A STUDY ON THE PERFORMANCE OF CIRCULAR FOOTING EMBEDDED IN GEOGRID REINFORCED FLYASH BEDS UNDER CYCLIC LOADING

Tejaswini B. R[1], S. Gangadara[2], H. C. Muddaraju[3], Bindiya K[4]

[1]*Assistant Professor, Civil Engineering Department, Sri Venkateshwara College of Engineering, Karnataka, India*
[2]*Associate Professor, Civil Engineering Department, UVCE, Bangalore University, Karnataka, India*
[3]*Assistant Professor, Civil Engineering Department, UVCE, Bangalore University, Karnataka, India*
[4]*Assistant Professor, Civil Engineering Department, JNNCE, Karnataka, India*

Abstract

The concepts of reinforced soil foundation (RSF) have been widely used in various geotechnical engineering applications. 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. A series of tests were conducted on embedded circular footing resting on polyethylene geogrid reinforced fly ash beds under repeated loading. The experimental results demonstrated that the fly ash can be used as a backfill material in place of any other frictional fill. This is indicated by the higher load carrying capacity of footings resting in fly ash reinforced beds.

Keywords: *Reinforced fly ash beds, repeated loads, cyclic resistance ratio, Settlement ratio.*

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1. INTRODUCTION

In the past three decades, reinforced soil foundations (RSF) have been widely used in various geotechnical engineering applications, such as bridge approach slab, bridge abutment, building footings, and embankment. Researchers have shown that the inclusion of reinforcement in soil foundations is a cost-effective solution to increase the ultimate bearing capacity and reduce the settlement of shallow footings compared to the conventional methods, such as replacing natural soils or increasing footings dimensions. Several Laboratory model load tests on geogrid reinforced sand have been published in the literature (E.C. Shin et al., (1999) [2], B. M. Das et al., (1994) [3], Khing et al., (1993) [4], K.S. Gill et al., (2011) [5], Nagy. A. Mahallawy et al., (2012) [6], P.S. Nagaraja., (2006) [7], S. Gangadara et al., (2013) [8]). The use of waste materials as fill for reinforced soil structures is desirable from an environmental as well as economic point of view. Coal based thermal power stations produce massive quantities of coal ash. Fly ash is about 90 % of total coal ash and poses serious environmental problems. The use of stabilized fly ash as a light weight fill in construction is common. The material can also be used in reinforced soil structures.

Most of the research work has been carried to study the behaviour of reinforced earth when exposed to static loading and the results on the study of behaviour of reinforced earth when exposed to dynamic loading are very scanty. Hence in the present investigation it is intended to study the influence of reinforcement distribution configurations viz., number of reinforcement and their spacing on the performance of reinforced fly ash beds under repeated loads. The repeated load tests are performed in an 'Automated Dynamic Testing Apparatus (ADTA)'specially designed, fabricated and calibrated for the purpose. A series of tests were conducted under controlled condition on the embedded circular footing resting in polyethylene geogrid reinforced fly ash beds.

2. MATERIALS AND METHODS

2.1 Fly Ash

The fly ash used in the study is collected from Raichur thermal power plant, Karnataka. It is a non-pozzolonic fly ash belonging to ASTM classification "C". This fly ash is directly collected from open dry dumps. Table 1 presents the properties of fly used.

Table -1: Properties of Fly ash

Physical properties	Test Results
Colour	Light grey
Specific gravity	2.07

Grain size distribution	
Sand fraction (%) Silt and clay fraction (%)	54.00 46.00
Atterberg's limits	
Liquid Limit (%) Plastic Limit (%) Plasticity Index (%)	31.80 -- Non plastic
Compaction characteristics	
Optimum moisture Content (%) Maximum Dry Density(kN/m^3)	23.00 12.70
Unconfined Compressive Strength at MDD(kPa)	51.40

2.2 Reinforcement

The geogrid used are biaxial grids with square aperture. Table 2 shows the properties of geogrid used.

Table -2: Properties of geogrid Reinforcement used

Physical properties		**Unit**	**Test Results**
Aperture size	MD	mm	34
	CD	mm	32
Roll width		m	3.9
Roll length		m	50
Tensile Properties			
Ultimate tensile strength	MD	kN/m	33.2
	CD	kN/m	31.1
Strain at ultimate	MD	%	14.4
	CD	%	6.9

**MD - Machine Direction*
CD - Cross Machine Direction

2.3 Footing

Mild steel Circular footing of diameter 100mm and thickness 4mm were used.

2.4 Mild Steel Tank

Experiments were carried in a circular mild steel tank of diameter 500mm and height 390mm.

2.5 Preparation of Fly Ash Bed

Fly ash bed is prepared by manual compaction to its Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). Unreinforced sample was compacted up to a height of 360mm in 3 equal layers of 120mm thick. For reinforced sample, the geogrid reinforcements were placed at predetermined spacing in between fly ash layers from the bottom of footing and 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 circular footing was placed at the given embedment depth exactly at the centre of the tank and by the same procedure the remaining height of the tank is compacted.

2.6 Method of Testing

The reinforced and unreinforced fly ash 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.

3. RESULTS AND DISCUSSIONS

To bring out the advantageous effects of providing reinforcement in fly ash beds, experiments are conducted on embedded circular footings resting on unreinforced and reinforced fly ash beds subjected to repeated loads.

3.1 Effect of Number of Reinforcement Layers (N)

Fig. 1 presents the number of load cycles versus settlement curve for 1B embedded circular footing with a loading magnitude of 450kPa and Spacing between the reinforcement as 0.3B spacing respectively. It can be seen from the fig. 1 that at any level of settlement, the embedded circular footing resting in 3 layer reinforced fly ash bed perform much better, by taking more number of load cycles compared to its counter parts on unreinforced, two layers and four layers reinforced fly ash beds. Fig. 2 presents the number of load cycles versus settlement curve for 1B embedded circular footing with a loading magnitude of 450kPa and Spacing between the reinforcement as 0.4B spacing respectively. It can be seen from fig. 2 that even the spacing between the reinforcement is increased to 0.4B, three layer reinforced fly ash bed perform better than its counter parts unreinforced, two layer and three layer reinforced fly ash beds by taking more number of load cycles at any given settlement. Hence by seeing the fig.1 and fig.2 the result clearly confirms that the optimum number of reinforcement layer is three. This is as per the accepted trend of results by earlier researchers.

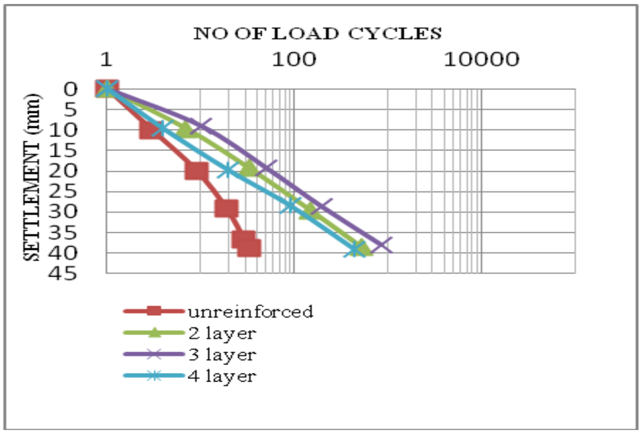

Fig. 1: Effect of number of reinforcement layers on the performance of 1B embedded circular footing in unreinforced and reinforced fly ash beds with P = 450kPa, S=0.3B.

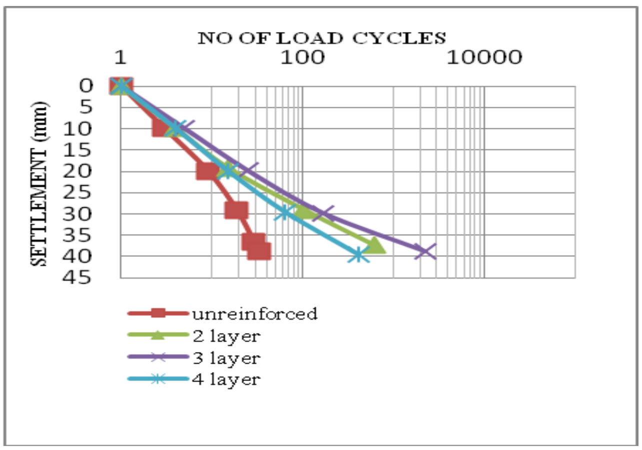

Fig. 2: Effect of number of reinforcement layers on the performance of 1B embedded circular footing in unreinforced and reinforced fly ash beds with P = 450kPa, S=0.4B.

3.2 Effect of Number of Reinforcement Layer (N) on Cyclic Resistance Ratio (CRR) and Settlement Ratio (SR)

The results of the experiments are analyzed in terms of Cyclic Resistance Ratio and settlement ratio using the definition given by Nagaraja .P.S (2006).

Cyclic Resistance Ratio (CRR)

$$CRR = \frac{\text{Number of Load Cycles Required To Cause a Settlement of ‘S’ in Reinforced Specimen}}{\text{Number of Load Cycles Required To Cause a Same Settlement of ‘S’ in Unreinforced Specimen}}$$

Fig. 3 and fig. 4 shows the cyclic Resistance ratio v/s Settlement Curve for 1B embedded circular footing resting in reinforced fly ash beds with two, three and four layer reinforcement with 0.3B and 0.4B spacing between the reinforcement subjected to the loading magnitude of 450kPa. It can be seen from the figures that at any level of settlement, the footing in three layer reinforced fly ash bed exhibit highest value of cyclic resistance ratio compared to its counterpart resting in two and four layer reinforced fly ash beds. For example circular embedded footing under repeated load of 450kPa and spacing between the reinforcement as 0.3B, the three layer reinforced fly ash bed exhibited a cyclic resistance ratio of 10 at a settlement of 28mm where as two and four layer reinforced fly ash bed exhibited a cyclic resistance ratio of 7 and 5 respectively under the same settlement. Similar trend of results were observed for reinforced fly ash beds when subjected to a repeated load of 450kPa and spacing between the reinforcement as 0.4B.

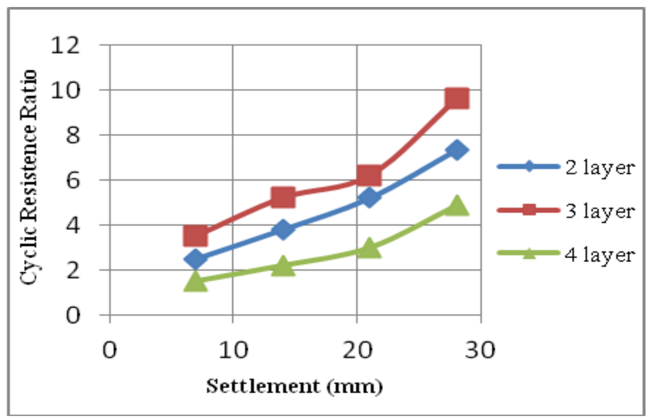

Fig. 3: Effect of number of reinforcement layers on CRR for 1B embedded circular footing in reinforced fly ash beds with P = 450kPa, S=0.3B.

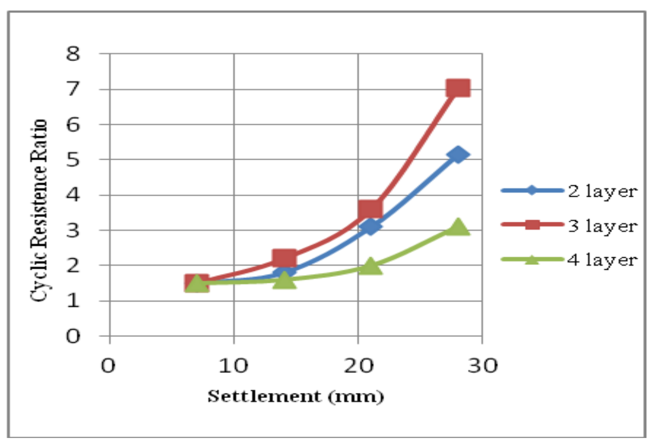

Fig. 4: Effect of number of reinforcement layers on CRR for 1B embedded circular footing in reinforced fly ash beds with P = 450kPa, S=0.4B.

Settlement Ratio (SR)

SR = Settlement of reinforced fly ash bed after N number of cycles

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Settlement of unreinforced fly ash bed after same N number of cycles

Fig. 5 and Fig. 6 presents the settlement ratio v/s number of load cycles curves for 1B embedded circular footing resting in reinforced fly ash beds with two, three and four layer of reinforcement with 0.3B and 0.4B spacing between the reinforcement subjected to a repeated load of 450kPa . It can be seen from these figures that at any number of load cycles the footing in three layer reinforced fly ash bed exhibit lower value of settlement ratio compared to its counterparts resting in two and four layer reinforced fly ash beds. For example circular embedded footing under repeated load of 450kPa and spacing between the reinforcement as 0.3B, the three layer reinforced fly ash bed exhibited a settlement ratio of 0.42 at a 20 number of load cycles where as two and four layer reinforced fly ash bed exhibited a settlement ratio of 0.48 and 0.66 under the same number of load cycles respectively. Similar trend of results were observed for reinforced fly ash beds when subjected to a repeated load of 450kPa and spacing between the reinforcement as 0.4B.

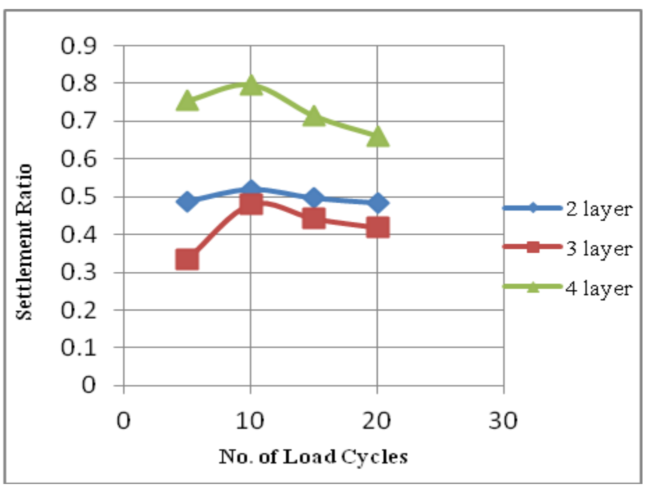

Fig. 5: Effect of number of reinforcement layers on SR for 1B embedded circular footing in reinforced fly ash beds with P = 450kPa, S=0.3B.

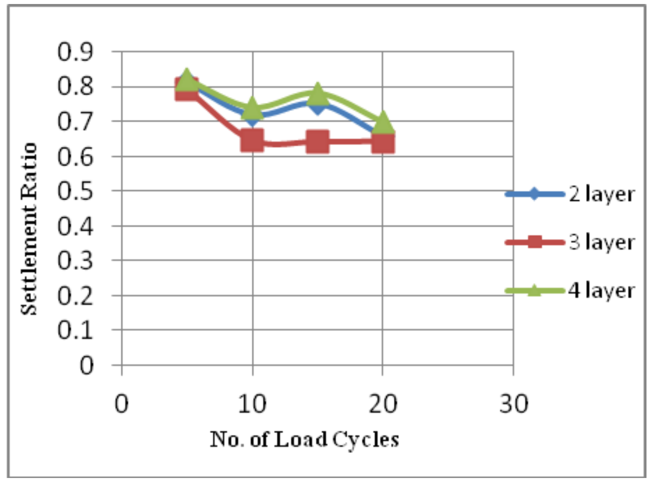

Fig. 6: Effect of number of reinforcement layers on SR for 1B embedded circular footing in reinforced fly ash beds with P = 450kPa, S=0.4B.

3.3 Comparison on the Effect of Reinforcement Spacing

Varying the spacing between the reinforcement may also play a very important role in the performance of embedded circular footing in reinforced fly ash beds. Experiments were conducted on embedded circular footing resting in reinforced fly ash beds by keeping depth of first layer of reinforcement constant i.e., (U) = 0.3B and varying the spacing(S) between the reinforcement as S = 0.3B and 0.4B. Fig. 7, Fig. 8 and Fig. 9 shows the results of Number of Load Cycles versus Settlement Curve for embedded circular footing subjected to a repeated load of 450kPa by varying the number of reinforcement layer as two, three and four. From the figures it can be seen that at any level of settlement when the spacing between the reinforcement is 0.3B it takes more number of load cycles when compared to the spacing between the reinforcement as 0.4B. For example fig. 7 shows the shows the comparison of spacing between the reinforcement of 1B embedment depth of circular footing in reinforced fly ash beds subjected to a repeated load of 450kPa with number of reinforcement layer as two, It can be seen from the figure that when the spacing between the reinforcement is 0.3B it takes more number of load cycles i.e., 525 cycles at a settlement of 38mm when compared to 0.4B spacing which takes less number of load cycles i.e.,383 cycles at the settlement of 38mm respectively. Similar trend is observed in the Fig. 8 and Fig. 9.

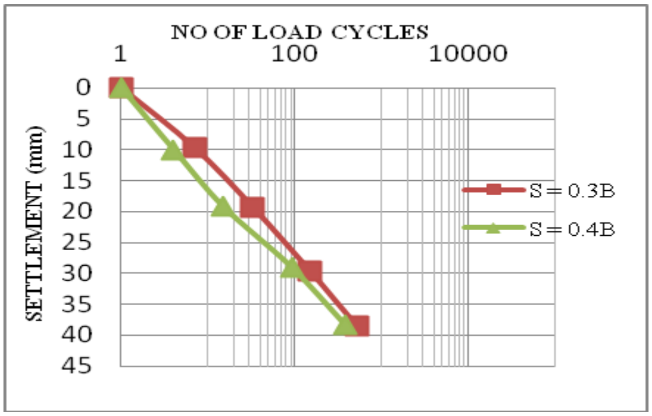

Fig. 7: Comparison of spacing between the reinforcement of 1B embedded circular footing in reinforced fly ash beds with P = 450kPa, N = 2.

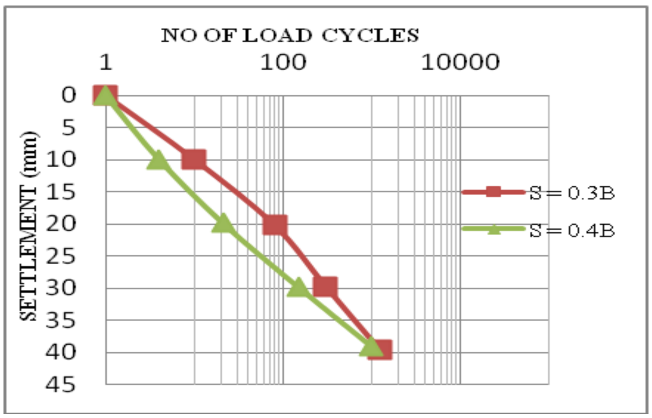

Fig. 8: Comparison of spacing between the reinforcement of 1B embedded circular footing in reinforced fly ash beds with P = 450kPa, N = 3.

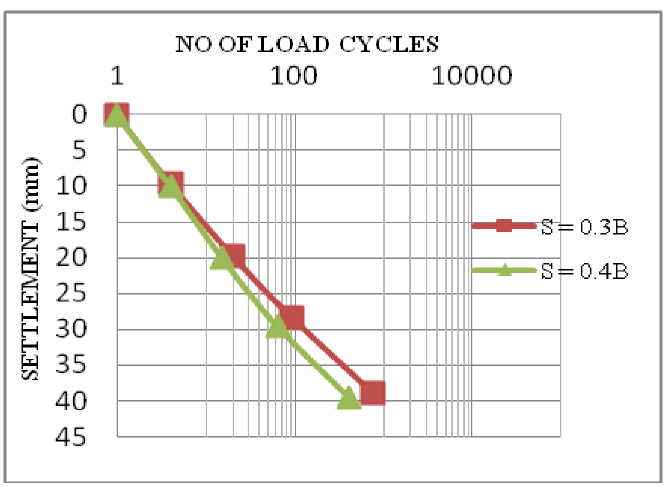

Fig. 9: Comparison of spacing between the reinforcement of 1B embedded circular footing in reinforced fly ash beds with P = 450kPa, N = 4.

4. CONCLUSIONS

Based on the results of experiments performed the following conclusions are drawn.

- Circular footing resting on reinforced fly ash beds perform better than its counterpart resting on unreinforced fly ash beds.
- 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.

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BIOGRAPHIES

Assistant Professor in Sri Venkateshwara College of Engineering, Bangalore. ME (Geo Technical Engineering), UVCE, Bangalore. BE (Civil Engineering), Dr. AIT, Bangalore

Associate Professor Dept of Civil Engineering UVCE, Bangalore University, Bangalore.56

Assistant Professor Dept of Civil Engineering UVCE, Bangalore University,Bangalore.56,

Assistant Professor in JNNCE, Shimoga. ME (Geo Technical Engineering), UVCE, Bangalore. BE (Civil Engineering), JNNCE, Shimoga