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ORIGINAL PAPER

Experimental study and numerical modelling on the performance of circular footing resting on geogrid—reinforced granular soil bed

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Abstract

In the recent decade, the use of geogrid to improve the settlement behaviour of granular soil has become a major topic. So, applying geogrid for shallow foundation soil reinforcement is an important technique for improving the granular loose sand soil. In this study, the performance of a circular footing based on a reinforced granular soil bed was evaluated using comprehensive experimental work on thirteen (13) soil models. Comparison between reinforced and unreinforced condition under circular footing was carried. The depth of geogrid and the number of layers under circular footings was chosen as the various parameters in this study. The results revealed that, the soil's bearing capacity increase with 15.29%, 23.61%, 36.78%, and 42.14% using one, two, three, and four geogrid layers at (u/B) of 0.5, respectively. At (u/B = 0.8), sand's load-carrying capacity improves by 11.15%, 17.76%, 30.66%, and 38.55% for one, two, three, four layer of reinforcement using Geogrid, respectively. For one, two, three, four layer of reinforcement using Geogrid at (u/B = 1.0), the load carrying capacity of sand increases by 8.53%, 12.38%, 22.88% and 32.43%, respectively. In addition, to model and verify the experimental models, and to check the validity of the chosen computational processes, both a 2-D Finite Element Program GeoStudio 2018 and PLAXIS (2D) software were used. The results show that PLAXIS (2D) and GeoStudio 2018 can be used to simulate the settlement of loose sand soil under circular footing.

Keywords GeoStudio 2018 · Geogrid · Settlement · PLAXIS · Reinforced soil

Abbreviations

u	Location of the top layer of reinforcement from the bottom of foundation.
b	Length of reinforced layer.
B	Width of foundation.
h	The distance between consecutive layers of geogrid.
d	The depth from base of footing to the last layer of reinforcement.
BCR	Bearing capacity ratio

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Introduction

The foundation is the lowest part of the superstructure and it sits on the soil surface at various depths. Before any construction work begins, it's possible that a soil investigation may be required. According to Kiran and Bacha (2015) as the number of layers of reinforcement under circular footings increases, geogrid reinforcement reduces circular footing settlement by 40% and improves sand load bearing capacity by 5–10%.

Hariprasad & Umashankari, 2016 investigated whether a reinforced layered system improves the load carrying capacity of a model circular foundation over an unreinforced layered system (unreinforced aggregate layer overlying sand layer). They concluded that, he model footing's load-bearing capacity would be improved by strengthening the aggregate layer and adding geogrid reinforcement to the aggregate layer.

Kolay, Kumar, & Tiwari, 2013 studied the bearing capacity of shallow foundations reinforced with geogrid. They found that depending on the reinforcing structure and sand

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bed density, the improved bearing capacity ratio as a result of geogrid reinforcement ranged between 1.8 and 5.35.

Zidan, 2012 conducted a number of laboratory scale bearing capacity studies on various prestressed reinforcing layers on a model square foundation. They reached the conclusion that the depth of reinforcement, the intensity of pre-stress, and the direction of pre-stress all affect soil bearing capacity.

Rowshanzamir & Karimian, 2016 conducted a study on the impact of geogrid reinforcement on the bearing capacity of shallow foundations. They showed that the improved ratio of bearing capability due to geogrid reinforcement varied from 1.8 to 5.35 depending on the reinforcing configuration and sand bed density.

On a model square foundation, (Dhatrak & Khan, 2014), conducted a series of laboratory scale bearing capacity experiments on various prestressed reinforcing layers. They reached the conclusion that soil bearing capacity is affected by the depth of reinforcement, the intensity of pre-stress, and the direction of pre-stress.

Budania et al., 2017 evaluated the effect of geo-grid strengthening on sand carrying capacity in their research. As the depth of the first layer of reinforcement increased, the bearing capacity of sand increased significantly, according to their findings. They found that, the initial layer of geo-grid should be constructed at a depth of 0.5 times the breadth of the footing, and in terms of reinforced sand load carrying capacity, increasing the number of reinforcement layers from one to four created the best results.

The performance of loose sand soil reinforced with geogrid layers was investigated by Albusoda and Al-Saadi (2020). They found that the geogrid layer prevents soil particles from moving into the area around it, and that after soil reinforcement, the displacement of the soil beneath the footing significantly reduces the uplift of the soil layer behind the footing.

Chen, 2007 studied the advantages of strengthening shallow foundations to maximize bearing capacity and decrease settlement. He discovered that while the bearing capacity of reinforced soil improves as the number of reinforcement layers increases (at the same vertical spacing), the bearing capacity ratio (BCR) decreases. In the vast majority of these conditions, geogrid reinforcement outperforms geotextile for soil foundation.

Chakraborty & Kumar, 2014 estimated the bearing capacity of a rigid circular rough foundation applied over a soil mass reinforced with a single and a group of two layers of horizontal circular reinforcement sheets using upper bound finite element limit analysis and linear optimization. The results show that adding reinforcement to the soil medium increases bearing capacity significantly, especially when using two layers of reinforcing sheets.

Demir et al., 2013 investigated the bearing capacity of a circular foundation on a geogrid-reinforced granular fill layer overlaying a natural clay deposit in an experimental and numerical study. They discovered that adding geogrid reinforcement to granular fill improves footing stability by generating tensile tension.

Vijaya & Gangadhara, 2010 performed an experimental investigation on the efficacy of reinforced sand beds under repeated pressures in the presence of water. They reached the conclusion that water in the reinforced sand bed has a significant impact on the cycle resistance ratio and Settlement Ratio. Under a particular dynamic loading, the cyclic resistance ratio increases while the settlement ratio decreases for such sand beds.

Elleboudy et al., 2016) examined how geogrid performed in gravel roads that were subjected to repeated loads. Based on the findings of the experimental and numerical analyses, they determined that one geogrid layer should be positioned in the upper quarter of the base layer for the best outcomes. Adding a geogrid layer at the interface between the base course layer and the subgrade reduced vertical deformation depth by around 26%, and using two layers of geogrid at the interface and in the upper quarter of the base course layer increased bearing ability while reducing the required base course layer thickness by around 34%.

Vijay & Maruthi, 2018) presented the results of laboratory model experiments of square footings supported on geogrid reinforced sand bed for various sand bed densities under loading conditions. The results reveal that load carrying capacity increases until the U/B ratio reaches 0.4, then decreases.

Chethan et al., 2017) used a series of laboratory model tests to investigate the bearing capacity of circular footings lying on reinforced sand bed. The tests were conducted on medium dense sand, and the results revealed that under circular footings, reinforced sand has a 10% higher load bearing capacity than unreinforced sand, and that the load carrying capacity of sand rises by 5% to 10% as the number of layers of reinforcement is increased.

In this study, experiments were carried out on both unreinforced loose sand soil and loose sand soil reinforced with Geogrids. Experiments with four layers of Geogrids at various spacing's were compared to those with only unreinforced loose sand. Reinforced soil has several advantages, including increased bearing capacity, reduced differential settlements, ease of construction, and cost savings. A 2-D Finite Element Program GeoStudio 2018 and the PLAXIS (2D) programme were also used to simulate and evaluate the experimental models in this research. The bearing capacities and settlements of reinforced soil foundations calculated with GeoStudio 2018 and PLAXIS (2D) Finite Element Programs are generally compatible with the laboratory model test results in this research.

Aim of the current study

(a) To analyze the performance of a circular footing supported by a vertically loaded reinforced loose sand bed.
(b) The effect of increasing the number of geogrid layers that were used to improve the bearing capacity of the loose sand soil.
(c) To investigate the effect of different reinforcement spacing on bearing capacity.
(d) Investigate the load settlement characteristics of both reinforced and unreinforced circular footings.
(e) Validating the chosen computational processes by comparing the results of physical laboratory model tests to those obtained using GeoStudio 2018 and PLAXIS (2D) software.
(f) This research deals with improving the properties of loose and soils using geogrids. The novelty in this research is a simulation of the laboratory model that was studied using the FEM programs to determine the efficiency of these programs in predicting laboratory results.

Experimental program

The Geotechnical Engineering Laboratory, Faculty of Engineering, and EL-Minia University used a thorough experimental scheme for this study to evaluate the performance of a circular footing lying on a reinforced loose sand bed subjected to vertical load. A total of thirteen (13) soil models were subjected to extensive testing. Geogrid is used to strengthen the loose sand bed. This study analyses and reports the findings of the tests and observations made during the experiments.

Materials and equipment's used

In the experiments, biaxial Geogrid and loose sand were used. The equipment used in this study included a steel circular foundation, hydraulic jack, proving ring, and dial gauges.

Test sand (sample collection and characteristics of sand)

The sand used in this project came from a location in Damaris, EL-Minya. In the model experiments, a cohesionless, dry, and clean sand was used as the base. Laboratory experiments revealed the properties of sand soil, as illustrated in Table 1 and Fig. 1. (ECP 202–2001). The relative density, and internal friction angle of sand of 33 ° was found to be 35% in a direct shear test box. The sand in this experiment was in a loose form.

Table 1 Geotechnical parameters of the sand that was used in this investigation

Properties	Value	Unit
D_{10}	0.24	mm
D_{30}	0.35	mm
D_{60}	0.55	mm
Uniformity coefficient (Cu)	2.29	–
Curvature coefficient (Cc)	0.93	–
Classification of soil (USCS)	SP	–
Relative density (RD)	35	%
Dry unit weight (γ_{dry})	16.9	kN/m^3
Friction internal angle (Ø)	33	°
Cohesion (C)	Zero	kN/m^2
Specific gravity (Gs)	2.61	–
Modulus of elasticity (E)	18,000	kN/m^2

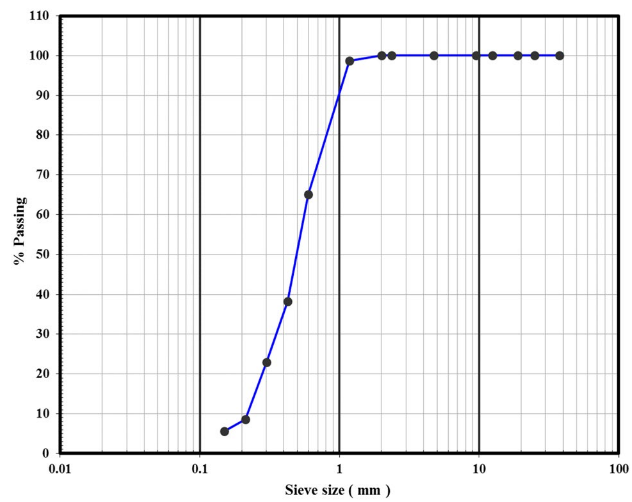

Fig. 1 Particle size distribution for sand used in the study

Geogrid

Geogrid is a type of geosynthetic that is used to reinforce foundations. They have a community of big openings that are evenly dispersed in both transverse and longitudinal directions. The perforations allow sand particles on both sides of the geogrid to have direct contact with each other, improving the geogrid-sand interaction. Polypropylene and high-density polyethylene are used to construct geogrids, which have a high modulus, but they can be made naturally, ultrasonically, or glue-bonded.

Throughout the investigation, Biaxal Geogrid (CE131) is used to reinforce the sand bed in the experimental models.

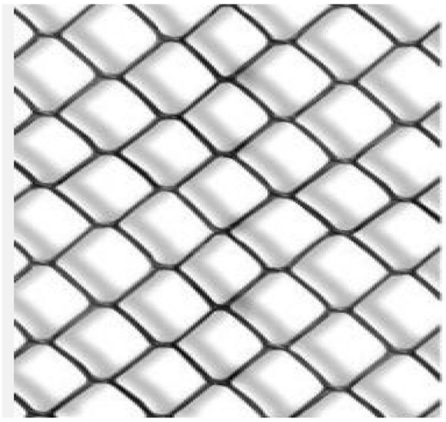

Fig. 2 Geogrid used in this study]. (Elleboudy et al., 2016)

Table 2 Physical and mechanical properties of geogrid (CE131)

Properties	Geogrid (CE131)	Unit
Form	Sheet	–
Colour	Black	–
Aperture shape	Square	–
Width	2.0	m
Length	30	m
Mesh aperture size	27 × 27	mm
Thickness of Mesh	5.2	mm
Tensile strength	5.8	kN/m
Mass per unit area	660	g/m^2
Elongation at max. load	16.5	%
Young's modulus, E	320	MPa

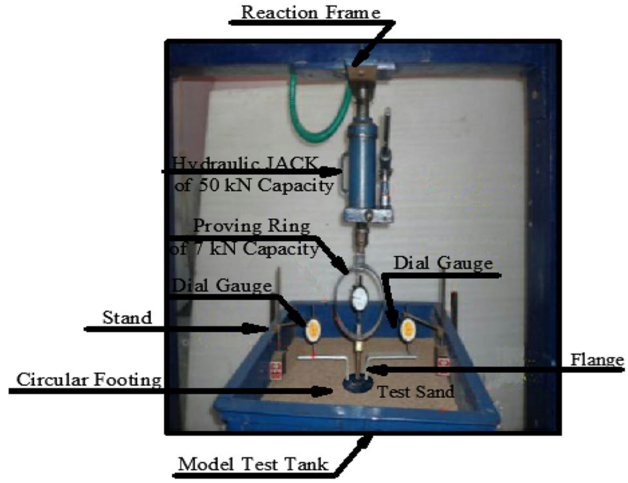

Fig. 3 Picture of test setup

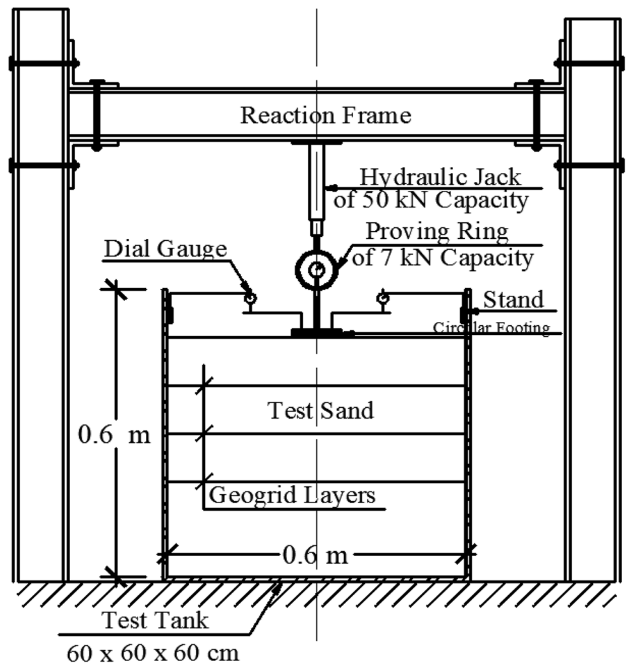

Fig. 4 Model footing tests geometry setup

Figure 2 shows an Al-Shrouk Industry Biaxal Geogrid (CE131) manufactured in Egypt. The manufacturer's physical and mechanical parameters for this geogrid are illustrated in Table 2.

Biaxial geogrid is made of polypropylene or polyethylene as raw materials by plasticizing, extruding, punching, heating, longitudinal stretching and transverse stretching. Bi-axial geogrids have a high tensile strength in both the longitudinal and transverse directions. This structure provides an ideal interlocking system for more effective force bearing and diffusion in the soil and is suitable for foundation reinforcement of large areas with permanent load bearing.

Model test tank

The tank size was chosen to minimise its experimental effect on footing pressure settlement behaviour, according to ElSaied (2017). At least six times the breadth of the footing, the tank's minimum height and width are required. The test tank is 600 mm in length, 600 mm wide, and 600 mm in depth, was designed and produced to carry out the test, as illustrated in Figs. 3, 4, and The test tank was made of steel with a thickness of 2 mm. The tank is braced on all four sides to prevent it from bulging during testing. The tank's interior walls were smoothed to lessen side friction.

Fig. 5 Model of circular footing

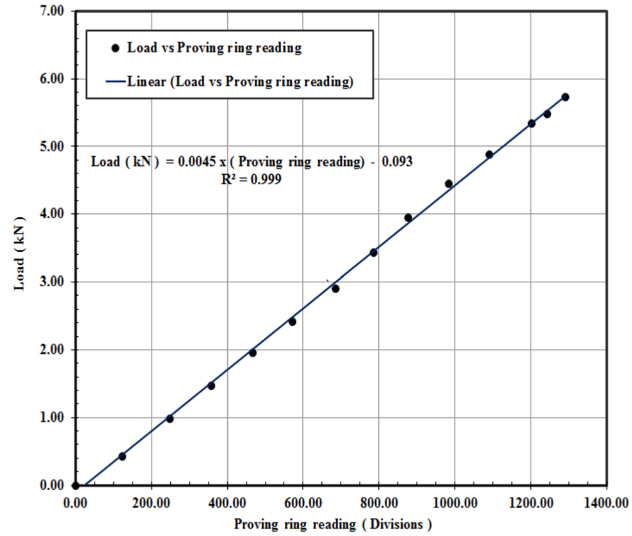

Fig. 7 Calibration chart of proving ring

Fig. 6 Hydraulic jack used

Fig. 8 Dial gauge used

Model footing

A steel model footing with a diameter of 100 mm and a thickness of 10 mm is employed for experimental purposes. A small groove runs through the middle of the footing, as shown in Fig. 5, to aid in the application of load.

Hydraulic jack

The hydraulic jack connecting to the proving ring with a maximum load of 50 kN is shown in Fig. 6.

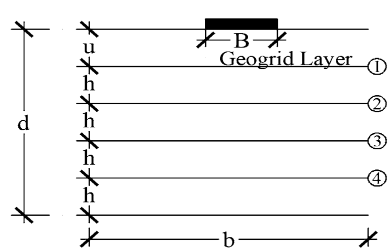

Fig. 9 Across Shows a cross-section of a sand bed with multiple number of reinforcement

Proving ring

During this experimental investigation, a proving ring with a capacity of 7 kN was used to test the applied loads on the base. The proving ring was calibrated with a universal compression machine. As shown in Fig. 7. The calibration equation was determined to be as follows:

Load (kN) = 0.0045 × Proving ring reading - 0.093.

The top of the proving ring is attached to the hydraulic jack, while the bottom is in contact with the metallic ball on the footing. Between the footing and the proving ring, a strong metallic ball acts as a hinge.

Dial gauge

To measure the average settlement of the footing, two dial gauges with a least count of 0.002 mm are provided, one on each footing, as shown in Fig. 8. Two dial gauges were

Table 3 Details of testing programme

Test no	Geogrid reinforcement		
	u / B	u, h	No. of layers
(1)	–	–	–
(2)	0.5	u = 5 cm	1
(3)		h = 5 cm	2
(4)		h = 5 cm	3
(5)		h = 5 cm	4
(6)	0.8	u = 8 cm	1
(7)		h = 8 cm	2
(8)		h = 8 cm	3
(9)		h = 8 cm	4
(10)	1.0	u = 10 cm	1
(11)		h = 10 cm	2
(12)		h = 10 cm	3
(13)		h = 10 cm	4

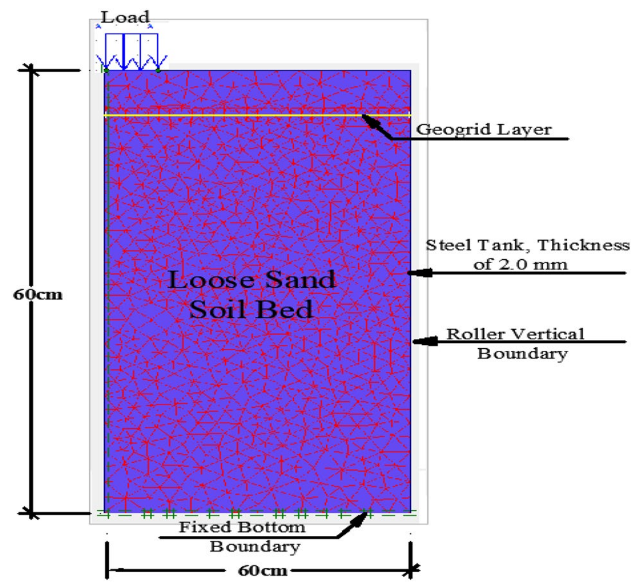

Fig. 11 Numerical model of loose sand soil bed reinforced with one geogrid layer

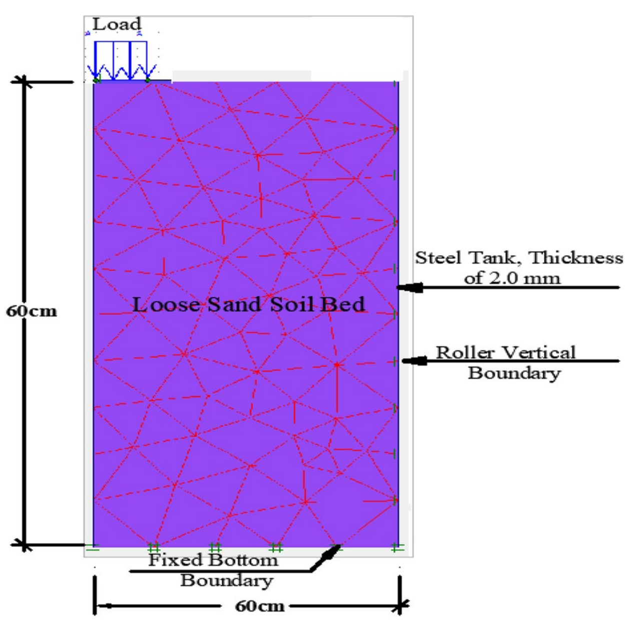

Fig. 10 Numerical model of loose sand soil bed without reinforcement

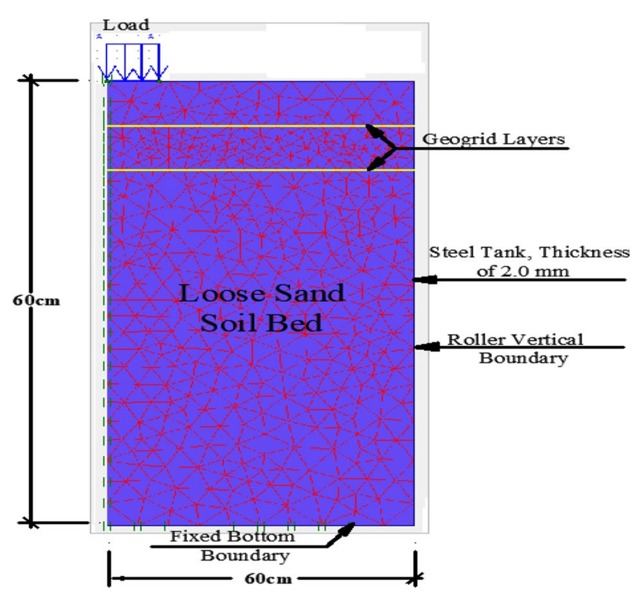

Fig. 12 Numerical model of loose sand soil bed reinforced with two geogrid layer

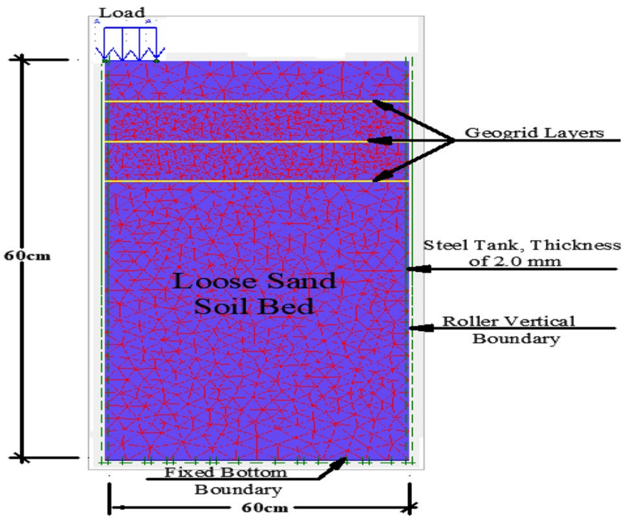

Fig. 13 Numerical model of loose sand soil bed reinforced with three geogrid layer

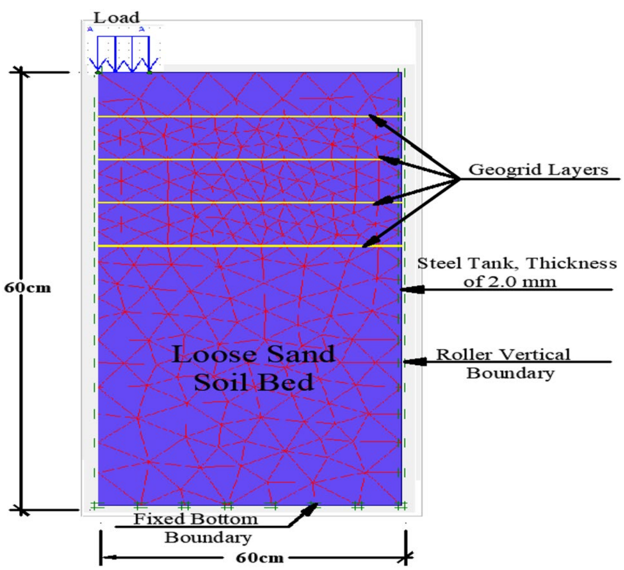

Fig. 14 Numerical model of loose sand soil bed reinforced with four geogrid layer

Table 4 Material properties used for PLAXIS models

Material		Properties		
		Unit weight	E-modulus	Poisson's ratio
Sand Soil	Value	16.9	18,000	0.30
	Unit	KN/m^3	KN/m^2	–
	Reference	Lab. Test	Lab. Test	[18]
Steel Tank	Value	78.5	2×10^8	0.30
	Unit	KN/m^3	KN/m^2	–
	Reference	[19]	[20]	[18]

Table 5 Properties of Geogrid used for PLAXIS models

Material		Properties		
		Mass per unit area	E-modulus	Mesh thickness
Geogrid	Value	600	320×10^3	5.2
	Unit	g /m^2	KN/m^2	mm
	Ref	Geogrid (CE131)	Geogrid (E131)	Geogrid (CE131)

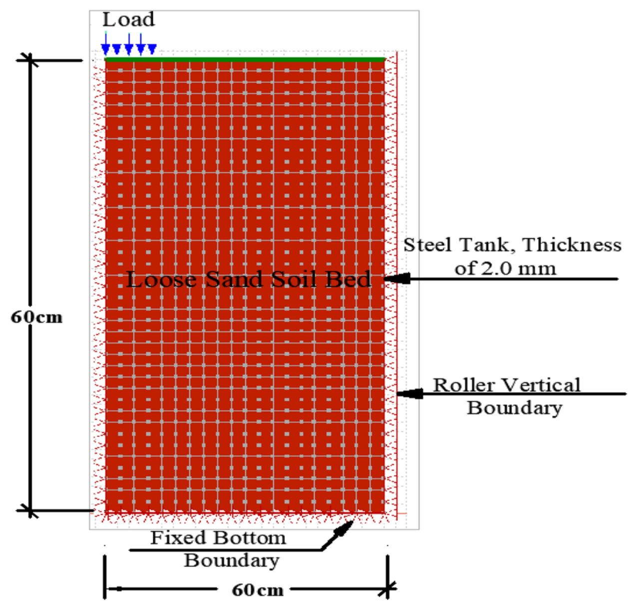

Fig. 15 Numerical model of loose sand soil bed without reinforcement

carefully placed on the flanges and two on the footing to measure the settlement of the footing. As shown in Figs. 3 and 4, a stand is used to support the dial gauge on footing.

Model test and methodology

General

In this experimental study, a laboratory model test was carried out on a circular base lying on loose sand and reinforced with multi-layered geogrid. Thirteen (13) soil models with 16.9 kN/m^3 in density and varying numbers of reinforcing geogrid layers were subjected to extensive testing (1, 2, 3, and 4). This study analyses and reports the results of the tests and observations made during the experiments.

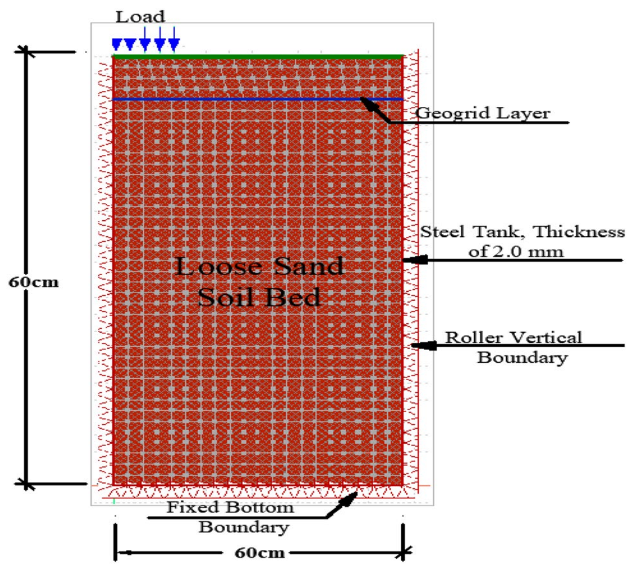

Fig. 16 Numerical model of loose sand soil bed reinforced with one geogrid layer

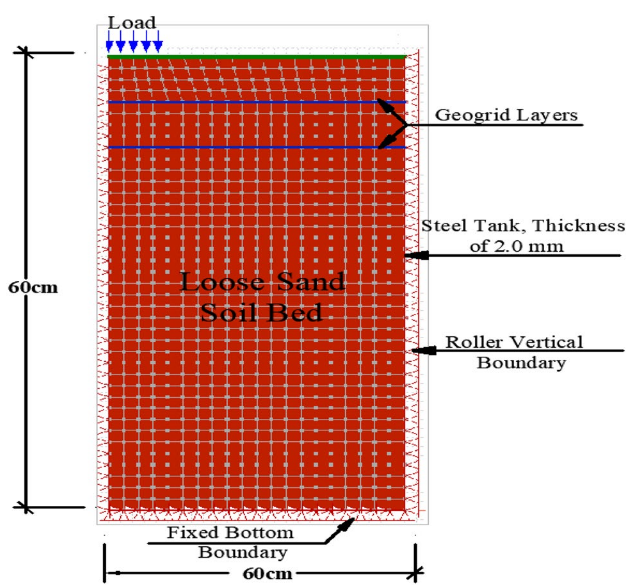

Fig. 17 Numerical model of loose sand soil bed reinforced with two geogrid layer

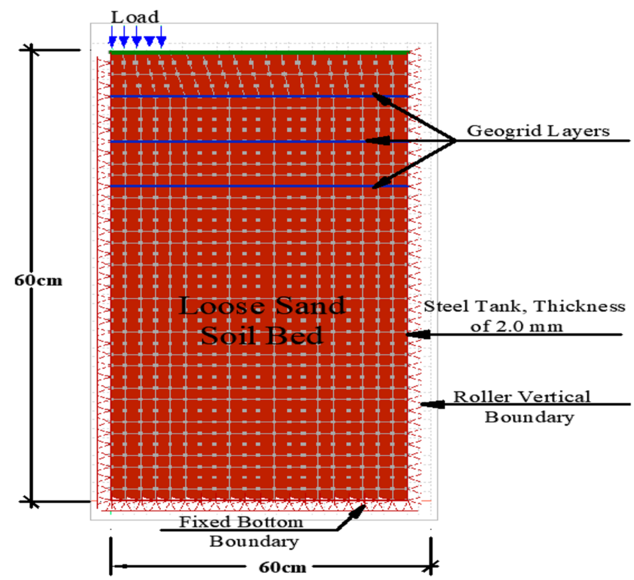

Fig. 18 Numerical model of loose sand soil bed reinforced with three geogrid layer

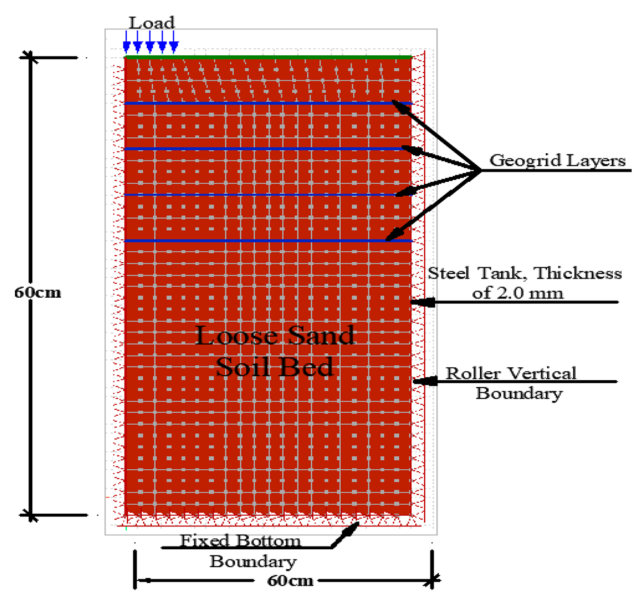

Fig. 19 Numerical model of loose sand soil bed reinforced with four geogrid layer

Foundation preparation

Placement of sand

The granular sand with a particle size of 4.75 mm passed through IS sieving was filled into the test tank with internal dimensions of 600 mm × 600 mm × 600 mm. After marking the estimated height of the steel tank, the tank was filled to that height (i.e. each five, eight, and ten centimetre height) as the same way of Hakeem (2018). The task was completed with the aid of a heavy hand compaction hammer. Hammers were dropped from a predetermined height, with considerable care taken to guarantee that the hammer drops fell uniformly and consistently on the same layer as well as all compacted layers. This kind of compaction was employed to ensure that the earth was compacted evenly and that the required unity weight was spread evenly.

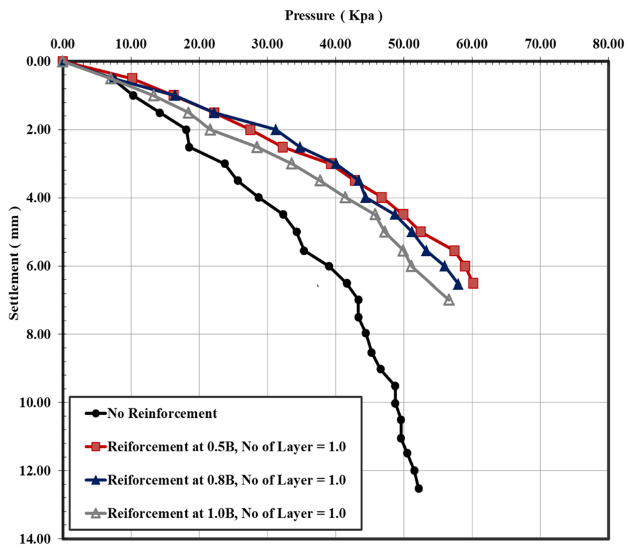

Fig. 20 Effect of (u/B) ratio on bearing capacity, sand with one layer of geogrid reinforcement

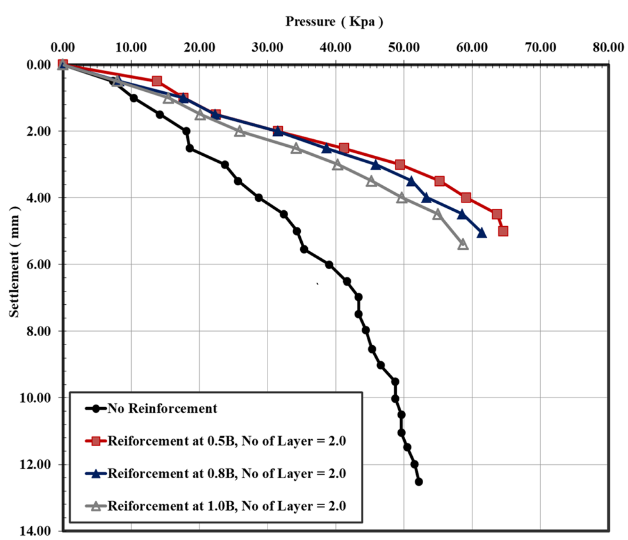

Fig. 21 Effect of (u/B) ratio on bearing capacity, sand with two layer of geogrid reinforcement

Placement of geogrid

Figure 9 shows a circular foundation with a width " B " that is supported by Geogrid reinforced sand. Geogrid is divided into four layers, each of which has a width of " b ". The top layer of geogrid is placed 'u' below the foundation's bottom layer. The spacing between consecutive layers of geogrid is " h ", while the depth from the footing's base to the last layer of reinforcement is " d ". The depth of the first layer " u " from the bottom of the footing is 5 cm, 8 cm, and 10 cm, and the distance between

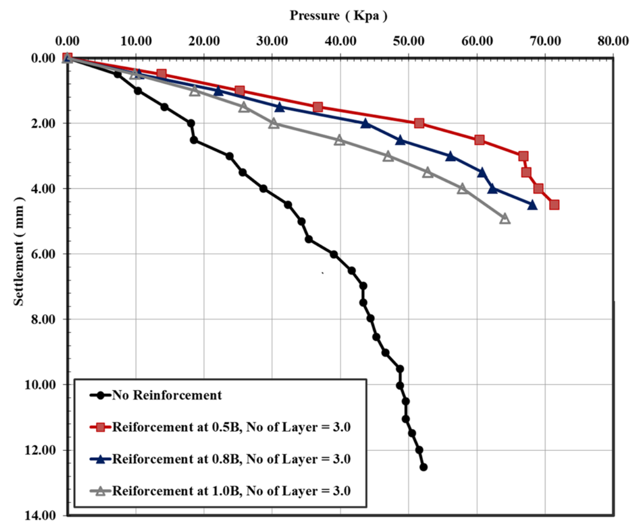

Fig. 22 Effect of (u/B) ratio on bearing capacity, sand with three layer of geogrid reinforcement

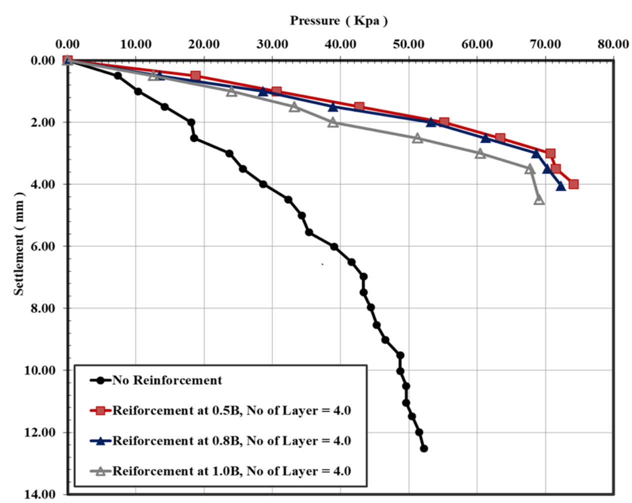

Fig. 23 Effect of (u/B) ratio on bearing capacity, sand with four layer of geogrid reinforcement

each subsequent layer " h " is 5 cm, 8 cm, and 10 cm, respectively.

Model test procedure

(a) The weight was carried vertically and centrally to the footing after levelling the surface and placing the footing on a predetermined alignment. Then, using the metal bar and hydraulic jack, connect the footing to the metal bar.

(b) The initial readings of two dial gauges are monitored once they touch the surface footing on the opposite corner of the footing.

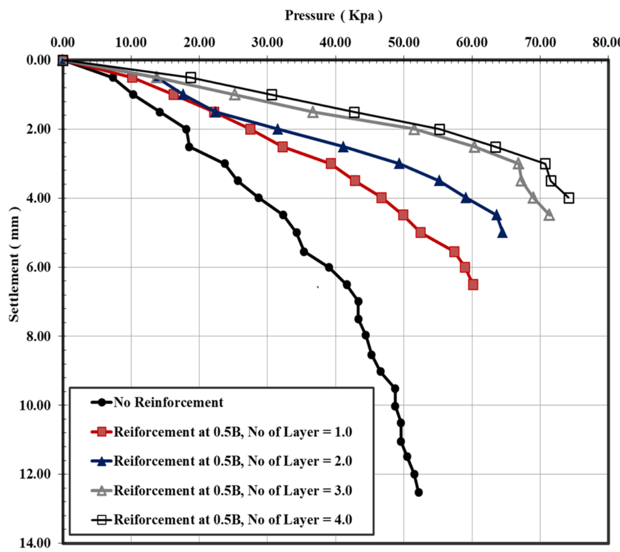

Fig. 24 Effect of no of layers on bearing capacity, for (u/B = 0.50) ratio

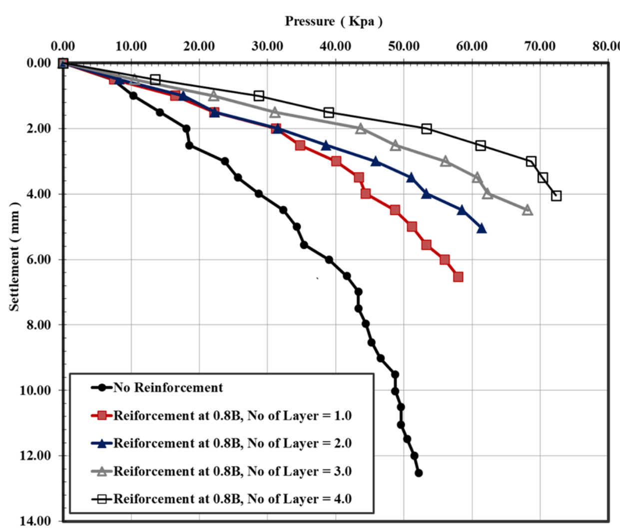

Fig. 25 Effect of no of layers on bearing capacity, for (u/B = 0.80) ratio

(c) After connecting the proving ring to the rigid frame, the load was applied, and the weight was placed on the footing, which was allowed to settle. After each load increment, two dial gauge readings and the footing settlement was monitored until it was stabilised. When the load was constant, the equipment was removed after the test, the tank was emptied, and then the tank was filled again for the following set of tests.

(d) The previous procedures were repeating again as shown in Fig. 9.

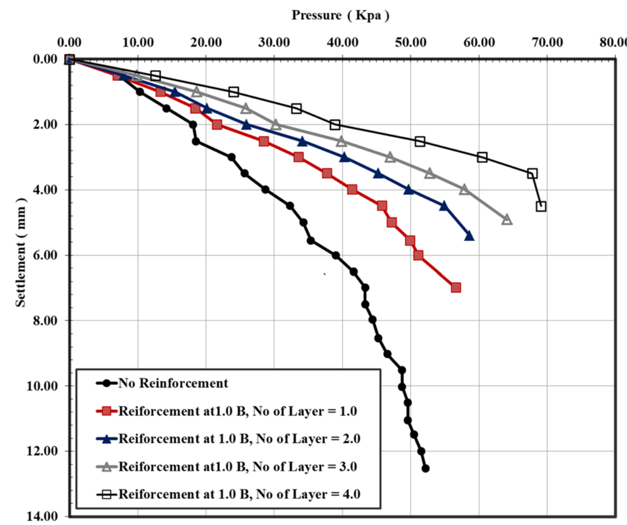

Fig. 26 Effect of no of layers on bearing capacity, for (u/B = 1.0) ratio

Table 6 The experimental model's estimated bearing capacity values

(u/B)	No. of layer	Bearing capacity(kN/m^2)
0.50	1	60.16
	2	64.50
	3	71.37
	4	74.17
0.80	1	58
	2	61.45
	3	68.18
	4	72.30
1.0	1	56.63
	2	58.64
	3	64.12
	4	69.10

Model test series

Total thirteen (13) numbers of tests are conducted with circular footing under reinforced and unreinforced condition as indicated in Table 3.

Numerical simulation

Geometry of the 2D problem using PLAXIS program

In this study, a physical laboratory model was used to investigate the performance of a circular footing resting on a reinforced loose sand base. Using the 2-D finite element

Table 7 Maximum difference between experimental and numerical model results

(u/B)	No. of layer	Difference between Exp. and Geostudio (mm)	Difference between Exp. and Plaxis (mm)
–	Without	0.51	0.52
0.50	1	0.09	0.41
	2	0.50	0.50
	3	0.61	0.39
	4	0.51	0.09
0.80	1	0.16	0.24
	2	0.60	0.25
	3	0.60	0.10
	4	0.65	0.45
1.0	1	0.17	0.29
	2	0.27	0.50
	3	0.69	0.16
	4	0.50	0.10

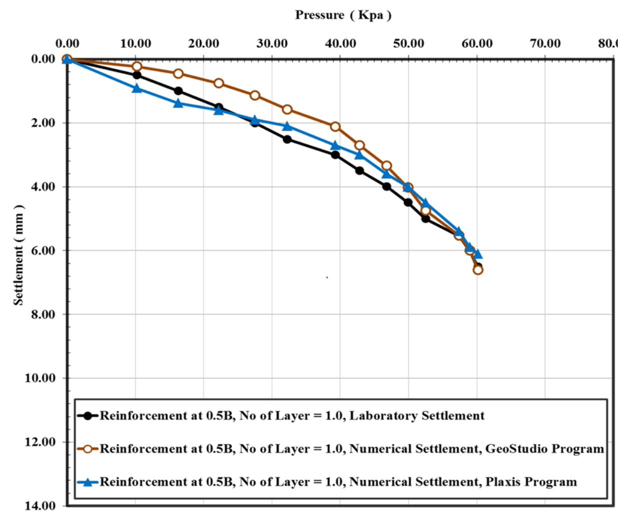

Fig. 28 Pressure versus settlement curves for reinforced loose sand bed with one layer Geogrid at (u/B = 0.5)

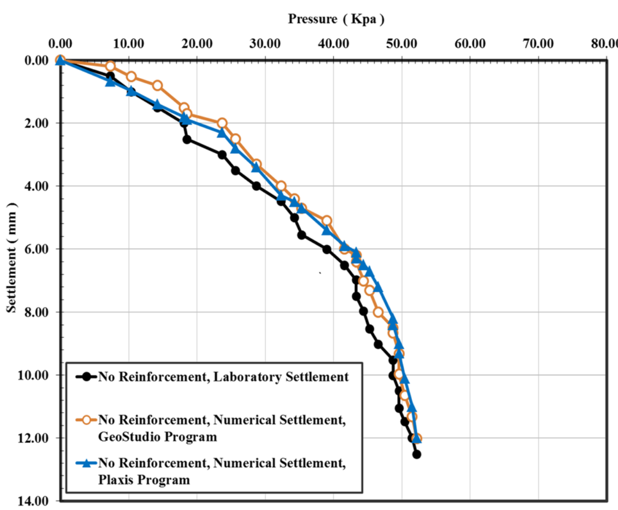

Fig. 27 Pressure versus settlement curves for unreinforced loose sand bed

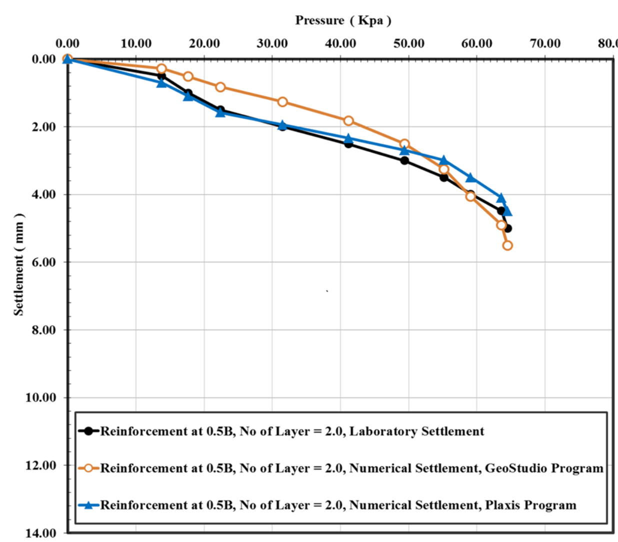

Fig. 29 Pressure versus settlement curves for reinforced loose sand bed with two layer Geogrid at (u/B = 0.5)

tool PLAXIS, the experimental models were then modelled and verified using 2D numerical analysis. The geometry of the numerical 2D model is shown in Figs. 10, 11, 12, 13, 14. Table 3 lists all of the testing parameters used in these numerical models. The experimental and numerical model results were then discussed.

Boundary conditions and mesh generation

By applying vertical load to the soil surface, boundary conditions were applied. In terms of boundary fixities, the model could only deform vertically (i.e. roller boundaries) while being totally fixed along the model base. The finite element model (or mesh) can be constructed once the geometry model is complete, as shown in Figs. 10, 11, 12, 13, 14.

Tables 4 and 5 show the parameters that were generated using similar methods to those performed in the construction of experimental models. Researchers were able to assess the bearing capacity of the loose sand soil bed by adjusting the model to simulate the interaction between settlement and applied loads. Finally, the physical model measurements were compared to the numerical results.

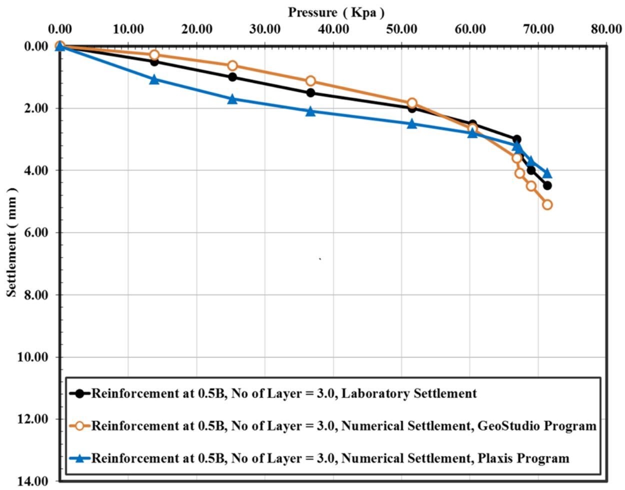

Fig. 30 Pressure versus settlement curves for reinforced loose sand bed with three layer Geogrid at (u/B = 0.5)

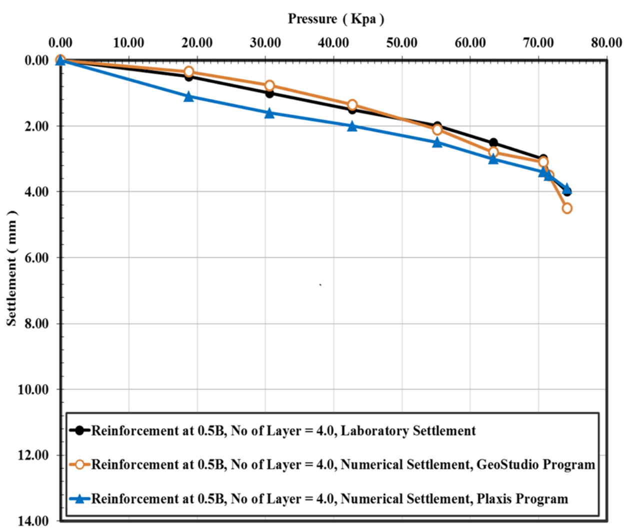

Fig. 31 Pressure versus settlement curves for reinforced loose sand bed with four layer Geogrid at (u/B = 0.5)

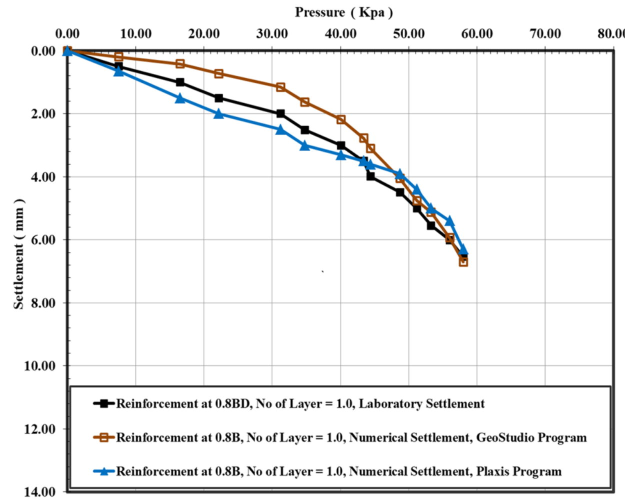

Fig. 32 Pressure versus settlement curves for reinforced loose sand bed with one layer Geogrid at (u/B = 0.8)

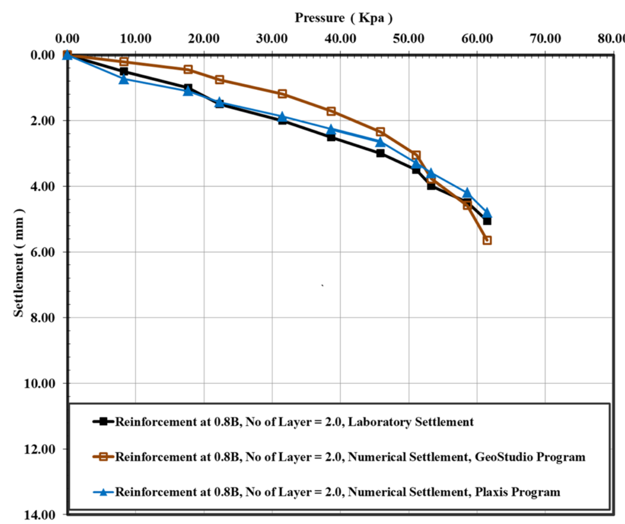

Fig. 33 Pressure versus settlement curves for reinforced loose sand bed with two layer Geogrid at (u/B = 0.8)

Geometry of the 2D Problem using GeoStudio 2018 Program

A physical laboratory model was built to test the performance of circular footing resting on a reinforced loose sand substrate, as previously mentioned. After that, using the 2-D finite element tool GeoStudio 2018, the experimental models were developed and confirmed using 2D numerical analysis. The geometry of the numerical two-dimensional model is shown in Figs. 15, 16, 17, 18, 19. To assign boundary conditions, a vertical load was applied to the soil surface. Only the vertical sides (i.e. roller boundaries) of the model were allowed to deform while staying entirely fixed along the model base. Once the geometry model is complete, the finite element model (or mesh) can be constructed. From 15 to 19, see Figs. 15, 16, 17, 18, 19. Table 3 also provides a list of all the testing parameters used in these numerical models. The experimental and numerical model results were then discussed.

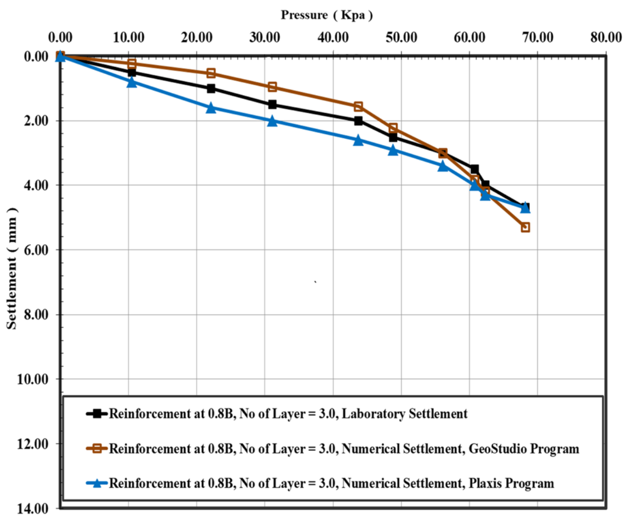

Fig. 34 Pressure versus settlement curves for reinforced loose sand bed with three layer Geogrid at (u/B = 0.8)

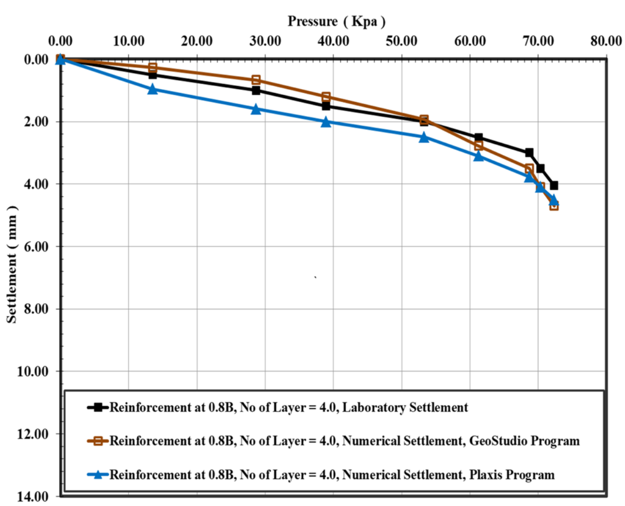

Fig. 35 Pressure versus settlement curves for reinforced loose sand bed with four layer Geogrid at (u/B = 0.8)

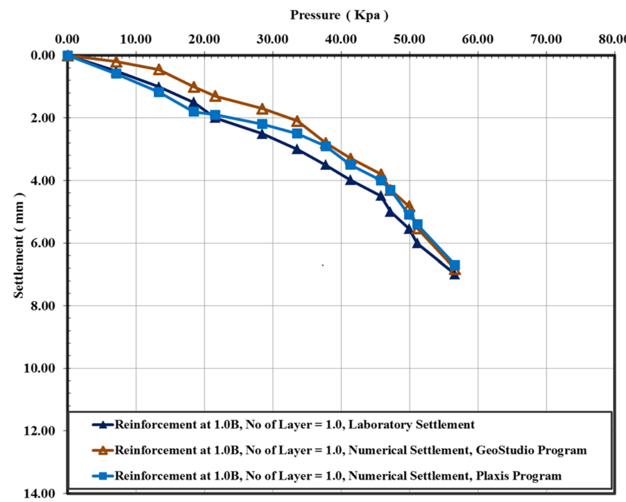

Fig. 36 Pressure versus settlement curves for reinforced loose sand bed with one layer Geogrid at (u/B = 1.0)

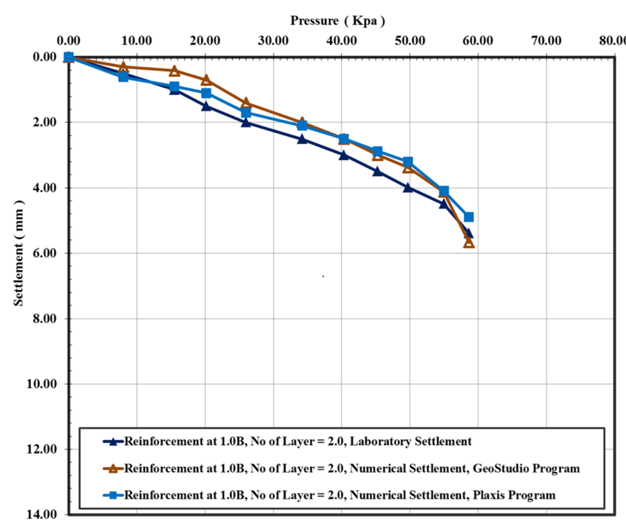

Fig. 37 Pressure versus settlement curves for reinforced loose sand bed with two layer Geogrid at (u/B = 1.0)

Material models' parameters

Tables 4, 5, list all of the soil parameters and geogrid used in these models. The model was adjusted to simulate the relationship between settlement and applied loads, allowing researchers to estimate the bearing capacity of the loose sand soil bed. Finally, the numerical results obtained were compared to the physical model measurements.

Results and discussion

General

Load testing was carried out on a model circular foundation with a diameter of 10 cm that has been resting on unreinforced and reinforced sand substrates. Multiple geogrid layers (1, 2, 3, 4) have been added to prepare the reinforced sand bed. The settlement of each load increment is recorded, and the test result is displayed as a load settlement curve.

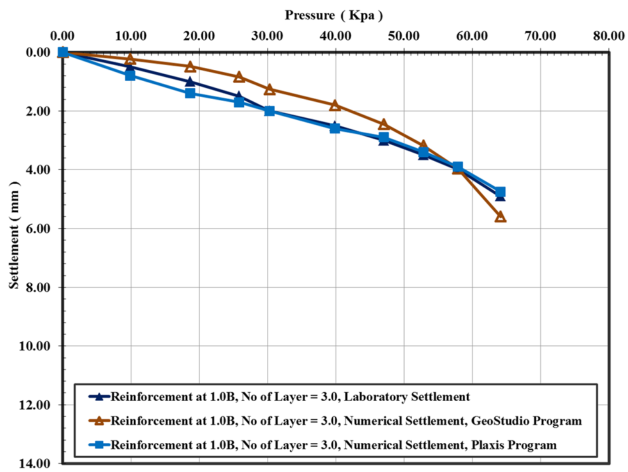

Fig. 38 Pressure versus settlement curves for reinforced loose sand bed with three layer Geogrid at (u/B = 1.0)

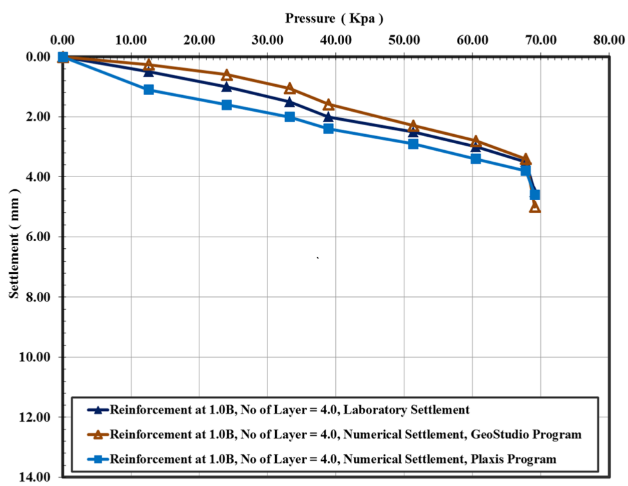

Fig. 39 Pressure versus settlement curves for reinforced loose sand bed with four layer Geogrid at (u/B = 1.0)

Effect of (u / B) ratio on bearing capacity of circular footing for experimental work.

For experimental models, Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 show the relationship between settlement and applying pressure. The bearing capacity values for these soils of varying (u/B) and number of geogrid layers are included in the Table 6. As (u/B) ratio increases the bearing capacity decreases Table 7.

Effect of number of geogrid layers ratio on bearing capacity of circular footing for experimental work

The effect bearing capacity of loose sand under circular footing increases as the number of layers increases, as illustrated in Table 5 and as shown in Figs. from 24,25, 26.

Comparison between experimental and numerical results

The relationship between settlement and applied pressure for loose sand soil is shown in Figs. 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, as measured in laboratory models and predicted using numerical models (Plaxis & Geostudio 2018). The numerical and experimental results were found to be in good agreement, with a maximum average difference as shown in Table 6.

Figures (27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39) show that the developed GeoStudio 2D and PLAXIS model successfully predicted the relationship between settlements and applying pressure. The difference in settlement values between numerical model results and laboratory model measurements may be due to one or more of the following factors:

- Errors in laboratory monitoring settlement measurements.
- Friction between sand and tank walls.
- Friction between sand bed and Geogrid layers, which might affect settlement measurements.
- The use of traditional methods to calculate the settlement, which affects the accuracy of the results.
- May be irregular distribution of sand, which affects the accuracy of the results.

Conclusions

The results of laboratory model tests aimed at evaluating the ultimate bearing capacity of a circular foundation supported by a multi-layered geogrid reinforced sand substrate and exposed to vertical centric load were recently reported. The following are recommended conclusions of this study: -

1. The load bearing capacity of the sand bed decreases as the u/B ration increases, indicating that the load carrying capacity decreases as the depth from the base footing to the first layer of reinforcement increases.
2. The load carrying capacity of sand increases by 15.29%, 23.61%, 36.78%, and 42.14% for one, two, three, four layer of reinforcement using Geogrid at (u/B = 0.5), respectively.

3. For one, two, three, and four layers of reinforcement using Geogrid, the load carrying capacity of sand increases by 11.15%, 17.76%, 30.66%, and 38.55%, respectively, at (u/B = 0.8).
4. The load carrying capacity of sand improves by 8.53%, 12.38%, 22.88%, and 32.43%, respectively, with one, two, three, and four layers of reinforcement using Geogrid at (u/B = 1.0).
5. For one, two, three, four layer of reinforcement using Geogrid at (u/B = 0.5), the settlement decreases by 48%, 60.06%, 64.14%, and 68.13%, respectively.
6. At (u/B = 0.8), the settlement of sand decreases by 47.77%, 59.66%, 62.5%, and 66.13% for one, two, three, four layer of reinforcement using Geogrid, respectively.
7. Also, the settlement of sand decreases by 44.16%, 56.1%, 60.7%, and 64.01% for one, two, three, four layer of reinforcement using Geogrid at (u/B = 1.0), respectively.
8. In this study, GeoStudio 2018 was used to simulate the settlement of flexible foundations on loose sand soils using the PLAXIS finite element 2D software. The investigation found that, when compared to the laboratory model, the numerical model produces satisfactory results in all of the cases studied.
9. To demonstrate the relationship between settlement and applied pressure, the proposed numerical model was tested by comparing FEM findings with laboratory observations.

Recommendations for future work

To avoid structural overloading, more study is needed to improve soil bearing capacity under various conditions. The research can be carried out under the following cases.

- The study can be done on a variety of soils with different properties.
- The study can be conducted on a variety of sands and in a variety of settings.
- The study can be carried out on a variety of geogrids of varied strengths.
- The experiment can also be carried out by changing the sizes of the same type of footing.
- In this study, Plaxis and Geostudio programs were used to simulate the performance of circular footing resting on Geogrid – reinforced sand, In the future study, the author recommends using another software such as ABAQUS, Midas, Flac to simulate these cases.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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