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Experimental Studies on Load Settlement Behavior of Cohesion less Soil using Bamboo

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Abstract**—** *The advent of industrialization has led to implementation various modern structures and mega construction but due to lack of good quality of soil it has become difficult for engineers to work or build on it. Ground improvement is required to change various properties of soil such as removal of air voids, increase in shear strength, reduction in compressibility etc. More over susceptibility to liquefaction, permeability etc can be also reduced by these techniques. Micro pilings, use of geotextile, use of reinforcement are some of such technique available. An attempt has been made to use bamboo mats in single layers in sub grade soil to improve the bearing capacity. Bamboo mats are cheap, locally available and may prove to be a sustainable solution in this field. At first bearing capacity of sub grade soil has been found out experimentally in the load test arrangement and the analytical values have been calculated by using Terzaghi (1943), Meyerhof (1963), Hansen(1957,1970), Vesic (1973), IS: 6403-1981. Proximity in experimental and analytical results (*Terzaghi) *in particular validates the acceptability of the experimental results. Comparison was done for bearing capacity of the sub grade with and without usage of bamboo as reinforcement. The parameters studied in this experimental investigation included the effects of the location of the top reinforcement layer of the bamboo grid.*

Keywords**— *Bamboo reinforcement, Bearing Capacity, Settlement, Soil reinforcement.***

I. INTRODUCTION

Various types of ground improvement techniques are required to utilize all types of soil, to improve soil parameters. Nowadays, numbers of ground improvement methods are available to overcome the problem. Horizontal and vertical reinforcements are used in shallow foundation to improve the bearing capacity of soil on which the structure stands. Many experiments are conducted on reinforced soil to improve the bearing capacity of soil and reduce the settlement to make it usable in future (Binquet and Lee 1975, Fragaszy and Lawton 1984; Guido, Chang and Sweeny 1986; Mandal and Sah 1992; Omar et al 1993a, 1993b; Das and Omar 1994; Shin and Das 2000; Dash, Abu-Farsakh et al 2013). Metal strips, geo textile, geo nets and conventional geo grid such as uniaxial and biaxial geo grid are used to conduct the experiments. The high cost of synthetic polymer has forced the researchers to explore the application of natural material in place of synthetic components. The cost of geo synthetic plays an important role in its selection. Very few researchers have done research on the application of natural synthetic on improving the bearing capacity of soil and reducing the settlement (Akinmusuru and Akinbolade 1981; Dixit 1985; Mandal and Manjunath 1994; Datye and Gore 1994; Sitharam and Hedge 2015; Dutta and Mandal 2016; Lal et al 2017; Dong et al 2010) but not much research has been done in this field.

Bamboo to improve the bearing capacity of the soil is the oldest and the cheapest technique. The easy availability of bamboo at low cost and eco-friendly nature proves that it is better than many costly geo synthetic materials available in market. Due to its tensile properties even being a natural reinforcement material bamboo has been accepted as a substitute to much geo grid reinforcement. The parameter studied in this experimental investigation includes the effect of the bamboo reinforcement on the bearing capacity and settlement of soil at different desired depths.

II. METHODOLOGY

A model steel tank of size 0.95m x 0.95m x 0.95m is prepared to conduct the plate load tests at the Jorhat Engineering College, Jorhat, Assam. It is made up of a loading frame, inverted hydraulic jack of capacity of 20kN, pumping unit, steel plates loaded with concrete cubes. The width of the test box is not less than 5 times the size of the test plate, so that the failure zones can freely develop without any interference from sides (Basheeruddin and Narayan, 2016). To measure the magnitude of applied load pre calibrated pressure gauge is used. Deflection dial gauges of 0.01mm least count placed to measure settlements of plates due to applied load.

Fig1: Test set up

III. MATERIALS USED

3.1 SAND

The material used for this study is sand from Mariani (Bhogdoi River) of Jorhat district, Assam. The sand is cleaned to remove the unwanted materials from it. It is oven dried and then sieved through IS sieve size of 4.75mm and portion passing is taken for the experiment. The properties of the sand namely uniformity coefficient (C_u), coefficient of curvature (C_c) (ISSCS), Zone of the sand (IS:383-1970), grading characteristics D_{10}, D_{30}, D_{60} are determined according to the mentioned Indian Standard Codes . The sand is classified as poorly graded sand (SP) with specific gravity 2.65.

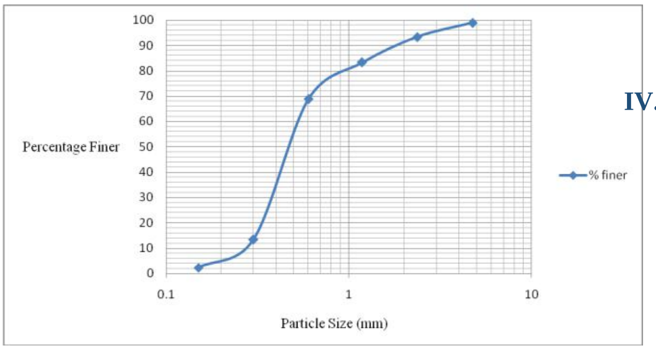

Fig2: Grain Size Distribution

Table1: Properties of collected Bhogdoi sand

D_{60}	D_{30}	D_{10}	C_u	C_c
0.53	0.37	0.28	1.89	0.92

3.2 MODEL FOOTING

Model footing (MF) for the tests is made up of mild steel plate having diameter 0.18m and thickness 0.006 m. Model footing surfaces are smooth.

Fig3: Model Footing

3.3 BAMBOO

Mat of ***Bambusa tulda*** (Jati Baah) which is chemically treated with copper chrome boron (CCB) of length 0.9x0.9 m, splints of width 3mm and thickness 1mm are prepared in Rain Forest Research Institute, Jorhat, Assam. The bamboo strips used are arranged in the planer form of bidirectional (square aperture) where the connection patterns are inter-woven, orthogonally interlocked for maintaining the equal aperture size during the preparation of bamboo grids for the research.

Fig 4: Bamboo Mat

IV. TESTING PROCEDURE

Load tests are conducted on the model test tank and test procedure is taken as per the guidelines from IS 1888:1982 for plate load test. The average relative density of 59.87% is adopted for all model tests. The average relative density and unit weight of sand bed is maintained as 59.87% and 16.04 kN/m^3, respectively. The number of drop is selected from the calibrated graph at a required density (59.87%) for all experiments. The number of drop obtained from the graph is maintained for all experiments during the preparation of the sand bed. A level is used to

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level the sand surface before placing of reinforcement and the model footing. Model footing is placed centrally, under the spindle of jack so that plate, reaction girder and spindle are coaxial. Load is applied in cumulative equal increment of 10kg where the dial gauge readings are recorded for each load increment. For the test with reinforcement is placed in the desired depth from the model footing and the same test procedure is repeated

4.1 INTERPRETATION OF RESULTS

The average settlements are calculated taking the average of the dial gauge readings. The cumulative settlement corresponding to load is observed which will be later plotted. Load intensity as ordinate and respective settlements as abscissa are plotted on log-log scale according to IS: 1888-1982, the yield value of soil which is determined as ultimate bearing capacity.

V. RESULTS AND DISCUSSION

The outputs are verified by comparing the experimental results of the model footings with analytical bearing capacity equations provided by Terzaghi (1943), Meyerhof (1963), Hansen(1957,1970), Vesic (1973), IS: 6403-1981. From the direct shear test the angle of internal friction (Ø) obtained for loose, medium and dense sand are 27.5°, 31°, 35°.

Table 2: Bearing Capacity Calculation with Various analytical equations

Diameter of plate, B = 0.18 m, Thickness of plate D_f =0.006m, q_{ult} (kN/m²) D_r = Relative density							
	D_r (%)	Ø°	Ter	Mey	Han	Ves	IS 6403-1981
Loose sand	34.8	27.5°	14.75	18	10.04	15.37	14.89
Medium sand	59.87	31°	25.82	38.26	18.75	26	26.12
Dense sand	70.24	35°	46.13	81.38	36.26	49	46.67

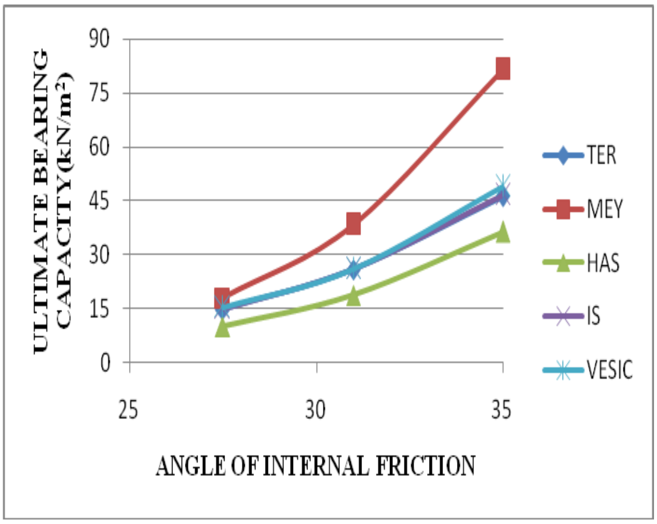

Fig.5: Ultimate Bearing Capacity V/S Angle of Internal Friction

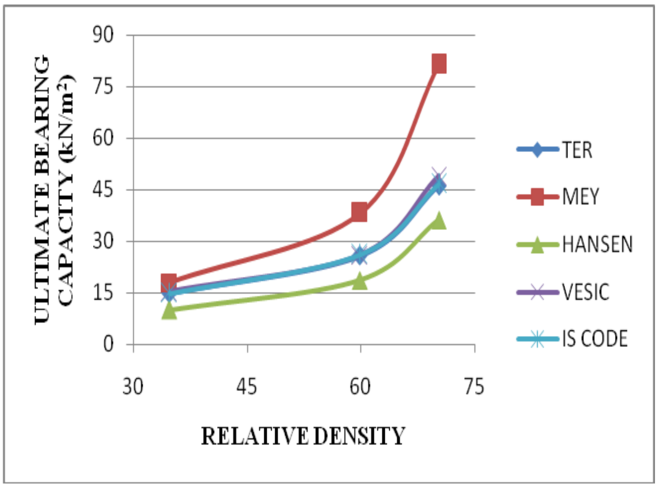

Fig.6: Ultimate Bearing Capacity V/S Relative Density

Bearing capacity of model footing of diameter 0.18m found out to be 23.80 kN/m² experimentally this is extracted from load-settlement graph. It matches with the results obtained from Terzaghi equation. Hence it can be concluded that results obtained from the experimental set up is reproducible.

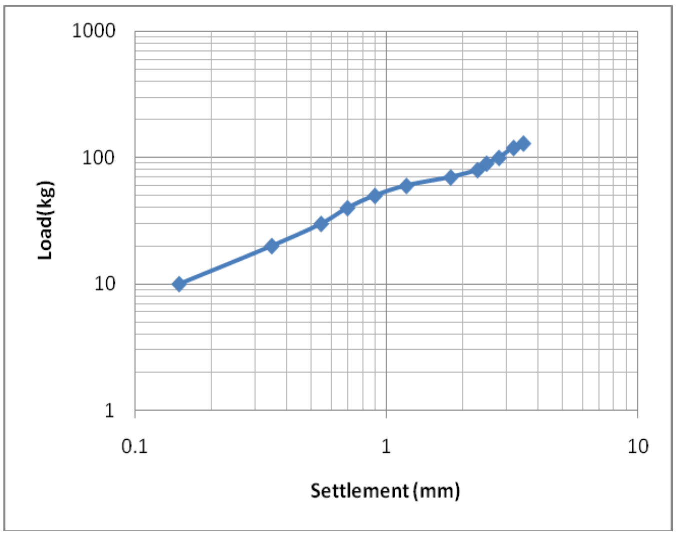

Fig 7: Load-Settlement Plot for Medium Sand (Unreinforced)

5.1 EFFECT OF VARYING DEPTHS OF BAMBOO REINFORCEMENT

The bamboo reinforcement having size of 0.9m x 0.9m, splints of width 3mm and thickness 1mm which are chemically treated with (CCB) placed in the sand bed at a depth of 0.5B, B, where B is the diameter of the model footing to obtain the bearing capacity of the model footing.

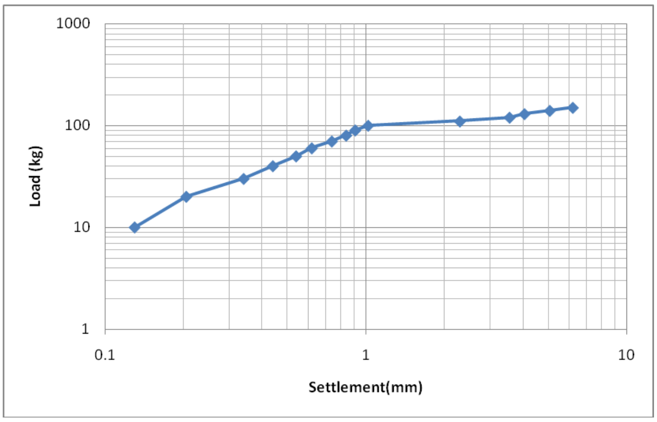

Fig 8: Load-Settlement Plot for Medium Sand Reinforced at depth 0.5B

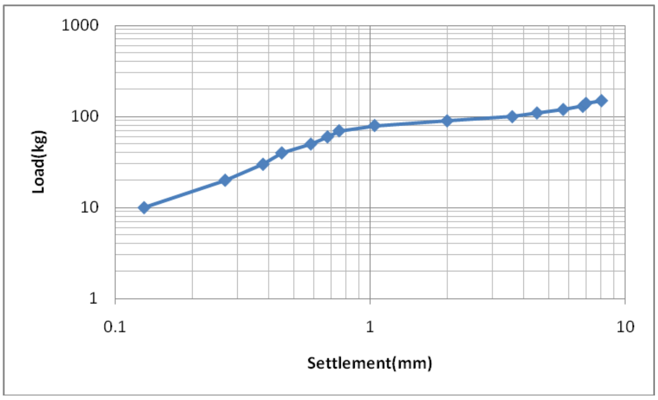

Fig 9: Load-Settlement Plot for Medium Sand Reinforced at depth B

VI. CONCLUSION

This paper gives an idea on the effect of bearing capacity of model footing with the insertion of bamboo reinforcement at a depth of 0.5B, B on locally available Bhogdoi sand. Based on the experimental and numerical study the following interpretation may be drawn.

1) Ultimate bearing capacity for model footing validated with various bearing capacity equations showing a similar values.
2) Comparison of the values of the ultimate bearing capacity from the theoretical equations depicting Meyerhof has the highest values whereas Hansen has the lowest.
3) The improvement of bearing capacities due to insertion of bamboo sheets is represented by "*Improvement Factor*" is the ratio of reinforced bearing capacity to unreinforced. The value is **1.43 and 1.14** at a depth of 0.5B and B respectively from footing.

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