity ratio remains constant is chosen as a effective length ratio. It can be also noticed that the effective length of reinforcement ratio (LR/Dc) affected by the relative density of sand, where effective (LR/Dc) for relative density 60% equal to 2.25 while it is equal to 1.75 for relative density 80%. This means that for soil with relative density 60%, the length of reinforcement (LR) required is more than for soil with relative density 80%. It should be mentioned that the depth ratio of footing (D_f/Dc) has no effect on the effective length of reinforcement ratio (LR/Dc). All the tests show a good increasing in the bearing capacity ratio (BCR) varying between (1.15 to 2.8) with using two layers of geogrid reinforcement. Also it is noted that the (BCR) for medium dense sand is larger than that for dense sand. This means that the reinforcement is more sufficient for medium sand than for dense sand



Figure(10): Bearing capacity ratio(BCR) versus length to diameter ratio (LR/Dc) ,for relative density (RD) 60%



Figure(11): Bearing capacity ratio(BCR) versus length to diameter ratio (LR/Dc) ,for relative density (RD) 80%

CONCLUSIONS

In the present research, the effective length of geogrid reinforcement layers in sand under circular footing was studied using experimental models. Based on the results and analysis of experimental model, the following conclusions can be summarized:-

1- The ultimate bearing pressure (q_u) increase with increasing length of reinforcement layer ratio (LR/Dc) up to a certain value. After this value of (LR/Dc) bearing pressure not change for any value of depth ratio (D_f/Dc) and relative density (RD %).

2- The effective length of reinforcement ratio (LR/Dc) affect by the relative density of sand.

3- The effective length of reinforcement ratio (LR/Dc) equal to 2.25 for sand with relative density 60%, while it is equal to 1.75 for sand with relative density 80%.

4- The effective length of reinforcement layer is not affected by depth ratio of circular footing. (D_f /Dc).

5- The bearing capacity of circular footing resting on sand increase with using two layers of geogrid reinforcement.

6- The enhancement in bearing capacity for medium sand is larger than that for dense sand when reinforcement the sand soil under circular footing.

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