International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 06, June-2015

An Experimental Study on Behaviour of Bearing Capacity and Settlement of Circular and Square Footing Resting on Reinforced Sand Bed Stratified with Lateritic Soil

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Abstract:- **The present investigation was undertaken to study the behavior of reinforced sand in improving the bearing capacity and settlement resistance under square footing and circular footing. Comparison is carried between reinforced and unreinforced condition under circular and square footing and also a lateritic soil is used as layer in sand bed. Comparison is carried between bearing capacity of only sand bed and lateritic layer mixed sand bed with reinforced and unreinforced condition under both footings. Locally available river sand was used along with 'geogrid' as a reinforcing material. The parameters selected were depth of the top layer of reinforcement below the footing and different shape of footings. Relationships between intensity of loading and settlement have been presented to determine the influence of the above parameters on the bearing capacity and settlement. It can be concluded that by a suitable arrangement of the reinforcing geogrid, the bearing capacity and settlement resistance of sand is improved as compared to the unreinforced sand. The effect of bearing capacity of sand below the footing for square plate and circular plate with variation in shape and the effect of permissible settlement is evaluated.**

Key words: Geogrid, Reinforcement, bearing capacity and settlement, direct shear test, reinforced & unreinforced.

1. INTRODUCTION

Soil is the integral part of the civil engineering practices, which can be used as a construction material in building construction practices. Construction of every structure may need the analysis of soil before starting of construction.

Foundation is the lower most part of the super structure which is resting on soil surface at different depths. It receives the overall load from the super structure and distributes uniformly to the ground, the total performance of a structure depends on performance of a foundation. So it should be strong enough to resist the load from super structure. The performance of the foundation depends on the performance of the soil below the foundation, the performance of the soil below the foundation depends upon strength of the soil. It means that the soil should have enough ultimate bearing capacity to resist the load from the foundation and to distribute the load to bellowed ground. The design of foundation depends upon the ultimate bearing capacity and the settlement of the soil below the foundation.

Ultimate bearing capacity means the load that the soil under the foundation can sustain before shear failure, the settlement means that the deformation of the soil below the footing under loading. Ultimate bearing capacity and settlement problem can be solved with the help of either analytical solution or experimental study. The theoretical study can be done by theory of plasticity and finite element method and the experimental study can be done in laboratory. As we know that the ultimate bearing capacity of the soil may vary from one soil to another soil. Some soil may have good ultimate bearing capacity and some have insufficient bearing capacity, it depends upon grain size of the soil, cohesion of the soil and also on the angle of internal friction in the soil particles. The insufficient bearing capacity soils may need to improve their strength by different methods. The strength of the soil can be improved by stabilization, reinforcing, grouting the soil and by other ground improvement techniques also.

Reinforcing technique is a type of ground improvement by providing metallic, synthetic fibres in the soil to improve the engineering behavior of the soil. Reinforcement of the soil is a specified method for improving the mechanical properties ofthe soil such as shear, compression, hydraulic conductivity and density. The ground improvement by providing reinforcement was also in practice in olden days. Babylonians were built ziggurats more than three thousand years ago using the principle of soil reinforcement. A part of the Great Wall of China is also an example of reinforced soil construction. Dutch & Romans had used soil reinforcing technique to reinforce willow animal hides & dikes. Basic principles of underlying reinforced soil construction was completely investigated by Henry Vidal of France who demonstrated it's wide application & developed the rational design procedure. Next modification of soil reinforcement was conceived by Lee, In 1973 he suggested set of design parameters for a reinforced soil structure.

Due to continuous increase of population land costs goes on increasing and availability of land in urban areas were decreasing. Therefore infill of urban facilitates to improve the undeveloped areas by sitting of new facilities. However undeveloped areas may possess weak foundation material this type of situation may challenges to geo technical engineers. To avoid the high cost of deep foundation modification of the foundation soil or the addition of a structure fill is essential.

Binquet & Lee (1975) investigated the mechanism of using reinforced earth slab to improve the bearing capacity of granular soils. They tested model strip footings on sand foundations reinforced with wide strips cut from household aluminum foil. An analytical method for estimating the increased bearing capacity based on the tests was also presented Fragaszy& Lawton also used aluminum reinforcing strips & model strip foundations to study the effects of density of sand & length of reinforcing strips on bearing capacity.

In this study, the experimental studies were carried on cohesionless soil in conjunction with cohesive soil reinforced with Geogrids have been presented. Tests have been conducted with the provision of Geogrids in four layers at various spacing & the results have been compared with the results of unreinforced condition of sand only. The main advantage of reinforced soil was improving of bearing capacity, reducing differential settlements and tilting of footing, ease of construction and good economy. The main objective of using a geosynthetic is to improve physical, mechanical, and hydraulic properties of soils.

In recent decades due to the best economy, performance and ease of construction the technique was used in all geotechnical applications such as roads, railways embankments, retaining walls and stabilization of slopes and also in soft ground improvements.

OBJECTIVE OF PRESENT STUDY

The objective of the present study is

a) To analyze the bearing capacity of model square and circular footings resting over reinforced sand bed subjected to vertical load.
b) Number of geogrid layers used as reinforcement
c) To analyze the spacing variation of reinforcement on bearing capacity
d) Comparison of load settlement characteristics of square and circular footing under reinforced and unreinforced condition.
e) In conjunction with sand layer the lateritic soil is also used as another layer and comparing with only sand layer

3. MATERIALSANDEQUIPMENTS

3.1 GENERAL

The main aim of this research is to study the bearing capacity and settlement of reinforced sand bed in conjunction with lateritic soil. So thesand and lateritic soil is the basic material which is used in this research work. Geogrid is used to reinforce the sand and soil. Static loading machine is the electrically operated machine used to apply the concentrated load onthe mild steel footing which is transferred to sand bed in form of distributed load. Wooden test tank of dimension 325mmX 325mm X 325mm is used to prepare the sand bed.

3.2 MATERIAL USED

- Sand
- Geogrid
- Test tank
- Lateritic soil
- Funnel
- Plumb bob
- Bearing ball

3.2.1SAND

3.2.1.1 SAMPLE COLLECTION

The sand used in research work is collected from the nearby construction site. Which is brought from the place called Sangareddy near Hyderabad in Telangana State. The sand is to make it free from soil, grass roots, and other organic materials and then the sample is dried in oven. A sand of 4.75mm IS sieve passing of required amount is taken for this work..

3.2.1.2 CHARACTERISTICS OF SAND

All experiments were conducted to a maximum density of 1.69g/cc and internal friction angle was found out to be $33^0$by direct shear test at this relative density. The characteristics of sand used in research work and the grain size distribution is listed in table 3.1 and figure 3.1 respectively.

Table 3.2: Geotechnical Property of Sand

Property	**Value**
Specific gravity *(G)*	2.67
Effective particle size *(D10)*	0.3mm
Mean particle size *(D50)*	0.53mm
(D60)	0.68mm
(D30)	0.46mm
Coefficient of uniformity (*Cu*)	2.26
Coefficient of curvature *(Cc)*	1.037
Maximum unit weight	$1.69gm/cm^3$
Minimum unit weight	$1.53gm/cm^3$
Maximum void ratio (*emax*)	0.74
Minimum void ratio (*emin*)	0.57
Angle of internal friction	33^0

3.2.2 GEOGRID

Geogrid is type of geosynthestics designed for reinforcement, they have high tensile strength and flexible to withstand the load without undergoing sudden breaking. They have uniformly distributed group of large openings in transverse and longitudinal directions. The openings are called aperture, The openings allow sand particle on either side of the mounted geogrid to come in direct contact which increases the interaction between the geogrid and sand. The geogrid features vary in polymer type and cross-sectional proportions. Geogrids are manufactured using high modulus polymer materials like polypropylene and high density polyethylene and are either inherently manufactured, ultrasonically or glue bonded. On the basis of strength direction, geogrids are classified as Biaxial and Uniaxial while classified as Rigid and Flexible based on rigidity.

3.2.2.1 PHYSICAL PROPERTIES:

The physical properties of geogrids can be measured directly in lab and are relatively straight forward. Which include the type of structure, shape, junction type, aperture size and thickness. Other properties that are of interest are density, mass per unit area etc.

Table 3.3: Physical Properties of Geogrid

Physical properties	**Values**
Aperture shape	Square
Aperture size	25.4 mm×25.4mm
Thickness	2 mm
Density	0.897 g/cc
Mass per unit area	0.066 g/cm^2
Tensile strength	7 KN/m^2

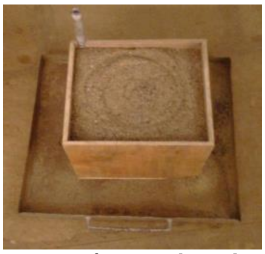
Picture-3.1: Geogrid Used In This Study

3.2.2.2 CHEMICAL PROPERTIES:

Polyolefin, polypropylene, polyethylene and polyesters used in geogrids have high resistance to a wide range of chemicals.

3.2.3 TEST TANK

Tank size is decided on the basis of IS code and from the results of some literatures. IS 1888-1962says that minimum size should be at least 5 times the width of test plate to develop the full failurezone without any interference of side. For cohesionless soil, Chumar (1972) suggested that the maximum expansion of failure zone will be 2.5 times the width of footing width along the sides and depth of foundation should be 3times the width of footing below the base of the footing. Keeping the above criteria in mind, 325mm long tank with 325mm width and 325mm height has been used for 105mm×105mm×5mm square footing and 92mm diameter circular footing of 10mm thickness during experimental work. Due to the tank size, there may be some scale effect which will influence the ultimate bearing capacity of footing resting over geogrid reinforced sand bed. The tank is made up of 15mm thick wooden pad. The number of lines were drawn at 10mm intervals on inner face of tank wall to ensure the height of sand filled in the tank and also to provide reinforcement at intervals of preferred depths.



Picture 3.2:1Picture of Test Tank Used In This Study

3.2.4 LATERITIC SOIL

Laterite is a surface formation in hot and wet tropical areas which is enriched in iron and aluminum and develops by intensive and long lasting weathering of the underlying parent rock. Lateritic soils can be described as a product of tropical weathering with red, reddish brown, or dark brown color, with or without nodules and that generally found below hardened ferruginous crusts or pan.

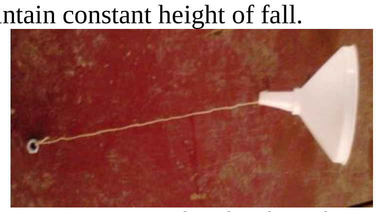
The soil sample is collected from the industrial area of bidar. The soil passing through 4.75mm IS sieve was taken for this experimental work. The properties of lateritic soil are as below in table.

Table3.7: Showing Geotechnical Properties of Lateritic Soil

Serial no	Properties	Results
1	Specific gravity	2.80
2	Liquid limit, LL (%)	35.20
3	Plastic limit, PL (%)	18.13
4	Plasticity index, PI (%)	17.07
5	Shrinkage limit	13.08
6	Maximum Dry Density (g/cc)	1.87
7	Optimum Moisture Content (%)	12
8	Percent passing IS NO 150mm sieve %	1.4
9	Angle of internal friction	8°
10	Coefficient of curvature (C_c)	1.2
11	Coefficient of uniformity (C_u)	5.99

3.2.5 FUNNEL

The funnel is used to do the pluviation technique (raining technique or rainfall technique). A funnel is used to pour the sand into the tank to get the uniform density throughout the tank and also to maintain the uniform density over the depth of the tank. The sand is poured at different heights to know the maximum and minimum density of sand after that sand is poured by fixing the height of fall to get required density. The thread was fixed to the bottom of the funnel to maintain constant height of fall.



Picture 3.3: Funnel Used In This Study

3.2.6 PLUMB BOB

A plumb bob is used to fix the centre of gravity of tank with static loading unit and loading frame. This is used to avoid eccentric loading on sand bed and footing.

3.2.7 BEARING BALL

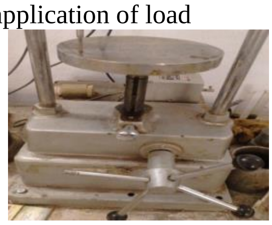
A ball is used to transfer the load from loading frame to footing on the sand bed which acts as a hinge between footing and proving ring, which helps the footing to take its own position during failure and also to coincide the footing face with sand surface during failure.

Picture3.4: Bearing Ball Used

3.3 EQUIPMENTS USED

3.3.1 STATIC LOADING UNIT

An electrically operated static loading unit is used to apply the load on the foundation during test. The whole loading unit consists of one electrical motor, one power pack and one loading frame with shaft. Power pack consist of one vertical jack inter connected with electric motor and it also consist of levers to operate by hand also. The loading system applies a load at a strain rate of 2.5mm/min. The frame is supported by a horizontal beam which provide there action to the frame during application of load



Picture 3.5: Static Loading Unit

3.3.2 PROVING RING

A proving ring CSS-1006-86-500kg of capacity 500kg is used to measure the applied load on the foundation during the experimental work.

The least count of this proving ring dial gauge obtained from calibration chart is 0.53kg. One small division of proving ring dial gauge is equal to 0.53kg.Top of proving ring is attached with the metallic frame of the set up at top of static loading unit while the bottom is in contact with the metallic ball which is resting on the footing. The rigid metallic ball between the footing and the proving ring acts as a hinge. When load is applied, the load is transmitted from proving ring to the footing via this metallic ball.

Table 3.8: Showing Calibration Chart of Proving Ring

Serial no	Load in Kg	Proving Ring Divisions
1	50	93
2	100	188
3	150	282.7
4	200	378
5	250	473.9
6	300	571.4
7	350	668.4
8	400	766.8
9	450	865
10	500	964.8

Picture 3.6: Proving Ring with Dial Gauge

3.3.3 DIAL GAUGE

A dial gauge which can measure the settlement with least count of 0.001mm is used during the experimental work. The dial gauge is fixed at the top of the wooden tank which is a foundation and needle of the dial gauge is placed on the topof the footing to measure the settlement of the footing. A steel bar which is supported by frame is used to support the dial gauge on footing.

Picture 3.7: Dial Gauge Used

3.3.4 MODEL FOOTINGS

Two model footing of size105mm*105mm square of 5mm thickness and 92mm diameter circular of 10mm thickness made up of mild steel is used for experimental work. A grove is made at the centre of top face of the footing to place a rigid metallic ball which connects the footing and bottom of proving ring which helps to apply a load. The footing is placed on the sand bed so as to make it rough so that friction between footing and foundation soil can develop during application of load

Picture 3.8: Circular Footing

Picture 3.9: Square Footing

4. MODEL TEST AND METHODOLOGY

4.1 GENERAL

To study the bearing capacity of loaded foundation, laboratory model test has been performed on square and circular footing resting on sand bed reinforced with multilayered geogrid. Model test is performed on sand remoulded at one density and number of reinforcement varied as 0, 1, 2, 3 & 4. Footing is resting on the surface of reinforced sand bed and embedded lateritic soil sand bed also. Metallic ball is used as load transferring medium between shaft and model footing.

4.2 SAMPLE PREPARATION

4.2.1 PLACEMENT OF SAND

Internal dimension of the test tank is measured and weight of sand to fill the tank up to a specified height is calculated using working density of 1.69gm/cc. Pluviation or rain fall technique was used to place the sand and trials are made to discover the height of fall of sand by allowing the sand to fall from different height to filling the tank upto desired height. After filling the tank up to desired height using raining technique, density of sand filled in tank for different trials is calculated. Height was fixed by doing number of trials and the density of sand for each height of fall was calculated and also the sand was placed to the maximum density of which we got from this rainfall technique, this maximum density was taken as working density for sample preparation. After finding out the height of fall, weight of sand require for 10cm thick layer to maintain the working density is taken and poured into the tank from specified height of fall using sand raining technique. For the preparation of reinforced sand sample, geogrid is placed at desired depth from bottom of footing after approximate leveling the surface to make it horizontal. Placement of geogrid is described in detail in section.

Picture 4.1: Placing of Sand

4.2.2 PLACEMENT OF GEOGRID

This fig shows a square 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’, d is the depth from base of footing to the last layer of reinforcement.

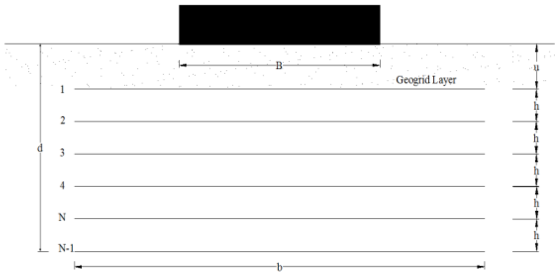


Figure 4.1 Cross-Section Showing Sand Bed with Multiple Number of Reinforcement

In case of reinforced sand bed, it is very essential to decide the magnitude of u / B, h/B and b / B to take the maximum advantage in bearing capacity of reinforced sand. After going through several literature, it has been found that (u/B) vary between 0.25 and 0.5, (b/B)cris 4.5 for square footing and (h/B) lies between 0.25 to 0.4. By keeping the above factor in mind, for this test these factors are varied as (u/B) = 0.47, 0.76, 0.95 and 1.42,Since in this test, width of footing B is 10.5cm so width of geogrid b is taken as 30cm. The depth of first layer u from bottom of footing is taken as 5cm,8cm,10cm and distance between each consecutive layer h is taken as 5cm, 8cm. During the sample preparation, square shaped geogrid of size 30cm*30cm has been taken and placed below the footing with first layer at the depth of 5cm,8cm and 10cm, other layers with 5cm and 8cm distance between two consecutive geogrid layer as shown in Figure 4.1.

Picture 4.2: Placing of Geogrid

4.2.3 PLACEMENT OF LATERITIC SOIL

The lateritic soil is used as a layer in between the sand layer, the amount of soil required to fill the depth of 10cm layer to a density of 1.87g/cc in sand bed is calculated. The amount of soil required to place is 19.75 Kg was weighed and mixed with OMC and placed in to the tank by maintaining OMC as layer by layer of thickness 5cm each and compacted manually to get required density.

4.3 EQUIPMENT SETUP

After preparation of reinforced or unreinforced sample, footing is placed over the top of sand bed in such a way that footing is parallel to the wall of test tank and (D_f/B=0). Proving ring of desired capacity is attached with the cylindrical shaft of static loading unit and brought into contact with footing through metallic rod in between frame and footing. Before making contact between shaft andfooting, ensure that shaft is vertical. A dial gauge of standard specification is placed at thecorner of the footing. The whole setup of equipment is shown in Figure 4.2.

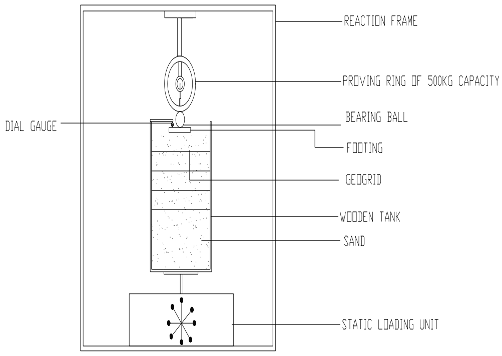


Fig-4.2: Pictorial View of Test Setup

Picture 4.3: Picture of Test Setup

Picture 4.4: Setup of Square Footing

Picture4.5: Setup of Circular Footing

4.4 MODEL TEST PROCEDURE

As we know earlier from the literature the loading frame is arranged and the static loading unit was fixed at the bottom of the rigid frame which is attatched with electric motor to apply the load at a constant strain rate of 2.5mm/min. after fixing of loading unit at the bottom of the frame the tank filled with sand or soil was placed on the top of the loading unit. The proving ring was fixed at the top of the frame exactly by coinciding centre of gravity the loading unit and sand filled tank. The bearing ball was placed below the proving ring over the footing and the footing was placed over the sand bed.

After placing of footing over sand bed in contact load is started to apply through static loading unit which is electric motor is switched on and load applied in intervals is recorded and respective settlement occurred is also noted. After taking the reading on proving ring and dial gauge, load applied is calculated by multiplying the number of division on proving ring by it's least count and corresponding settlement is calculated by multiplying the dial gauge reading by it's least count i.e. 0.001mm. Now the load-settlement curve is drawn and by using double tangent method or tangent intersection method experimental bearing capacity is extracted.

4.5MODEL TEST SERIES

Total thirty six numbers of tests are conducted with square and circular footing under reinforced and unreinforced condition with lateritic soil and with only sand bed.

Table 4.1: Model Test Series

Serial no	Reinforced Condition	No. of Tests (square footing)	No. of Tests (circular footing)
1.	One layer 5cm depth	1	1
2.	One layer 8cm depth	1	1
3.	Two layer 5cm interval	1	1
4.	Two layer 8cm interval	1	1
5.	Three layer 5cm interval	1	1
6.	Three layer 8cm interval	1	1
7.	Four layer 5cm interval	1	1
8.	One layer at 5cm depth	1	1
9.	One layer 10cm depth	1	1
10.	One layer 15cm depth	1	1
11.	Unreinforced Condition	1	1
12.	With unreinforced lateritic soil layer	1	1
13.	One layer geogrid with lateritic soil	1	1
14.	Two geogrid layers with lateritic soil	1	1
15.	Three geogrid layers with lateritic soil	1	1
16.	One geogrid layer at 5cm depth	1	1
17.	One geogrid layer at 10cm depth	1	1
18.	One geogrid layer at 15cm depth	1	1

5. RESULTSAND DISCUSSION

5.1 GENERAL

Load tests have been performed on model square and circular footings of size 10.5cm□10.5cmand 9.2cmdiameter respectively resting over unreinforced as well as reinforced sand bed. For preparing reinforced sand bed, multiple number (2, 3, 4) of geogrid layers have been introduced. Settlement corresponding to each load increment is noted and the test result is plotted in term of load-settlement curve. Ultimate bearing capacity for each test is determined from load-settlement curve using tangent intersection method. The tangent intersection method be can done as shown in figure.

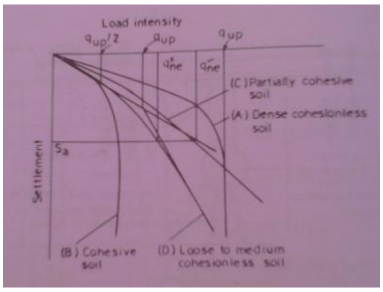
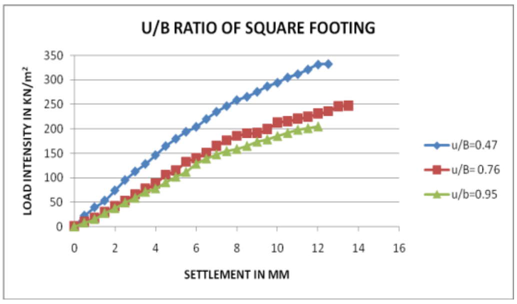


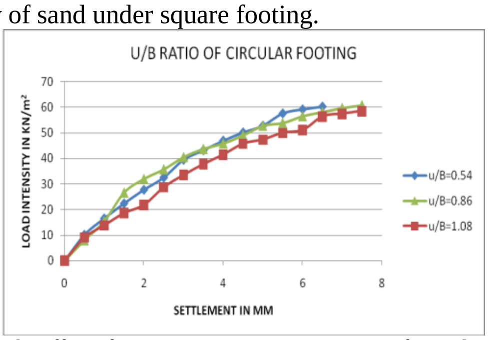
Fig 5.1:Tangent Intersection Method

5.2 EFFECT OF U/B RATIO ON BEARING CAPACITY WITH ONLY SAND



Graph 5.1a: Effect of U/B Ratio on Bearing Capacity of Square Footing

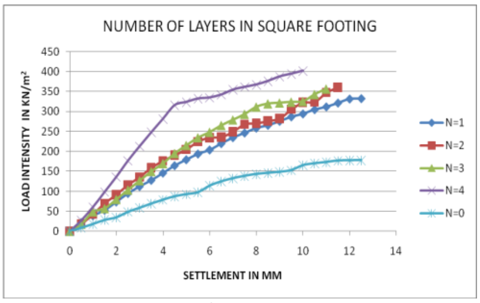
In the above graph the bearing capacity of u/B=0.47 having 222.44KN/m^2, u/B=0.76 having 215.33KN/m^{2}and u/B=0.95 having 212.66KN/m^2. Therefore we have to know that the variation of bearing capacity of sand under square footing in reinforced condition is varying with the depth of top layer reinforcement (u), as depth u increases the bearing capacity goes on decreasing. Sothe u/B ratio was affecting the bearing capacity of sand under square footing.



Graph 5.1b: Effect of U/B Ratio on Bearing Capacity of Circular Footing

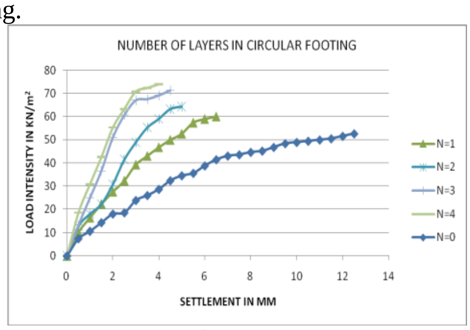
From the above graph we can say thatthe bearing capacity of u/B=0.54 having 87.07KN/m^2, u/B=0.86 having 86.22KN/m^{2}and u/B=1.08 having 85.36KN/m^2. Therefore the depth of top layer reinforcement is affecting the bearing capacity of sand under circular footing. As u/B ratio increases the bearing capacity decreases.

5.3 EFFECT OF NUMBER OF GEOGRID LAYERS WITH ONLY SAND BED



Graph 5.2a: Number of Layers under Square Footing

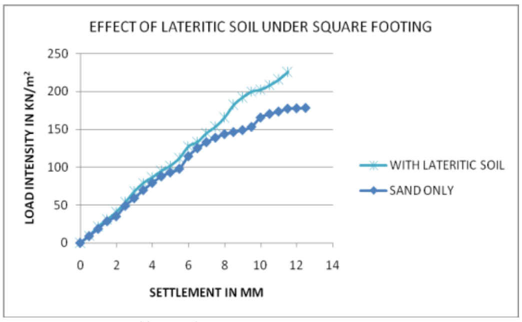
From this graph the bearing capacity of unreinforced sand(N=0) is 143.25KN/m^2, reinforced one layer(N=1) having 222.44KN/m^2, reinforced two layer (N=2) having 234.9KN/m^2, reinforced three layer (N=3) having 272.27KN/m^2, and reinforced four layer (N=4) having 295.41KN/m^2, we have to know that effect of number of layers on bearing of sand under square footing, as number of layers increases the bearing capacity of soil goes on increasing.



Graph 5.2b: Number of Layers under Circular Footing

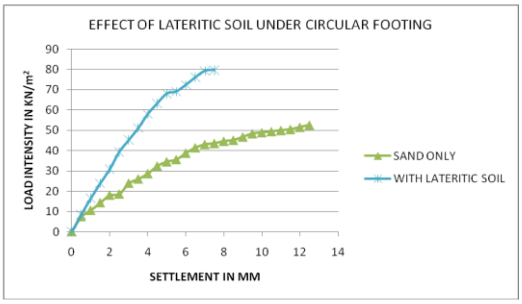
From this graph the bearing capacity of unreinforced sand(N=0) is 77.48KN/m^2, reinforced one layer(N=1) having 87.07KN/m^2, reinforced two layer (N=2) having 94.45KN/m^2, reinforced three layer (N=3) having 104.78KN/m^2, and reinforced four layer (N=4) having 109.21KN/m^2, we have to know that effect of number of layers on bearing of sand under circular footing, as number of layers increases the bearing capacity of soil goes on increasing.

5.4 EFFECT OF LATERITIC SOIL LAYER ON BEARING CAPACITY IN UNREINFORCED CONDITION



Graph 5.3a: Effect of Lateritic Soil under Square Footing

In the above graph the comparison was made between the bearing capacity of only sand bed and lateritic soil embedded sand bed under square footing in unreinforced condition. The bearing capacity of only sand bed is 143.25KN/m^2 and the bearing capacity of lateritic soil embedded sand bed is 158.40KN/m^2.

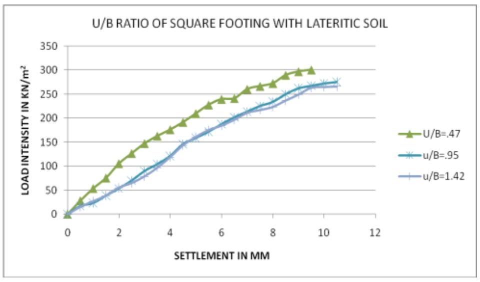


Graph 5.3b: Effect of Lateritic Soil under Circular Footing

In the above graph the comparison was made between the bearing capacity of only sand bed and lateritic soil embedded sand bed under circular footing in unreinforced condition. The bearing capacity of only sand bed is 77.48KN/m^2 and the bearing capacity of lateritic soil embedded sand bed is 118.06KN/m^2

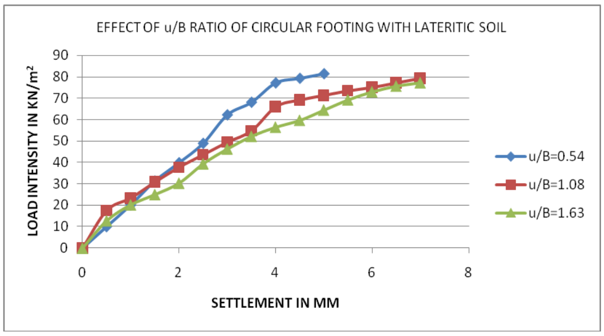
From the above two graphs we seeing that the effect of lateritic soil on bearing capacity of sand under square and circular footing in unreinforced condition. The lateritic soil with OMC and MDD is effecting the bearing capacity of sand bed, due to its cohesiveness and angle of internal friction.

5.5 EFFECT OF U/B RATIO ON BEARING CAPACITY WITH LATERITIC SOIL LAYER



Graph 5.4a: Effect of U/B Ratio of Square Footing with Lateritic Soil

In the above graph we can see that the effect of u/B ratio on the bearing capacity of lateritic soil layered sand bed under square footing. From the graph the u/B=0.47 having bearing capacity 235KN/m^2,the u/B=0.95 having the bearing capacity 215.33KN/m^2, the u/B=1.42 having bearing capacity 197.75KN/m^2. As the u/B increases the bearing capacity goes on decreasing.

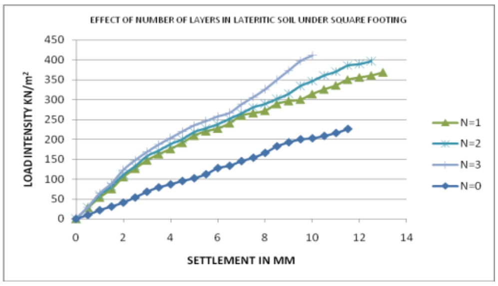


Graph 5.4b: Effect of U/B Ratio on Circular Footing with Lateritic Soil

In the above graph we can see that the effect of u/B ratio on the bearing capacity of lateritic soil layered sand bed under square footing. From the graph the u/B=0.54 having bearing capacity 119.54KN/m^2, the u/B=1.08 having the bearing capacity 115.64KN/m^2, the u/B=1.63 having bearing capacity 113.64KN/m^2. As the u/B increases the bearing capacity goes on decreasing.

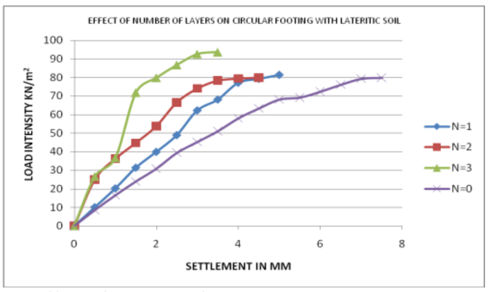
In this condition the bearing capacity increased by decreasing the u/B ratio, it means that depth of top layer reinforcement increases the bearing capacity decreases in lateritic soil embedded sand bed also.

5.6 EFFECT OF NUMBER OF GEOGRID LAYERS ON BEARING CAPACITY WITHLATERITIC SOIL LAYER



Graph 5.5a: Effect of Number of Layers in Lateritic Soil Under Square Footing

From this graph the bearing capacity of unreinforced sand with embedded lateritic soil layer(N=0) is 158.40KN/m^2, reinforced one layer(N=1) having 235KN/m^2, reinforced two layer (N=2) having 267.82KN/m^2, reinforced three layer (N=3) having 274.51KN/m^2. We have to know that effect of number of layers on bearing of sand under square footing with embedded lateritic soil, as number of layers increases the bearing capacity of soil goes on increasing.

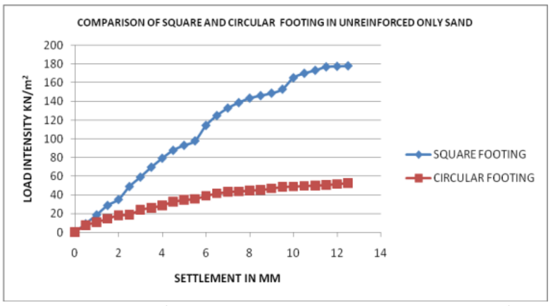


Graph 5.5b: Effect of Number of Layers on Circular Footing with Lateritic Soil

From this graph the bearing capacity of unreinforced sand with embedded lateritic soil layer (N=0) is 118.06KN/m^2, reinforced one layer (N=1) having 119.54KN/m^2, reinforced two layer (N=2) having 125.54KN/m^2, reinforced three layer (N=3) having 138.73KN/m^2. We have to know that effect of number of layers on bearing of sand under circular footing with embedded lateritic soil, as number of layers increases the bearing capacity of soil goes on increasing.

From the above two graphs we have to know that the number of layers affecting the bearing capacity, as number of layers increases the bearing capacity will also goes on increasing, The geogrid reinforcement gives an effect in lateritic soil embedded sand bed also.

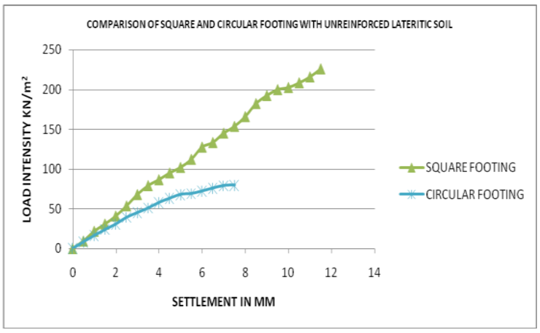
5.7 COMPARING BEARING CAPACITY OF SQUARE AND CIRCULAR FOOTING WITH ONLY SAND BED



Graph 5.6: Comparison of Square and Circular Footing In Unreinforced Sand Only

From the above graph we have to know that the load carrying capacity of square footing is comparatively more than circular footing in unreinforced condition. The bearing capacity of only sand bed under square footing was 143.25KN/m^2 and under circular footing was 77.48KN/m^2.

5.8 COMPARING BEARING CAPACITY OF SAND WITH LATERITIC SOIL LAYER UNDER BOTH FOOTINGS



Graph 5.7: Comparison of Square and Circular Footing With Lateritic Soil

From the above graph we have to know that the load carrying capacity of square footing is comparatively more than circular footing in unreinforced condition. The bearing capacity of embedded soil layer sand bed under square footing was 158.40KN/m^2 and under circular footing was 118.06KN/m^2.

Above graph shows that the comparative study of square and circular footing embedded with lateritic soil. The square footing is performing well than the circular footing.

5.9 RESULTS OF ONLY SAND BED AND LATERITIC SOIL LAYER UNDER BOTH FOOTINGS.

The allowable settlement of the plate obtained from the Plate Load Test Equation was 9mm for square footing and 8mm for circular footing.

$$[S_f/S_p]= [B_f/B_p]^2 \, [(B_p+0.3)/(B_f+0.3)]^2$$

Table 5.1:Bearing Capacity of Both Footings

Serial no	Condition of footing	Bearing capacity of square footing In KN/m^2	Allowable settlement of square footing in mm	Bearing capacity of circular footing In KN/m^2	Allowable settlement of circular footing in mm
In Sand BedOnly					
1	Unreinforced condition	143.25	8.5	77.48	5.6
2	Reinforced one layer at 5cm depth	222.44	6.8	87.07	3.3
3	Reinforced two layer at 5cm interval	234.9	6.7	94.45	2.5
4	Reinforced three layer at 5cm interval	272.27	6.3	104.78	2.4
5	Reinforced four layer at 5cm interval	295.41	5.5	109.21	2
6	Reinforced one layer at 8cm depth	215.33	8.1	86.22	3.4
7	Reinforced two layer at 8cm interval	220.66	7.7	90.22	3.2
8	Reinforced three layer at 8cm interval	243.80	7.7	98.88	2.7
9	Reinforced one layer at 10cm depth	212.66	9.1	85.36	3.7
10	Reinforced one layer at 15cm depth	185.96	7.5	77.34	4.5
In Sand With lateritic soil layer					
1	Unreinforced with lateritic soil layer	158.4	7.1	118.06	3.6
2	Reinforced one layer at 5cm depth	235.0	5.9	119.54	3.2
3	Reinforced two layer at 5cm interval	267.82	5.2	125.54	2.7
4	Reinforced three layer at 5cm interval	274.51	4.7	138.73	2.2
5	Reinforced one layer at 10cm depth	215.33	6.7	115.64	3.3
6	Reinforced one layer at 15cm depth	197.75	6.8	113.64	3.4

6. CONCLUSION

The results of laboratory model tests conducted to determine the ultimate bearing capacity of asquare and circular footing supported by multi-layered geogrid reinforced sand bed subjected to vertical centric load have been reported. Tests have been conducted on medium dense sand.

1. From the above results we can conclude that reinforced sand have 30% more load carrying capacity than unreinforced sand under square footing and 10% more in circular footing.
2. As u/B ratio increases the load carrying capacity of sand bed goes on decreases by 3 to 5% in square footing and 1to 2% decreases in circular footing, it means depth from base footing to first layer of reinforcement increases the load carrying capacity decreases
3. The load carrying capacity of sand increases by 5% to 10% with increase in number layer of reinforcement under both square and circular footings.
4. The inclusion of lateritic soil layer increases the load carrying capacity of sand by 10% under square footing and 30% under circular footing in reinforced and unreinforced condition.
5. When compared to the behavior of square and circular footing under reinforced and unreinforced condition the square footing performs good and have high load carrying capacity than circular footing.
6. The three layer reinforced sand bed have bearing capacity of 272.27KN/$m^2$and the sand bed with embedded lateritic have high bearing capacity of 274.51KN/m^2, the lateritic soil and geogrid reinforcement performed good within the depth less than the width of the footing.
7. It was observed that the geogrid reinforcement reduces 20% settlement in square footing and 40% in circular footing. Lateritic soil embedment can reduce the settlement of 15% in square and 30% settlement in circular footing.
8. Therefore we can conclude that the boundary forces, earthquake resistance and gravity forces can also minimized by this type of layer system.

7. SCOPE FOR FUTURE STUDY

The scope for future study is needed to improve the bearing capacity of soil at different conditions in order to resist the over load of structures. the study can be conducted for following conditions are as below.

- The study can be carried for different soil having different properties
- The study can also be conducted for different types of geogrids of having different strengths
- The study can be conducted for the different types of sand at different conditions
- The study can be conducted for the sand by varying its relative densities
- The is to be needed to conduct at different depths of footings and also different types of footings
- The study can also be done by taking same type of footing by varying its sizes
- The study can also be conducted for different foundation depths and different types of foundations
- The study can also to be carry by taking different grain sizes of sand
- The study can also be conducted by laying intermediate layers of different soils and also at different depths

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