Study on the Effect of Loading Parameters on the Performance of Footing Resting on Reinforced Sand Beds

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Abstract: **soil reinforcement is one of the ground improvement techniques to enhance the engineering properties of soil. This concept was widely used in the geotechnical field. In the present investigation geogrid-PVC pipe was used as reinforcement material to improve the load settlement characteristics of the square footing. In order to evaluate the effect of loading magnitude and frequency of loading on the performance of footing resting on reinforced sand beds, experiments are conducted with different loading magnitude and loading frequency. Experiment results clearly shows that loading parameters affect the performance of square footing resting on reinforced sand beds. The results of experiments are analyzed in terms of cyclic resistance ratio and settlement ratio.**

***Keywords*: Reinforced sand bed, square footing, geogrid, PVC pipe, loading magnitude, Frequency of loading, 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 day's geogrids are used widely in the geotechnical field due to its cost effectiveness and ease of availability in markets. Several laboratory tests are conducted using this geosynthetic 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 And Soil and reinforcement parameters that influence the performance of reinforced soil structure under repeated loading which is published in the literatures Shine EC et al.,(2002)[9], (Mansour Mosallanezhad et al.,(2008)[2], M. Mosallanezhad et al.,(2010)[3], Mostafa EI Sawwaf et al.,(2010)[4], Mostafa EI Sawwaf et al.,(2012)[5],. Ravi Gupta et al.,(2014)[7],Sareesh Chandrawanshi et al.,(2014)[8],P.K Jain et al.,(2014)[6], Aminaton Marto et al.,(2016)[1]). Sudhakar, A.R et al., (2016)[10],. In the present investigation soil reinforcement system is formed from the combination of geogrid and PVC pipes. Geogrid act like reinforcement and supporting 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. Objectives of the present study is, to study the effect of loading parameters (i.e., loading magnitude and frequency of loading) on the performance of square of footing on reinforced sand beds.

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) Rib (mm)	 5 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 ×100mm

   Thickness= 4mm

3. Mild steel tank:

   Diameter = 500mm

   Height = 390mm

2.2 Methods

2.2.1 Preparation of Test Sample

Unreinforced sand sample was compacted up to a height of 360mm in 3 equal layers of 120mm thick. For reinforced sample, the geogrid-pipe 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 5mm 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). This machine has the capability of generating 3 different types of loading waveforms viz., sinusoidal, square and saw tooth. 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 a layer of geogrid and PVC pipe as shown in Fig 1.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 increasing 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

Effect of Loading Parameters on the Performance of Footing on Reinforced Sand Beds

In order to bring out the effect of loading magnitude and frequency of loading on the performance of footing resting on reinforced sand bed, experiments are conducted by varying loading magnitude and frequency of loading. The tests are conducted for Geogrid pipe (3D geogrid) reinforcements, by varying the number and spacing of reinforcement. From the experimental investigation it is obtained that the optimum number of reinforcement layer was found to be 3 and optimum spacing between the reinforcement was found to be 0.3B (where B is size of the square footing).This section presents the results of such an experiments conducted with different loading magnitude of 200kPa, 300kPa, and 400kPa and different frequency of loading of 1Hz and 2Hz.

3.1 Effect of Frequency of Loading

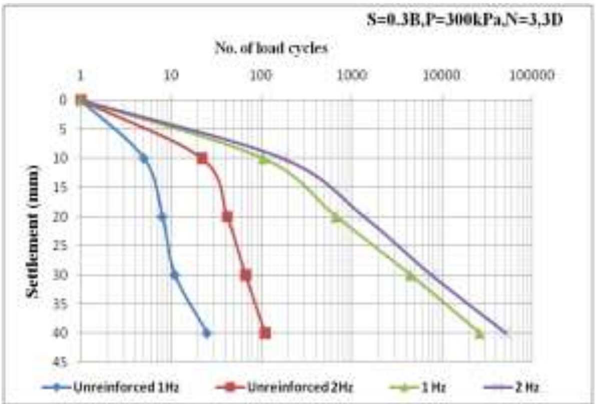


Fig 3: Comparison of frequency of loading on the performance of square footing resting on the reinforced sand beds under a repeated load of 300kPa (N=3),S=0.3B.

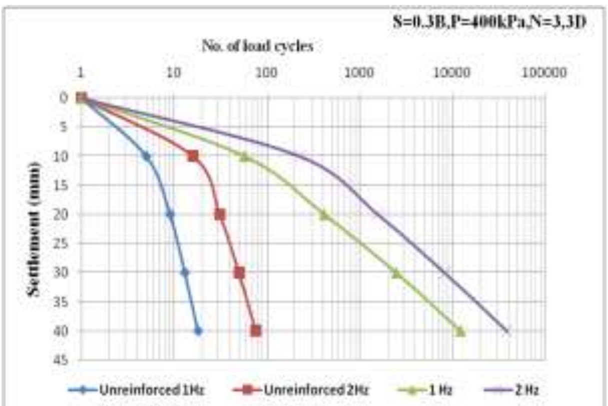


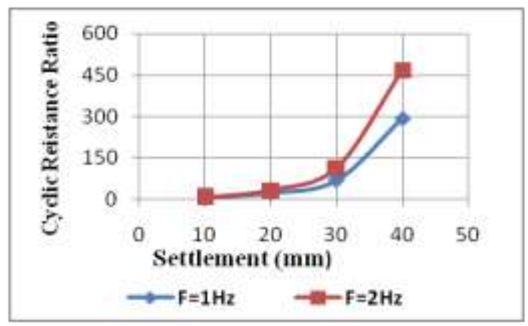
Fig 4: Comparison of frequency of loading on the performance of square footing resting on the reinforced sand beds under a repeated load of 400kPa (N=3),S=0.3B.

Fig 3 and Fig 4 corresponds to the settlement of surface footing resting on 3 layer of geogrid-pipe reinforced sand bed with reinforcement spacing of 0.3B and subjected to repeated load of 300kPa and 400kPa respectively. The data in these figures also includes the settlement of footing resting on unreinforced sand. It can be seen from Fig 3, that the footing on unreinforced sand bed at frequency of loading 1Hz and 2Hz resisted about 25 and 111 load cycles for 40mm settlements where as its counterparts with 3 layer of reinforcement having spacing of 0.3B at frequency of loading 1Hz and 2Hz resisted about 26,410 and 51,864 load cycles for the same amount of settlement level respectively. These figures clearly shows that the footing resting on unreinforced sand bed perform better at frequency of loading 2Hz by resisting more number of load cycles compare to its counterpart subjected to 1Hz loading frequency. Also in geogrid pipe reinforced sand bed, footing subjected to frequency of loading 2Hz resist nearly 2 times more number of load cycles compare to its counterpart with loading frequency of 1Hz. Similar trend of results are observed in Fig 4, for the footing resting on 3 layer of reinforced sand bed having 0.3B spacing and subjected to repeated load of 400kPa at frequency of 1Hz and 2Hz. It can be seen from Fig 4, that the footing on unreinforced sand bed at frequency of loading 1Hz and 2Hz resisted about 18 and 76 load cycles for 40mm settlements where as its counterparts with 3 layer of reinforcement having spacing of 0.3B at frequency of loading 1Hz and 2Hz resisted about 12,435 and 39,305 load cycles for the same amount of settlement level respectively

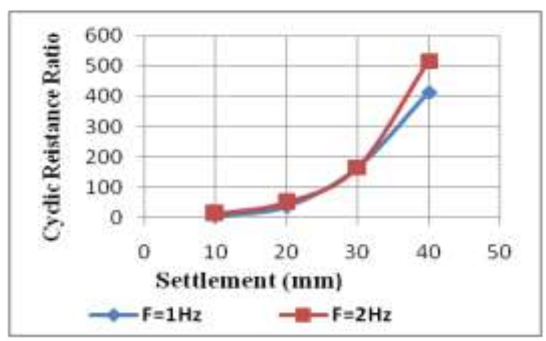
These results clearly indicates that the footing resting on unreinforced and reinforced sand bed at frequency of loading 2Hz perform better by resisting more number of load cycles compare to its counterpart subjected to 1Hz loading frequency.

3.1(I) Cyclic Resistance Ratio

$$CRR = \frac{\text{Number of load cycles required to cause a settlement of 'S' in reinforced specimen}}{\text{Number of load cycles required to cause a same settlement of 'S' in unreinforced specimen}}$$



a] Exitation Condition: P=300kPa,N=3,S=0.3B



b] Exitation condition : P=400kPa,N=3,S=0.3B

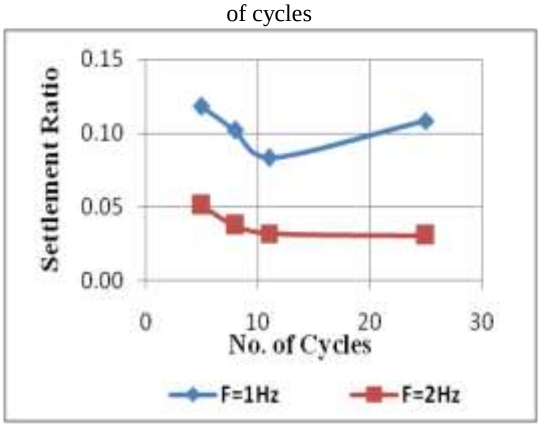
Fig 5: Effect of Frequency of Loading on CRR

Fig 5(a) and Fig 5(b) corresponds to the results for footing resting on 3 layer reinforced sand bed at 0.3B spacing subjected to a repeated load of 300kPa and 400kPa respectively at loading frequency of 1Hz and 2Hz. It can be seen from the Fig 5(a), that CRR increased from 6 at 10mm settlement level to 293 at 40mm settlement for footing at frequency of loading 1Hz. These values are 8 at 10mm settlement level and 467 at 40 mm settlement level for footing at loading frequency of 2Hz. Further,It can be seen from the Fig 5(b), that CRR increased from 10 at 10mm settlement level to 415 at 40mm settlement for footing at frequency of loading 1Hz. These values are 14 at 10mm settlement level and 517 at 40 mm settlement level for footing at loading frequency of 2Hz.

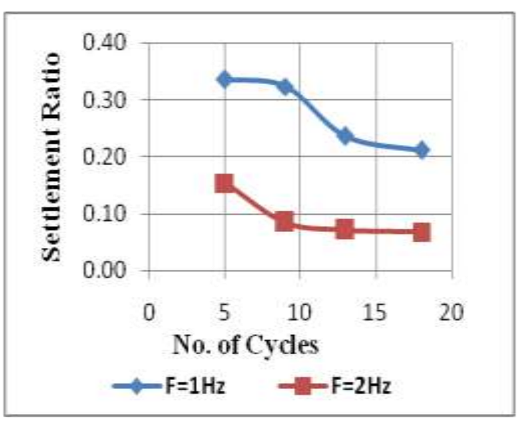
These results clearly indicates that the footing subjected to higher loading frequency exhibit higher value of CRR by resisting more number of load cycles compared to the footing subjected to lower loading frequency exhibit lower CRR value.

3.1(II) Settlement Ratio

$$SR = \frac{\text{Settlement of reinforced sand bed after N number of cycles}}{\text{Settlement of unreinforced sand bed after same N number of cycles}}$$



a] Exitation condition : P=300kPa,N=3,S=0.3B



b] Exitation condition : P=400kPa,N=3, S=0.3B

Fig 6 : Effect of frequency of loading on SR

Fig 6(a) and Fig 6(b) presents the Settlement Ratio (SR) of square footing subjected to a repeated loading of 300kPa and 400kPa at loading frequency 1Hz and 2Hz, with a sine type of loading wave form and resting on 3 layer of reinforced sand beds with reinforcement spacing of 0.3B.

Fig 6(a) at 25 load cycles the footing at frequency of loading 1Hz exhibeted a SR value of 0.11, where as at same number of load cycles for footing at loading frequency of 2Hz exhibite SR value is 0.03. Further, from Fig 6(b) at 18 load cycles the footing at frequency of loading 1Hz exhibeted a SR value of 0.21, were as at same number of load cycles for footing at loading frequency of 2Hz exhibite SR value is 0.07. A comparative study of Settlement Ratio values for 1Hz and 2Hz frequency of loading indicates that the Settlement Ratio value is lower for footing on sand beds at frequency of 2Hz compared to the footing on sand beds at frequency of 1Hz, at any number of load cycles.This decrease in value Settlement Ratio indicates that footing undergo less settlement when it is subjected to higher loading frequency.

3.2 Effect of Loading Magnitude

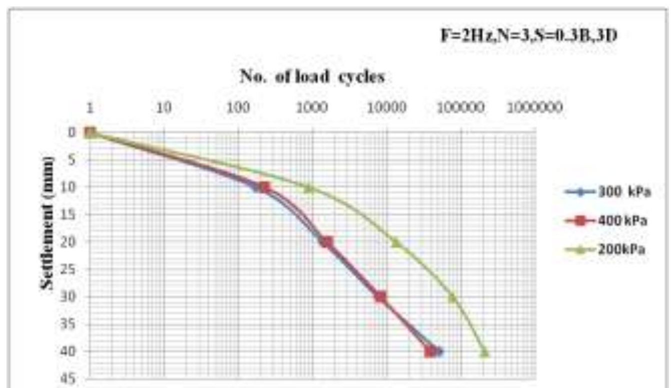
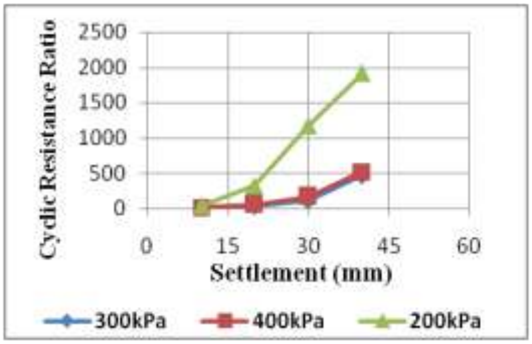


Fig 7: Comparison of loading magnitude on the performance of square footing resting on3D geogrid reinforced sand bed under a repeated load (N=3, S=0.3B,F=2Hz).

Fig 7 presents the results of experiments conducted on geogrid-pipe (3D) reinforced sand beds with 3 layer of reinforcement at spacing of 0.3B at frequency of loading 2Hz subjected to loading magnitude of 200kPa, 300kPa and 400kPa. It can be seen from Fig 7 were footing subjected to repeated load of 200kPa, 300kPa and 400kPa.Footing resting on geogrid pipe reinforced sand bed subjected to a repeated load of 200kPa resisted about 2,12,521 load cycles for 40mm settlement where as its counterpart subjected to repeated load of 300kPa and 400kPa resist 51,864 and 39,305 load cycles for the same amount of settlement level respectively. These results clearly indicate that the footing resting on geogrid pipe reinforced sand bed subjected to repeated load of 200kPa exhbit the intresting results compare to the reinforced sand bed subected to repeated load of 300kPa and 400kPa. Footing subjected to repeated load of 200kPa resist more number of load cycles, there is an increase of 4 and 5 times more load cycles compared to the 300kPa and 400kPa loading magnitude respectively.

3.2(I) Cyclic Resistance Ratio



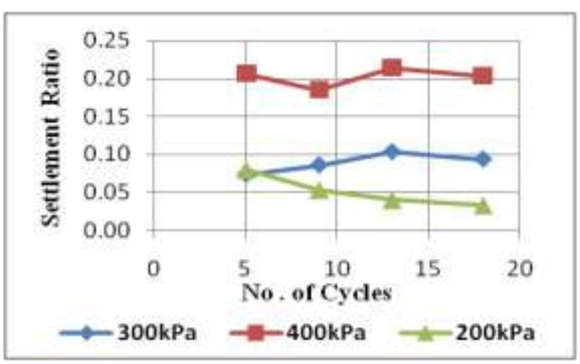
a] Exitation condition: N=3,S=0.3B, F=2Hz

Fig 8: Effect of Loading Magnitude on CRR

A comparative study of Cyclic Resistence Ratio (CRR) for footing resting on reinforced sand beds subjected to loading magnitude of 200kPa, 300kPa and 400kPa, indicates that the CRR is higher for footing subjected to repeated load of 200kPa compared to the footing subjected to repeated load of 300kPa and 400kPa at any settlement level.

Fig 8(a) corresponds to the results for footing resting on 3 layer reinforced sand bed at 0.3B spacing subjected to a repeated load of 200kPa ,300kPa and 400kPa at loading frequency of 2Hz. It can be seen from the figure that CRR increased from 8 at 10mm settlement level to 1900 at 40mm settlement for footing subjected to 200kPa repeated load. These values are 6 nad 4 at 10mm settlement level and 573 and 437 at 40 mm settlement level for footing subjected to repeated load of 300kPa and 400kPa respectively. This clearly indicates that the footing subjected to lower loading magnitude resist more number of load cycles by exhibit higher value of CRR compared footing subjected to higher loading magnitude exhibit lower value of CRR.

3.2(II) Settlement Ratio



a] Exitation condition : F=2Hz, N=3, S=0.3

Fig 9: Effect of Loading Magnitude on SR

Fig 9(a), presents the Settlement Ratio (SR) of square footing subjected to a repeated loading of 200kPa, 300kPa and 400kPa at loading frequency 2Hz, with a sine type of loading wave form and resting on 3 layer of geogrid-pipe reinforced sand beds with reinforcement spacing of 0.3B. Fig 9(a), at 18 load cycles the footing subjected to repeated load of 200kPa exhibeted a SR value of 0.03, where as at same number of load cycles for footing sunjected to repeated load of 300kPa and 400kPa,SR value is 0.09 and 0.20 respectively.

This results clearly indicates that the footing subjected to lower loading magnitude exhibit lower value of Settlement Ratio and it undergo less settlement comapered to the footing subjectedto higher loading magnitude.

IV. CONCLUSIONS

1. Reinforced sand beds perform better than the unreinforced sand beds.
2. The excitation parameters viz., loading magnitude and frequency of loading has an influence on the performance of footing in reinforced sand bed.
3. The footing tested at higher frequency (2Hz) exhibits higher CRR and lower SR values compared to the footing exposed to lower frequency of loading (1Hz), exhibits lower CRR and higher SR value. This confirms the trend that the footing tested at higher frequency performs better than the footing tested at the lower frequency.
4. Footing performs better when they are subjected to lower loading magnitude (200kPa) by taking more number of load cycles & undergoing less settlement when compared to the footing subjected to higher loading magnitude(300kPa and 400kPa) in geogrid-pipe reinforcement condition.

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