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Effect of reinforcement Spacing on the Performance of Embedded Circular Footing in Reinforced FlyAsh

S. Gangadara, H.C. Muddaraju

Abstract— Fly ash, having certain desirable characteristics is now recognized as a valuable substance in many applications. A study is under-taken to expand the knowledge concerning reinforced earth by investigating the potential benefits of using reinforced earth to improve the bearing capacity and to reduce the settlement of Fly ash beds, a waste material replacing the soil under repeated loading. The stress-strain behavior and strength properties of fly ash are improved with the inclusion of geosynthetic materials. The use of reinforced earth concept has been widely accepted in many areas of construction but the utilization of flyash in place of back fill soil has not gained much attention of researchers. The present work aims at conducting experiments on embedded circular footing in unreinforced and reinforced fly ash beds subjected to repeated loading in order to investigate the effect of reinforcement spacing on their performance. The experimental results clearly demonstrated that the spacing of reinforcement is an important parameter to be considered and the optuimum spacing of the reinforcement is 0.3B, where B is the diameter of the circular footing.

Index Terms— Cyclic Resistance Ratio, Embedded circular footing, Flyashbed, Geogrid reinforcement, Reinforced soil, Repeated loads, Settlement Ratio.

1 Introduction

SAFE disposal of flyash, a waste end product of thermal power plants, is a challenge that the engineers and environmentalist are facing in the modern era of urbanization. One safe method of disposing this waste byproduct is to utilize them in the civil engineering construction activity. The reinforced earth is a construction method which is gaining more popularly among the civil engineers because of its inherent characteristics of simplicity, design confidence and the easy method of construction. The reinforced earth is a combination of tensile reinforcements and a frictional back fill soil. Generally a well graded sand or gravelly sand is used as a backfill material as they offer adequate friction and provide good drainage. Attempts are also being made to use non soil material like flyash for the backfill in the reinforced earth construction. With the usage of flyash in the backfill not only the method of construction becomes more economical, the disposal problem of flyash is also taken care to some extent. Further the non reactive flyash, which is not conserved in other industries like cement manufacturing, can also be effectively used in the backfill. The research work carried out on the utility of flyash when subjected to monotonic or static loading have established clearly the effectiveness of flyash as backfill material. However the studies on the performance of this backfill material when subjected to repeated loads is limited.

In many practical situations, the dynamic loads are applied at certain depth below the ground level simulating embedded conditions. (eg. Foundations, bridge abutments etc). The circular foundation, which is predominatly used in axi-symmetric structures has economic advantages over boxed foundation and has received little attention of researchers to investigate the benefits of soil reinorcement. (Dash et al.2003; Boushehrian and Hataf 2003; Yoon et al.2004; Deb et al.2004; Bera et al.2005; Shivakumar Babu et al.2006; Tafreshi and Dawson 2010 ;). Hence the present invistiagion has been carried out to understand the effictiveness of reinforced fly ash beds where in a circular footing is embedded.

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The objective of the present investigation to examine the effect of reinforcement spacing on the performance of embedded footing in unreinforced and reinforced fly ash beds subjected to repeated loading. For this purpose 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 are conducted under controlled conditions on the embedded footing resting in polyethylene geogrid reinforced flyash beds. This paper presents the results of all such experiment performed and discussion thereon.

2 Matirials and Methods

2.1 Fly Ash

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

2.2 Reinforcement

Polyethylene reinforcement in the form of Biaxial Geogrid is used in the present investigation. Table- 2 presents the properties of geogrid used.

2.3 Model Footing

Mild Steel Footing

Size of Circular footing, B= 100mm

Thickness of the footing, t = 4mm

2.4 Preparation of Fly ash beds

Fly ash bed is prepared by manual compaction at its optimum moisture content, to maximum dry density. Unreinforced sample is compacted up to a height of 360mm in 3 equal layers of 120mm thick. For reinforced sample, the geogrid reinforcements are placed at predetermined spacing in between fly ash layers from the bottom of footing, and by the same procedure remaining height of the tank is compacted. The reinforcements are provided in the shape of circular discs. A clearance of 5mm is provided to ensure that no friction was generated between the reinforcement and the walls of the tank.

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TABLE 1
FLY ASH PROPERTIES

Physical properties	Test Results
Colour	Light grey
Specific gravity	2.07
Grain size distribution	
Sand size fraction (%)	15
Silt and clay size fraction (%)	85
Atterberg's limits:	
Liquid Limit (%)	31.8
Plastic Limit (%)	--
Plasticity Index (%)	Non plastic
Compaction characteristics	
Optimum moisture Content (%)	23
Maximum Dry Density(kN/m^3)	12.7
Unconfined Compressive Strength at MDD(kPa)	51.4

TABLE 2
REINFORCEMENT PROPERTIES

Physical properties		Unit	Test Results
Aperture size	MD	mm	34
	CD	mm	32
Ultimate tensile strength	MD	kN/m	33.2
	CD	kN/m	31.1
Strain at ultimate	MD	%	14.4
	CD	%	6.9

2.5 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 model footing 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 RESUTLS AND DISCUSSIONS

The results of the experiments carried out have been represented in terms of cyclic load-settlement curves in figures 1 to 4. The experiments are conducted under loading pressure of 350 kPa and 450 kPa. Figure.1 shows the cyclic load- settlement curves plotted for unreinforced fly ash beds at different loading pressures. Figures.2 to4 indicate the results of the experiments conducted on reinforced fly ash beds with three layers of reinforcement which is kept constant in all the cases and with a constant depth of first layer of reinforcement (u/B = 0.3B) but varied spacing of 0.3B, 0.4B and 0.5B between the reinforcement layers, B being the diameter of circular footing., respectively.

The following statements can be drawn from the observation of trend of curves presented in Fig.1 to Fig.4. a) The performance of embedded circular footing in fly ash beds, either unreinforced or reinforced is better when the loading pressures applied are of lower magnitude. b) The magnitude of settlement reduced considerably when the flyash beds are reinforced with geogrids.c) Irrespective of spacing of reinforcement, all the embedded footings in reinforced flyash beds exhibited better performance than their counterparts which are embedded in unreinforced flyash beds.d) The trend of result (c), is observed to be true under all the tested cyclic pressures.e) A cross comparison of these figures reveals that the optimum spacing of the reinforcement is about 0.3B where B is diameter of circular footing.

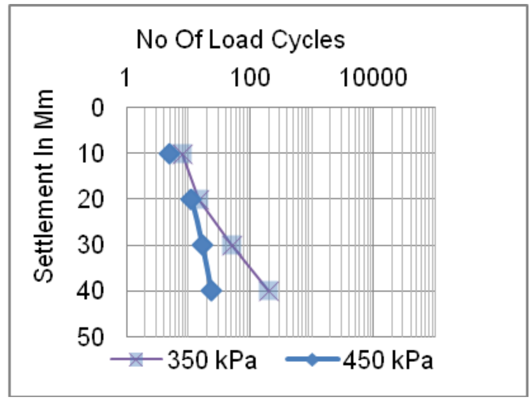

Fig. 1. Performance of embedded circular footing in unreinforced fly ash beds at loading pressures of 350 kPa and 450 kPa.

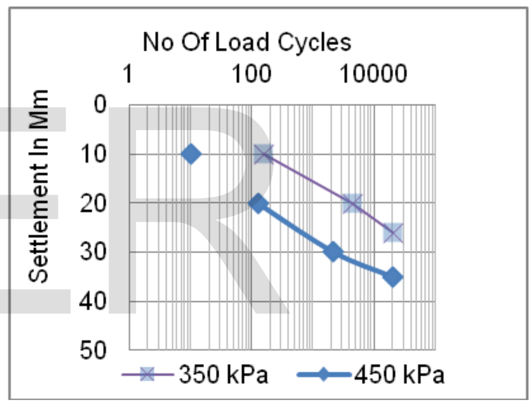

Fig. 2. Performance of embedded circular footing in reinforced fly ash beds (S=0.3B) at loading pressures of 350 kPa and 450 kPa.

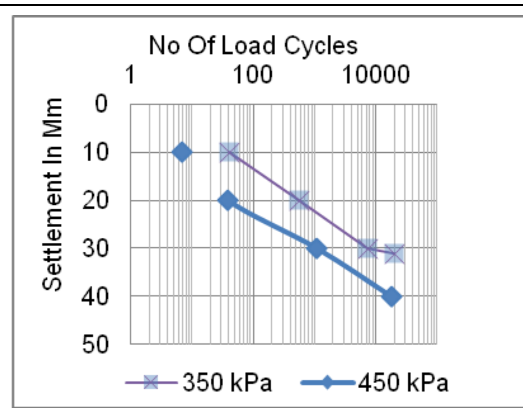

Fig. 3. Performance of embedded circular footing in reinforced fly ash beds (S=0.4B) at loading pressures of 350 kPa and 450 kPa.

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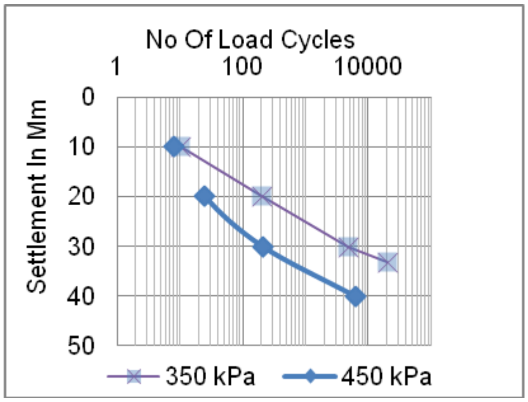

Fig. 4. Performance of embedded circular footing in reinforced fly ash beds(S=0.5B) at loading pressures of 350 kPa and 450 kPa.

3.1 Effect of Reinforcement Spacing on the Performance of Embedded Circular Footing

Fig 5 and fig 6 presents a comparision on the performance of embedded footing in reinforced flyash beds having reinforcements at different spacing under a pressure of 350kPa and 450kPa respectively. It can be seen from fig 5that the settlement of footing in 0.3B spaced reinforced fly ash beds is 26 mm after 20,000 load cycles (350kPa).It increases to 31 mm for 0.4B spacing reinforced fly ash bed and to 33.5 mm for 0.5B spacing reinforced fly ash bed under the same number of cyclic loads. Comparison of settlement values for three different spacing configurations at the same number of loading cycles of 20,000 indicates 0.3B spacing can be considered as optimum spacing. Similarly fig.6 shows the results of the experiments conducted at a loading pressure of 450 kPa.It can seen that even at 450 kPa loading, the curve for 0.3B spaced flyash bed has excelled in its resistance to the loading by taking up more number of load cycles and by showing reduced settlement when compared to other flyash beds with 0.4B and 0.5B spacing values. The footing in reinforced fly ash beds settles by 35 mm and supports 20000 load cycles at a spacing of 0.3B, at 0.4B spacing the footing settles to 40 mm and. takes up 18003 load cycles and at 0.5B spacing the footings settle to 40 mm but bears just 6223 load cycles. The influence of spacing of reinforcement on the performance of footing embedded in fly ash beds is confirmed from the results plotted and assuring better performance of footings in reinforced fly ash beds at a spacing 0.3B between the reinforcement layers.

3.1 Effect of Reinforcement Spacing on the Performance of Embedded Circular Footing

The results of the experiments are analyzed in terms of cyclic resistance ratio (CRR) and the Settlement ratio (SR) by using the following definitions, as given by Nagaraja (2006).

$$CRR = \frac{\text{Number of Load Cycles Required to Cause a Settlement of 'S' In Reinforced Specimen}}{\text{Number of Load Cycles Required to Cause Same Settlement 'S' In Unreinforced Specimen}} \quad (1)$$

$$SR = \frac{\text{Settlement of reinforced sand bed after } N \text{ number of cycles}}{\text{Settlement of unreinforced sand bed after same number of cycles } N} \quad (2)$$

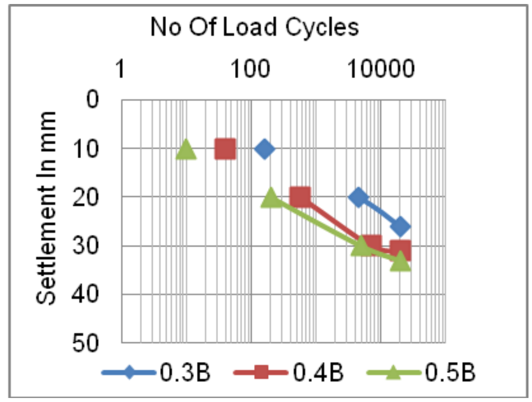

Fig. 5. Effect of reinforcement spacing on the performance of circular footing at P=350 kPa.

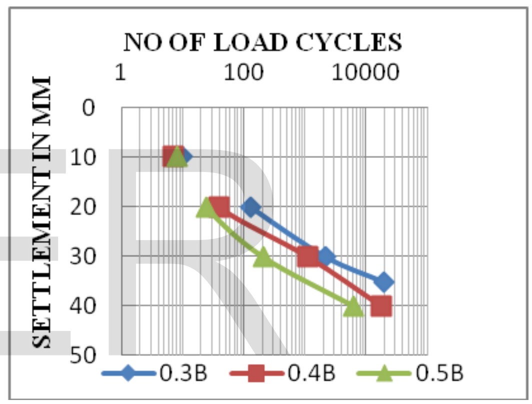

Fig. 6. Effect of reinforcement spacing on the performance of circular footing at P=450 kPa.

Fig 7 and 8 plots the Cyclic Resistance Ratio curves for embedded footings in flyash beds tested at a cyclic pressure of 350kPa and 450kPa respectively. In each of these cases, the test results pertaining to the reinforced flyash beds with reinforcement spacing 0.3B,0.4B and 0.5B are shown. It can be seen from the fig.7 that the CRR at a settlement of 20 mm for 0.3B spaced flyash bed is about 274, for 0.4B spacing it is 35 and that for 0.5B spacing is 12. Initially for all the flyash beds having different reinforcement spacing the CRR is almost the same but it increases with the increase in settlement value. From the graphs it is understood that the curve for 0.3B spaced flyash bed shows the maximum value of CRR which in turn means that0.3B is the optimum. In Fig.8 the curves for CRR follows almost the same trend as that at spacing of 0.3B and 0.4B with CRR values at 20 mm settlement as 13 for 0.3B spacing, 12 for 0.4B spacing and least value of about 2 for 0.5B spacing. Initially up to a settlement of 5 mm at all the spacing configurations the CRR is almost the same but it increases with the increase in settlement value after about 10 mm settlement. Here also 0.3B spaced flyash bed shows better performance. The cyclic resistance ratio of footings in reinforced fly ash beds having reinforcement at a spacing of 0.3B is higher under any magnitude of loading intensity than other spacing configuration indi-

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cating that the performance of footings excels at this spacing. The CRR value reduces when spacing between the reinforcement layers increases thus indicating that the reinforcement spaced closer yield better results and 0.3B is the optimum one.

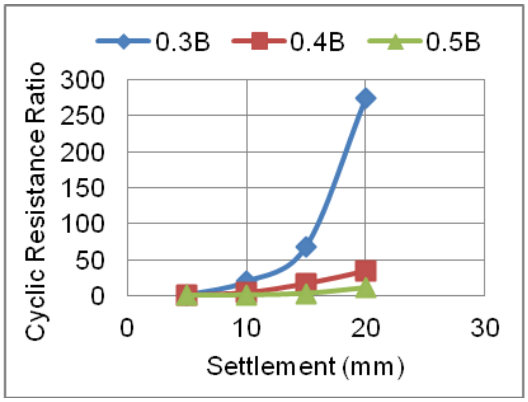

Fig. 7. Effect of reinforcement spacing on the cyclic resistance ratio at P=350 kPa.

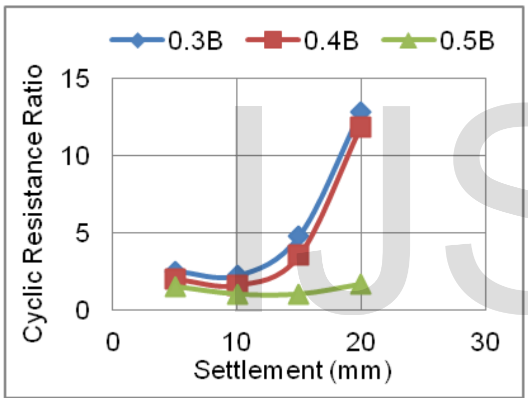

Fig. 8. Effect of reinforcement spacing on the cyclic resistance ratio at P=450 kPa.

Fig 9 plots the Settlement Ratio curves for embedded footings in flyash beds tested at a cyclic pressure of 350kPa. In this, the test results pertaining to the reinforced flyash beds with reinforcement spacing 0.3B, 0.4B and 0.5B are shown. It can be seen from fig.9 that the SR value for 0.3B spaced flyash bed is 0.27, for 0.4B spacing it is 0.33 and that for 0.5B spacing is 0.6. The values indicate that the settlement ratio increase as the spacing increases. From the graphs it is understood thatthe curve for 0.3 B spaced flyash bed shows the minimum value of SR which in turn means 0.3B is the optimum. The values indicate that the settlement ratio increase as the spacing increases. The settlement ratio is less than unity in all the cases of footings in reinforced fly ash beds which clearly states that the provision of reinforcement is better in reducing settlement when footings are subjected to dynamic loading. At a spaced flyash bed of 0.3B is the value of SR is minimum under any magnitude of loading intensity than other spacing configuration indicating that the performance of footings excels at this spacing. The SR value reduces as the number of load cycles increases and after 500 load cycles the SR value is not much affected.

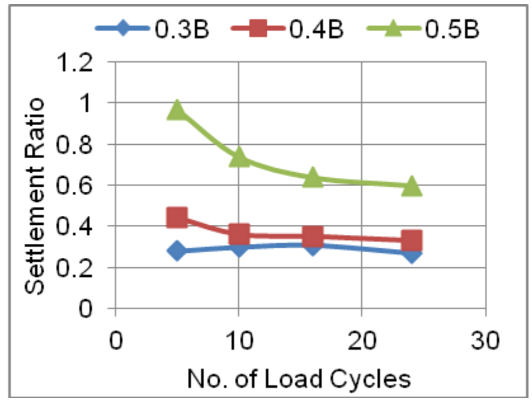

Fig. 9. Effect of reinforcement spacing on the settlement ratio at P=350kPa.

4 Conclusions

The following conclusions are drawn from the results of the experiments conducted in the present investigation:

1. Under any excitation pressure and any reinforcement spacing configuration, the performance of embedded circular footing in reinforced flyash bed is better than its counterpart in unreinforced flyash bed.
2. The performance of embedded circular footings is better when the footings are subjected to lower loading magnitudes irrespective of whether or not the reinforcement is included in fly ash beds.
3. The Cyclic Resistance Ratio and Settlement Ratio clearly indicated that the optimum reinforcement spacing is 0.3B.where B is diameter of circular footing.

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