Study on the Performance of Square Footing Resting on Reinforced Sand Beds under Repeated Loading

H.C.Muddaraju[1], Avinash.N [2], Mashyala Sharanamm[3]

[1]Assistant Professor, Civil Engineering Department, UVCE, Bangalore, Karnataka, India
[2] Research Scholar, Civil Engineering Department, UVCE, Bangalore, Karnataka, India
[3]Post graduate student, Civil Engineering Department, UVCE, Bangalore, Karnataka, India

***Abstract*: - Various soil improvement techniques have been used to enhance the engineering properties of soil. One of the improvement techniques is soil reinforcement. This concept was widely used in the geotechnical field. In the present investigation plain-geogrid and geogrid-PVC pipe was used as reinforcement material to improve the load settlement characteristics of the square footing. And comparison was made between the 2D geogrid and 3D geogrid to investigate the effectiveness of inclusion of plain geogrid (2D geogrid) and geogrid-pipe (3D geogrid) on the improvement in the load settlement characteristics of sand bed under repeated loading.**

***Keywords*: Reinforced sand bed, geogrid, PVC pipe, repeated loads, Cyclic Resistance Ratio, Settlement Ratio.**

I. INTRODUCTION

The concept of soil reinforcement was used since ancient times; one of the oldest method of soil reinforcement is the inclusion of natural reinforcement material such as wood, bamboo and tree trunks. In 1960's Henry Vidal a French architect and engineer introduced the modern concept of soil reinforcement. In recent year major part of land that are available for construction of structure is found to have poor bearing capacity which needs to be improved. One of the method that has recently gained more recognitions is soil reinforcement due to its cost effectiveness, ease of construction and it is less time consuming. The term Reinforced soil refers to soil that has been strengthened by placement of reinforcing material within the soil mass in the form of strips, bars, sheets or grids. When the load is applied to the soil mass this reinforcement materials resist the tensile stresses which is developed within the soil mass through friction, adhesion or bearing resistances.

Now a day's geogrids are used widely in the geotechnical field due to its cost effectiveness and ease of availability have been in markets. Several laboratory tests conducted using geogrid reinforcement material to improve the stiffness and stability of the structure and skirts which is used as reinforcement to improve the stability by confining the sand (Mansour Mosallanezhad et al.,(2008)[3], M. Mosallanezhad et al.,(2010)[4], Ravi Gupta et al.,(2014)[5],Sareesh Chandrawanshi et al.,(2014)[6],P.K Jain et al.,(2014)[7], Abhishek Singh et al., (2016)[1], Aminaton Marto et al.,(2016)[2]). In the present investigation soil reinforcement system is formed from the combination of geogrid and PVC pipes. Geogrid act like reinforcement and supports the PVC pipe to stand in proper vertical direction. In this system geogrid sheet reinforce the sand by increasing the shear resistance due to development of tensile strength and PVC pipe prevent the lateral movement of sand.

II. MATERIALS AND METHODS

2.1 Materials

Poorly graded sand, biaxial geogrids and PVC pipes are used in the study. Properties of sand and Geogrid are shown in Table 1 and Table 2 respectively.

Table 1: Property of sand

Property	Test Result
Grain Size Distribution:	
Clay and Silt size (%)	0
Sand Size (%)	100
Gravel Size (%)	0
Coefficient of Uniformity, Cu	3
Coefficient of Curvature, Cc	0.92
Dry Density, (kN/m³) @ 36 % relative density	15.4
Specific Gravity, G	2.68
Frictional angle (degrees)	34
Maximum dry density (kN/m³)	17.8
Minimum dry density (kN/m³)	14.3

Table 2: Properties of Geogrid

Properties	Value
Thickness :	
Joint (mm)	5
Rib (mm)	2.4
Structure	Bi oriented, mesh type, Hexagonal aperture
Aperture size @ junction (mm)	26.1
Tensile Strength (kN/m)	7.74

The dimensions of PVC pipe, footing and steel tank are,

1. PVC pipe :

   Diameter = 20 mm

   Length = 20 mm

2. Mild steel footing :

   Size of square footing = 100mm

   Thickness= 4mm

3. Mild steel tank:

   Diameter = 500mm

   Height= 390mm

2.2 Methods

2.2.1 Preparation of Test Sample

Preparation of Sand Bed

Unreinforced sand sample was compacted up to a height of 360 mm in 3 equal layers of 120mm thick. For reinforced sample, the geogrid reinforcements were placed at predetermined spacing in between sand layers from the bottom of footing, and by the same procedure remaining height of the tank is compacted. The reinforcements were provided in the shape of circular discs. A clearance of 5 mm was provided to ensure that no friction was generated between the reinforcement and the walls of the tank. The square footing was placed on the final level surface exactly at the center of the tank.

2.2.2 Procedure for Testing

In the present investigation an Automated Dynamic Testing Apparatus (ADTA), is used for repeated load application. ADTA is specially designed, fabricated, and calibrated for this purpose. ADTA the machine is capable of applying a maximum load of 20kN and maximum frequency of 2Hz (in steps of 0.1Hz). The salient feature of the machine is the capability of generating 3 different types of loading waveforms viz., sinusoidal, square and saw tooth. The system works on **"MOVICON- 9.1"** software that is capable of generating the above type of waves. The reinforced and unreinforced sand beds are subjected to repeated loading in the Automated Dynamic Testing Apparatus. The excitation values, viz., cyclic pressure (repeated load), and frequency are selected and fed in to the computer. The load is applied on to the test plate and the settlements are measured through three different LVDT"s placed orthogonal to each other. The load cell and the LVDT"s are in turn connected to the control unit, where the analog to digital conversion takes place, and is recorded in the data acquisition system. The measured settlements after each cycle of loading are recorded in the data acquisition system, which is then recovered through the computer.

2.2.3 Geogid – PVC Pipe System

Soil reinforcement system is formed from the combination of geogrid and PVC pipes, geogrid acting like reinforcement and support the PVC pipes to stand in a proper vertical direction. In this system Geogrid sheet reinforce the sand by incresing the shearing resistance due to the development of tensile strength and PVC pipe prevents the lateral movement of the soil.

Fig 1: Layer of Geogrid-PVC Pipe

III. RESULTS AND DISCUSSIONS

To bring out the effect of reinforcement configuration i.e., number of reinforcement layer and spacing of reinforcement, the tests are conducted with 1,2 and 3 layers and with a spacing of 0.3B and 0.4B

3.1 Number of reinforcement layer (N)

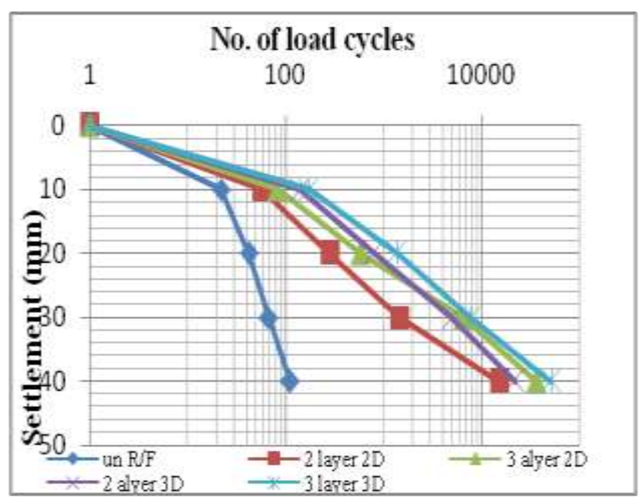

Fig 2: Effect of number of reinforcement layer on the performance of square footing resting on 2D and 3D geogrid reinforced sand beds under a repeated load (P=300kPa;S=0.3B).

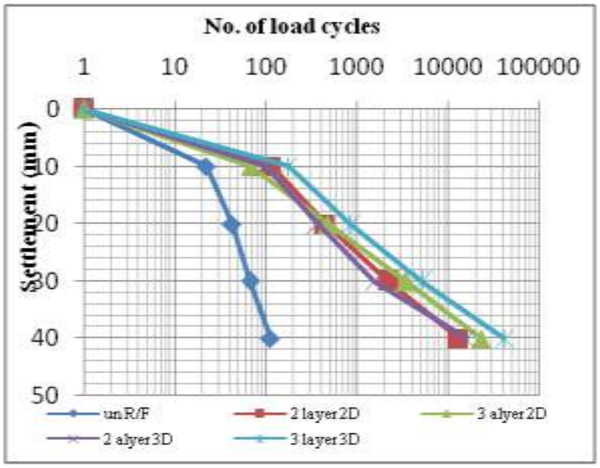

Fig 3: Effect of number of reinforcement on the performance of square footing resting on 2D and 3D geogrid reinforced sand beds. under a repeated load (P=300kPa;S=0.4B).

Fig 2 and Fig 3 present the results of experiments conducted on plain geogrid (2D) and geogrid-pipe (3D) reinforced sand bed with 2 and 3 layer of reinforcement with 0.3B & 0.4B reinforcement spacing respectively, and subjected to a cyclic load of 300kPa.

From these figures it can be seen that at any level of settlement the footing on sand bed with 3 layer of reinforcement (both 2D and 3D) resists more number of loading cycles compared to footing resting on unreinforced and sand bed with 2 layer of reinforcement (both 2D and 3D).

It can be seen from Fig 2, that the footing on unreinforced sand bed resisted about 111 load cycles for 40mm settlement, where as its conterpart with 2 layer of 2D & 3D geogrid reinforcement having reinforcement spacig of 0.3B resisted about 15,134 and 21,969 load cycles respectively, for the same amount of settlement level. Also for 3 layer of 2D & 3D geogrid reinforcement, these numbers are 36,702 & 51,864 load cycles respectively for the 40mm settlement level. These clearly shows that the footing resting on 3 layer geogrid-pipe (3D) reinforced sand bed perform better by resisting more umber of load cycles compared to unreinforced and 2 layer reinforced sand beds, both in 2D and 3D geogrid reinforcement. Similar ternd of results are observed in Fig 3 ,for footing resting on unreinforced, 2D geogrid and 3D geogrid reinforced sand beds under a repeated load of 300kPa with spacing of reinforcement S=0.4B.These results clearly indicate that the optimum number of reinforcement layer is 3 for both 2D and 3D reinforced sand beds.

3.2 Spacing of reinforcement (S)

Varying the spacing between the reinforcement may also play a very important role in the performance of square footing in reinforced sand beds. Experiments are conducted on square footing resting on reinforced sad beds by keeping depth of first layer of reinforcement constant (i.e., U=0.4B) and varying the spacing (S) between the reinforcement as S=0.3B and S=0.4B (where B is size of the square footing).

It can be seen from the Fig 4 , that the footing on unreinforced sand bed resisted about 111 load cycles for 40mm settlement,where as its counterparts with 3 layer of 2D and 3D reinforcement having a spacing of 0.3B resisted about 36,704 and 51,864 load cycles respectively, for the same amount of settlement level. Reinforcement spacing of 0.4B for 2D and 3D geogrid reinforced sand bed these values are 23,271 and 41,578 load cycles respectively for 40mm settlement.This clearly shows that the footing resting on geogrid-pipe(3D) reinforced sand bed with a 3 layer reinforcement having spacing between the reinforcement as 0.3B perform better by resisting more number of load cycles compared to its unreinforced and reinforced sand beds at spacing between the reinforcement as 0.4B.

From these results it is clear that the optimum spacing of reinforcement is 0.3B, both in 2D and 3D geogrid reinforcement.

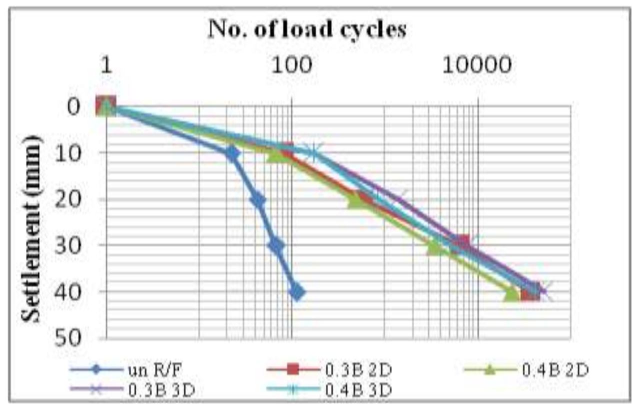

Fig 4: Effect of reinforcement spacing on the performance of square footing resting on the 2D& 3D geogrid reinforced sand beds under a repeated load (P= 300kPa; N=3).

3.3 Comparison of 2D and 3D geogrid reinforcement

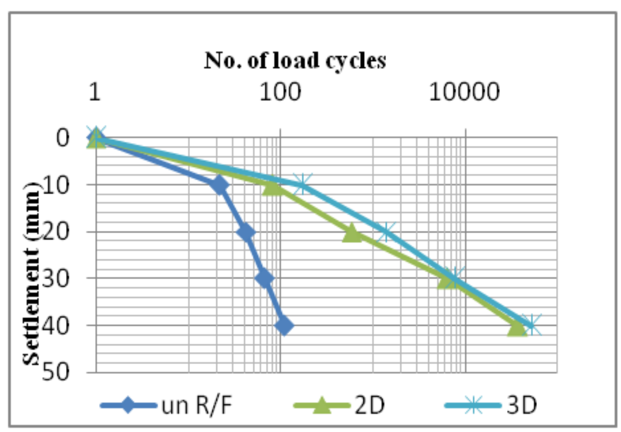

Fig 5: Comparison of performance of square footing resting on 2D and 3D geogrid reinforced sand beds under a repeated load of

Fig 5 corresponds to the settlement of surface footing resting on plain geogrid reinforced sand bed and geogrid-pipe reinforced sand bed subjected to a repeated load of 300kPa. The data in these figures also includes the settlement of footing resting on unreinforced sand bed. The effect of inclusion of plain geogrid (2D geogrid) and geogrid-pipe (3D geogrid) in the sand beds on the settlement characteristics of surface footing is apparent from these figure.

It can be seen from the Fig 5, that the footing on unreinforced sand bed resisted about 111 load cycles for 40mm settlement where as its counterparts resting on 2D and 3D geogrid reinforced sand beds resisted about 36,704 and 51,864 load cycles respectively for the same amount of settlement. This observation clearly demonstrates that the inclusion of geogrid reinforcement, both 2D and 3D, is effective in improving the settlement characteristics of sand bed when subjected to cycle loading.Further it is intersting to observed that the 3D geogrid reinforced sand bed resisted more number of load cycles than its counterpart resting on 2D geogrid reinforced sand bed (51,864 load cycles against 36,704 load cycles). An increase of 41% is achived by the introduction of 3D reinforcement against 2D reinforcement. This observation clearly demonstated that the inclusion of geogrid-pipe (3D geogrid) is very effective when compared to plain geogrid (2D geogrid) in increasing the cyclic load settlement characteristics of footing.

3.3 (I) Cyclic Resistance Ratio

Number of load cycles required to cause a settlement of 'S' in reinforced specimen

CRR= --

Number of load cycles required to cause the same settlement of 'S' in unreinforced specimen

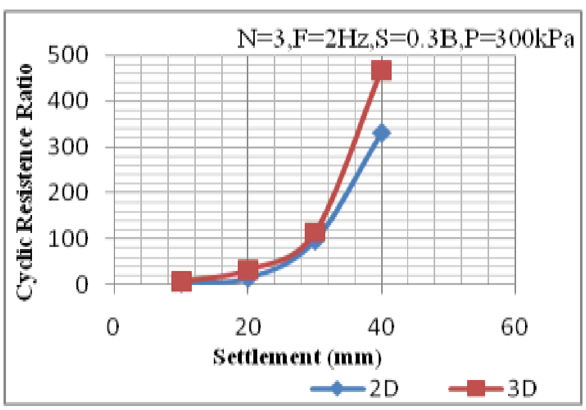

Fig 6: Effect of 2D & 3D Geogrid R/F on CRR

Fig 6 presents the Cyclic Resistence Ratio (CRR) of square footing resting on 3 layer of reinforced sand bed with reinforcement spacing of 0.3B. subjected to a repeated loading of 300kPa.

Fig 6 presents the CRR curves for footing on both 2D and 3D geogrid reinforced sand bed. It can be seen clearly from this figure that inclusion of 3D reinforcement is to increase the CRR value. An increase in CRR value indicates that the footing on 3D geogrid reinforced sand bed is resisting more number of load cycles than its counterpart on unreinforced and 2D geogrid reinforced sand bed at the same settlement level. The Cyclic Resistence Ratio increased from 6 at 10mm settlement level to 331 at 40mm settlement level for footing on 2D geogrid reinforced sand bed. These values are 8 and 467 at 10mm and 40mm settlement level respectively for footing on 3D geogrid reinforced sand bed. This data clearly explains the fact that the provision of 3D reinforcement in the sand bed is to increase the CRR value there by indicating that the number of load cycles resisted by footing on 3D reinforced sand bed is much more than its counterpart resting on 2D geogrid reinforced sand bed.

3.3 (II) Settlement Ratio

Settlement of reinforced sand bed after N number of cycles

SR= ---

Settlement of unreinforced sand bed after same N number of cycles

Fig 7 presents the Settlement Ratio (SR) of square footing resting on sand beds with 3 layer of reinforcement having spacing of 0.3B, subjected to a repeated loading of 300kPa.

It can be seen from Fig 7, that inclusion of 3D reinforcement lower the value of Settlement Ratio comapared to the inclusion of 2D reinforcement. These lower value of Settlement Ratio indicate that the footing on 3D reinforced sand beds undergo less settlement than its counterpart on 2D geogrid reinforced sand bed, at any number of load cycles

The Settlement Ratio value is 0.21 at 111 load cycles for footing on 2D geogrid reinforced sand beds. This value is 0.18 at same number of load cycles for 3D geogrid reinforced sand bed.These data clearly explains the fact that the provision of 3D reinforcemet in sand bed is to decrease the Settlement Ratio value , there by indicating that the footing resting on 3D reinforced sand beds undergo less settlement than its counterpart resting on 2D geogrid reinforced sand beds.

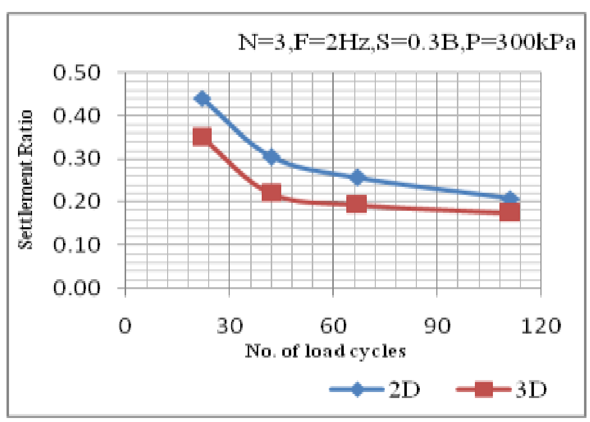

Fig 7: Effect of 2D & 3D Geogrid R/F on SR

IV. CONCLUSIONS

1. Footing resting on Reinforced sand beds perform better than the unreinforced sand beds.
2. Footing resting on 3 layer reinforced sand bed will perform much better by resisting more number of load cycles & undergoing less settlement when compared to the square footing resting in 2 layer reinforced sand bed increase of both geogrid (2D) & geogrid-pipe(3D) reinforcement.
3. The footing on geogrid-pipe reinforced sand bed with N=3, S=0.3B exhibited maximum improvement compared to that on plain geogrid reinforcement.
4. The optimum number of reinforcement layer is found to be 3 and optimum spacing of reinforcement is 0.3B both in 2D and 3D geogrid reinforcement.
5. An increase of 41% is achived by the introduction of 3D reinforcement against 2D reinforcement. This indicates that the inclusion of 3D geogrid is more effective when compared to 2D geogrid in increasing the cyclic load settlement characteristics of footing.
6. Footing resting on 3D geogrid reinforced sand bed shows the highest value of cyclic resistence ratio and lowest value of settlemet ratio compared to the 2D geogrid reinforcement.

REFERENCES

[1]. Abhishek Singh, BR Phanikumar, Ram Prasad. (2016). ***"Load-settlement response of varying sand media reinforced by geogrids"***.International Journal of Applied Research 2016; 2(5): 1106-1109.

[2]. AminatonMarto, MohsenOghabi, Amin Eisazadeh (2013).***"The Effect of Geogrid Reinforcement on Bearing Capacity Properties of Soil Under Static Load"***.EJGE. Vol. 18.

[3]. Mansour Mosallanezhad , Nader Hataf , ArsalanGhahramani. ***"Experimental Study of Bearing Capacity of Granular Soils, Reinforced with Innovative Grid-Anchor System"***.GeotechGeolEng (2008) 26:299–312.

[4]. M. Mosallanezhad, N. Hataf and A. Ghahramani. (2010).***"Three dimensional bearing capacity analysis of granular soils, reinforced with innovative grid-anchor system".*** Iranian Journal of Science & Technology, Vol. 34, No. B4, pp 419-431.

[5]. Ravi Gupta, Rakesh Kumar, P.K. Jain. ***"Behaviour of circular footing resting on three dimensional confined sand".***Int J AdvEngg Tech/Vol. V/Issue II/April-June,2014/11-13.

[6]. SareeshChandrawanshi, Rakesh Kumar, Dr.Suneet Kaur, Dr. P.K. Jain. ***"Effect of skirt on pressure settlement behaviour of model circular".*** Int J AdvEngg Tech/Vol. V/Issue II/April-June,2014/01-05.

[7]. P.K. Jain, Rakesh Kumar and Ravi Gupta. ***"Behavior of circular footing resting on two dimensionally and three dimensionally skirted foundations in medium dense sand".*** Int. J. Adv. Engg. Res. Studies/III/IV/July-Sept.,2014/45-47.