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Execution and Performance Of Strip Footing On Multistratified Geogrid Reinforced Sand Bed

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Abstract: *Since the publication of Terzaghi's theory on the ultimate bearing capacity of shallow foundations in 1943, results of numerous studies—both theoretical and experimental—by various investigators have been published. Most of the studies relate to the case of a vertical load applied centrally to the foundation. Meyerhof (1953) developed empirical procedures for estimating the ultimate bearing capacity of foundations subjected to eccentric and inclined loads. Based on the review of the existing literature on the bearing capacity of shallow foundations, it appears that limited attention has been paid to estimate the ultimate bearing capacity when the foundation is subjected to both eccentric and inclined load and the objective of present study stems from this paucity. Besides, only a few studies have been made to estimate the average settlement of embedded footings when subjected to eccentric load. The braced soil is the earth where the metallic, produced or geogrids are given to work on its planning conduct. The procedure of ground improvement by giving stronghold was moreover eventually in previous occasions. Babylonians produced ziggurats more than 3,000 years back using the rule of soil support. A piece of the Great Wall of China is in like manner an instance of reinforced soil improvement. Essential norms covered up reinforced soil improvement was not completely investigated till Henry Vidal of France who showed its wide application and developed a sound arrangement technique. A further adjusted interpretation of soil fortress was achieved by Lee who suggested a great deal of plan limits for soil fortified constructions in 1973.*

1. Introduction

Geogrids are typically used for:-

1. Slope Reinforcement: Highway embankments, overpasses, landslide or erosion- prone surfaces and landfill walls.
2. Base Reinforcement: Foundations for roads, parking lots, railroad track beds, airport tarmacs and runways.
3. Wall Reinforcement: Retaining walls, airport noise barriers, bridge supports and sea walls.
4. Berm Reinforcement: Spillway channels for earthen dams, levees and waste containment ponds.

Till date, several laboratory model tests have been carried out relating to the Load Bearing Capacity of Shallow Foundations supported by sand reinforced with various materials such as geogrids, geotextiles, rope fibers, metal strips and bars.

The use of geogrids for soil reinforcement has greatly increased over the last decade primarily because of following reasons:

1. Geogrids are dimensionally stable.
2. have high tensile modulus (that means low strain at high load)
3. open grid structure (that provides enhanced soil reinforcement interaction)
4. positive shear connection characteristics
5. light weight
6. long service life

2. Experimental Setup

2.1 Sample Collection

The sand collected from the river bed is made free from foreign matters i.e. roots, organic matters etc. and is

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cleaned by washing. Then it is oven dried and properly sieved, passing through 700 μ and retaining on 300 μ IS sieve. Dry sand is used as soil medium for the test as it does not include the effect of moisture and hence the apparent cohesion associated with it. Also due to non-availability of laboratory facilities, the conducting of test in a complex situation developed due to presence of moisture and cohesion has been avoided.

2.2 Characteristics of Sand

Washed, air dried siliceous yellow sand was used as the granular bed. The grain size distribution is shown in Fig. 1, and sand properties are illustrated in Table I. Properties of Geogrid reinforcement.

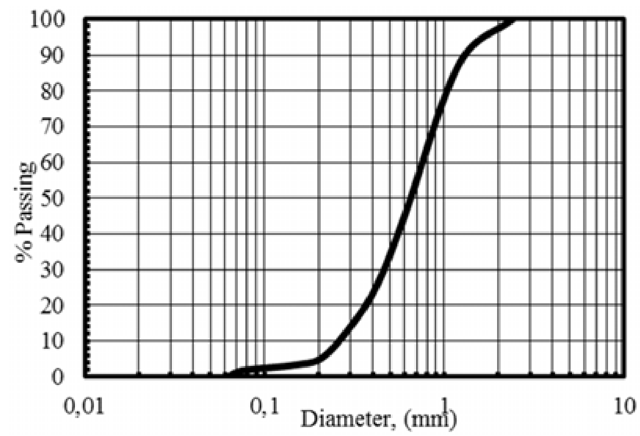

Fig. 1

The characteristics of sand used are as follows:

1. Specific gravity G = 2.618
2. Maximum void ratio emax = 0.995
3. Minimum void ratio emin = 0.664
4. Relative density Id = 72%
5. Dry density γd = 1.49 gm/cc

Angle of internal friction at the adopted density Φ = 42.34°

The sand used in the experimental program was collected from the river bed of a nearby river. It is made free from roots, organic matters etc. by washing and cleaning. The above sample was then oven dried and sieved by passing through 710 micron and retained on 300 micron IS sieve to get the required grading. Dry sand is used as soil medium for the test as it does not include the effect of moisture and hence the apparent cohesion associated with it. The geotechnical properties of the sand used are given in Table 3.

Table 1 Grain Size Analysis

Sl. No.	Sieve size (μ)	Wt. of sand retained (g)	% Retained	Cumulative % retained	Cumulative % finer
1	710	0	0	0	100.0
2	600	132.7	26.54	26.54	73.46
3	500	72.50	14.50	41.04	58.96
4	425	239.8	47.96	89.00	11.00
5	300	55.00	11.00	100.0	0

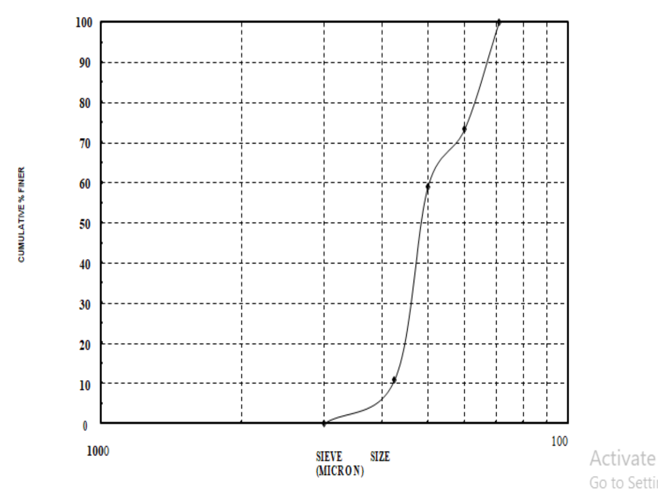

Fig 2 Grain Size Distribution Curve

Table 2 Direct Shear Test Results

Sl. No.	Normal stress (kg/cm2)	Shear stress (kg/cm2)
1	0.315	0.309
2	0.630	0.523
3	0.945	0.811

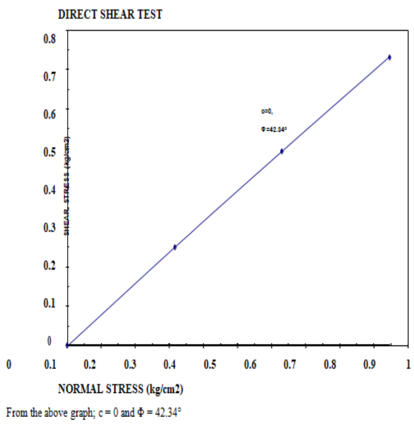

Fig 3 Plot of Shear Stress Vs Normal Stress

2.3 Geogrids Used

Tensar BX1100 geogrid is used as reinforcement. The physical and mechanical properties of the geogrid as listed by the manufacturer are given below:

Table 3

Polymer	Polypropylene
Aperture shape	Rectangle
Aperture size (MD/XD) (mm)	25/33
Rib thickness (mm)	0.75
Junction thickness (mm)	2.80
Tensile strength at 5% strain (KN/m) XD	8.46
Tensile strength at 5% strain (KN/m) MD	13.42
Long term allowable strength in crushed aggregated MD	N/A

(N.B. MD – Machine direction, XD – Cross machine direction)

2.4 Test Tank

Bearing capacity tests were conducted in a box measuring 100 cm x 37 cm x 65 cm and made up of mild steel of 8 mm thickness. Scales are fitted on the internal walls of the box so that it will be helpful in maintaining the required density accurately. The sides of the box are heavily braced to avoid lateral yielding. The following considerations are taken into account while deciding the dimension of the box.

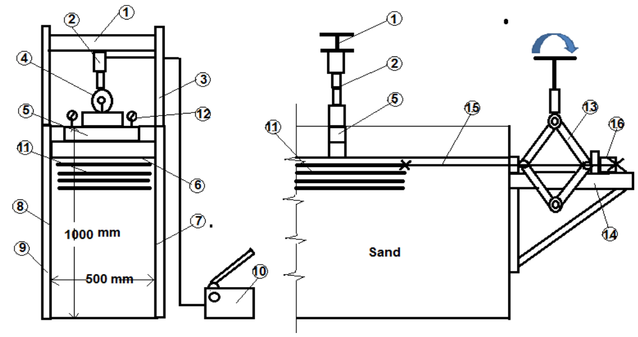

Fig. 4 Schematic representation of experimental setup

1-Reaction beam 2- Hydraulic jack 50kN 3- Loading frame column 4- Load ring 5- Stepped strip footing 6- Foundation level 7- Perspex transparent side 8- Steel plate 3 mm 9- Stiffeners 2L 50*5 mm 10- Control unit of jack 11- Geogrid reinforcement 12- Dial gauge 13- Lateral straining jack 14-Supporting table 15- 4 wires 1mm 16- Reaction beam of wires.

2.5 Equipments Used

1. Static hydraulic loading system
2. LVDT indicator
3. Load cell indicator
4. Model footing

Static hydraulic loading system

The Hydraulic Pressure Testing Equipment is designed to test concrete and soil samples at high pressure. The testing pressure can be set from zero to 115 bar to get pressing force of 10 T in Cylinder - 1 and 20 T in Cylinder - 2. The test piece is kept on the machine base. Test pieces up to 1000 mm x 1500 mm can be tested.

The equipment comprises of the following main units.
Hydraulic System
Test Stand
Electric Control Panel

Hydraulic System
The system comprises of a 150 lit reservoir mounted on which the gear pump is placed along with the various hydraulic elements. The piston pump is driven by a 3.75 kW/ 5 HP, 1440 rpm AC motor.

The system maximum pressure is 115 bar. The system is provided with standard elements like pressure relief valve, return line filter, suction filter, pressure gauge with isolation valves, oil level and temperature indicator, etc.
The system is provided with the following hydraulic elements:-

Gear Pump

The gear pump develops the test pressure of 115 bar (max.). The pump gets the oil supply from the reservoir. The gear pump design pressure is 210 bar against required maximum system pressure of 115 bar.

Electric Motor

A 3.73 kW/5 HP, 1440 RPM, foot mounted AC motor drives the gear pump. The direction of rotation of the motor (and the pump) is marked on the motor body. The motor drives the pump through a geared coupling.

Breather

A breather cum oil filling cap is provided on the reservoir for filling of oil and maintain the inside pressure of the reservoir to atmosphere.

Return Line Filter

The return line filter filters the hydraulic oil returning to the reservoir from the system during the operation. A 20 filter is provided.

LVDT indicator

Linearly Variable Displacement Transducer indicator is used to measure the settlement of the footing produced due to application of pressure on the footing. Its accuracy is up to 0.001 mm

Load cell indicator

This instrument is used to indicate the load applied on the footing due to increase in pressure after regular intervals of time. Accuracy is up to 1 kg for 10 T load cell indicator and 2 kg for 20 T load cell indicator.

Model footing

Model footing used for laboratory tests is made of mild steel plate of size 8 cm x 36 cm x 2.5 cm. The length of the footing is made almost equal to the width of the tank, in order to create plane strain conditions within the test arrangement. A cross-mark is made exactly at centre of the footing for the centric application of load on the footing.

3 Test Procedures

1. Upon filling the tank up to the desired height, the fill surface is leveled and the footing is placed on a predetermined alignment such that the loads from the cylindrical ram will be transferred vertically to the footing.
2. Then the LVDT indicator is placed at a suitable position on the footing to measure the settlement of footing during the experiment. The LVDT digital indicator is set to 80. The load cell indicator is set to 280.
3. The static hydraulic loading system is switched on and the beam is moved up. The four pins are removed and then the beam is moved down to the suitable position and at this position the four pins are again inserted to keep the beam in locked position during experimentation.
4. The cylindrical ram is moved down to place it exactly over the cross-hair marked on the footing.
5. The NITAL software is started and a time limit is fixed to perform this experiment. The load is applied on the footing by increasing the pressure.
6. The load on the footing and the corresponding settlement are noted after regular intervals of time (say 5 min.).
7. The processes of load application is continued till there is failure of foundation sand due to sudden excessive settlement, which can be observed in the Load cell indicator where the load taken by the footing get decreased continuously.
8. On completion of the load test, he equipment are removed, box emptied and the box again refilled for the next set of load test.

4 Geometric Parameters

This fig shows a strip foundation of width ‘B’ supported on Geogrid reinforced sand. There are four layers of geogrid, each having a width ‘b’. The top layer of geogrid is located at a depth u below the bottom of the foundation. The distance between consecutive layers of geogrid is ‘h’.

Here, B = width of foundation L = length of foundation
u = Dist of top layer of reinforcement from the bottom face of foundation. d = Depth of foundation
b = Width of each reinforcement layer l = Length of each reinforcement layerd = u + (N-1) h

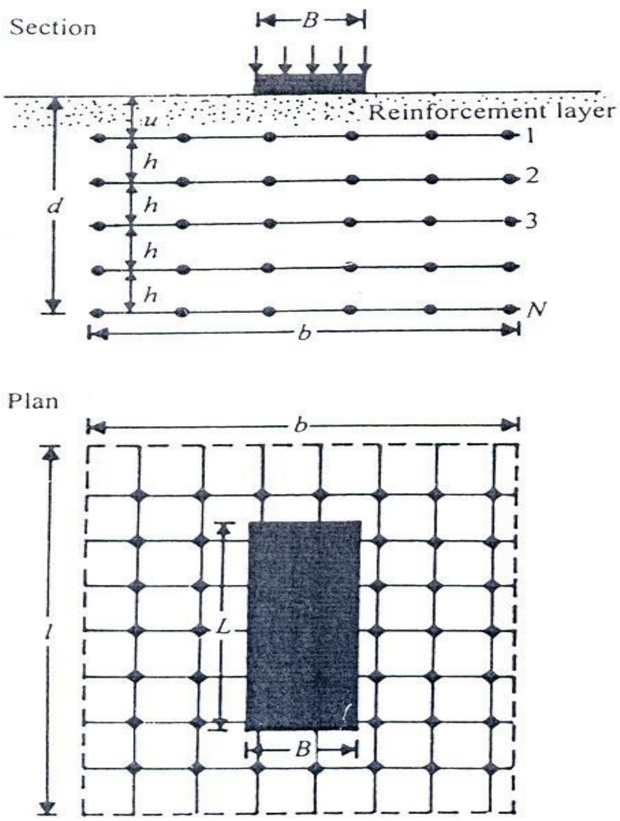

Fig. 5

5. Results and Discussions

From the test results, the load intensity versus the settlement curves are plotted. In each case, the ultimate bearing capacity is determined from the plotted graphs.

5.1 Tests on Unreinforced Sand

The test was conducted on unreinforced sand using 8cm width of footing. For vertical loading condition, the ultimate bearing capacity, Qu of a strip foundation on unreinforced sand is expressed by following two established theories.

1. Terzhagi theory

$qu = 0.5\gamma BN\gamma$ where $N\gamma$ = bearing capacity factor $N\gamma = 2(Nq + 1) \tan\Phi$

$Nq = e\pi\tan\Phi \tan2(\pi/4 + \Phi/2)$

Using the above relationship, the theoretical ultimate bearing capacity for the present test conditions has been calculated.

$N\gamma = 185.44$

$qu = 1105.22$ gm/cm^2

Ultimate load taken by the footing = 318.304 kg

2. Meyerhoff theory

$qu = 0.5\gamma BN\gamma\ F\gamma sF\gamma dF\gamma i$

$F\gamma s = 1+ 0.1(B/L) \tan2(\pi/4 + \Phi/2) = 1.114$

$F\gamma d = 1$

$F\gamma i = 1$

Using the above relation it has been found out that – qu = 996.85 gm/cm^2

Ultimate load taken by the footing = 287.10 kg

The experimental data required for the determination of qu (expt.) are given as below:

Table 4 Load intensity Vs Settlement (N =0)

Sl. No.	Load Intensity (kg/cm^2)	Settlement (mm)
1	0	0
2	0.3	-0.27
3	0.5	-0.56
4	0.8	-0.90
5	0.973	-1.25
6	1.215	-1.65
7	1.469	-2.10
8	1.750	-2.75
9	2.058	-3.50
10	2.306	-4.30
11	2.554	-5.10

5.2 Tests on Reinforced Sand

Tests were conducted on strip foundations supported on multilayered geogrid (BX1100) reinforcements at various depths of below base of foundation (i.e. d/B = 0.6, 0.85, 1.10) Huang and Menq (1997) have provided a tentative relationship to determine the ultimate bearing capacity of a strip foundation on reinforced sand based on wide slab mechanism.

Case 1:

The relationships can be expressed as:- $quR = 0.5(B+\Delta B) \gamma N\gamma + \gamma dNq$

$\Delta B = 2d \tan\beta$

$\tan\beta = 0.68 - 2.071(h/B) + 0.743(CR) + 0.03(b/B) + 0.076N$

CR is Cover Ratio = w/W = 0.107 w = width of longitudinal ribs

W = centre to centre spacing of longitudinal ribs $N\gamma = 2(Nq + 1) \tan\Phi$

$N_q = e^{\pi \tan\Phi} \tan^2(\pi/4 + \Phi/2)$

$q_{uR} = 0.5(B+\Delta B)\ \gamma N_\gamma + \gamma d N_q$ is valid in the following ranges only. $0 \leq \tan\beta \leq 1$

$0.25 \leq h/B \leq 0.5$

$0.02 \leq CR \leq 1.0$

$1 \leq b/B \leq 10$

$1 \leq N \leq 5$

$0.3 \leq d/B \leq 2.5$

Case 1:

$d/B = 0.6$, $N = 2$

$\tan\beta = 0.5289$

$\Delta B/B = 2(d/B) \tan\beta = 0.6347$ $q_{uR} = 2.253$ kg/cm2

Case 2:

$d/B = 0.85$, $N = 3$

$\tan\beta = 0.6049$

$\Delta B/B = 1.028$

$q_{uR} = 2.908$ kg/cm2

Case 3:

$d/B = 1.10$, $N = 4$

$\tan\beta = 0.6809$

$\Delta B/B = 1.498$

$q_{uR} = 3.639$ kg/cm2

Case 4:

$d/B = 1.35$, $N = 5$

$\tan\beta = 0.7569$

$\Delta B/B = 2.0436$

$q_{uR} = 4.444$ kg/cm2

The experimental values and the corresponding load intensity vs settlement graph have been obtained for the above mentioned conditions and are as follows:

Table 5 Load intensity Vs Settlement (N =2)

Sl. No.	Load Intensity (kg/cm^2)	Settlement (mm)
1	0	0
2	0.4	-0.28
3	0.8	-0.85
4	1.2	-1.52
5	1.6	-2.20
6	2.0	-3.10
7	2.4	-4.50
8	2.8	-6.10
9	3.2	-8.00
10	3.6	-9.50

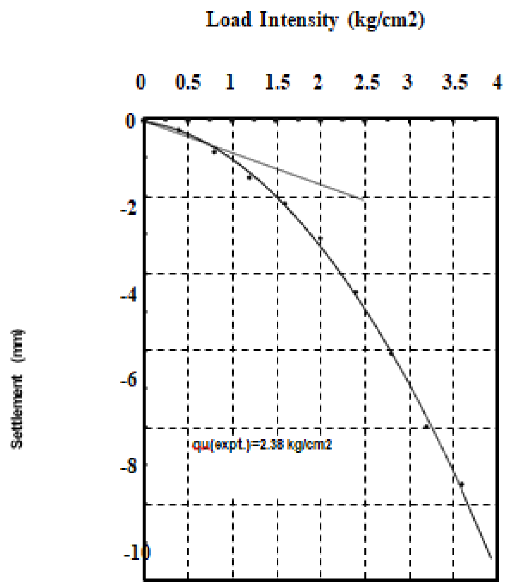

Fig 6 Determination of $q_{u\ (expt.)}$ for reinforced case of loading, N = 2

Table 6 Load intensity Vs Settlement (N =3)

Sl. No.	Load Intensity (kg/cm^2)	Settlement (mm)
1	0	0
2	0.4	-0.40
3	0.8	-0.72
4	1.2	-1.20
5	1.6	-1.70
6	2.0	-2.19
7	2.4	-2.90
8	2.8	-3.50
9	3.2	-4.20
10	3.6	-5.10
11	4.0	-5.80
12	4.4	-6.78
13	4.8	-7.70
14	5.2	-8.83
15	5.6	-9.80
16	6.0	-11.10
17	6.4	-12.40

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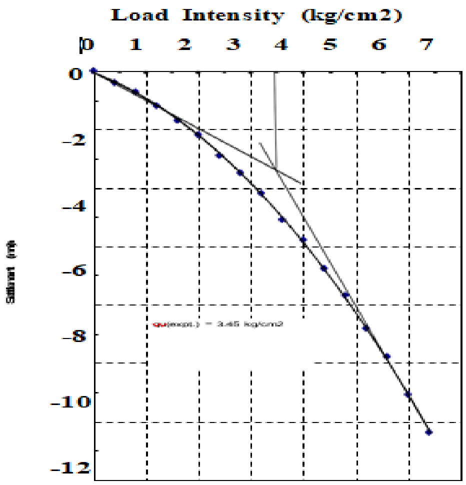

Fig 7 Determination of qu (expt.) for reinforced case of loading, N = 3

Table 7 Load intensity Vs Settlement (N =4)

Sl. No.	Load Intensity (kg/cm^2)	Settlement (mm)
1	0	0
2	0.8	-0.9
3	1.6	-1.6
4	2.4	-2.8
5	3.2	-3.9
6	4.0	-5.2
7	4.8	-6.3
8	5.6	-7.7
9	6.4	-9.2
10	7.2	-10.6
11	8.0	-12.3
12	8.8	-14.0
13	9.6	-15.8

6. Conclusion

The impact of pre-stressing of soil reinforcement on the strain agreement relation of strip footing became investigated through an experimental and numerical analysis. The ultimate bearing capacity obtained from the tests has been compared with the theoretical value developed by Huang & Menq,Depending on the received effects and the carried out analysis, the following conclusions can be driven:

- Soil geogrid reinforcement with out pre-stressing became insignificant in enhancing stiffness of mattress soil for relatively shallow basis intensity of right all the way down to one time footing intensity.
- Pre-stressing of geogrid reinforcement appreciably improved mattress soil stiffness. Pre-stressing of reinforcement effects in growing interplay among reinforcement and surrounding soil ensuing in better axial pressure carried through reinforcement.
- Bed soil bearing strain will increase with the growth of prestraining ratio. Pre-stressing of the2 pinnacle maximum layers effects in improving mattress soil stiffness as compared to unmarried pinnacle layer pre-stressing.
- The experimental load carrying capacity of a foundation on homogeneous sand or on reinforced sand is always more than its theoretical load carrying capacity.
- For the same soil, footing size and geogrid specification, the experimental and theoretical values of ultimate bearing capacity increase and the settlement increases with increase in number of geogrids.
- The difference between experimental and theoretical values also increases with increase in number of geogrid layer. The maximum % difference between the experimental and theoretical values is 18.71%.
- BCRu increases with increase in d/B ratio. From fig 4.5, it is oncluded that BCRu would reach a maximum at some d/B .

7. Future Scope

The current proposal relates to the examination on the bearing limit and settlement of loaded strip footing on dry sand bed. Because of time imperative all different viewpoints identified with shallow foundations couldn't be examined. The future examination work should address the beneath referenced focuses:

- Large scope study ought to be completed to approve the present created conditions.
- Settlement, disappointment example and stress dissemination of eccentrically loaded footing can be tentatively contemplated. Numerical constitutive demonstrating of the current work

should be possible and contrasted and the current outcomes.

- The current work can be stretched out to foundation on cohesive soil.
- The current work can be stretched out to strengthened soil condition.

Keeping in view of the limitations on time, available laboratory facilities and its scope of present investigation, only a part of the problem was experimentally investigated. It is necessary to investigate the ultimate load at failure and the corresponding settlement in cohesive soil with geogrids as reinforcement. Comprehensive investigation, both experimental and technical of the problem with geogrid as reinforcement is desirable.

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