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Effect of Bamboo Grid and Geonet on Bearing Capacity of Clayey Soil by Varying the Depth of First Reinforcement Layer

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***Abstract**:- Soil reinforcement is a technique to modify the engineering properties of the natural soil. Nowadays, natural materials have been used for ground improvement. This study aims to the use of locally and naturally available bamboo as a reinforcing element due to its cost effectiveness. Bamboo grid shows better performance than geonet reinforcement. In this study, the optimum number of reinforcements was kept constant as three. The optimum depth of first reinforcement layer was obtained for maximum bearing capacity as 30mm. The spacing between two successive reinforcement layers is maintained 50 mm throughout the test series.*

***Keywords**:- Soil reinforcement, Bamboo grid, Geonet, Bearing Capacity*

INTRODUCTION

`When structures have to be constructed on difficult ground conditions, replacing soft soil with high-quality fill material is most commonly recommended method to improve bearing capacity and to decrease settlement. Alternatively, soil reinforcement can be an adaptable technique to improve the performance of ground. Nowadays environmental sustainability gains more importance in construction and hence uses of natural material in soil have more significance nowadays.

Bamboo is a perennial grass which exists abundantly in tropical and subtropical zones of the world. Bamboo is fast growing plant and it matures with 2-5 years. Bamboo is very strong in tension. Known as renewable natural resources and biodegradable, bamboo is found to as an efficient material adopted in decreasing the global warming effects and to save the environment from chemical waste. Bamboo has desirable properties needed for geosynthetics, so bamboo can be used as tension reinforcement in soil. Durability of bamboo is a major concern in soil applications. Different preservation techniques are available to enhance the durability. From various methods coating with bituminous material is found to be easier and cost effective.

Coir is 100 % organic fibre from coconut husk. Naturally resistant to rots, moulds and moisture, it needs no chemical treatment. Since it is hard and strong, it can be spun and woven into matting. They also have the strength and durability to protect the slopes from erosion, while allowing vegetation to flourish. Coir geonet, commonly used for drainage purpose, can be used to improve bearing capacity of clay. It has been recognized as a feasible alternative to geosynthetics for reinforcement applications, due to its longevity and excellent engineering properties. It is best suited for low-cost applications in developing countries due to its availability at low prices compared to its synthetic ones.

I. LITERATURE REVIEW

Mandal and Sah (1992) conducted bearing capacity test to determine the effectiveness of geogrid reinforcement on clay subgrade. It was seen that bearing capacity and settlement behaviour got increased. Maximum bearing capacity ratio of about 1.36 was obtained at u/B = 0.175. The maximum percentage reduction in settlement was observed when the reinforcement is at depth of 0.25B from the base of the square footing.

Omar et al. (1993) conducted model test to determine the ultimate bearing capacity of sand reinforced with geogrid when supported by strip and square footing. Tests were conducted by varying the parameters like number of grid layers, width of the geogrid, depth of first reinforcement layer from the base of the footing. The effective depth of reinforcement for the maximum bearing capacity was found to be 2B for strip footing and 1.4B for square footing. The maximum width of reinforcement for maximum bearing capacity ratio was obtained as 8B for strip foundation and 4.5B for square foundation. The maximum depth of placement of first reinforcement layer should be within B.

Adams et al. (1997) conducted large scale model footing load test to evaluate the effect of single and multiple layers of geosynthetic reinforcement. Stiff biaxial geogrid and geocell were the two geosynthetic materials used in this study. Parameters like number of reinforcement layers, spacing between reinforcement layers, the depth to the first reinforcement layer, plan area of the reinforcement, type of reinforcement and soil density were discussed. The depth to the top layer of the reinforcement layer from the base of the footing should be within 0.25B for maximum improvement in bearing capacity.

Tafreshi and Dawson (2010) carried out model test on strip footing supported on geocell and planar reinforced sand beds with same characteristics of geotextiles. The parameters studied include reinforcement with number of planar layers of geotextile and height of geocell below the footing base. The efficiency of reinforcement was decreased by increasing the number of planar reinforcement layers, the height of geocell reinforcement and reinforcement width. Significant improvement in bearing pressure and footing settlement can be achieved using a lesser quantity of geocell material as compared to planar geotextile.

Kolay et al. (2013) done research on the improvement of bearing capacity of silty clay soil with sand layer on top and placing geogrids at different depths. Model tests were performed on the soil for rectangular footing resting on top of it. Increase in bearing capacity of soil overlain by sand layer by placing a geogrid layer at the interface of the two soil was found to be 16.67%. But it shows 33.33% improvement if the geogrid placed at mid depth of the sand layer. Also, the bearing capacity increases by the increase in number of geogrid layers.

Yuan et al. (2014) done research on using bamboo network reinforcement technology on hydraulic fill soft soil foundation treatment to improve bearing capacity. Bearing capacity of hydraulic fill super soft soil surface layer was improved 323% after 3 months than early treatment. It improves 695% after 3 months treatment than no treatment.

Asaduzzaman and Islam (2014) described about the soil improvement using bamboo reinforcement. Bearing capacity of the soil was increased up to 1.77times and 2.02 times for single layered and multiple layered reinforced soil system. BCR increases with increase in number of reinforcement layers. The load carrying capacity is maximum and settlement is minimum when reinforcement is placed at 0.3B for single layered system.

Bazne et al. (2014) investigated the possibility of using geonet as reinforcement in addition to drainage purposes. The parameters studied were shape and size of the footing, number of layers, length, spacing and depth of first layer of geonet reinforcement. Geonet reinforcement significantly increases the bearing capacity of soft clayey soil up to 6 times more that its original condition. From various shape of the footing, square footing showed better performance with a BCR of 7.6. Optimum length of reinforcement for 2- and 3-layer models were found to be 2B.

Chacko and Joseph (2016) conducted a small-scale laboratory model test on unreinforced soil and soil reinforced with geogrid, bamboo grid and bamboo rods. In this bamboo specimens were coated with bitumen. Soil reinforced with bamboo showed increase in bearing capacity. Performance of bamboo grid was found to be better than geogrid.

Maulana et.al (2018) done experimental studies with embankment model using iron scrap on peat soil which were supported by bamboo grid and pile with diameter of 2 cm with length 20 cm and spacing of 20 cm and 10 cm. Installation of bamboo piles combined with bamboo grids was able to reduce settlement and deflection of the bamboo grid and ultimately maintain stability of the embankment.

II. SCOPE OF THE STUDY

This study aims to use the naturally and locally available bamboo and geonet to improve the bearing strength of soft ground. Also, to replace the conventional materials including steel and polymer plastics with bamboo as reinforcing element due to cost effectiveness.

III. OBJECTIVES

The main objectives are:

- To study the effect of varying depth of first reinforcement layer on load carrying capacity of soil using
  a. Bamboo grid
  b. 400 GSM Coir Geonet

IV. MATERIALS USED

a. Clayey soil

Soil used in this study was collected from Amaravila, Neyyatinkara town, Thiruvanthapuram. The initial properties of the collected soil are tabulated in Table I. Fig.1 shows the particle size distribution of soil.

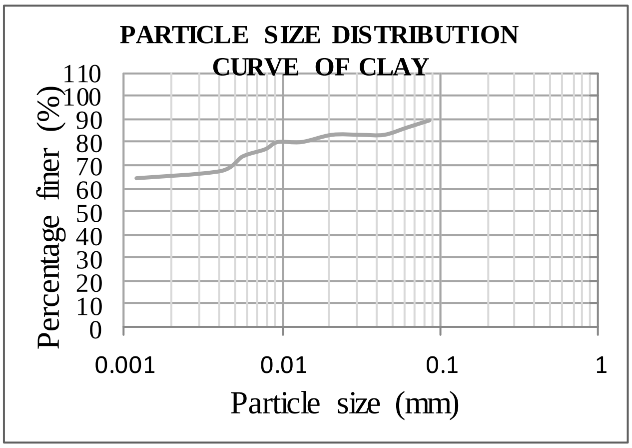

Fig.1.Particle Size Distribution Curve

Table I. Initial Properties of Soil

Properties	Value
Specific gravity	2.63
Natural moisture content (%)	38
Liquid limit (%) (IS 2720 PART 51985)	56
Plastic limit (%) (IS 2720 PART 51985)	20
Plasticity index (%) (IS 2720 PART 51985)	36
Shrinkage limit (%) (IS 2720 PART 51985)	17.68
Percentage of clay (IS 2720 PART 4)	64
Percentage of silt (IS 2720 PART 4)	24
Percentage of sand (IS 2720 PART 4)	12
Maximum dry density (kg/cm³) (IS 2720 PART 7)	1.57
Optimum moisture content (%) (IS 2720 PART 7)	20.5
Unconfined compressive strength (Kg/cm²) (IS 2720 PART 7)	0.48
IS Classification	CH

b. 400 GSM Coir Geonet

Coir geonet of 400 GSM were collected from Geonet Envirosolutions Pvt. Ltd., Kochi for this study. The properties of the materials are given in the Table II. (As provided by the supplier). Fig.2 shows 400 GSM Geonet.

Fig.2. 400 GSM Geonet

Table II. Properties of 400 GSM (Provided by the supplier)

Characteristics	400 GSM
Mass / unit area, g/m² (min)	400
Width, cm, Min	100 or as required
Length, m	50 or as required
Thickness at 20kPa, mm, Min.	6.5
Ends (Wrap)	180
Pcks (wefts)	160
Break load,Wet (kN/m), Min a. Machine direction b. Cross machine direction	 7.0 4.0
Peak load, Dry (kN/m), Min a. Machine direction b. Cross machine direction	 3.0 2.0
Peak load, Wet (kN/m), Min a. Machine direction b. Cross machine direction	 7.5 4.0
Trapezoidal Tearing strength (kN) at 25 mm gauge length, (Min) a. Machine direction b. Cross machine direction	 0.18 0.15
Mesh size, mm, (Max)	20.0 x 16.75

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c. Bamboo grid

Locally available bamboo was cut into strip of 10 mm width of required length. It is then made into grid of aperture size similar to the aperture size of 400 GSM geonet. Fig.3 shows bamboo grid used in this study.

Fig.3 Bamboo grid

V. EXPERIMETAL SETUP AND METHODOLOGY

The laboratory plate load tests were conducted as per IS 1888:1982. The foundation bed was prepared in a steel tank of size of 500 mm x 500 mm x 500 mm. A steel plate of square shape of size 100mm and 12 mm thick was used as model footing. The load was applied through a hand operated hydraulic jack. The applied load was measured by using precalibrated proving ring. Fig.4 shows the experimental set up.

Fig.4 Experimental Set up

The clay bed was prepared in square tank of dimension 500 mm x 500 mm. The soil was mixed with water content below its liquid limit. Before filling the tank with soil, inside walls were coated with oils to avoid friction. The soil was uniformly compacted in 50 mm thick layers to achieve desired height of foundation. After the preparation of bed, plate load tests were performed and settlement of each loading was measured using dial gauges. Fig. 5 shows the prepared clay bed.

Fig. 5 Prepared clay bed

A series of plate load tests were conducted to study the effect of bamboo grid and 400 GSM Coir Geonet. Test series were listed in the Table III.

Table III. Test Series

Test series	Details	Influencing Parameters
A	Unreinforced bed	-
B	Clay bed overlaid by bamboo grid reinforced sand bed	Constant parameter: N=3
C	Clay bed overlaid by geonet reinforced sand bed	Constant parameter: N=3

The typical layout of the test series is shown in Fig .6. The parameters used in this study are described below:

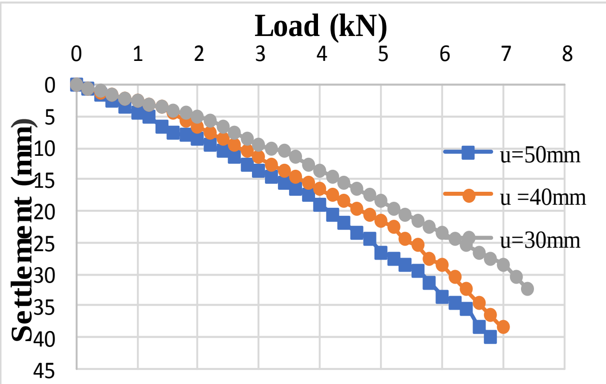
B = width of model square footing

u = depth of first reinforcement layer from the base of footing

h = spacing between two successive reinforcement layers

d = depth of the last reinforcement layer from the base of the model footing

N = number of geogrid layers



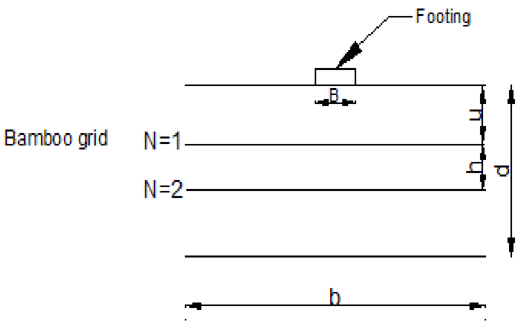


Fig.6 Typical lay out of bamboo grid / geonet reinforcement in the model

VI. RESULTS AND DISCUSSIONS

Here defined a dimensionless parameter called Bearing Capacity Ratio (BCR) to determine the increase in bearing capacity of soil when soil is reinforced to that without reinforcement. It is expressed as,

$$BCR = Q_R/Q$$

Where Q_R = ultimate bearing capacity of soil with reinforcement

Q = ultimate bearing capacity of soil without reinforcement

a. Effect of varying the depth of first reinforcement layer

Plate load test was conducted to determine the effect the variation of depth of first reinforcement layer from the base of the footing in the foundation bed. The test was done by varying the depth of first reinforcement layer. The number of layers is fixed as 3. The spacing between two successive reinforcement layers is maintained 50 mm throughout the test series.

i. Soil reinforced with bamboo grid

Load – Settlement behaviour of soil reinforced with bamboo grid by varying the depth of first reinforcement layer is shown in Fig.7. Table IV. Shows the bearing capacity values of soil reinforced with bamboo grid by varying depth of first reinforcement layer.

Fig.7 Load – Settlement behaviour of soil reinforced with bamboo grid by varying depth of first reinforcement layer

Table IV Bearing capacity value of soil reinforced with bamboo grid

u (mm)	Bearing capacity (kN/m²)
50	680
40	700
30	740

It is observed that by increasing the depth of first reinforcement layer the load carrying capacity also increases. The bearing capacity is maximum when the first reinforcement layer is placed at a depth of 30mm.Various researchers investigated that optimum depth of first reinforcement layer for maximum capacity found to be vary between 0.25 to 0.5 (Omar et al. (1993), Adams and Collins (1997)). Table V. shows BCR and u/B values for soil reinforced with bamboo. Variation of BCR and u/B for soil with bamboo reinforcement is shown in Fig.8.

Table V. BCR and d/B values for soil reinforced with bamboo

u/B	BCR
0.5	4.86
0.4	5
0.3	5.3

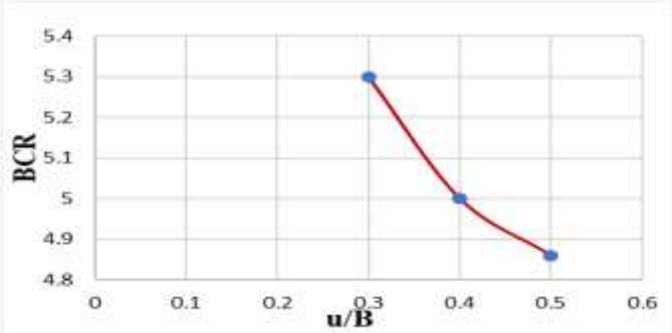


Fig.8 Variation of BCR and u/B for soil with bamboo reinforcement

From the result obtained, the bearing capacity decreases with increase in u/B. the clay bed can bear maximum bearing capacity when the reinforcement is placed near to the base of the footing. By increasing the depth, the load carrying capacity get reduced.

ii. Soil reinforced with 400 GSM Geonet

Load – Settlement behaviour of soil reinforced with 400 GSM geonet by varying the depth of first reinforcement layer is shown in Fig. 9. Table VI. Shows the bearing capacity value of soil reinforced with 400 GSM geonet by varying the depth of first reinforcement layer.

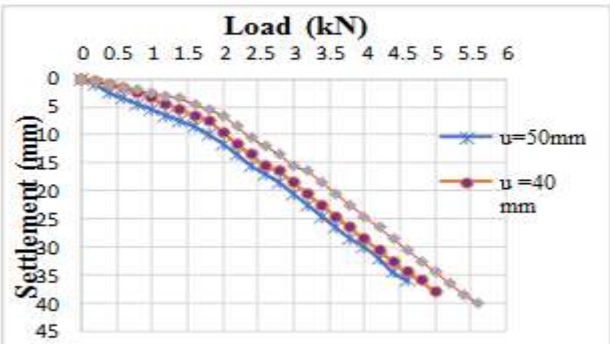


Fig.9. Load – Settlement behaviour of soil reinforced with 400 GSM Geonet in various layers

Table VI. Bearing capacity value of soil reinforced with 400 GSM geonet by varying depth of first reinforcement layer

u (mm)	Bearing capacity (kN/m²)
50	460
40	500
30	560

The variation is similar to bamboo grid reinforcement. The bearing capacity increases with decrease in depth of first reinforcement layer from the base of model footing. The maximum bearing capacity as 560kN/m² was obtained when depth of the first reinforcement layer is at depth of 30mm from the base of footing. But soil reinforced with bamboo grid show better performance than that of 400 GSM geonet.

Variation of BCR and u/B for soil reinforced with 400 GSM geonet is depicted in Fig.10.Table VII. Shows BCR and u/B values for soil reinforced with 400 GSM geonet.

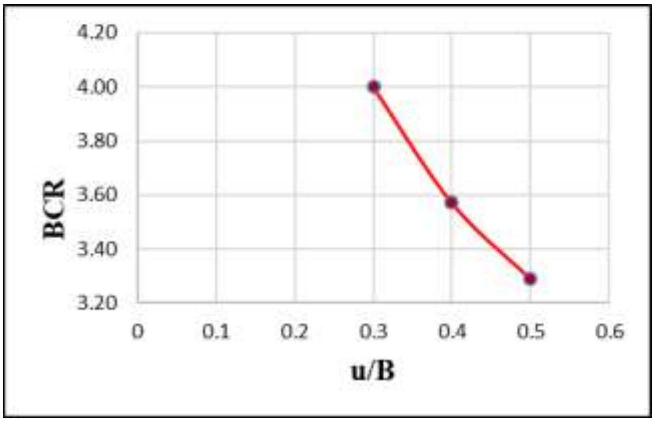


Fig.10. Variation of BCR and u/B for soil reinforced with 400 GSM geonet

Table VII BCR and u/B values for soil reinforced with 400 GSM geonet

u/B	BCR
0.5	3.29
0.4	3.57
0.3	4.00

From the test result obtained, it is found that bearing capacity ratio decreases with increase in u/B as in the same case of bamboo grid reinforcement. The optimum value of BCR is 4.

VII. CONCLUSIONS

The following conclusions were obtained based on the model study conducted.

- Better performance was obtained with soil reinforced with a bamboo grid than that of soil reinforced with geonet.

- As the depth of first reinforcement layer decreases bearing capacity get increased.
- When the depth of first reinforcement layer was placed at a depth of 30mm from base of footing, the load carrying capacity was maximum.

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