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Effect of Bamboo Grid and Geonet on Clay

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***Abstract*: When structures have to be constructed on weak soil, soil reinforcement is an adaptable technique to improve ground. Uses of natural material in soil have more significance nowadays. Bamboo is a natural material which possesses high tensile strength. This study intent to explore the use of locally available bamboo as a reinforcing element. This paper also focussed on the comparison of using bamboo grid and geonet on bearing capacity behaviour of soil. The performance of bamboo grid was found to be better than that of genet reinforcement. The optimum number of reinforcement layer was obtained for maximum bearing capacity as 3 with spacing of 50 mm. In this study depth of first reinforcement layer from the base of footing was kept constant.**

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

1. Introduction

When structures have to be constructed on challenging 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. Now-a-days 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 to adopt 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 geotextile, a natural geotextile manufactured out of coir fibers, 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.

2. 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.

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.

Marto and Orthman (2011) presented a paper on the potential use of bamboo as green material for soft clay reinforcement. Three embankments, viz; BGC embankment, HSG embankment and UR embankment were constructed to determine the performance. From the test results, BGC embankment shows better performance than UR embankment and HSG embankment.

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.

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.

3. 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 use bamboo as reinforcing element to replace the conventional materials including steel and polymer plastics due to cost effectiveness.

4. Objectives

The main objectives are:

- To study the effect of varying the number of planar reinforcement layer (N) on load carrying capacity of soil using
  a) Bamboo grid
  b) 400 GSM Coir Geonet

5. 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 1. Fig. 1 shows the particle size distribution of soil.

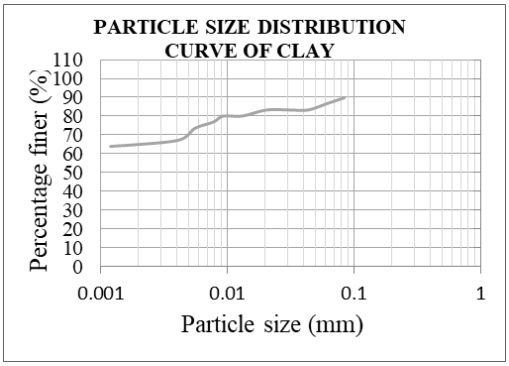

Fig. 1. Particle Size Distribution Curve

Table 1
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 (g/cm^3) (IS 2720 PART 7)	1.57
Optimum moisture content (%) (IS 2720 PART 7)	20.5
Unconfined compressive strength (Kg/cm^2) (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 2. (As provided by the supplier). Fig. 2 shows 400 GSM Geonet.

Table 1
Properties of 400 GSM (Provided by the supplier)

Characteristics	400 GSM
Mass / unit area, g/m^2 (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	7.0
b. Cross machine direction	4.0
Peak load, Dry (kN/m), Min	
a. Machine direction	3.0
b. Cross machine direction	2.0
Peak load, Wet (kN/m), Min	
a. Machine direction	7.5
b. Cross machine direction	4.0
Trapezoidal Tearing strength (kN) at 25 mm gauge length, (Min)	
a. Machine direction	0.18
b. Cross machine direction	0.15
Mesh size, mm, (Max)	20.0 x 16.75

Fig. 2. 400 GSM Geonet

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.

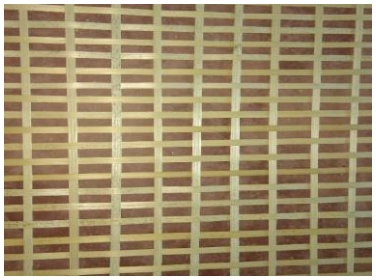

Fig. 3. Bamboo grid

6. Experimental 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.

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. 4 shows the experimental set up.

Fig. 4. Experimental Set up

Table 3
Test Series

Test series	Details	Influencing Parameters
A	Unreinforced bed	-
B	Clay bed reinforced with bamboo grid	Constant parameter: u/B =h/B = 0.5 Variable parameter: N = 1,2,3,4

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 3.

The typical layout of the test series is shown in Fig. 5. 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

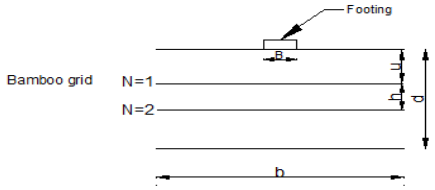

Fig. 5. Typical lay out of bamboo grid/geonet reinforcement in the model

7. 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 number of planar reinforcement layer

The test series were carried out by varying the number of reinforcement layers. Number of layers(N) varies from 1 to 4. The spacing between two successive reinforcement layers (h) and the depth of first reinforcement layer from the base of footing (u) were maintained as 50 mm throughout the test.

1) Soil reinforced with bamboo grid

Load – Settlement behaviour of soil reinforced with bamboo grid in various number of layers is shown in Fig. 6, and Table 6, shows the bearing capacity value of soil reinforced with bamboo grids.

From the result, it can be observed that the load carrying capacity gets increased with increase in number of bamboo grid layers. The optimum number of layers of reinforcement was obtained as N= 3 with bearing capacity of 680 kN/m^2. This is because of the reinforcement action of the geogrid. Table 5. shows the BCR and d/B values corresponding to number of reinforcement layers.

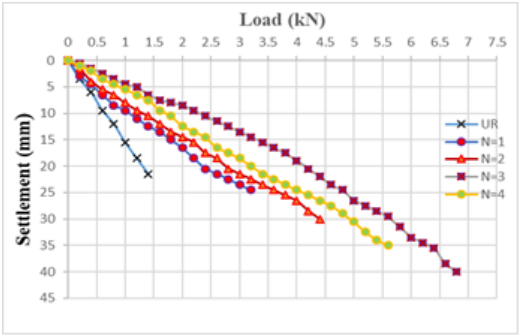

Fig. 6. Load – Settlement behaviour of soil reinforced with bamboo grid in various layers

Bearing capacity also increases with increase in depth of reinforcement. It is observed that increment was only up to 1.5B beyond which it decreases. The optimum bearing capacity ratio is 4.86. Fig.7. shows variation of BCR and d/B for soil with bamboo reinforcement.

Table 4
Bearing capacity value of soil reinforced with bamboo grids

Number of layers (N)	Bearing capacity (kN/m^2)
0	140
1	320
2	440
3	680
4	560

Table 5
BCR and d/B values for number of bamboo grid layers

Number of layers (N)	d/B	BCR
0	0	0
1	0.5	2.29
2	1	3.14
3	1.5	4.86
4	2	4

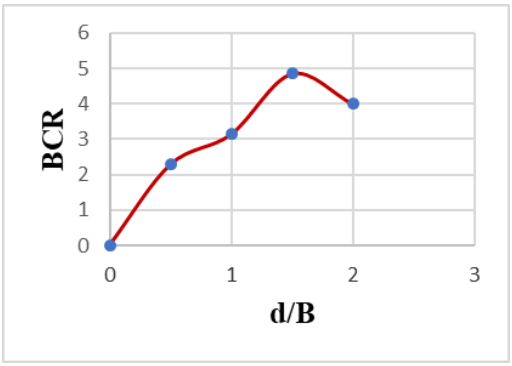

Fig. 7. Variation of BCR and d/B for soil with bamboo reinforcement

2) Soil reinforced with 400 GSM Geonet

Load – Settlement behaviour of soil reinforced with 400 GSM Geonet in various number of layers is shown in Fig. 8. Table VI. shows the bearing capacity value of soil reinforced with 400 GSM Geonet.

From the results, it is found to be similar in case of bamboo geogrid reinforcement, the bearing capacity gets improved due to reinforcement action. The maximum bearing capacity was obtained as 460 kN/m2 when 3 layers were used. Variation of BCR and d/B for soil reinforced with 400 GSM Geonet is depicted in Fig. 9. Table 7, shows BCR and d/B values corresponding to number of 400 GSM Geonet reinforcement layers.

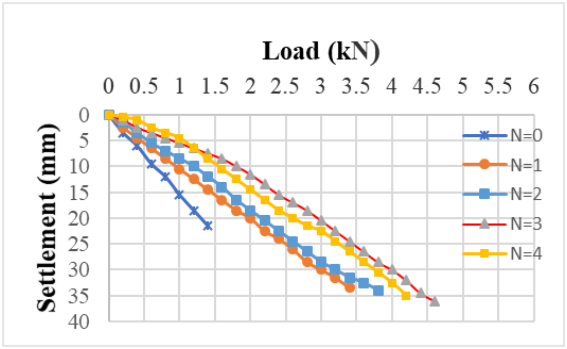

Fig. 8. Load – Settlement behaviour of soil reinforced with 400 GSM Geonet in various layers

Table 6
Bearing capacity value of soil reinforced with 400 GSM Geonet

Number of layers (N)	Bearing capacity (kN/m^2)
0	140
1	340
2	380
3	460
4	420

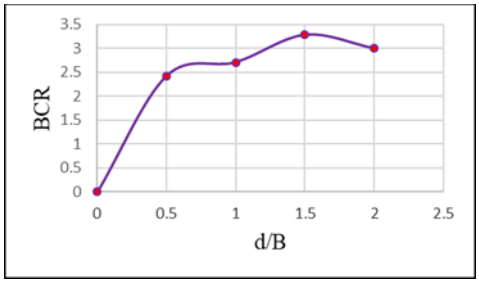

Fig. 9. Variation of BCR and d/B for soil reinforced with 400 GSM Geonet

Table 7
BCR and d/B values corresponding to number of 400 GSM Geonet reinforcement layers.

Number of layers (N)	d/B	BCR
0	0	0
1	0.5	2.43
2	1	2.71
3	1.5	3.29
4	2	3.0

Here BCR increase as depth of reinforcement layer increases up to 1.5B and then decreases. Hence the optimum value is obtained at 1.5B.

8. Conclusions

Based on the model study conducted, the following conclusions were obtained.

- Better performance was obtained with soil reinforced with a bamboo grid than that of soil reinforced with geonet.
- In both cases, the optimum number of reinforcement layer for maximum bearing.

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