Experimental Study on the Performance of Reinforced Sand Beds Under Repeated Loads in Presence of Water

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EXPERIMENTAL STUDY ON THE PERFORMANCE OF REINFORCED SAND BEDS UNDER REPEATED LOADS IN PRESENCE OF WATER

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ABSTRACT

The performance and behavior of reinforced soil structure, both in the field and the laboratory are well documented. In the field situation, when the reinforced sand beds are used as a construction tool or as a ground improvement method, it is often the situation that they are subjected to the effect of water. In this study series of repeated load tests were conducted on mild steel square footing of 100mm size resting on a sand bed placed in a 500mm-dia, 390mm deep mild steel tank. Reinforcement location and spacing were selected based on optimization of previous research results. The sand beds were inundated to different levels viz full and partial. The results of the experiments demonstrated the impact of pressure of water on the performance of reinforced earth when subjected to repeated loading. The reinforced sand beds are very efficient under the repeated loads and the presence of water table has a considerable influence on their performance. The cyclic resistance ratio of the reinforced sand bed increases and the settlement ratio reduces considerably, when reinforcements are introduced in them.
Key words: Reinforcement, Saturation, Geogrid, Repeated load

INTRODUCTION

The use of reinforcement as a means of ground improvement technique is lost to the history. The material obtained by the combination of earth and reinforcement is termed as ‘Reinforced Earth’. Many researchers have contributed immensely to the better understanding of the concepts, design procedures and construction methods of reinforced soil structure through laboratory studies, field investigations and monitoring of constructed structure ((Binquet and Lee,1975; Milovic1977,1979; Akinmusuru and Akinbolade, 1981; Ramaswamy,1985; Saran,1985; Guido,1985,1989; Mandal and Dixit,1986; Singh and Bindumadhava,1986; Sreekantaiah 1987,1988; Ramanatha Iyer, 1988; Dembiki and Jermolowicz,1988; Bergado, et.al, 2001; Hoe.I.Ling, et.al, 2001; Zhenggui Wang and Richwein, 2002, Nagaraja 2006). The first laboratory investigation on the application of reinforced earth for foundation was reported by Yang in 1972 and thereafter Binquet and Lee in1975, reported most comprehensive work on this problem.

The performance of any reinforced structure depends on the physical properties of the backfill material or the ground, which is intended to be improved. The best-suited backfill material is the Dry, frictional granular soil. However, in many of the field situation, where even the best backfill material is used, the dry back fill material may be saturated because of ingress of water due to many reasons. Due to this, the performance of the Reinforced soil is expected to differ. There is no literature available on the performance of saturated Reinforced sand beds. Hence, in the present investigation, an attempt has been made to study the load- settlement behavior of Geogrid reinforced sand beds as influenced by the varying water levels under repeated loads

OBJECTIVES

In light of the above, the objectives of the present work is to,
1. Evaluate the influence of water inundation on the behavior of reinforced sand beds when subjected to repeated loads.
2. Evaluate the influence of different reinforcement parameters on the performance of inundated sand beds.

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To fulfill the above objectives laboratory experiments are performed under controlled conditions on polyethylene geogrids reinforced sand beds. The dynamic load tests are performed with an Automated Dynamic Testing Apparatus (ADTA) specially designed, fabricated and calibrated for the purpose (Nagaraja, 2006). A mild steel square footing of 100 mm size resting on a sand bed prepared in a 500 mm dia and

390 mm deep mild steel tank is used for the purpose. The experiments are performed on poorly graded sand reinforced with geogrids up to a maximum of 20000 load cycles. The effect of reinforcement configuration on the behavior of sand beds is investigated and results of the tests performed indicated that the provision of reinforcement is effective even when the sand beds are inundated and the degree of improvement is dependent on the reinforcement configuration.

EXPERIMENTAL DETAILS

Materials

Sand. A poorly graded sand is used in the present investigation. Table 1 presents the properties of the sand used. The sand is classified as poorly graded sand (SP) according to Indian Standard Classification System (ISCS).

Table 1 Properties of Sand used

Property	Value
Grain Size Distribution	
Clay and Silt size, %	0
Sand size, %	100
Gravel size, %	0
Coefficient of Uniformity, C_u	2.63
Coefficient of Curvature, C_c	1.28
Effective diameter of particle, $D_{10\ mm}$	0.24
Dry density, γ_d (kN/m^3) @ 50% relative density	16.4
Specific Gravity, G	2.63

Reinforcement Material. The Reinforcement used is a biaxial mesh type geogrid with oval aperture opening. Table 2 presents the properties of geogrid used.

Experimental setup

Model studies are conducted in the present investigation. The sand beds are prepared in a circular mild steel tank by sand raining technique, both in the unreinforced and reinforced state. Then the sand beds are inundated with water using the entry nozzles provision provided at the bottom of the tank. The rigid mild steel footing is placed on the surface of the sand bed, thus prepared. The repeated loads are applied on these footings and the settlement is measured.

The sand beds are tested under three different conditions.
i. Reinforced and unreinforced sand bed without water (dry sand bed).
ii. Reinforced and unreinforced sand bed with water at a depth of 1B below the footing. Where B is the width of the footing.
iii. Reinforced and unreinforced sand bed fully inundated with water.

Table 2 Properties of Reinforcement

Property	Value
Mass per unit area (kN/m^2)	0.0072
Thickness	
Warp (mm)	2.0
Weft (mm)	2.0
Joint (mm)	3.0
Structure	Bioriented, mesh type, Oval aperture
Aperture Size @ Junction	
Warp (mm)	8
Weft (mm)	6
Tensile strength	
Warp (kN/m)	4.07
Weft (kN/m)	4.03

Test tank and Model Footing**.** The dimensions of footing and steel tank are;

1. Mild steel footing
   Size of square footing: 100 mm
   Thickness : 4 mm
2. Mild steel tank
   Diameter : 500 mm
   Height : 390 mm

Guided by the findings of the earlier researchers, the test tank diameter to model footing width ratio of 5 is maintained in the present investigation (Shin et al,2002; Sitaram and Sireesh, 2004) to eliminate the confinement effect of the rigid test tank.

Test set up for Repeated load tests. The repeated load tests are performed with an Automated Repeated load test apparatus, specially designed, fabricated and calibrated for the purpose. The machine is a sophisticated computer controlled devise, runs on software MOVICON. Fig 1 shows the schematic diagram of experimental set up.

Preparation of Sand bed. Both the unreinforced and reinforced sand beds are prepared in the test tank by sand raining technique to get the required density. In case of reinforced sand beds, the reinforcements are introduced at the required position during sand bed preparation. The biaxially oriented geogrids are placed as reinforcement in the sand bed in circular shape and placed concentrically below the footing, with no grid being used more than once. A minimum spacing of 0.3B (where B is the width of footing =100mm) is maintained in all the experiments, as this minimum thickness

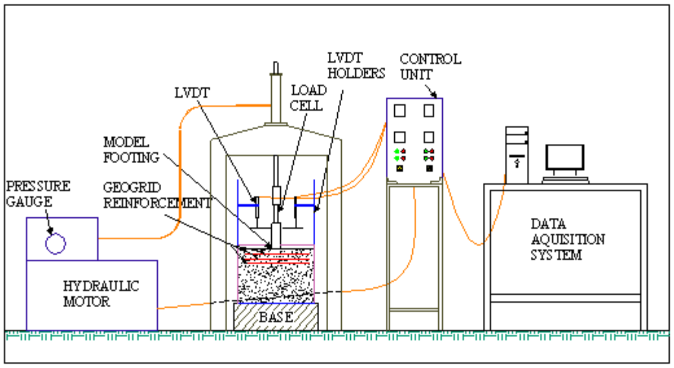

Fig 1 Schematic Diagram of Experimental setup

Automated Repeated Loading Apparatus has the following features.

Loading Magnitude : 0 to 20kN

Loading Frequency : 0 to 2 Hz in steps of 0.1 Hz

is necessary for the reinforcement action. Also the first layer of the reinforcement is placed at a minimum depth of 0.3B (U=0.3B), as this minimum thickness becomes essential for confinement. A clearance of 5mm between the inner surface of the tank and the reinforcement edge is maintained to ensure that no friction is generated between the reinforcement and the walls of the test tank.

Inundation Procedure. After preparing the reinforced or unreinforced sand beds, the water is introduced into the test tank from the bottom of the tank through the entry nozzle. The level of water in the tank is monitored through the standpipe attached to the tank and is controlled to the desired level, using the control valve.

Method of testing. The reinforced and unreinforced sand beds are subjected to repeated loading in the Automated repeated load Test Apparatus. Depending on the inundation condition the water is allowed to fill the tank and monitored in the stand pipe. The excitation values viz. amplitude of loading, type of waveform, frequency are selected and fed in to the computer. The repeated load is applied on the test plate and the settlements are measured through three different LVDTs placed orthogonal to each other.

RESULTS AND DISCUSSIONS

The reinforcement configuration include the depth of first layer of reinforcement (U) from the bottom of the footing, Spacing between the reinforcement layers (S) and the number of reinforcement layers (N). In the present study experiments are conducted to evaluate the influence of the above factors on the performance of reinforced sand beds. The efforts of the experiments conducted are directed towards establishing the optimum combination of the reinforcement configuration to obtain the maximum benefit. The results of the experiments are analyzed in terms of Cyclic Resistance Ratio (CRR) and the Settlement Ratio (SR). The following definition of Cyclic Resistance Ratio and Settlement Ratio, as given by Nagaraja (2006), is used in the present investigation.

The Cyclic Resistance Ratio or CRR is the ratio of the number of load cycles taken by the reinforced sand bed to that of unreinforced sand bed at the same level.

The effect of reinforcement configuration on the settlement behavior of sand beds is brought out in terms of Settlement Ratio (SR) and is defined as, the ratio of the settlement of the footing for a given number of cycles in reinforced sand bed to that of unreinforced case.

Effect of number of reinforcement layers (N)

To bring out the effect of inclusion of reinforcement, the experiments are conducted on both unreinforced and reinforced sand beds having water at different levels. Fig 2, presents the results of one such experiments performed on the dry sand bed and Fig 3 and Fig 4 plots the results performed on sand bed with water at a depth of 1.3B below the footing and sand bed fully inundated with water respectively. Fig. 2 shows the experiment performed on dry sand bed with 1, 2 , 3 and 4 layers of reinforcement at S = U = 0.3B at an amplitude of 250 kPa at 2 Hz frequency with half sine type of loading waveform along with experiment conducted on unreinforced dry sand bed. It can be seen from the figure that, the unreinforced sand beds experiences a large settlement at less number of load cycles and with the increase in number of reinforcement layers in the sand bed the settlement decreases. For example, at a loading cycle of 20, the unreinforced dry sand bed experiences a settlement of about 34 mm where as reinforced sand beds with 1, 2, 3 and 4 layers experiences a settlement of about 8 to 6mm. This shows the effectiveness of the inclusion of geogrid reinforcement.

Fig 3 demonstrates a considerable improvement in the behavior of partly inundated sand beds upon the introduction of reinforcement. The reinforced partly inundated sand bed exhibit considerable reduction in the settlement values at any number of load cycles compared to their unreinforced counterpart. For example, the partly inundated unreinforced sand bed experiences a settlement of about 14 mm at a loading cycle of 20 where as its counterparts with 1, 2, 3 and 4 number of reinforcement layer experiences a settlement of 8, 6, 5 and 4.7 mm at the same number of loading cycles respectively. This clearly indicates that the provision of reinforcement is effective even in the sand beds that are partly inundated with water.

Fig 4 shows the effect of reinforcement layers on the performance of sand bed with water level at the base of the footing (Fully inundated, FI). The reinforced fully inundated sand beds also exhibit considerable reduction in the settlement values at any number of load cycles compared to their unreinforced counterpart. For example, the fully inundated unreinforced sand bed experiences a settlement of about 32 mm at a loading cycle of 20 where as its counterparts with 1, 2, 3 and 4 number of reinforcement layer experiences a settlement of 14.0, 8.0, 7.5 and 7.0 mm, respectively at the same number of loading cycles. This clearly indicates that the provision of reinforcement is effective even in the sand beds that are fully inundated with water.

It is inferred from Fig 3 and 4 that,

a) inclusion of reinforcement is effective in reducing settlement even in case the water is present in the sand bed.
b) even in cases having water present, the maximum improvement is obtained in case of sand beds having three number of reinforcement layers.

Attempts are further made to evaluate the effect of number of reinforcement layers in terms of Cyclic Resistance Ratio and Settlement Ratio. Fig 5 and Fig 6 presents the details of Cyclic Resistance Ratio and Settlement Ratio respectively for sand beds with 1, 2, 3 and 4 layers of reinforcement subjected to 250 kPa pressure at 2 Hz frequency.

Fig 5 plots the effect of number of reinforcement layers on Cyclic Resistance Ratio for sand beds reinforced with 1, 2, 3 and 4 layers at 20 mm settlement. It is observed from the figure that, CRR value increases with increase in number of reinforcement layers irrespective of the water level in the sand beds. It is seen from Fig 5 that for any given sand bed, the CRR increases with increasing number of reinforcement layers. Partly inundated sand bed showed maximum CRR of 77 compared to the dry and fully inundated sand bed (62 and 36 respectively). Further, the partly inundated sand bed showed maximum CRR (77) of all the sand beds inundated at different water levels. The improved performance of the partly inundated sand beds may be attributed to the capillary forces developed in the sand beds.

Fig 6 plots the effect of number of reinforcement layers on Settlement Ratio for sand beds reinforced with 1, 2, 3 and 4 layers of reinforcement. It is observed from Fig 6 that, the SR reduces with increase in number of reinforcement layer irrespective of the water level in the sand beds. Partly inundated sand bed showed least value of SR (0.23) compared to the dry and fully inundated sand bed (0.27 and 0.36 respectively). Further, the partly inundated sand bed showed least SR value (0.23) of all the sand beds inundated at different water levels. Maximum Cyclic Resistance Ratio and least Settlement Ratio are observed in the sand beds with 3 and 4 layers of reinforcement, for all the sand beds.

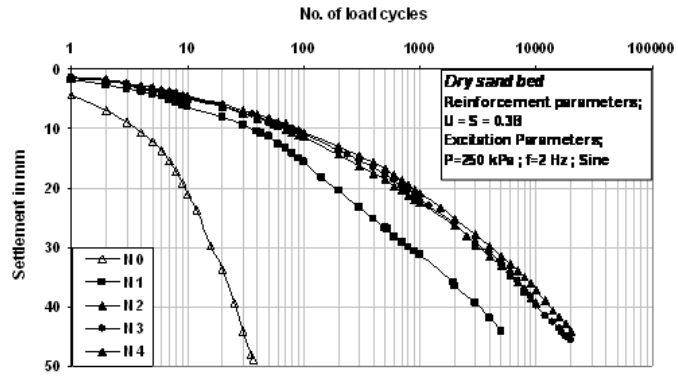

Fig 2 Effect of number of reinforcement layers on the performance of Dry sand bed (S = U = 0.3B)

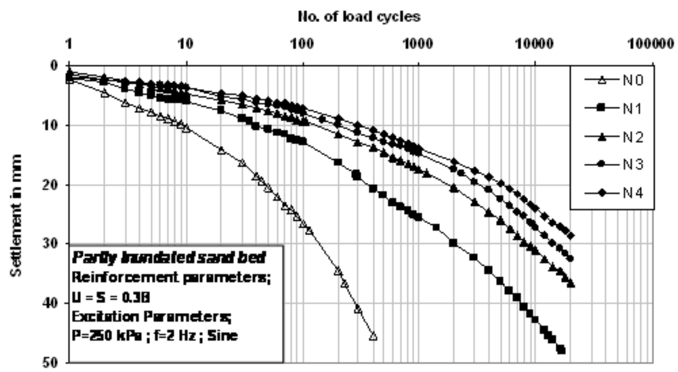

Fig 3 Effect of number of reinforcement layers on the performance of sand bed with water level at 1.3B below the footing (N = 3, S = U = 0.3B)

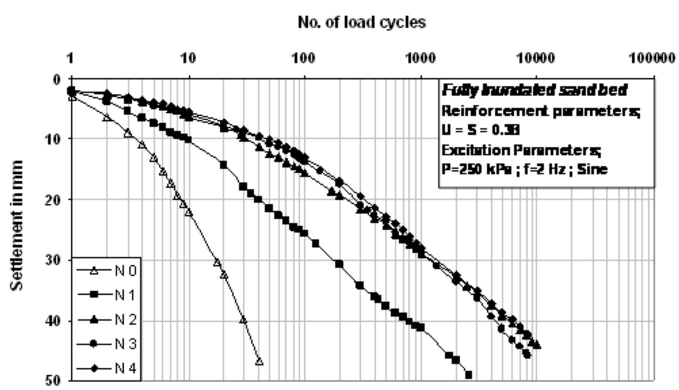

Fig 4 Effect of number of reinforcement layers on the performance of sand bed with water level at the base of the footing (N = 3, S = U = 0.3B)

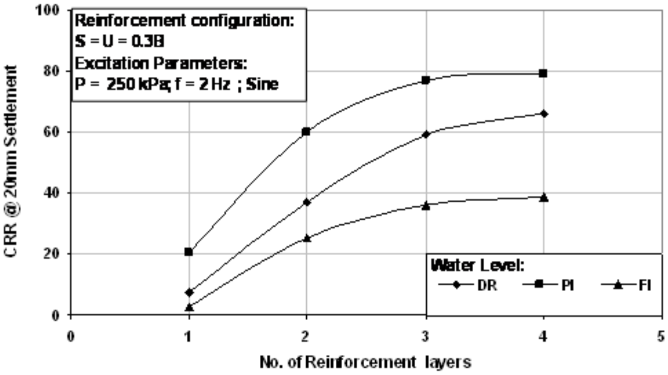

Fig 5 Effect of number of reinforcement layers on CRR for sand beds with water at different level (N = 3, U = S = 0.3B)

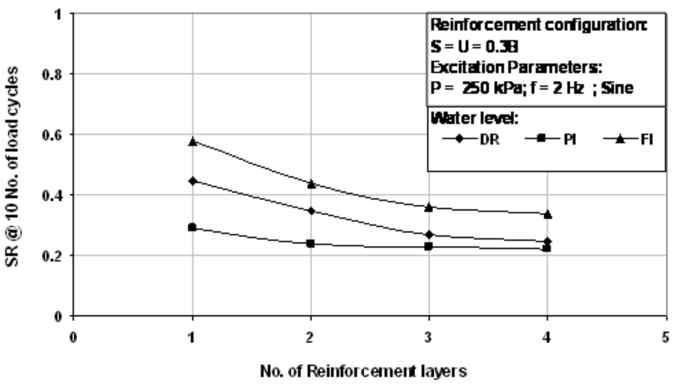

Fig 6 Effect of number of reinforcement layers on SR for sand beds with water at different level (N = 3, U = S = 0.3B)

Effect of spacing of reinforcement layers (S)

Fig 7 plots the Cyclic Resistance Ratio against the depth of water for 3 layer reinforced sand beds having reinforcement at 0.3B and 0.4B. It is seen from Fig 7 that, the maximum CRR is observed for partly inundated sand bed compared to the dry and fully inundated sand bed for both S = 0.3B and 0.4B. For example, at S=0.3B the CRR of partly inundated sand bed is 55, where as for dry and fully inundated sand bed, the CRR is 36 and 17 respectively. Similarly at S=0.4B, the CRR value of partly inundated sand bed is 30, where as for dry and fully inundated sand bed, the CRR is 22 and 14 respectively. And least CRR of 17 and 14 is observed for fully inundated sand bed, at S=0.3B and 0.4B respectively.

Fig. 8 plots the Settlement Ratio against the depth of water for 3 layers reinforced sand beds having a reinforcement spacing of 0.3B and 0.4B. It is observed from Fig 8 that, the least SR is observed for partly inundated sand bed compared to the dry and fully inundated sand bed at S=0.3B and 0.4B. For example, at S=0.3B the SR of partly inundated sand bed is 0.22, where as for dry and fully inundated sand bed, the SR is 0.33 and 0.52 respectively. Similarly at S=0.4B, the SR of partly inundated sand bed is 0.25, where as for dry and fully inundated sand bed, the SR is 0.38 and 0.57 respectively. Maximum SR of 0.52 and 0.57 is observed for fully inundated sand bed, at S=0.3B and 0.4B respectively.

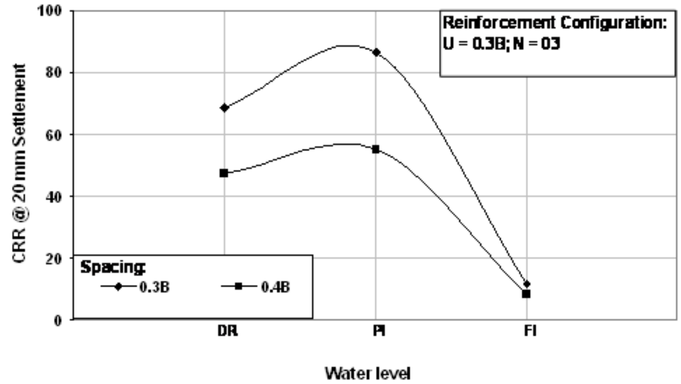

Fig 7 Effect of spacing of reinforcement layers on CRR For sand beds with water at different level (N = 3, U = S= 0.3B)

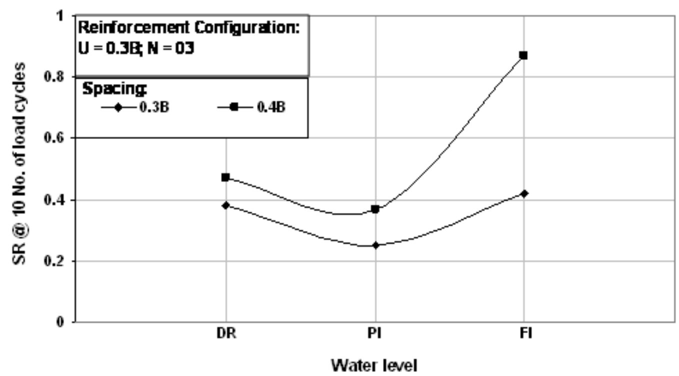

Fig 8 Effect of spacing of reinforcement layers on SR for sand beds with water at different level (N = 3, U = S = 0.3B)

Effect of first reinforcement layer depth (U)

Fig 9 plots the Cyclic Resistance Ratio against the depth of water for 3 layer reinforced sand beds having first layer of reinforcement at U=0.3B and 0.4B. It is seen from Fig 9 that, maximum CRR is observed for partly inundated sand bed compared to the dry and fully inundated sand bed for both U=0.3B and 0.4B. Example, at U=0.3B, the CRR of partly inundated sand bed is 55, where as for dry and fully inundated sand bed, the CRR is 36 and 17, respectively. Similarly at U=0.4B, the CRR value of partly inundated sand bed is 21, where as for dry and fully inundated sand bed, the CRR value is 12 and 8 respectively. And least CRR of 17 and 8 is observed for fully inundated sand bed at S=0.3B and 0.4B respectively.

Fig 10 plots the Settlement Ratio against the depth of water for 3 layer reinforced sand beds having first layer of reinforcement at U=0.3B and 0.4B. It is observed from Fig 10 that, the least SR is observed for partly inundated sand bed compared to the dry and fully inundated sand bed for both U=0.3B and 0.4B. For example, at U=0.3B the SR of partly inundated sand bed is 0.23, where as for dry and fully inundated sand bed, the SR is 0.33 and 0.45 respectively. Similarly at S=0.4B, the SR of partly inundated sand bed is 0.31, where as for dry and fully inundated sand bed the SR is 0.47 and 0.54 respectively. And maximum SR of 0.54 and 0.45 is observed for fully inundated sand bed, at S=0.3B and 0.4B respectively.

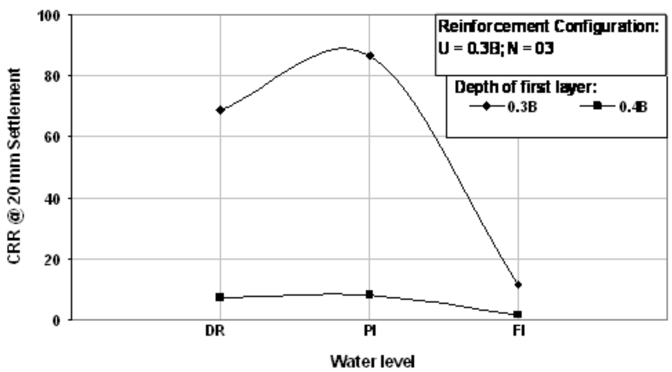

Fig 9 Effect of depth of first layer of reinforcement on Cyclic Resistance Ratio for sand beds with water at different level (N = 3, U = S = 0.3B

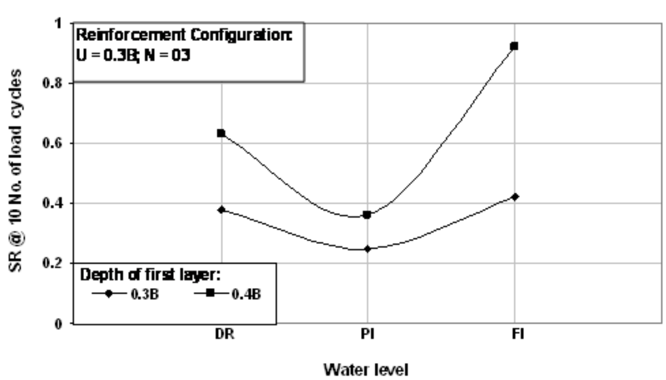

Fig 10 Effect of depth of first layer of reinforcement on Settlement Ratio for sand beds with water at different level (N = 3, U = S = 0.3B)

CONCLUSIONS

Based on the detailed experimental investigation performed and the discussion presented thereon, the following conclusions are drawn.

1 The reinforced sand beds perform better than the unreinforced sand beds regardless of the water level under repeated loads indicating the provision of reinforcement is effective in improving the load - settlement characteristics of sand beds.

2. The partly inundated unreinforced and reinforced sand beds showed better performance, as they are probably affected by the development of capillary forces.

3. The presence of water in the reinforced sand bed considerably influences the Cyclic Resistance Ratio and Settlement Ratio. The Cyclic Resistance Ratio increases for such a sand beds where as the Settlement Ratio reduces for the same sand bed under a given dynamic loading.

4. From the experimental results, it is observed that the optimum reinforcement configuration is N = 3, S=0.3B and U=0.3B, for all inundation condition.

REFERENCES

Akinmusuru, J.O. and Akinbolade, J.A., [1981]. “Stability of Loaded Footings on Reinforced Soil”, Journal of Geotechnical Engineering Division, ASCE 107, No. GT6, pp 819-827.

Bergado, D.T., Teerawattanasuk, C., Wongsawonon, T and Voohpruex, P., [2001]. “Interaction between Hexagonal Wire Mesh Reinforcement and Silky Sand Backfill”, Geotechnical Testing Journal, Vol.107, No.1, GTJODI, pp. 23-38.

Binquet.J. and Lee.K.L., [1975]. “Bearing Capacity Analysis of Reinforced Earth Slabs”, Journal of Geotechnical Engineering Division, ASCE 101, No Gt12, pp 1257-1276.

Das, B.M., [2001]. “Dynamic Loading on Foundation on Reinforced Sand”, Geosynthetics in Foundation Reinforcement and Erosion Control Systems. Geotech Special Technical Publication, 76, ASCE, pp. 19-33.

Dembiki, E. and Jermolowwicz, P., [1988]. “Model tests of Bearing capacity of a weak sub soil reinforced by Geotextile”, Proceedings of First Indian Geotextiles conference on Reinforced soil and Geotextiles, Bombay, Vol. 1, C.67 – C.72.

Gerald P. Raymond., [2002]. “Reinforced ballast behavior subjected to repeated load”, Geotextiles and Geomembranes, Vol.20, pp 39-61.

Guido, V.A., Biesaidecki, G.L. and Sullivan, M.J., [1985]. “Bearing Capacity of a Geotextile Reinforced Foundation”, Proceedings 11th International Conference on SMFE (3), Sanfransisco, 1777-1780.

Guido, V.A., Dong, K. Chang and Michael, A. Sweeney., [1986]. “Comparision of Geogrid and Geotextile reinforced earth slabs”, Can. Geotech Jl, Vol. 23, pp 435 - 440.

Guido, V.A., and John Squreciati., [1994]. “Dynamic plate loading tests on Geogrid Reinforced subgrades”, Proc. 13th Intl. Conf. on Soil Mechanics and Foundation Engg., New Delhi, Vol. 2, pp. 1283 – 1286.

Hoe I. Ling and Zheng Liu., [2001]. "Performance of Geosynthetic - Reinforced Asphalt Pavements", Journal of Geotechnical and Geo environmental Engineering, Vol. 127, No. 2, 177-184.

Jones, Colin J. F. P., [1984]. "Earth Reinforcement and Soil Structures", Butterworths and co Ltd.

Kotake, N., Tatsuoka, F., Tanaka, T., Siddiquee, M. S. A. and Huang, C.C., [2001]. "FEM Simulation of the Bearing capacity of level Reinforced sand ground subjected to footing load", Geosynthetics International, Vol. 8, No. 6, pp 501 – 549.

Madhavi Latha, G. and Murthy, V.S., [2007]. "Effect of Reinforcement form on the behavior of geosynthetic reinforced sand", Geotextile and Geomembranes, Vol.25, pp 23 - 32.

Milovic, D., [1977]. "Bearing capacity tests on reinforced sand", Proceedings of 9th International Conference on Soil Mechanics and Foundation Engineering, Tokyo, Vol. 1, 651 – 654.

Miller, G.A., The, S.Y., Li, D. and Zaman, M.M., [2000]. "Journal of Geotechnical and Geoenvironmental Engineering", Vol. 126, No. 2, 139 -147.

Nagaraja P. S., [2006]. "Behavior of model footing resting on geogrid reinforced sand beds under Monotonic, Cyclic and Dynamic loads", Ph.D. Thesis submitted to Bangalore University, Bangalore, India.

Ramaswamy, S.V. and Abdul Khader, S., [1997]. "Performance of Nonwoven geotextiles under repetitive loading", Indian Geotechnical Conference, 5 - 7, pp 273 - 276.

Scott, E. Shewbridge and Jorge, B. Sousa, [1991]. "Dynamic properties of reinforced sand", Journal of Geotechnical Engineering, Vol. 98, SM4, pp 389 - 397.

Shin. E.C., Kim D. H. and Das. B.M., [2002]. "Geogrid - reinforced railroad bed settlement due to cyclic load", Geotechnical and Geological Engineering, Vol. 20, pp. 261-271.

Sreekantaiah, H.R., [1987]. "An investigation of a Rectangular footing on reinforced Sand", Proc. Indian Geotcehnical Conference, Bangalore. Vol. 1, pp. 121-124.

Singh, H.R. and Bindhumadhava., [1986]. "Response paper to: Under what situations are Geotextiles more effective than traditional methods for ground improvement and Drainage", Proceedings of Indian Geotechnical Conference, Delhi. Vol. 2, pp. 205-210.

Sitaram, T.G. and Sireesh, S., [2004]. "Model studies of embedded circular footing on Geogrid reinforced sand beds", Ground Improvement, Vol. 8, No. 2, pp. 69 - 75.

Toul, C.M. and Lok, T.M.H., [2007]. "Numerical Simulation of Foundations on Soil with Single Reinforcement", Geosynthetics and Natural Fibres. 13th ARC 2007. Kolkata.

Tufenkjian, Mark. R and Mladen Vucetic., [2000]. "Dynamic failure Mechanism of Soil Nailed Excavation Models in Centrifuge", Journal of Geotechnical and Geoenvironmental Engineering. pp. 227-235.

Unnikrishnan, N., Rajagopal, K. and Krishnaswamy, N.R. [2002]. "Triaxial Behaviour of Reinforced Clay under Static and Cyclic Loading", Indian Geotechnical Journal, 32, 216 - 233.

Vercueil, D., Billet, P. and Cordary, D., [1997]. "Study of the liquefaction resistance of a saturated sand reinforced with Geosynthetics", Soil Dynamics and Earthquake Engineering, Vol.16, 417-425.

Yamamoto Kentaro, [2001]. "Failure Mechanisms and bearing capacities of reinforced foundations", Geotextiles and Geomembranes, Vol. 19, 127 - 162.

Yang, G.L. and Wang, Y.H., [2001]. "Displacement behavior of wrapped - reinforced wall subjected to the cyclical loading", Journal of the Southeast Asian Geotechnical Society, Vol. 32, No. 1, pp 33 - 36.

Yegian, M.K. and Kadakal, U., [1998]. "Geosynthetic Interface behavior under Dynamic loading", Geosynthetics International, Vol. 5, Nos. 1 - 2, pp 1 -16.