Bearing Capacity of Reinforced Pond Ash

Joyanta Maity, Bikash Chandra Chattopadhyay

***Abstract*— An experimental study of the bearing capacity of a square footing resting on reinforced Pond Ash was conducted in this investigation. In India, the problem of ash disposal is expected to become severe due to the limited space available for ash disposal near most of the power plants. This calls for strategies to encourage and establish technological concepts for bulk utilization of Pond Ash, which should not only be cost-effective but also environmentally safe. In this present investigation, a series of bearing capacity model test were carried out on square footing of size 10cm x 10cm resting on the reinforced Pond Ash bed which was prepared at OMC with required density. The tests were conducted without and with different no of geojute layers. The experiments were also be carried out with different densities of foundation medium, different u/B ratio, and with different size of reinforcing material sheet. From the test result it is observed that the ultimate bearing capacity of square footing on reinforced and unreinforced Pond ash bed is increases with the increase of the density of foundation bed, . Also, the bearing capacity of reinforced Pond ash bed increases with the increase of number of reinforcing layer and length of the reinforcing material sheet up to a certain limit, after that there is no improvement. Maximum improvement in ultimate beanng capacity of reinforced Pond ash bed can be achieved at u/B ratio of 0.25, with length of geojute sheet of 6B and with four number of geojute layers.**

***Index Terms*— Reinforced Pond Ash, Square footing, Bearing capacity model test, Cost- effective.**

I. INTRODUCTION

Reinforced soil structure is an effective technique for increasing the strength of soil. In the recent years, reinforced soil is widely in use as the construction material in formation of sub grade for roads, railway tracks airfields and hard standings and in retaining walls or abutments. Reinforced soil foundation bed consists of horizontally embedded geosynthetics or thin flat metal strips, ties or grids. Introduction of a layer of reinforced soil between the footing and weak subsoil can increase the bearing capacity substantially, thus avoiding the necessity of large and costly footing structure such as combined footing or raft footing.

The concept of reinforced earth was first introduced by Henry Vidal of France in 1964. Although the original work done by Vidal used galvanized metal strips as the reinforcing material; geofabric material can also be used effectively. Both biodegradable and synthetic varieties of woven or non-woven geofabrics have been used to improve the strength of soil as well as for other engineering purposes like drainage, filtration, slope protection, soil erosion control etc. The first significant study on strip foundations has been done by Binquet and Lee (1975) who concluded that the bearing capacity of sand increases almost three times with certain amount of aluminum foil strips reinforcement. Several authors also studies strip foundations but reinforced with different materials such as steel bars (Verma and Char, 1986), steel grids, geotextile and geogrids (Khing et al, 1993). Other researchers adopted circular footing, square footing (Akinmusuru and Akinbolade, 1981; Guido et al, 1985) or rectangular footing. All of these researchers indicated that reinforcement increased the bearing capacity and reduced the corresponding settlement of the foundations compared to the unreinforced soil.

In our country a number of thermal power plants are producing million tons of flyash annually. It is a waste material in a by-product of combustion of pulverized soil. Besides fly ash, other type of ash is bottom ash that is generally heavier than fly ash. These two ashes, flyash and bottom ash in slurry form mixing together are deposited into pond is called Pond Ash. The disposal of ash produced in thermal power station is posing serious problem considering the storage, space and cost involvement. Waste not properly utilized or disposed may also be hazardous. The discharge of fly ash into lakes, rivers or ash ponds and into sea disturbs the ecology of the region. The portions of it which escapes into atmosphere eventually settles down over many hectors of lands in the vicinity of the power station and could haring about perceptible change in soil characteristics. To solve the problem of disposal and to reduce or control the environmental pollution, there is an immediate need for increasing its utilization in the country to a suitable high level in the near future. So an attempt has been made for utilizing Pond Ash, increasing the bearing capacity and reducing the consolidation settlement by the use of reinforcement up to large extent.

II. PROPOSED INVESTIGATION

A. Experimental set up:

To investigate the effect of reinforcement, on bearing capacity of Pond Ash, a series of routine tests were performed in a systematic manner.

The model footing tests were performed in a square tank of 65cm x 65cm and 30cm in depth and the model footing used in this experiment was made from mile plate, had the dimension of 10cm x 10cm and 1.5cm in thickness. The constituents of experimental set up are shown in figure 1. For model tests, a hammer was used for compaction of foundation medium. The weight of the hammer was 5 kg. The height of fall of hammer was 10cm from the top surface of the foundation medium.

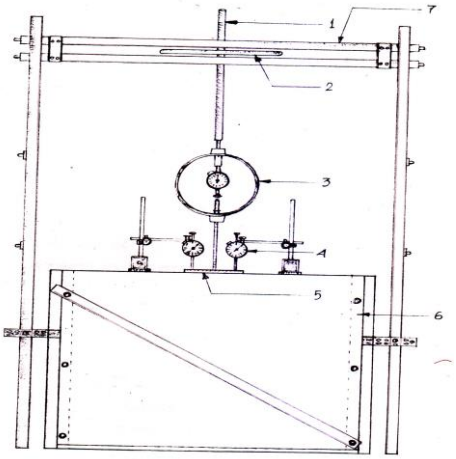

Fig.1 Experimental Set up
(1. Threaded shaft, 2. Rotating wheel, 3. Proving ring 4. Dial gauge 5. Square footing, 6. Tank 7. Reaction frame.)

B. Material used:

Table 1: PHYSICAL PROPERTIES OF POND ASH:

Properties	Value
Specific gravity	2.25
Uniformity coefficient, (Cu)	2.82
Coefficient of curvature,(Cc)	0.65
Effective size,(D_{10} mm)	0.081
Optimum moisture content (%)	34
Maximum dry density (gm/c.c)	1.07
Cohesion (C kN/m^2)	14
Angle of internal friction	34.5°

Table 2: PHISICAL PROPERTIES OF GEOJUTE

PROPERTIES	Geojute
Mass per unit area (gm/m^2)	635
Thickness (mm)	1.1
Apparent Opening size(mm)	0.18
Breaking strength in warp direction (kN/m)	16.4
Breaking strength in weft direction (kN/m)	15.99
% Elongation at break in warp direction	11.9
% Elongation at break in warp direction	11.7
Angle of Internal Friction (φ)	44°

Pond Ash:

Pond Ash was chosen as foundation medium in the present study. The Pond Ash was collected from Kolaghat Thermal Power plant. Then it was air dried under sunrays for two days and pulverized. Different laboratory tests were carried out to find out the different physical properties such as grain size distribution, specific gravity, maximum dry density at OMC, cohesion and angle of shearing resistance. The physical properties of the Pond ash are given in table 1.

Geojute:

Commercially available natural Geojute sheet was used as reinforcement material. The physical properties of the Geojute are given in table 2.

C. Preparation of Reinforced Pond Ash bed:

The model tests were conducted in a square box as described earlier. The Pond ash collected from the Thermal Power Plant, were air dried under sunrays for two days and the pulverized in the laboratory. For model test the pulverized Pond ash was taken and its moisture content had been determined. Now required amount of water is added to the soil to get constant moisture content about 34% (OMC). To get the uniform moisture content, Pond ash and water were mixed thoroughly. Now the moist Pond ash was placed in the test tank in layer by layer and compacted in 25mm thick layers by a standard hammer of about 5kg with a free fall of 10cm. In this way the foundation tank was filled up by Pond ash. In case of reinforced bed, Geojute were placed at desired depth from the bottom of the footing.

D. Test Procedure:

After preparation of foundation bed, it was leveled and the model square footing was centrally placed on the Pond ash bed. The footing and the rotating shaft was connected through a proving ring with the help of a steel rod and the thread of the shaft, two dial gauges were placed, one at left and the other at right end of the model footing to record the settlement of the footing. After the load was applied manually by rotating the wheel of the loading frame anti-clockwise so that the shaft moved downward without rotation. The load applied to footing was measured through the proving ring and the settlement of the footing was measured with the help of two dial gauge. In this way, load was applied until failure takes place. Now with the help of calibration chart the loads corresponding to different settlement were obtained and were plotted in the graph as shown later.

E. Types of test performed:

Several types of model tests were performed to investigate the effects of different parameters such as length of geojute reinforcement (l), number of geojute layers (n), depth of uppermost geojute layer (u) from base of the footing, using different compacting energy of geojute reinforced foundation bed (see Table 3).

Types of test performed were divided into following series:

Series - A: Test conducted on geojute reinforced Pond Ash bed with different u/B ratio.

Series - B: Test conducted on reinforced pond ash bed with different numbers of Geojute layers.

Series - C: Test conducted on reinforced pond ash bed with different length of Geojute sheet.

Series - D: Test conducted on geojute reinforced pond ash bed with different compacting energy.

Table 3: Parameters used in the model test:

u/B ratio	0, 0.1, 0.25, 0.5, 0.75
No of Reinforcement layers	1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th}
Length of reinforcement (cm)	0, 20, 30, 40, 50, 60.
Compacting energy (m-N/m^3)	13500, 27000, 54000.

III. RESULT AND DISCUSSION

The results for different test series of model tests have been presented in Table 4 to 7.

Table 4: Ultimate Bearing Capacity for various u/B ratio of Geojute reinforced Pond ash bed:

u/B Ratio	Ultimate Bearing Capacity (kN/m^2)
0.00	320
0.10	415
0.25	490
0.50	407
0.75	345

Table 5: Ultimate Bearing Capacity for various length of geojute sheet of Geojute-reinforced Pond ash bed:

Length of Reinforcement (cm)	Ultimate Bearing Capacity (kN/m^2)
0	310
20	365
30	412
40	440
50	472
60	493

Table 6: Ultimate Bearing Capacity for different compacting energy of Geojute-reinforced Pond ash bed:

Compacting energy ($m\text{-}N/m^3$)	Ultimate Bearing Capacity (kN/m^2)	
	One layer	Two layers
13500	462	526
27000	656	803
54000	864	1297

Table 7: Ultimate Bearing Capacity for different no. of Geojute layers of Geojute-reinforced Pond ash bed.

No. of layers	Ultimate Bearing Capacity (kN/m^2)
0	310
1	462
2	526
3	610
4	695
5	672

From the model test results, the effects of different parameters on the bearing capacity of geojute reinforced pond ash are discussed as below.

(A) EFFECT OF u/B RATIO:

The influence of the ratio of the depth of upper most Geojute layer from base of the footing and footing width is defined by u/B ratio on the bearing capacity of foundation was studied in the Test series A. Figure 2 shows the variation of UBC of square footing with u/B ratio on reinforced Pond Ash bed.

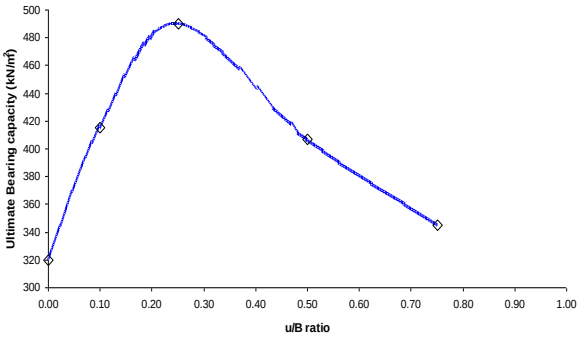

Fig.2 Variation of UBC of square footing with u/B ratio on reinforced Pond Ash bed.

From figure, it is shown that with the increase of u/B ratio from 0 to 0.25, Ultimate Bearing Capacity increases and reaches a maximum value of $490kN/m^2$ and after that ultimate bearing capacity decreases with the increase of u/B ratio up to 0.75, then it gains constant values. The slight increase in the performance of improvement with u/B of 0.25 may be due to the effect of soil cushion spreading load over larger area of Geojute and preventing the Geojute sheet from direct contact with the footing that would bring an early buckling. With further increase in the u/B ratio, the Pond ash between the footing and the Geojute layer would squeeze out leading to larger settlements. This is reflected in the reduction of bearing capacity for higher u/B ratios. From these results, it may be concluded that when Geojute layer is placed at depth greater than 0.75B, its contribution to the improvement is only marginal.

(B) EFFECT OF NUMBER OF LAYERS:

The effect of number of layers of Geojute is studied in the test series B. The type and size of reinforcement, the vertical spacing between the reinforcement, and density of foundation medium are kept constant for all the tests in this series. Figure 3 shows the variation of UBC of square footing with no. of geojute layers. From figure it is shown that bearing capacity increases with the increase in number of layers. The maximum ultimate bearing capacity occurred for 4 no. of layers of reinforcement placed at u/B = 0.25, after that the ultimate bearing capacity decrease up to certain limit.

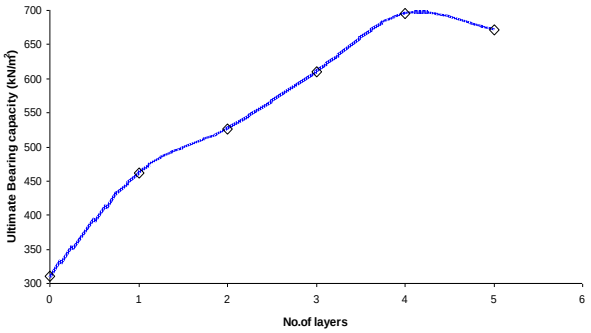

Fig.3 Variation of UBC of square footing with no. of geojute layers.

(C) EFFECT OF LENGTH OF REINFORCING ELEMENT:

The effect of the length of reinforcing element on the Ultimate bearing capacity is studied in the test series C.

These tests were performed with length of geojute sheet 2B, 3B, 4B, 5B and 6B. Figure 4 shows the variation of UBC of square footing with the length of reinforcement. From figure it is shown that with the increase in length of geojute sheet the ultimate bearing capacity increases rapidly up to the length of geojute of 4B, after that its improvement nearly equal. Maximum ultimate bearing capacity of 493 kN/m^2 can be get for the length of 6B of one layer geojute reinforced pond ash.

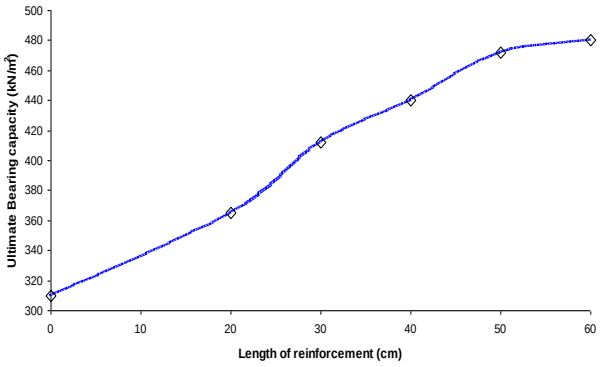

Fig.4 Variation of UBC of square footing with length of reinforcement.

(D) EFFECT OF DRY DENSITY:

The influence of the dry density of the Pond ash was investigated in test series D. Fig. 5 shows the variation of UBC of square footing with compacting energy on reinforced Pond Ash bed. From the figure it is shown that the ultimate bearing capacity of reinforced pond ash increases with the increase of dry density. With the increase in relative density of soil, the frictional resistance between the Geojute layer and the Pond ash increases, thereby increasing the resistance to downward penetration of Pond ash below the Geojute and hence a higher improvement in load carrying capacity. On the other hand, the soils with higher relative density had exhibited higher rate of increase of bearing capacity as compared to that at smaller based on the dilation of the Pond ash and the resulting strains in Geojute layers.

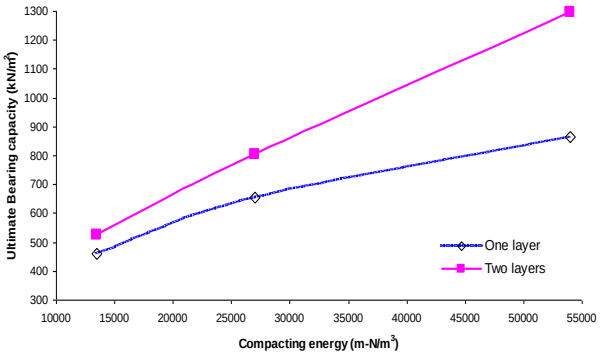

Fig.5 Variation of UBC of square footing with compacting energy on reinforced Pond Ash bed.

IV. CONCLUSION

Based on the discussion of the test results, following conclusions can be drawn.

The depth of uppermost layer of reinforcement from the base of footing has significant effect on bearing capacity. Ultimate bearing capacity of Geojute-reinforced (one layer) Pond ash bed increases with the increase of u/B ratio from 0 to 0.25 and reaches a maximum value and after that ultimate bearing capacity decreases with the increase of u/B ratio and then it gains almost constant values.

The ultimate bearing capacity of the geojute reinforced pond ash increases with increase of number of reinforcing layers. For u/B ratio of 0.25, maximum ultimate bearing capacity can be achieved at 4th layers.

Ultimate bearing capacity of Geojute-reinforced (one layer) Pond ash bed increases with the increase of length of Geojute sheet. Maximum ultimate bearing capacity can be achieved for the length of Geojute sheet of 6B. However, for economical purpose we should use Geojute sheet of length 4B, as it has Ultimate bearing capacity nearly equal to that of Geojute sheet length of 6B.

Ultimate bearing capacity of Geojute reinforced Pond ash bed, increases enormously with the increase of dry density of foundation bed.

REFERENCES

[1] Akinmusuru, J.O. & Akinbolade, J.A. (1981) *'Stability of loaded footings on reinforced soil.'* ASCE, Vol-107, No GT6, June 1981,page 819-827.

[2] Binquet, J & Lee, K.L. (1975) *'Bearing capacity tests on Reinforced Earth slabs.'* ASCE, Vol-101, No-GT12, Dec. 1975, page 1241-1255.

[3] Binquet, J & Lee K.L. *'Bearing capacity analysis of Reinforced Earth slabs.' ASCE,* Vol-101, No-GT12, Dec. 1975, page 12571276.

[4] Guido, Vito A.; Biesiadecki, G.L. & Sullivan, M.J. *'Bearing capacity of a geotextile reinforced foundation.'* Proceedings XI ICSMFE, Vol-3, 1985, page 1777.

[5] Khing, K.H.; Das, B.M.; Puri, V.K.; Cook, E.E.& Yen, *S.C. 'The bearing capacity of a strip foundation on Geogrid Reinforced sand.'* Geotextiles & Geomembranes, Vol-12, 1993, page 351361.

[6] Verma, B.P. & Char A.N.R. *'Bearing capacity tests on reinforced sand sub grades.'* Journal of Geotechnical Engineering, Vol-112, No-7, 1986, page 701-707.

Joyanta Maity, PhD (JU) is Assistant Professor of C.E. Dept., Meghnad Saha Institute of Technology, Kolkata. His research interests include ground improvement techniques, use of alternative materials and use of natural geofibers in Civil Engineering.

Bikash Chandra Chattopadhyay, PhD (IIT, Kharagpur) is Professor of C.E. Dept., Meghnad Saha Institute of Technology, Kolkata. He has been engaged in teaching geotechnical engineering, research and consultency over last 46 years and received Leonard's award for the best PhD thesis from IGS in 1987