A Study on the Performance of Embedded Footings in Unreinforced and Reinforced Flyash Beds

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***Abstract*— The use of stabilized flyash as a light weight fill in construction is common. The material can also be used in reinforced soil structures.Flyash is produced in millions of tons and the environmentally acceptable disposal of this material has become an increasing concern. Keeping this point in view the researchers started making use of flyash in construction works. Quality construction materials are not readily available in many locations and are costly to transport over long distance. Hence, over the last few years, environmental and economic issues have stimulated interest in development of alternative materials that can fulfil design specifications. The use of flyash as backfill material fulfils the requirement such as good friction, freely draining. When flyash is provided with reinforcement it solves two problems. i.e., elimination of solid waste problem on one hand and provision of a needed construction material on other. The laboratory experimental results reported by various researchers and the field reports where flyash is being used as a backfill has proved beyond doubt that fly ash is an effective alternate for the backfill. Guided by this in the present investigation it is aimed to study the effectiveness of reinforced flyash beds under monotonic and repeated loads. Laboratory monotonic and repeated load experiments are conducted on reinforced flyash beds by varying the reinforcement parameters and the loading pattern.To bring out the effect of embedment of footing and to demonstrate the performance of embedded footing in reinforced flyash beds subjected to repeated loads, experiments are planned and conducted on embedded footings in unreinforced and reinforced flyash beds.**

Keywords*— Reinforced flyash bed, Repeated loads, Cyclic Resistance Ratio, Settlement Ratio.

1.INTRODUCTION

To evaluate the beneficial effects of providing reinforcement in fly ash beds on the performance of different shaped footings. Experiments are conducted on surface footings in fly ash beds subjected to repeated loads. (Nagaraja. 2006, Bera,et al 2007, Sreekantaiah,.et al 1987, Dash S et.al. 2003). The experiments are conducted to study the effect of embedment of footing and to demonstrate the performance of embedded footing in reinforced flyash beds subjected to repeated loads. Experiments are planned and conducted on embedded footings in unreinforced and reinforced flyash beds. The depth of embedment of footing varied as D=0B, 1B and 2B. D=0B indicates the footings placed on the surface of flyash beds. Further in the experiments with reinforced flyash beds, both the reinforcement configuration and the repeated loading pattern are varied. In this paper for the sake of brevity, only typical results are presented. However, where ever the clarity is required all the experimental results are presented. In this discussion the depth of embedment of footing is expressed in terms of size of the footing (B). For example, if embedment depth D=1B means that the depth of embedment is equal to (i) size of footings for square footing (ii) diameter of footings for circular footing and (iii) least dimension of size for rectangular footing.

2.0 MATERIALS 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 flyash belonging to ASTM classification “C”. This fly ash is directly collected from open dry dumps. The property of flyash is given in Table 1.

Table-1. FlyAsh Properties

Physical properties	Test Results
Specific gravity	2.07
Sand size fraction (%)	15
Silt and clay size fraction (%)	85
Gradation	Uniformly graded
Liquid Limit (%)	31.8
Plastic Limit (%)	--
Plasticity Index (%)	Non plastic
Optimum moisture Content (%)	23
Maximum Dry Density(kN/m^3)	12.7

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.

Table-2. Reinforcement Properties

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

2.3 *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.

2.4 Method of Testing

The reinforced and unreinforced fly ash beds are subjected to repeated loading in the Automated Dynamic Testing Apparatus. The features of Automated Dynamic Testing Apparatus equipment is detailed in Nagaraja (2006). 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. The measured settlements after each cycle of loading are recorded in the data acquisition system.

3.0 RESUTLS AND DISCUSSIONS

Fig 1 plots the number of load cycles v/s settlement curves for square surface footings (blue colour line)1B embedment footings (red colour line footing) and 2B embedment (green colour line footing) lines resting in/on unreinforced flyash beds subjected to a repeated load of 250kPa. It is to be reiterated that the repeated load tests are conducted up to a maximum of 40mm settlement or 20,000 load repetitions,which ever occurred earlier. It is seen from Fig.1that surface footing on unreinforced flyash bed experienced a maximum settlement of 40mm after152 number of load repetitions. The embedded footing with 1B and 2B embedment depth experienced a settlement of 40mm at 62 and 2,928 load cycles respectively. From this observation it is clear that the embedment of the footing has an influence on the settlement behavior of footing in unreinforced flyash beds. Such a change can be attributed to the increased overburden on the footing which in turn increases the shear resistance of the soil mass.

Fig.2 plots the number of load cycles versus settlement curves for 3 different footings with embedment depth D=0B (surface footing) D=1B and D=2B resting on 2 layer reinforced flyash beds, subjected to a repeated loading of 250kPa. It is convincingly clear from the curves in Fig 2 that the embedment of footing in flyash bed has a marked influence on their performance .At any number of load cycles the surface footing (D/B=0) exhibits lesser settlement value than their counter parts embedded (D/B=1 and D/B=2) in reinforced flyash beds. For example at 1000 number of load cycles, the footing with D/B=0 experienced a settlement of about 13mm under specified testing conditions (P=250kPa), where as footing with embedment depth D=1B experienced a settlement of 27mm and that with D=2B experienced a settlement of 20mm. Simillar trend of result is observed at all the loading cycles. Further the footing with D/B=0 (surface) exhibited a final settlement of 29mm after 20,000 load cycles where as footing with D=1B and D=2B experienced 38mm and 31mm settlement after 20,000 load cycles. Simillar trend of results is observed in Fig 3 and Fig 4 also for embedded footing in reinforced flyash beds with 3 and 4 number of reinforcement layers, subjected to 250kPa repeated load. Also the experiments conducted with higher magnitude of repeated load (350kPa) also yielded the same trend of results. For the sake of brevity, these experimental results are not presented in this section. However, these results are presented in the subsequent section to bring out the effect of repeated loading magnitude on embedded footings. The effect of footing embedment in the reinforced flyash beds is further brought out in terms of Cyclic Resistance Ratio and Settlement Ratio.

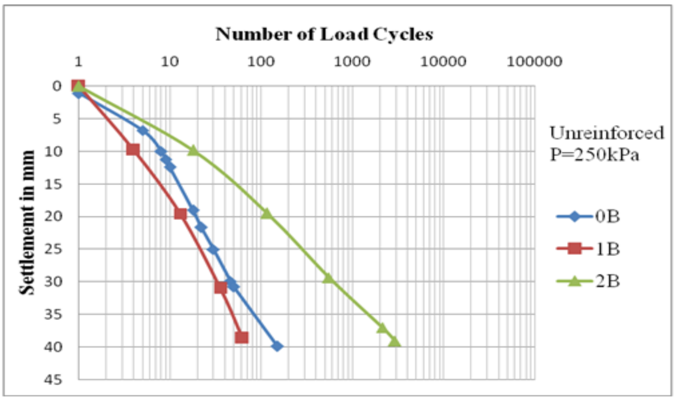


Fig.1 Effect of embedment on the performance of square footings in unreinforced flyash beds

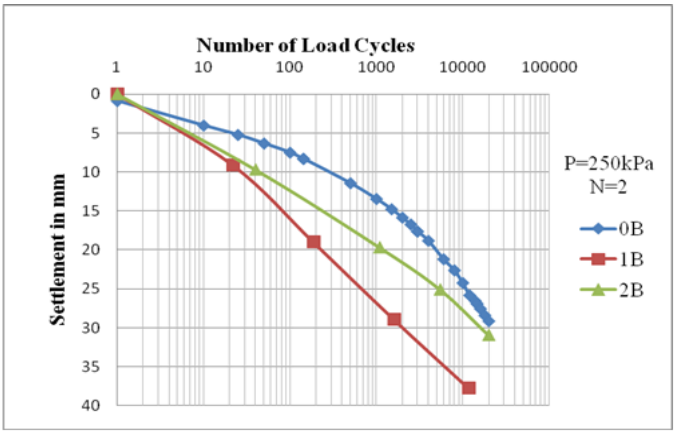


Fig.2 Effect of embedment on the performance of square footings in 2 layer reinforced flyash beds

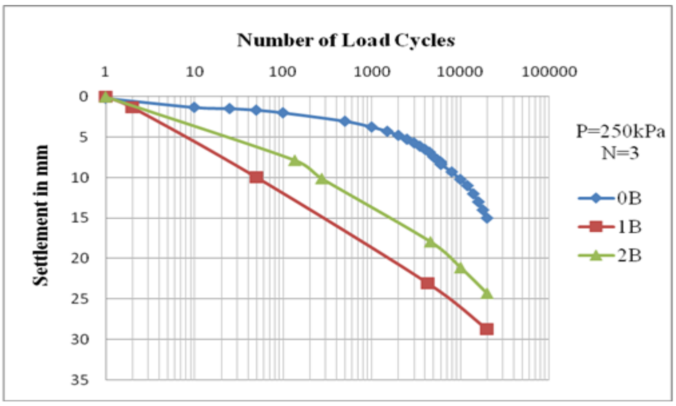


Fig.3 Effect of embedment on the performance of square footings in 3 layer reinforced flyash beds

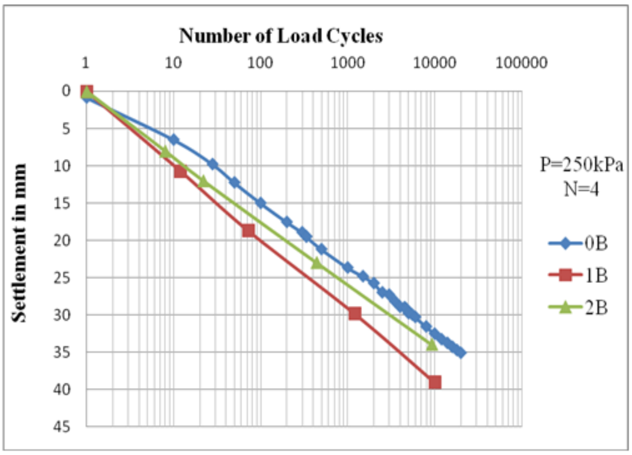


Fig.4 Effect of embedment on the performance of square footings in 4 layer reinforced flyash beds

3.1 Cyclic Resistance Ratio

The results of the experiments performed to understand the behavior of surface and embedded footing are analyzed in terms of CRR (cyclic resistance ratio) and the SR (settlement ratio) using the definitions given by Nagaraja

$$CRR = \frac{\text{Number of load cycles required to cause a settlement of S in reinforced specimen}}{\text{Number of load cycles required to cause a settlement of S in unreinforced specimen}}$$

Fig 5 plots the Cyclic Resistance Ratio at a settlement level of 15mm against embedment depth for footings in 2,3 and 4 layered reinforced flyash beds, respectively.All these footings are subjected to a repeated load of 250kPa. It can be seen Fig.5 that the Cyclic Resistance Ratio decreases as the depth of embedment increases for any flyash bed reinforced with geogrid reinforcement. For example the footings at D/B=0 (surface footing) on 2 layer reinforced flyash bed (Fig 5) exhibits a Cyclic Resistance Ratio of 100 where as its counter parts placed at D=1B and D=2B exhibits a Cyclic Resistance Ratio of 15 and 8 respectively. The same trend is observed in Fig.5 for 3 and 4 layer reinforced flyash beds. The data presented in Fig.5 proves beyond doubt that the embedment of the footing in flyash beds has a detrimental effect on their performance, indicated by the reduced values of CRR. Such a decrease in the resisting capacity of the reinforced flyash beds can be attributed to the reduced lateral confinement of the flyash bed. Also as the depth of embedment increases, the stress intensity at the geogrid level increases due to the increased overburden on the footing. Simillar trend of result is observed at different settlement level also. Further it is interesting to observe across Fig.5 that at any embedment depth, the CRR values reduces at the number of reinforcement layer in the flyash bed increases. The surface footing (D/B=0) showed Cyclic Resistance Ratio of 100 ,23 and 10 for 2,3 and 4 layer reinforced flyash bed respectively. The footing with D/B=1 and D/B=2 showed Cyclic Resistance Ratio of 4,5 and 3 for 2,3 and 4 layered reinforced flyash beds respectively.

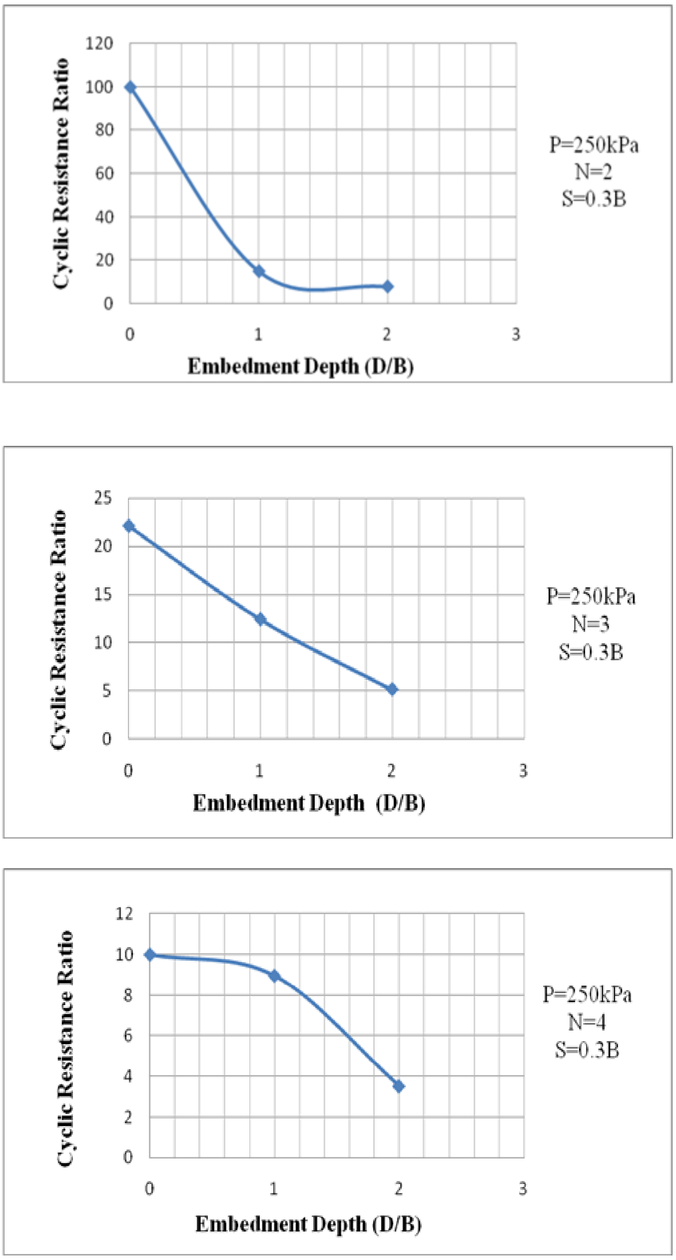


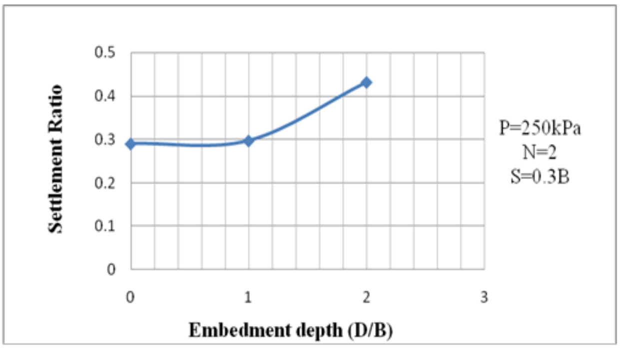
Fig.5 Effect of embedment depth on CRR for footings in 2,3and 4 layer reinforced flyash beds

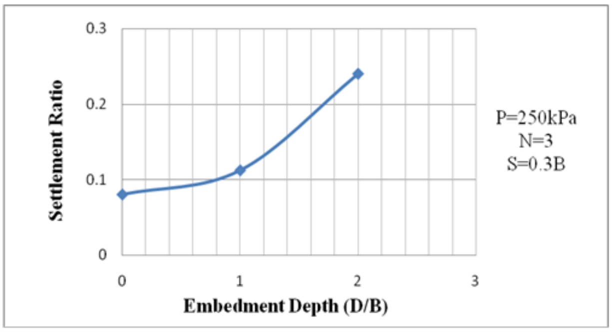
3.2 Settlement Ratio

To bring out the effect of reinforcement on the settlement behavior of footings in the term flyash beds, Settlement ratio is calculated from the experimental results. In the present study, SR (settlement ratio) is defined as:

$$SR = \frac{\text{Settlement of reinforced flyash bed after N number of cycles}}{\text{Settlement of unreinforced flyash bed after N number of cycles}}$$

Fig.6 presents the variation of Settlement Ratio with embedment depth for footings resting on 2, 3 and 4 layer of geogrid reinforced flyash beds, respectively. It can be observed from these figures that the Settlement Ratio of the footings increases as the depth of embedment of footing increases, thus clearly demonstrating that the settlement of the footing in reinforced flyash bed increases as the depth of their embedment increases. For example footing resting on 2 layer reinforced flyash bed (D=0B) exhibits a Settlement Ratio of about 0.28 where as its counterpart with embedment depth D=1B and 2B exhibits a Settlement Ratio of 0.3 and 0.42 respectively. Similar kind of results is observed in case of 3 and 4 layer reinforced flyash beds also.





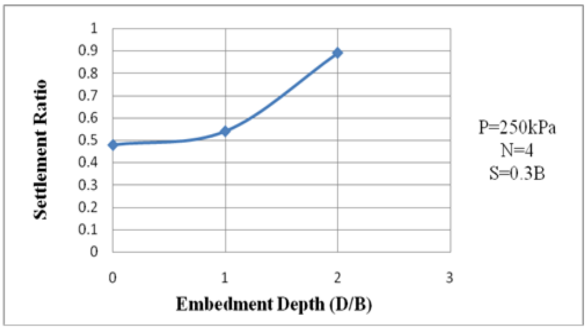


Fig.6 Effect of embedment depth on SR for footings in 2,3 and 4 layer reinforced flyash beds

4.0 CONCLUSIONS

1 The provision of reinforcement in case of embedded footing (0B, 1B and 2B) footings is effective in increasing the resistance number of load cycles and decreasing the settlement.

2 Based on cyclic resistance values, the optimum number of the reinforcement layer is 3 optimum number of geogrid layers is much dependent on the vertical spacing between geogrid layers.The provision of reinforcement is effective in increasing the cyclic resistance ratio of embedded square footings.

3 The provision of reinforcement layer is effective in decreasing the settlement ratio of embedded square and circular footings. The settlement ratio ranged from 0.07 to 1.0.

4 This interlock enables the geogrid to resist the horizontal shear stresses built up in the flyash bed under the footing and to transfer them to the adjacent stable layers of flyash bed and thereby improve the vertical behavior of the footing. However the optimum number of reinforced layer appears to be 3 for all the different shaped footings.

5.0 REFERENCES

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