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An Experimental Study on Behaviour of Square Footing Resting on Reinforced Sand Bed under Static and Repeated Loading Using Geosynthetic Material

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Abstract: ***In several structures in addition to static loads the foundations are subjected to dynamic loads like machine loads, seismic loads and moving wheel loads, petroleum tanks and ship repair tracks. In this study an attempt is made to evaluate the static and cyclic behavior of square footing resting on sand sub grade by conducting plate bearing and cyclic plate load tests in model box. The load-displacement characteristics were found from static plate bearing tests from which modulus of sub grade reaction (K) was found which is used in pavement design and evaluation. Also from cyclic plate load tests from which cyclic parameters (C_u, C_ϕ, C_τ, C_ψ) was evaluated which is a parameter used in the design of machine foundations. To implement this objective, a cyclic plate load tests were performed to study the of reinforced soil foundation. The sand bed consists of horizontally placed polyester geogrid reinforcement in different layers and observed the effect of number of reinforced layers, effect of loading on bearing capacity, effect of width of reinforcement, effect of top layer spacing of reinforcement on dynamic properties.***

Keywords: Cyclic loading, Geogrid, Coefficient of Elastic Uniform Compression, Coefficient of Non Uniform Compression, Coefficient of Uniform Shear, Coefficient of elastic non uniform shear, Modulus of Sub Grade Reaction.

1. Introduction

The sub grade of highway or foundation of structures require the special attention of the civil engineer when subjected to weight of machine or vehicle and the foundation loads are dynamic nature in addition to static loads. Dynamic analysis to evaluate the response of earth structures to dynamic stress applications, such as those produced by machine loads, seismic loads and moving wheel loads are finding increased application in civil engineering practice. As it is well established that a foundation weighs several times as much as a machine, a dynamic load associated with the moving parts of a machine is generally small as compared to its static load.

In this type of foundation a dynamic load applies repetitively over a large period of time but its magnitude is small, and it is therefore necessary that the soil behavior be elastic, or else deformation will increase with each cycle of loading until the soil becomes practically unacceptable. Similar type of loading can be expected on pavement, the moving wheel loads are dynamic in nature due to repeated application of moving wheel loads the settlement of soil sub grade will increase with each application and finally leads to the sub grade failure. In dealing with these types of loads the coefficient of elastic uniform compression of soil C_u is the most

Important parameter to be determined which can calculate by cyclic plate load test in the model box. An Attempt has been made in this paper to study a point of this phenomenon. In the current research, two types of tests on circular plate subjected to cyclic and static loads are performed. However, the main objective of the present study is to evaluate the dynamic elastic constants of locally available sand with geogrid reinforcement using large scale model box.

2. Background

Since N. Hataf, A.H. Boushehrian and A. Ghahramani ,(2010) conducted that by use of grid-anchor increasing the number of their layers in the same proportion as that of the cyclic load applied, the amounts of permanent settlements are reduced and the numbers of loading cycles to reach it are decreased, A.Asakereh1, S.N. Moghaddas Tafreshi2, M. Ghazavi2, (2011); J S Vinod, B. Indraratna, B. Indraratna,(2011); M.V.S. Sreedhar, A. Pradeep Kumar Goud, (2012); Asakereh, M.Ghazavi, S.N.Moghaddastafreshi, (2013).

3. Materials and Experimental Setup

The sand use for the investigation is brought from a Bhugao river 10Km from Rajkot City, Gujarat (State), the relative density of sand is used 50% for all the tests and the geogrid use a polymer uniaxial geogrid. The properties of the sand in unreinforced condition are determined by different soil test as per relevant Indian Standards shown in Table 1. The salient features and properties of geogrid are listed in Table 2.

Table 1: Properties of Sand

Sr.No	*Properties of sand*	*Value*
1	D_{10}	0.35 mm
2	D_{30}	0.58 mm
3	D_{60}	1.1 mm
4	Coefficent of Uniformity, C_u	3.14
5	Coefficent of Curvature, C_c	0.87
6	Types of Soil	SP
7	Y_{max}	1.83 gm/cm^3
8	Y_{min}	1.61 gm/cm^3
9	Specific Gravity G	2.58
10	Angle of Friction ϕ	32^o
11	Relative Density	50%
12	Dry Density	1.71 gm/cm^3

Table 2: Properties of geogrid Reinforcement used

Sr.No	*Properties*	*Value*
1	**Peak tensile strength**	
	Machine direction	250 KN/m
	Cross machine	30 KN/m
2	**Physical Properties**	
	Colour	Black
	Coating	PVC
	Aperture Size	15x15 mm

3.1 Test-set-up

A tank of size 750X750X750 mm is use in the present study. Hand operating jack is used and having a capacity of 2 tonn for performing static and cyclic plate load tests. A 150mmX150mm square steel plate is use to exert pressure on the prepared sand bed, the experimental test set up is shown in figure.

Figure 1: Experimental setup

Table 3: u/B ratio corresponding first reinforcement depth

u/B Ratio	*First reinforcement depth(u)*
0.2	3.2cm
0.4	6.4cm
0.6	9.6cm

4. Results and Discussion

4.1. Static Loading on Un-Reinforced and Reinforced Sand:

The load-settlement curve for plate load test on unreinforced sand and reinforced sand bed plotted and shown in the fig.2. From the Fig.2 it is observed that (a) The settlement of footing was decreases with increases No of layer of Geogrids (N) and increases in width of geogrid (Bˈ). Settlement of footing without geogrids which was 33.93mm, decreased to 22.13mm at u/B=0.2, Bˈ=4B and N=4 showing 34.77% decreased. (b) The ultimate bearing capacity of sand without geogrids which was 63kN/m^2, increased to 118kN/m^2 with using geogrid reinforcement at u/B=0.2, B'=4B and N=4 showing 87.30% increased.

4.2. Cyclic plate load test with reinforcement sand

The experimental results of the applied cyclic loads, incrementally (loading, unloading and reloading) with footing settlement rested on reinforced sand with Bˈ/B = 1, Bˈ/B = 2, Bˈ/B = 3, Bˈ/B = 4 for u/B = 0.2, 0.4 and 0.6 are shown in Fig.3-4-5-6 and the following observations were made. It indicates that in each stage due to unloading, a small amount of settlement rebounds which named elastic or recoverable settlement (the amount of elastic rebound of the soil increases with increase in the stress level) while a major part of the settlement is plastic settlement and remains in the system.

It can be seen that, the load v/s footing settlement response of reinforced sand bed is far better than the un-reinforced case. This is due to the frictional resistance at the interface of the sand and reinforcement which would have prevented the soil mass from shearing under vertical applied load.

The footing resting on the soil-reinforcement composite will carry more loads. This shows that settlement of sand improvement is totally depends on the position of the reinforcement and density within the sand bed. The response of the reinforced sand bed is seen to improve as the depth ratio u/B= 0.2 and thereafter shows a increasing trend. As the increase in the width of the geogrid reinforcement settlement of sand is decrease. For Bˈ/B = 4 and U/B=0.2 there is a maximum value of settlement 26.83mm is observed when compared with other width of reinforcement Bˈ/B = 1, Bˈ/B = 2, Bˈ/B = 3 the values are, 35.52mm, 33.34mm, 29.95mm respectively. The value of settlement of the sand for different width of reinforcement and u/B ratios is exclusively given in table 4.

Table 4: Settlement of sand for different width of reinforcement and u/B ratio

	Settlement (mm)		
	N=1, u/B=0.2	**N=1, u/B=0.4**	**N=1, u/B=0.6**
Bˈ/B=1	35.52	37.53	39.41
Bˈ/B=2	33.33	35.43	37.47
Bˈ/B=3	29.95	32.84	35.52
Bˈ/B=4	26.83	29.91	33.94

4.3 Effect of Reinforcement Top Layer Spacing (u)

Fig-11-12-13-14, shows the coefficient of uniform compression of the footing with B'/B = 1, B'/B = 2, B'/B = 3, B'/B = 4, corresponding to number of reinforcement layers for different u/B ratio 0.2, 0.4 and 0.6, respectively. Fig-11-12-13-14 shows that with increases width of reinforcement and u/B ratio also increase coefficient of uniform compression. In fig.11 obtained maximum value of coefficient uniform compression for B'/B=4 and u/B=0.2 C_u is 15.42x10^4kN/m^3 is observed when compared with other width of reinforcement B'/B = 1, B'/B = 2, B'/B = 3 the values are, 9.88x10^4kN/m^3, 11x10^4kN/m^3, 13.25x10^4kN/m^3 respectively.

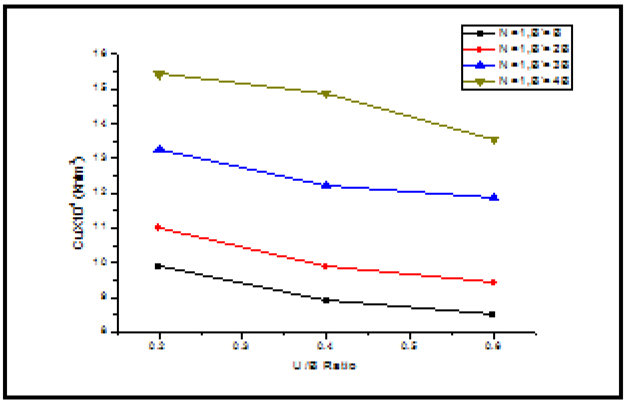

Figure 2: Top layer spacing (u/B) vs. C_u for N=1 and different width of geogrid.

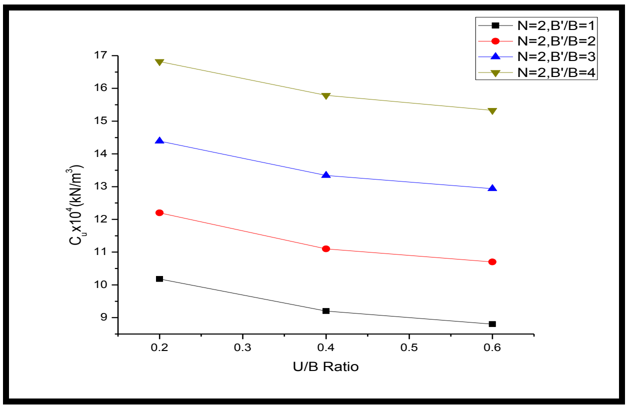

Figure 3: Top layer spacing (u/B) vs. C_u for N=2 and different width of geogrid

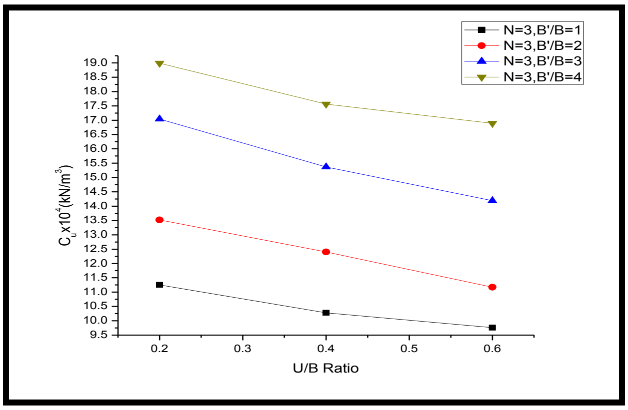

Figure 4: Top layer spacing (u/B) vs. C_u for N=3 and different width of geogrid

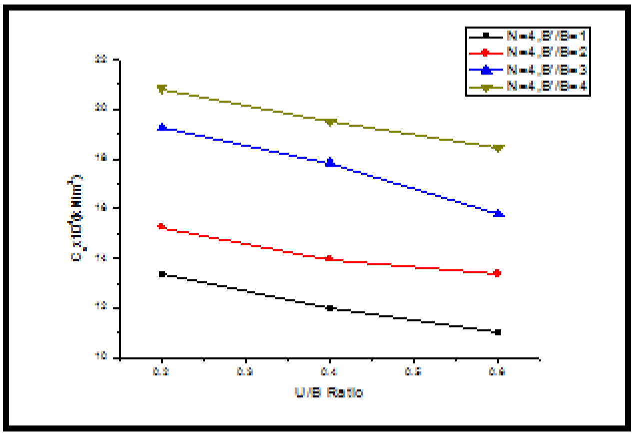

Figure 5: Top layer spacing (u/B) vs. C_u for N=4 and different width of geogrid.

4.4 Effect of Numbers of Reinforcement Layer (N)

Fig-15-16-17-18, shows the coefficient of uniform compression of the footing with B'/B = 1, B'/B = 2, B'/B = 3, B'/B = 4 correspond to u/B ratio 0.2, 0.4, 0.6, for different numbers of reinforcement layer N=1, N=2, N=3, N=4, respectively.

Fig-15-12-13-14 shows that with u/B ratio and Numbers of reinforcement layer also increase coefficient of uniform compression. In fig.18 obtained maximum value of coefficient uniform compression for N=4 and u/B=0.2 C_u is 20.83x10^4kN/m^3 is observed when compared with other Numbers of reinforcement layer N = 1, N = 2, N = 3 the values are, 9.88x10^4kN/m^3, 12.20x10^4kN/m^3, 17.04x10^4kN/m^3 respectively.

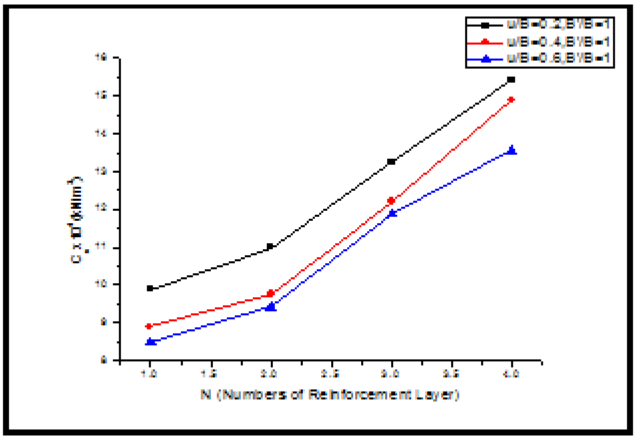

Figure 6: Numbers of Reinforcement (N) vs. C_u for B'/B=1 and different top layer spacing of geogrid

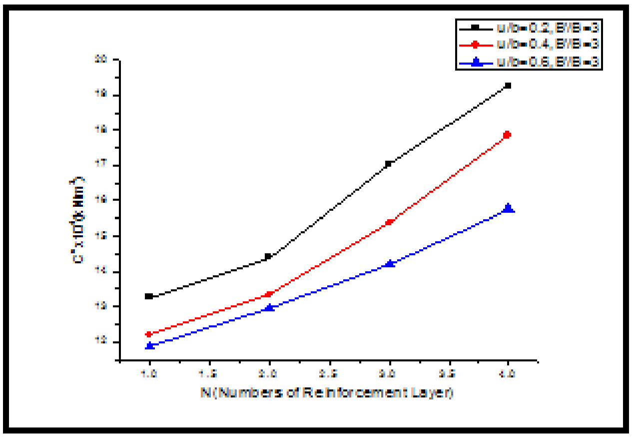

Figure 8: Numbers of Reinforcement (N) vs. C_u for B'/B=3 and different top layer spacing of geogrid

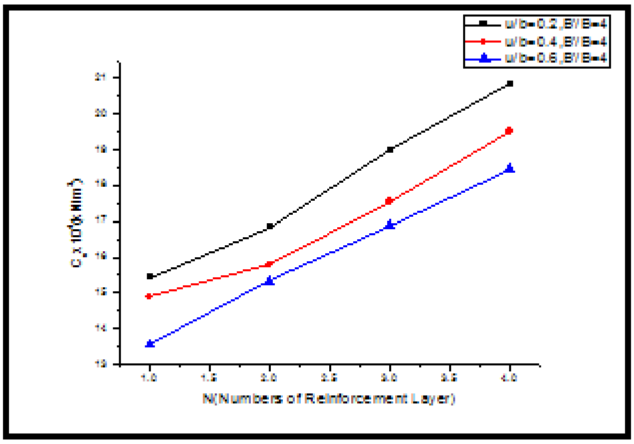

Figure 9: Width of geogrid (B'/B) vs. C_u for N=2 and different top layer spacing of geogrid.

4.5. Effect of Width of Reinforcement (B'/B)

Fig-19-20-21-22, shows the coefficient of uniform compression of the footing with N = 1, N= 2, N = 3, N = 4, correspond to u/B ratio 0.2, 0.4 and 0.6, for different width of reinforcement layer B'/B = 1, B'/B = 2, B'/B = 3, B'/B = 4 respectively.

Fig-19-20-21-22 shows that with u/B ratio and different width of reinforcement layer also increase coefficient of uniform compression. In fig.22 obtained maximum value of coefficient uniform compression for B'/B=4 and u/B=0.2 C_u is observed 20.83x10^{4}kN/m^3 when compared with other width of reinforcement layer B'/B = 1, B'/B = 2, B'/B = 3 the values are, 9.88x10^{4}kN/m^3, 12.20x10^{4}kN/m^3, 17.04x10^{4}kN/m^3 respectively.

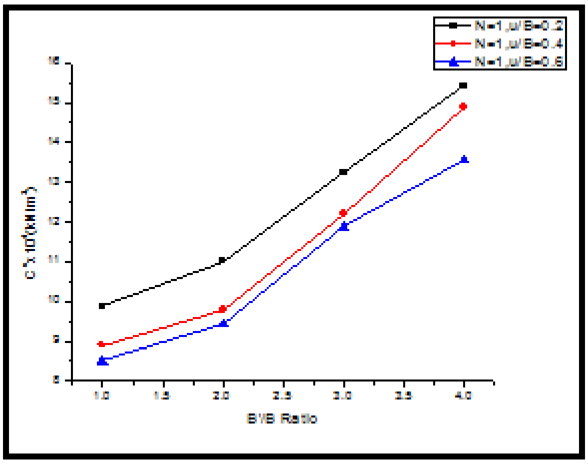

Figure 10: Width of geogrid (B'/B) vs. C_u for N=1 and different top layer spacing of geogrid

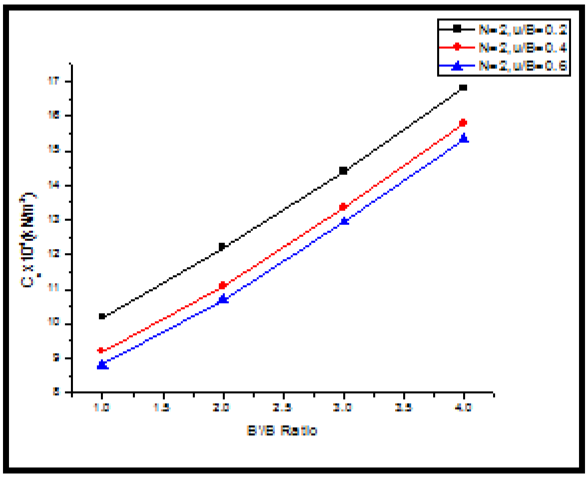

Figure 11: Width of geogrid (B'/B) vs. C_u for N=2 and different top layer spacing of geogrid.

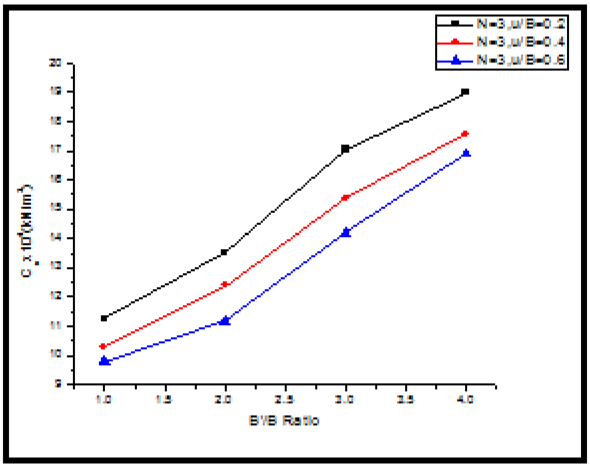

Figure 12: Width of geogrid (B'/B) vs. C_u for N=3 and different top layer spacing of geogrid

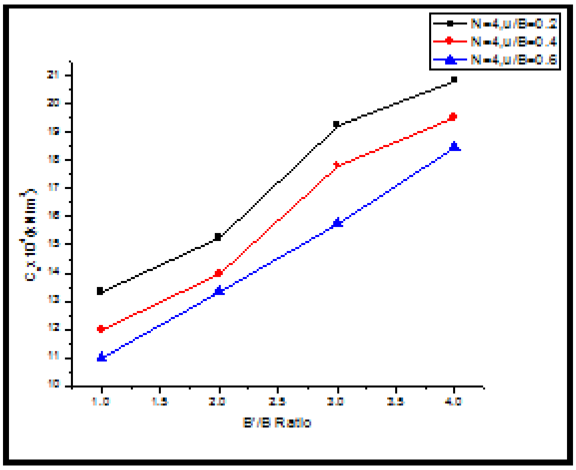

Figure 13: Width of geogrid (B'/B) vs. C_u for N=4 and different top layer spacing of geogrid.

5. Conclusion

The ultimate bearing capacity of sand increased with using geogrid reinforcement. The settlement of footing was decreases with increases No of layer of Geogrids (N) and increases in width of geogrid (B'). Settlement of footing without geogrids decreased.

Modulus of sub grade reaction (K) increase with using geogrid reinforcement. Co-efficient of elastic uniform compression (Cu) increase with using geogrid reinforcement. Co-efficient of Elastic uniform compression (Cu) and other cyclic parameter (Cτ, Cϕ, Cψ) decreases with increasing top layer spacing (u/B) of geogrids layers and increases with increases width of geogrid (B'/B) and also depends on Number of layer of geogrids(N).

For design purposes, engineers need to balance between reducing spacing and increasing geogrid tensile modulus. The author believes that a value of h/B = 0.2 can be a reasonable value for use in the design of reinforced soil.

References

[1] Basavaraj Hotti1, P.G. Rakaraddi2, Sudharani Kodde3, "Behavior of square footing resting on reinforced sand subjected to incremental loading and unloading." IJRET: International Journal of Research in Engineering and Technology, (2014).
[2] Tejaswini B. R1, S. Gangadara2, H. C. Muddaraju3, Bindiya K4 (May 2014), "A Study on The Performance Of Circular Footing Embedded In Geogrid Reinforced Flyash Beds Under Cyclic Loading." Volume: 03 Special Issue: 06 |RRDCE – 2014.
[3] H.N Ramesh, Dr.L.manjesh, Vijaya Kumar.H.A, (September. 2013), "Effect of Static and Cyclic Loading on Behavior of Fiber Reinforced Sand." IOSR Journal of Engineering (IOSRJEN) e-ISSN: 2250-3021, p-ISSN: 2278-8719 Vol. 3, ||V3|| PP 56-63
[4] S. Gangadhara, H. C. Muddaraju,(December 22-24,"Effect on the performance of different shapes of footings resting on reinforced flyash beds under repeated load." 2013Roorkee.
[5] Asakereh, M.Ghazavi, S.N.MoghaddasTafreshi 22 May 2013 "Cyclic response of footing on geogrid-reinforced sand with void." The Japanese geotechnical journal, www. Science direcr.com.
[6] S.N. Moghaddas Tafreshi, A.R. Dawson, "Laboratory Tests of Footing Supported on Geotextile – Reinforced Sand UnderRepeated Loading." (2012)
[7] M.V.S. Sreedhar, A. Pradeep Kumar Goud, December 2011, "Behaviour of geosynthetic reinforced sand bed Under cyclic load."
[8] Mostafa El Sawwaf , Ashraf Kamal Nazir "Behavior of repeatedly loaded rectangular footings resting on reinforced sand." January (2011), Alexandria Engineering Journal.
[9] J S Vinod, B. Indraratna, B. Indraratna, "Behaviour of geocell reinforced foundation under cyclic loading." December 15-17, 2011, Kochi.
[10] A.Asakereh1, S.N. Moghaddas Tafreshi2, M. Ghazavi2, "Strip footing behavior on reinforced sand with void subjected to repeated loading." (2011), International Journal of Civil Engineering.
[11] B.M.DAS, Principal of foundation Engineering, PP-267-286.
[12] Robert M. koerner, "Designing with geosynthetics", practice hall, Fourth Edition, 1999, PP-222-226.
[13] IS.1888: (1982). "Indian Standard Method of Load Test on Soils."BIS, New Delhi, India.
[14] IS.5249: (1992). "Indian Standard method of Test for Determination of Dynamic Properties of Soils." BIS, New Delhi, India.

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