Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 1, Number 3; August, 2014 pp. 1-4

http://www.krishisanskriti.org/jceet.html

Soil Strengthening Using Horizontally Stiffed Sand Column with Geosynthetic Grid

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Abstract: **According to the point of view of laying foundation on black cotton soil which is found in major part of India, it is considered to be the most troublesome soil. It expands or swells to large extent when comes in contact with water or moisture, in dry weather it shrinks easily as well. Currently there are many methods adopted to check the swelling and shrinking nature of soil. However using deep foundation in such soil is found to be more economical and reliable than any other means. The sand column or pile is one of the approaches to lay the foundation on wet and soft soil. The sand column gets its load bearing capacity from the surrounding soil as well as the hard strata upto which it is made. In addition to this the column is provided with horizontal stiffness to increase the bearing capacity of soil. In recent years the effect of sand column by encasing it with geogrid is done but the effect of horizontal stiffness provided across the cross section of sand column is not yet examined for black cotton soil. Thus the horizontal stiffness is provided using a circular layer of geosynthetic material at various depths. In this research the effect of horizontal stiffness on sand column is analysed to amend the load bearing capacity of sand column through load settlement test on single sand column setting up it in black cotton bed under moderate environment in test cylinder. Effect is checked for both treated and untreated soil. The test result shows an impressive improvement in load bearing capacity of sand column especially when the stiffness is provided within the depth equals to twice the diameter of the column.**

Keywords: **sand column, black cotton soil, geosynthetic grid, horizontal stiffness.**

1. INTRODUCTION

Black cotton soil is prone to large change in the volume with subsequent wetting and drying, thus reducing the load bearing capacity of the soil and irregular settlement which is a point of concern since it hinders the construction. Currently there are many methods adopted to check the swelling and shrinking nature of soil which includes modifying it with admixture like lime, fly ash, cement etc. But the soil confinement is one of the used methods for improving soil capacity. Therefore higher techniques have come upon like granular sand pile installation .This adopted technique is done by partial replacement of soft soil via well compacted sand at regular interval. The sand column gets its load bearing capacity from the surrounding soil which provides lateral confinement to it as well as the hard strata upto which it is made. Better results are obtained when the technique of using horizontal reinforcement in the form of circular cut net placed at different depths are used to improve the load bearing capacity, controls the horizontal movement of soil under the footing and provided significant confinement tools for the supporting soil. Reduced lateral movement prevents the clay movement inside the sand .They acts like reinforcement in it.

2. TEST METHODOLOGY

To simplify the test methodology, testing on a single sand column according to unit cell concept given by Priebe, simulates the sand column arranged in regular pattern in field. The experiments are conducted using 57mm diameter sand column installed in a tank filled with black cotton soil having dimensions of 260mm high and 180 mm a diameter. Assuming the triangular pattern the equivalent area of one unit cell given by Priebe is 1.05xdiameter of tank. Throughout the test the unconfined compressive strength is taken as 52kN/m^2.

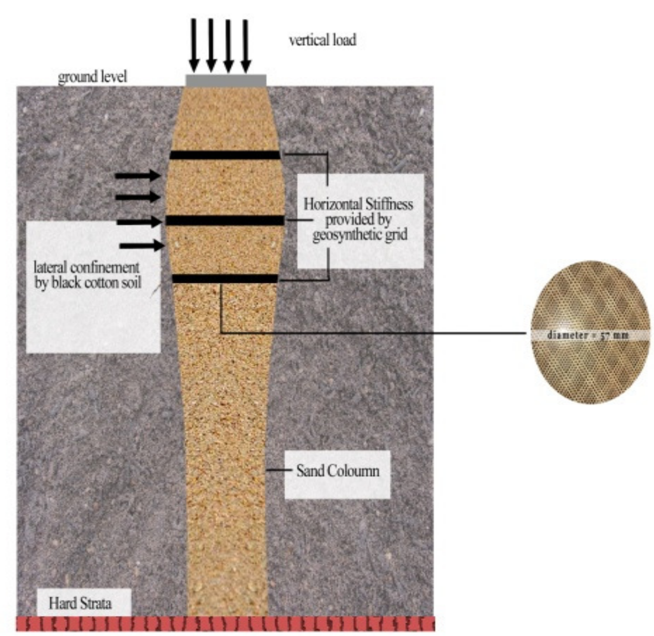

Figure-1: Schematic diagram of horizontally stiffed pile

Laboratory Model

To access the full limiting axial stress the diameter of the pile is to be taken at least one fourth of the depth of the column. A schematic diagram of the setup is shown in figure-1. During the test the footing used are circular in shape having diameter equal to57mm same as that of the diameter of the pile. The model footing was made of a steel circular plate with a diameter of 57 mm, and 12 mm thickness. A rough base condition was achieved by fixing a thin layer of sand onto the base of the model footing with Epoxy glue. The load is transferred to the footing through a ball bearing which was placed between the footing and the proving ring. This is done so as to utilize the full axial pressure applied by the proving ring and to get precise results. Loading is done using the proving ring having capacity of 3kN, and the setup gives a constant settlement rate of 1.25mm/min. A dial gauge is used to measure the displacement at various time intervals. Load test is done for at least 10min i.e. till the settlement reaches at least 12.5mm.

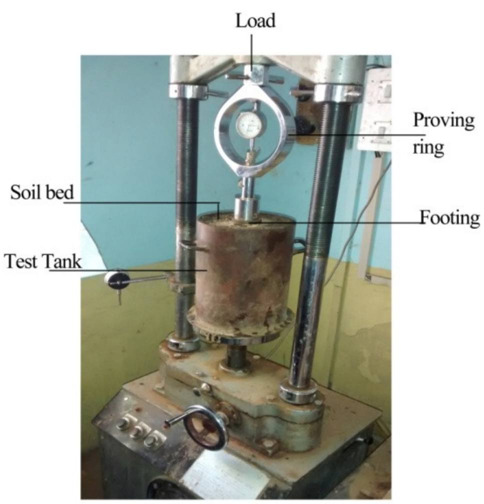

Figure-2: Test setup

A. Materials Used

i) **Black Cotton soil:** The soil used throughout the experiments is black cotton soil rich in organic matter, soft and is taken from the SPA Bhopal. Initially it contains a lot of moisture, therefore the soil is oven dried, hammered and from that the soil fraction passed from 0.075mm sieve is used to get the basic properties of the soil, which are given below.

Table 1: Properties of black cotton soil

Properties of soil	Values
L.L.(%)	54
P.L. (%)	31
P.I. (%)	23
Specific Gravity	2.64
Optimum Moisture Content (%)	25.2
Maximum Dry density (kN/m3)	15.9
Classification(IS:1498-1972)	CH
Degree of Saturation	100%
Unconfined Compressive Strength(kN/m2)@water content 32%	52

ii) Sand

Table 2: properties of sand

Properties of soil	Values
Specific gravity	2.67
D_{10} (mm)	0.36
D_{30} (mm)	0.52
D_{60} (mm)	0.61
C_u	1.74
C_c	1.22
Classification(IS:1498-1972)	SP
Maximum dry Density, γmax(kN/m3)	17.5
Minimum Dry Density, γmin(kN/m3)	15.4
Cohesion (kN/m^2)	2.78

iii) **Geosynthetic grid**

the geosynthetic grid have the following properties, Aperture Size = 1mm, Stiffness 15kN/m, Weight 260 gm/m^2. Properties are as they are provided by manufacturer.

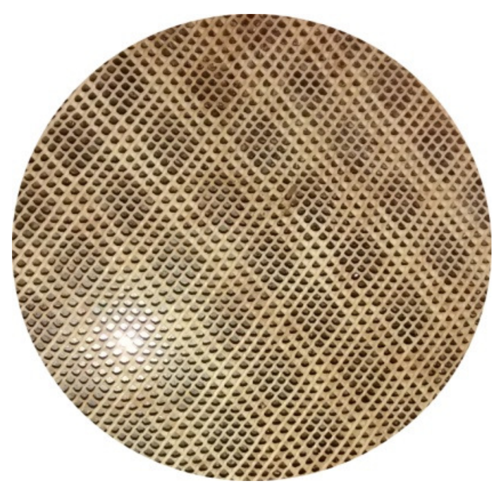

Figure-3: Geosynthetic Grid

B. Preparation of Soft Soil Bed

Test cylinder of diameter 180mm and depth 260mm is used for the experiments. The diameter of the column to be installed is 57mm same as that of the footing. The inner walls of the circular tank are greased properly so that the friction between the soil and the wall is reduced. The soil bed prepared having the water content 32% and the unconfined compression strength of the soil obtained from unconfined compression test **52kN**. The soil is then filled in the tank in layers by properly tampering them using tampering rod, so as remove the air voids.

C. Construction of sand column

Sand column in the clay bed was constructed by embedding the steel cased pipe into the clay bed at the center. The diameter of the steel pipe is same as that of sand pile to be constructed i.e. 57cm. Manually load is applied so that the casing pipe is inserted into the bed till the base. But before this grease like lubricant is applied at the outer and inner surface of the steel pipe so that clay is not disturbed in the process. When the pipe is being inserted completely to the base, pipe is then withdrawn with care. Sand is then poured into the pile gap in layers. Tampering it at stages for proper compaction. Geosynthetic grids are placed horizontally over the sand layers at different heights by measuring it with the help of the scale from above. Moisture in the sand is required upto 7 % so that it doesn't absorb the moisture of the clay. Density of the sand column is computed by knowing the quantity and volume of the sand poured which was found to be 17.5kg/m^3.

Figure-4: Load test on sand column

3. RESULTS AND DISCUSSIONS

Consequences of treatment of soil with sand column and further stiffening it:- The graphical plot of load settlement analysis done on untreated soil, sand column installed in soil bed, horizontally stiffed sand column at top and bottom half of the pile are as shown in figure-5 and figure-6

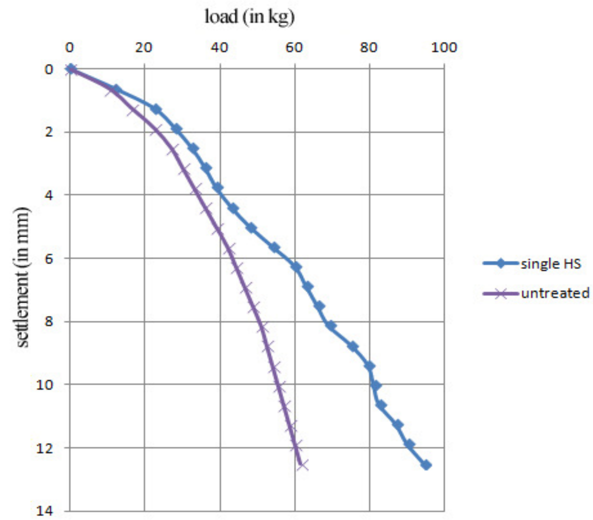

Figure-5: Load settlement graph for untreated and treated soil

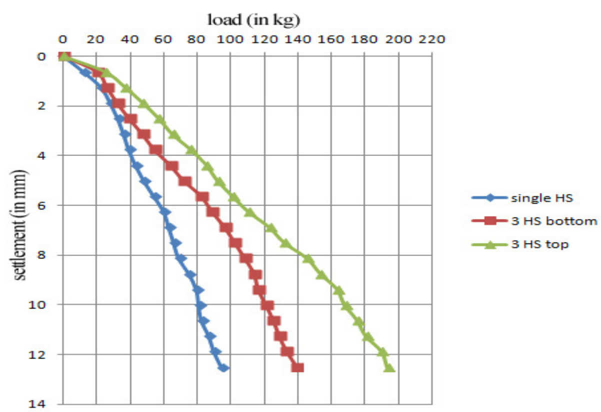

Figure-6 Load settlement graph for pile having horizontal stiffness at various depths

As the curve depicts, the load bearing capacity increases with the installation of sand column. The capacity further increases on providing horizontal stiffness.

The ultimate load carrying capacity in each case was determined by Allowable Bearing capacity = 1/2 times load corresponding to of 10% of D(diameter of granular pile = 57mm) settlement

4. CONCLUSIONS

The tests done on the untreated soil bed and soil treated with sand column and further stiffed with geosynthetic grid gives interesting output. The pattern of variation in load bearing capacity of soil after installation of sand column agrees with the literature. Some of the important conclusions drawn from the research work are as:

1. The load bearing capacity of black cotton soil from settlement analysis is improved satisfactorily. The load carrying capacity of the untreated soil is increased to 28% with the installation of sand column

2. The load carrying capacity is further increased by providing horizontal stiffness to the sand column in the form of geosynthetic strips.

3. Comparing with the stiffness provided at the bottom half, stiffness provide at the top half increase the bearing capacity by much more factor.

Stiffness in the form of geosynthetic strips provided at the bottom half in three layers increases the ultimate load carrying capacity of untreated soil by 102.38 %. On the other hand if the layers of same are provided at the top half it increases the ultimate load carrying capacity of untreated clay by 150%.

5. ACKNOWLEDGMENTS

All the tests were conducted in the laboratory of Maulana Azad National Institute of Technology, Bhopal (M.P). The support and guidance provided by Dr. Rakesh Kumar and Head of the Department Dr. Anil Sharma is appreciable.

NOTATION

The following symbols are used in this paper:
D10, D30, D60 = Effective Sizes;
Cu = Uniformity Coefficient;
Cc = Coefficient of Curvature
L.L. = Liquid Limit
P.L. = Plastic Limit
P.I. = Plasticity Index
HS = Horizontal Stiffness

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