International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 3 Issue 3, March 2015

Behaviour of Square Footing Resting on Reinforced Sand Bed under Static and Cyclic Loading Using Geogrid

Lalji Baldaniya[1], Pratik B. Somaiya[2]

[1]P G Scholar, Marwadi Education Foundation Group of Institutions, Gujarat, India

[2]Assistant Professor, Marwadi Education Foundation Group of Institutions, Gujarat, India

Abstract: ***In several structures 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 paper 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 tests. The load – displacement characteristics were found from static plate bearing tests from which modulus of sub grade reaction was found which is used in pavement design and evaluation. Also from cyclic plate load tests coefficient of elastic uniform compression (C_u), coefficient of non uniform compression (C_ϕ), coefficient of uniform shear(C_τ), damping coefficient (ξ), was evaluated which is a parameter used in the design of machine foundations. In the present study the plate bearing and cyclic plate load tests are conducted for layered sand.***

Keywords: Cyclic Plate Load Tests, Co-Efficient of Elastic Uniform Compression, Coefficient of Non Uniform Compression, Coefficient of Uniform Shear, Damping Coefficient, 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 therefore necessary the soil behavior be elastic, or 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 type of loads the co-efficient 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. Literature Review

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); Gangadhara, H. C. Muddaraju, (2013); Tejaswini B. R1, S. Gangadara2, H. C. Muddaraju3, Bindiya K4, (2013); Tejaswini B. R1, S. Gangadara2, H. C. Muddaraju3, Bindiya K4, (2014); Basavaraj Hotti1, P.G. Rakaraddi2, Sudharani Kodde3, (2014).

Review of the literature revealed that various laboratory investigations have been conducted on geogrid reinforced sand but these investigations were limited in their scope and concentrated on square footing resting on reinforced sand under static and cyclic loading. Review of the literature revealed that various laboratory investigations have been conducted that

Basavaraj Hotti1, P.G. Rakaraddi2, Sudharani Kodde3 [1] They investigate the results of laboratory model tests on square footings supported on geogrid reinforced sand bed under incremental loading and unloading conditions for different densities of sand bed and U/B ratio. The effect of sand for the density 1.59 gm/cc, 1.69 gm/cc, and 1.79 gm/cc and for different U/B ratio of 0.2, 0.4, and 0.6. They were found that when the intensity of load is increase also cyclic parameters coefficient of elastic uniform compression C_u, coefficient of elastic uniform shear C_τ, coefficient of elastic non-uniform shear C_ψ and the coefficient of elastic non uniform compression C_ϕ is also increases.

Table 1: Values of C_u, C_τ, C_φ, C_ψ for unreinforced conditions of sand bed for different densities

Density (gm/cc)	**C_u*10^4 KN/m^3**	**C_τ*10^4 KN/m^3**	**C_ϕ*10^4 KN/m^3**	**C_ψ*10^4 KN/m^3**
1.59	6.40	3.65	12.62	5.47
1.69	10.76	6.14	21.24	9.21
1.79	12.67	7.24	25.05	10.89

Table 2: Values of Cu, Cτ, Cφ, Cψ for reinforced conditions of sand bed for different densities and U/B ratios.

U/B ratio	**Density (gm/cc)**	**Cux10^4 kN/m3**	**Cτx10^4 kN/m3**	**Cφx10^4 kN/m^3**	**Cψx10^4 kN/m^3**
0.2	1.59	15.57	8.89	30.75	13.33
0.2	1.69	16.20	9.25	32.00	13.87
0.2	1.79	16.42	9.38	32.45	14.07
0.4	1.59	16.12	9.21	31.86	13.81
0.4	1.69	16.40	9.37	32.42	14.05
0.4	1.79	16.54	9.45	32.69	14.17
0.6	1.59	13.75	7.85	27.16	11.77
0.6	1.69	14.88	8.50	29.41	12.75
0.6	1.79	16.00	9.14	31.62	13.71

Tejaswini B. R1, S. Gangadara2, H. C. Muddaraju3, Bindiya K4 [2] Investigated most of the research work has been carried out by making use of frictional soil as a backfill material and fewer attempts have been made by making use of fly ash as backfill material. In the present study fly ash is used as a backfill material. This study highlights the performance of circular footing resting in reinforced fly ash beds under repeated loads.

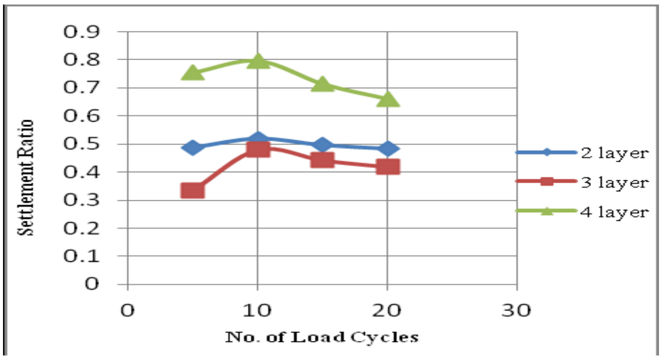

Figure 1: Effect of number of reinforcement layers on SR for embedded circular footing in reinforced fly ash beds with P = 450kPa, S=0.3B.

Circular footing resting in 3 layer reinforced fly ash beds will perform much better by taking more number of load cycles and undergoing less settlement when compared to the circular footing resting in unreinforced, two and four layer reinforced fly ash beds. The three layers reinforced fly ash beds showed highest value of cyclic resistance ratio and lowest value of settlement ratio in cases of 1B embedment depth of circular footing. Optimum spacing between the reinforcement was found to be 0.3B.

Tejaswini B. R1, S. Gangadara2, H. C. Muddaraju3, Bindiya K4 [3] They investigate the static and cyclic behavior of circular footing resting on sand and clay sub grade by conducting plate bearing and cyclic plate load tests in large model box tests. From cyclic plate load tests coefficient of elastic uniform compression (C_u) was evaluated which is a parameter used in the design of machine foundations Co efficient of Elastic Uniform compression C_u and CBR increases with the introduction of fiber reinforcement and the Modulus of sub grade Reaction (K) is more in fiber reinforced sand than unreinforced sand. [$C_u = p/s_e$] KN/$m^{3,}$ [$k= p/\Delta$]

.

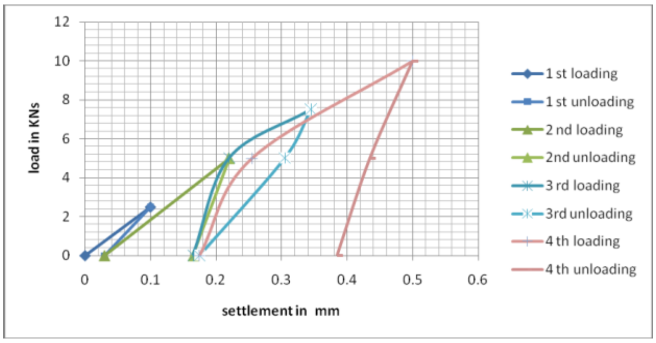

Figure 2: Cyclic Loading Curve to evaluate Coefficient of Elastic Uniform Compression of Un reinforced sand.

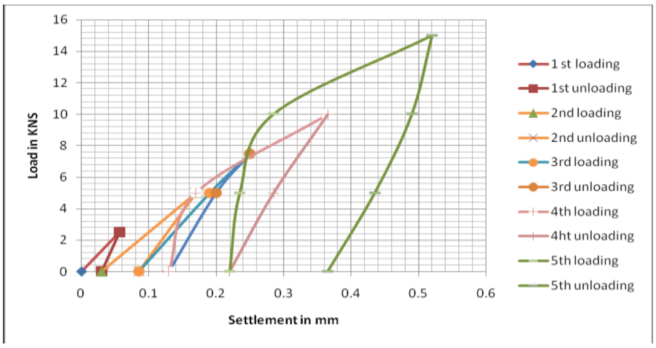

Figure 3: Cyclic loading to Evaluate Co efficient of elastic Uniform compression of sand reinforced with fiber

Gangadhara, H. C. Muddaraju [4] They investigate the results of tests conducted on model footing resting on reinforced and unreinforced fly ash beds subjected to repeated loads. The fly ash beds were reinforced with geo grids. Model footing used for this investigation is square in shape of 100mm size, circular footing of 100mm diameter, and rectangular footing of size 100 x 80mm. For the footings the optimum number of reinforcing layers is four. In this experiment 300kpa and 350kpa loads has been applied on three footing over 2, 3, 4 layer. After that by experiment they were find out Cyclic resistance ratio (CRR) and settlement ratio(SR).

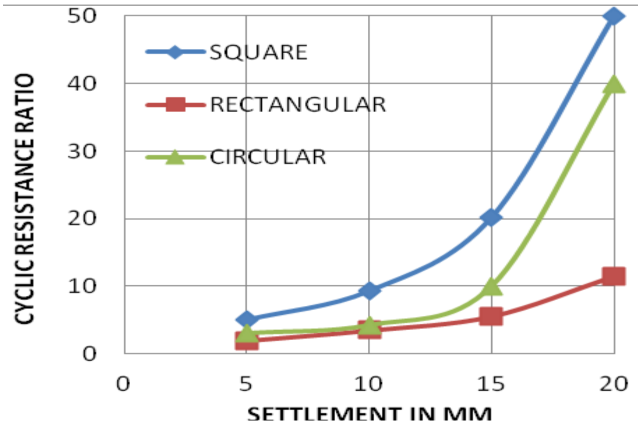

Figure 4: Shape effect of footings on CRR value for fly ash beds subjected to a loading magnitude of 350kPa of 2, 3, and 4 Layers.

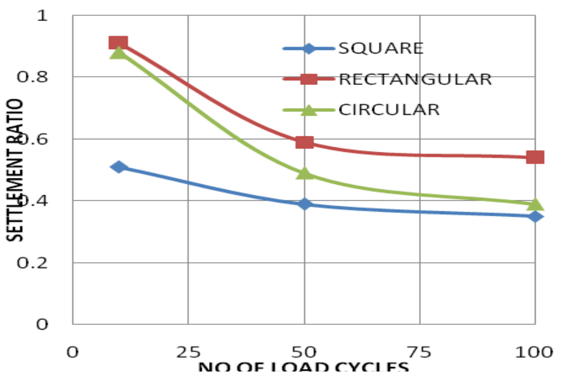

Figure 5: Shape effect of footings on SR value for fly ash beds subjected to a loading magnitude of 350 of 2, 3, and 4 Layers.

Asakereh, M.ghazavi, S.n.moghaddastafreshi [5] They investigate footing constructed on unreinforced and geogrid-reinforced sand with circular a void subjected to a combination of static and repeated loads. The size of testing tank with 1000 mm length, 1000 mm height, and 220 mm width and a data acquisition system. The actuator can produce monotonic or repeated loads to a maximum capacity of 10 kN with different amplitudes and different frequencies up to 1 Hz via an electromechanical control system capable of producing a repeated load with desired amplitude and frequency. The settlement of the footing was measured for up to 5000 cycles of loading and unloading.

The soil-footing systems with sufficient geo grid-reinforcement and sufficient void embedment depth behave much more stiffly and are thus capable of handling greater loads with lower settlement than those in unreinforced soil without a void. The undesirable effect of the void on the footing behaviour can be eliminated. In addition, the results show that the values of footing settlement increase rapidly during the initial loading cycles; thereafter the rate of settlement is reduced significantly as the number of loading cycle's increases.

S.N. Moghaddas Tafreshi, A.R. Dawson [6] They investigate model tests performed on strip footings supported on unreinforced and geo textile-reinforced sand bed under a combination of static and repeated loads. Footing settlement due to initial static applied load and up to 20000 subsequent load repetitions was recorded, until its value become stable or failure occurred due to excessive settlement. Effect of the number of reinforced layers (N) and intensity of repeated load (q_{dyn}/q_{stat}) at optimum values of u/B, h/B and b/B. The static pre-loading, q_{stat} applied prior to repeated loading and the values of additional dynamic load, q_{dyn} were selected as 20, 30 and 50% of q_{stat} (q_{dyn}/q_{stat}=20%, 30% and 50%.

The magnitude of the maximum footing settlement and the number of cycles required to be stabled of the footing settlement are a function of the initial applied static load (q_{stat}), the amplitude of the repeated load (q_{dyn}) and the mass of reinforcement below the footing base (N). For a given value of amplitude of repeated load, with increase in the number of reinforcement layers, the footing settlement decreases while the efficiency of reinforcement was decreased by increasing the mass of reinforcement.

M.V.S. Sreedhar, A. Pradeep Kumar Goud [7] They investigate the static and cyclic behaviour of Sand reinforced with geo synthetic products by conducting load tests in a large size tank of 1200 x1200 x900 mm internal dimensions. The sand bed of 500mm thick was compacted at a relative density of 90% in dry state and is reinforced with four geo synthetic products viz., Polymeric Woven Geo textile, uni-axial geo grids of two different capacities and a coir geo textile.

The size, shape, depth of placement and the surcharge were maintained same. A square model footing of 100mm size was used as the loading unit. Static and Cyclic Plate Load tests are carried out separately on unreinforced sand and sand reinforced with each type of geosynthetic product. The results indicated that, the geo synthetic products with higher mobilized tensile strength have shown better improvement in BCR and C_u values.

Mostafa El Sawwaf , Ashraf Kamal Nazir [8] They investigate the effect of geo synthetic reinforcement on the cumulative settlement of repeatedly loaded rectangular model footings placed on reinforced sand.Tests of series 1 were performed to determine the ultimate monotonic bearing capacity. Tests of series 2 were performed on unreinforced sand under vertical repeated loads. Tests of series 3 were performed to study the effect of sand reinforcement on the footing response under the same loads. The studied parameters include the initial monotonic load levels, the number of load cycles, and the relative density of sand along with geosynthetic parameters including size and number of layers. Both the ultimate bearing load and the cumulative settlement were obtained and analyzed.

J S Vinod, B. Indraratna, B. Indraratna [9] They investigate the results of model tests on the settlement behaviour of strip footing resting on geo cell reinforced sand during cyclic loading. Model tests were carried out in a steel tank with interior plan dimensions of 380 mm x 300 mm, and 400 mm in height. The soil used was uniform beach sand and it was compacted to a relative density of 70%.

The geo cell mattress was constructed using triax geo grid in a chevron pattern. Tests were conducted by first subjecting the strip footing to an initial sustained static load and then superimposing additional predetermined cyclic loads. The laboratory results highlight that cyclic stress ratio and frequency has a significant influence on the settlement behaviour of geo cell reinforced foundation. For a given value of *N*, settlement of geo cell reinforced bed increases with the cyclic stress ratio and frequency.

A.Asakereh1, S.N. Moghaddas Tafreshi2, M. Ghazavi2 [10] They investigate a series of laboratory model tests on strip footings supported on unreinforced and geo grid-reinforced sand with an inside void. The footing is subjected to a combination of static and cyclic loading. The influence of various parameters including the embedment depth of the void, the number of reinforcement layers, and the amplitude of cyclic load were studied.

For a given amplitude of cyclic load, with increasing the number of reinforcement layers and with increasing the embedment depth of void to a certain value, the footing settlement decreases. Both the number of reinforcement layers and the void embedment depth have a large influence on the footing behavior under static and repeated load, as increasing of these two parameters can reduce the footing settlement.

3. Materials and Methods

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 3: 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 4: Properties of geogrid Reinforcement used

Sr. No	*Properties*	*Value*
1	**Peak tensile strength**	
	Machine direction	250 KN/m
	Cross machine direction	30 KN/m
2	**Physical Properties**	
	Colour	Black
	Coating	PVC
	Textile type	High Tenacity Low Shrinkage Polyester Yarn
	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 6: Experimental setup

3.2 Test Specimens

3.2.1 Unreinforced sand specimen

The total depth of 500mm sand bed is prepared in the tank by placing the sand in 100mm lift to the desired density and again same procedure is repeated for the next layers to get the total required Depth.

3.2.2 Reinforced specimen:

(1) Increase number of layer of geogrid N=1,2,3,4 (2) u/b = 0.2,0.4,0.6 (3) b/B = 1,2,3,4.

3.3 Methods

The tests will performe in a well stiffened square steel tank specially fabricated in such a way that its size is five times that of the diameter of the plate. The experimental test set up is shown in Fig 6. The characteristic of sand is as given in Table 1 and the characteristics of reinforcing material is given in Table 2 and Static and Cyclic plate load tests were carried out as per IS 5249:1992.All the tests were conducted on the model box using 150mmX150 mm dia square plate. The load deflection values were recorded by applying incremental loads through the hand operating jack. From static plate load test the modulus of sub grade Reaction (K) is obtained, and From Cyclic Plate Load test, the co-efficient of elastic uniform compression of soil (C_u), coefficient of non uniform compression (C_ϕ), coefficient of uniform shear (C_τ), damping coefficient (ξ),is obtained. Both these (K & C_u, C_ϕ, C_τ, ξ) parameters are important in designing the pavement and structures.

Modulus of Subgrade Reaction (K) of both Reinforced and Unreinforced sand and BC soil is obtained by conducting Static Plate load test, Similarly co-efficient of elastic uniform compression (C_u), coefficient of non uniform compression (C_ϕ), coefficient of uniform shear (C_τ), damping coefficient (ξ) of Reinforced and unreinforced sand and BC soil is obtained by conducting Cyclic plate load test.

3.4. Discussion

Based on the various researchers it is observed that generally they are change the basic parameters of geosynthetic reinforcement and find out bearing capacity of soil, settlement of soil, and also find dynamic parameters. Also they proved that by the increase number of reinforcement layer bearing capacity and dynamic parameter will be improve and static and dynamic loading effect decrease from the soil structures.

4. Conclusion

Review of the literature revealed that various laboratory investigations have been conducted on geo grid reinforced sand but these investigations were limited in their scope and concentrated on square footing resting on reinforced sand under static and cyclic loading. As per literature review they were found dynamic parameter by varying basic parameter of reinforcement layer and determine which optimum number of reinforcement layer gives highest strength. The basic parameters are given below:
(1) Effect of the Number of layer of Reinforcement (N), (2) u/B, (3) b/B
Where, N = Number of layer of reinforcement
u = Depth of the top layer of reinforcement
b = Width of geo grid
B = Width of footing

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] Is.1888: (1982). “Indian Standard Method of Load Test on Soils, ”BIS, New Delhi, India.
[12] Is.5249: (1992). “Indian Standard method of Test for Determination of Dynamic Properties of Soils,” BIS, New Delhi, India.