

Improvement of Bearing Capacity of Clayey Soil Using Stone Column with Reinforcement

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Abstract: Nowadays most of the land is covered by Black Cotton Soil. The construction of a structure on the Black Cotton Soil is quite miserable due to its inadequate engineering properties. Improvement of sub grade using conventional design methods which are preloading, dredging, and soil displacement techniques, among all these methods, the Stone column technique is preferred because it provides the primary aspect of reinforcement and also to improve the strength and reduces the settlement. When stone column loaded in soil undergoes excessive bulging due to inadequate lateral support from the surrounding clay soil. To avoid excessive bulging, Stone column is encased with geo reinforcement. In present study experiments done on Stone column with and without reinforcement. The floating Stone column is reinforced with geosynthesis of varying encasement depths of 0.25L, 0.5L, 0.75L, and 1L where L is length of column to improve bearing capacity and reduce lateral bulging.

Keywords: Black cotton soil, stone column, geo synthetics reinforcement, Coarse Aggregate, CBR test, Settlement Rate.

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I. INTRODUCTION

1. Areas particularly region are covered with the thick layers of clayey soil deposits, having very low shear strength and high compressibility. These soil deposits are not suitable for the formation of sub-grade. Due to excessive settlements, large lateral flow of soil underlying structures results in loss of global and local stability. In view of the increasing developments in the region in the recent past industries, a number of ports, buildings, roads, tunnels, bridges are being built. Construction of highway embankments using conventional design methods which are preloading, dredging, and soil displacement techniques, among all these methods, the Stone column technique is preferred because it provides the primary aspect of reinforcement and also to improve the strength and reduces the deformation. The load carrying capacity of the Stone column is a function of the rate of application of the load and the lateral confinement offered by the surrounding soil. In soils, this confinement is very low and consequently, failure occurs. The use of compacted Stone columns as a technique of soil reinforcement is frequently implemented in cohesive soils to increase the bearing capacity of the foundation soil, to reduce the settlement, and to accelerate the consolidation of the surrounding saturated soft soil.

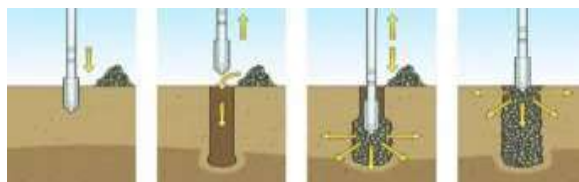
1.1 CLAYEY SOIL

For expensive clayey soil, the Indian name is given as BLACK COTTON SOIL. The name “Black Cotton soil” has an agriculture origin. Most of these soils are black in color and are good for growing Cotton and occurring in Maharashtra, Gujarat, Madhya Pradesh, Karnataka, parts of Andhra Pradesh and Tamilnadu.



1.2. STONE COLUMN

The principle of stone column is to replace loose material by compacted stone, together with densification and reduction in compressibility of the surrounding ground to form a composite material. Because the stone columns will deform under applied load, the capacity of the columns depends on the degree of stiffening achieved in the surrounding soil as well as on the internal friction of the columns.



1.3. GEO SYNTHETICS

Geo synthetics are synthetic products used to stabilize terrain. They are generally polymeric products used to solve civil engineering problems. This includes eight main product categories: geo textiles, geo grids, geo-nets, geo-membranes, geo-synthetic clay liners, geo-foam, geo-cells and geo-composites.



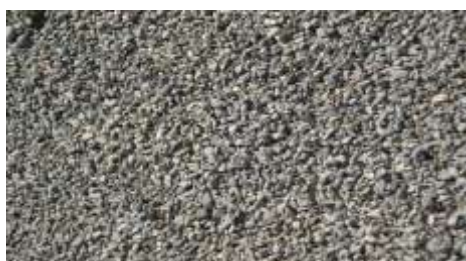
1.4. PVC pipe

To increase Bearing Capacity of Black Cotton Soil Stone column is one of the method's we conduct this experiment in laboratory by CBR apparatus use of PVC pipe of certain diameter (1 inch 2 inch 3 inch etc...) is necessary.



1.5. Coarse Aggregate

In the stone column method as the name mention use of stone is necessary. in this experiment we are going to use Coarse aggregate. The size of Coarse aggregate is depends on the size and area of the field where stone column is to be installed.



II. Objectives

1. To determine the basic properties of Black Cotton Soil.
2. Making it more stable by improvement of stability by controlled compaction, proportioning and addition of reinforcement
3. To study load carrying capacity and settlement behavior of black cotton soil.

4. To study the strength properties of geosynthetics.
5. To study drainage properties of stone columns.

III. Materials And Methodology

3. Materials used for the study

The major materials, which have been used in the experimental investigation include:

- Soil samples collected from near our college campus for their geotechnical properties and strength characteristics.
- Stone Column and Geo synthetics, which are collected from stores.

3.1 STUDY METHODOLOGY

Following steps are followed during this study.

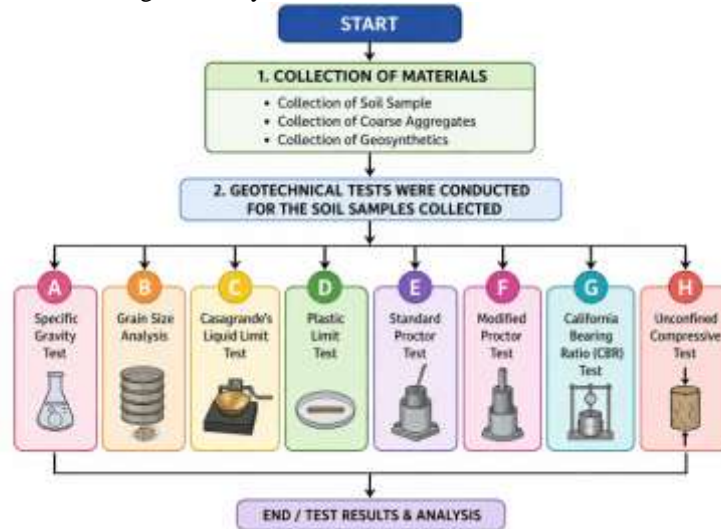


Figure 1: Flowchart showing the methodology

IV. Experimental Observation

4.1. General

The basic preliminary tests, Sieve analysis, Moisture content, Specific gravity, Atterberg limits, In situ density, Standard Proctor Test, Unconfined compression tests, and CBR were conducted on Black cotton soil. Later CBR tests on only Black cotton soil, Soil with stone column, and finally Stone column with reinforcement were conducted.

4.2 Specific Gravity

Table 1: Specific gravity

Trail No	01	02	03	Average Specific gravity of soil = 2.94
Specific Gravity	2.88	3.11	2.84	

4.3 Moisture content

Table 2: Moisture content

Trail no	01	02	03	Average Moisture content of the soil = 16.18%
Container No	1.1	1.2	1.3	
Moisture content in %	14.28	20	14.28	

4.4. In situ density by core cutter

Table 3: Core cutter in situ density

Mass of the soil, gm	2038
Volume of the core cutter, cc	981.74
Density of soil, gm/cc	2.07
Moisture content of soil	16.18
In situ dry density of soil, gm/cc	1.78

4.5 Liquid Limit using Casagrande

Trail no	1	2	3	4	5
Container no	1.1	1.2	1.3	1.4	1.5
No of blows	20	28	33	47	51
Water content (%)	62	52	44	36	33.33
liquid limit of the soil is WLL = 55.42%					

Table 4: Liquid limit test

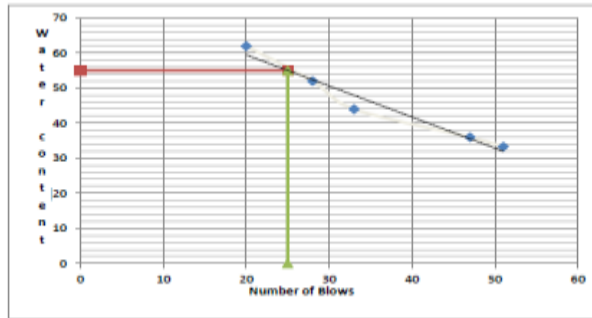


Figure 2: Liquid Limit Graph

4.6 Plastic limit test

Table 5: Plastic limit

Trail no	01	02	03	04	Average plastic limit is given by = 26.67%
Container No	1.1	1.2	1.3	1.4	
Plastic limit	20	30	26.26	30	

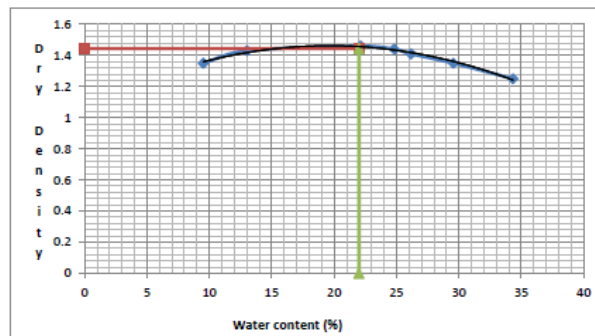


Figure 3: Standard proctor curve

4.7 Proctor compaction test

Table 6: Compaction test

Sl no	Mass of soil gm	Water content %	Density of Soil, gm/cc	Dry density of Soil, gm/cc	Optimum moisture content = 22% Maximum mass dry density = 1.46gm/cc
1	1710	9.52	1.61	1.35	
2	1726	13.03	1.62	1.43	
3	1902	22.14	1.79	1.46	
4	1918	24.83	1.80	1.44	
5	1902	26.17	1.79	1.41	
6	1866	29.55	1.75	1.35	
7	1802	34.34	1.69	1.25	

4.8 California Bearing Ratio Test

Optimum moisture content = 22% , Load of proving ring = 5.61Kg/Div

Least count of penetration dial 1 div = 0.002mm

CBR = (Load at 2.5mm penetration test)/ (Load at 2.5mm penetration from standard) x100

Load at 2.5mm penetration = 1370Kg

4.8.1: California Bearing Ratio of Black cotton soil

Table 7: CBR of Black cotton Soil

Penetration of Plunger in mm	Proving ring dial gauge reading in divisions	Load in Kg
0	0	0
0.5	0	0
1	0.2	5.61
1.5	0.4	11.21
2	0.8	22.43
2.5	1.2	33.64
3	1.6	44.85
4	2	56.07
5	2	56.07
7.5	2.4	67.28
10	2.4	67.28
12.5	2.6	72.88

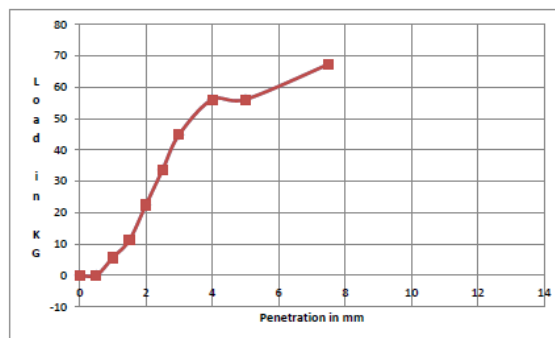


Figure 4: Load penetration curve of BCS

From graph,

$$CBR = (33.64) / (1370) \times 100 = 2.455\%$$

4.8.2 CBR of Black Cotton Soil with Geo textile

Table 8: CBR of Black cotton Soil with 1 layer

Penetration of Plunger in mm	Proving ring dial gauge reading in divisions	Load in Kg
0	0	0.00
0.5	3	16.82
1	7	39.25
1.5	10	56.07
2	10	56.07
2.5	12	67.28
3	12	67.28
4	13	72.88
5	13	72.88
7.5	13	72.88
10	13	72.88
12.5	14	78.49

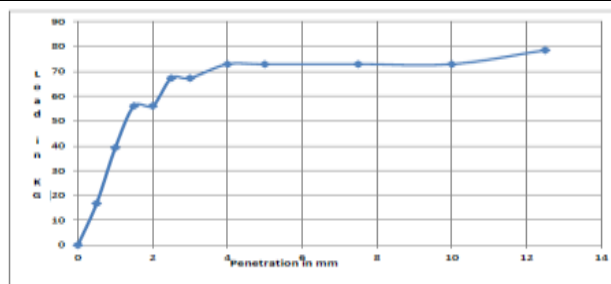


Figure 5: Load penetration curve of BCS with 1 layer

Table 9: CBR of Black cotton Soil with 2 layer

Penetration of Plunger in mm	Proving ring dial gauge reading in divisions	Load in Kg
0	0	0.00
0.5	1	5.61
1	1	5.60
1.5	3	16.82
2	9	50.46
2.5	13	72.88
3	14	72.49
4	16	98.70
5	17	95.31
7.5	18	100.92
10	18	100.92
12.5	18	100.92

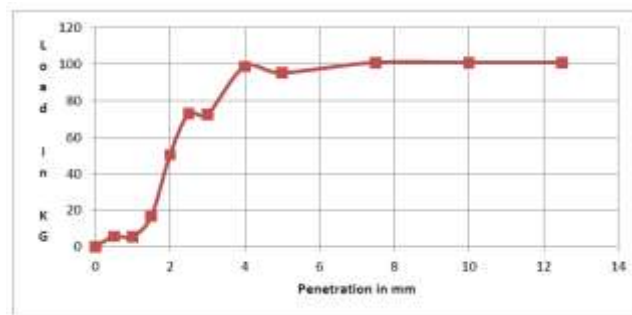


Figure 6: Load penetration curve of BCS with 2 layer

Table 10: CBR of Black cotton Soil with 3 layer

Penetration of Plunger in mm	Proving ring dial gauge reading in divisions	Load in Kg
0	0	0.00
0.5	1	5.61
1	4	22.43
1.5	9	50.46
2	10	56.07
2.5	12	68.28
3	15	84.10
4	15	84.10
5	16	89.70
7.5	16	89.70
10	18	100.92
12.5	18	100.92

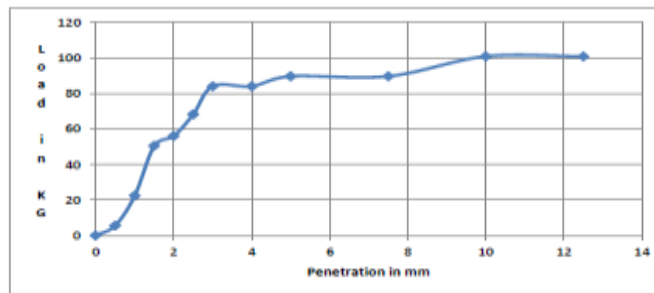


Figure 7: Load penetration curve of BCS with 3 layer

From graph

$$\text{CBR} = (68.4) / (1370) \times 100 = 4.99\%$$

CBR of Black Cotton soil with a layer of geo textile = 4.99%

4.8.3 Black Cotton Soil including Stone column with reinforcement

We use PVC pipe of 1.5 inch (38.4mm) in this test

Table 11: CBR of Black cotton Soil with 1 stone column with reinforcement

Penetration of Plunger in mm	Proving ring dial gauge reading in divisions	Load in Kg
0	0	0.00
0.5	1	5.61
1	3	16.82
1.5	5	28.03
2	9	50.46
2.5	13	108.00
3	13	108.46
4	16	153.32
5	16	153.32
7.5	16	192.56
10	16	192.56
12.5	16	192.56

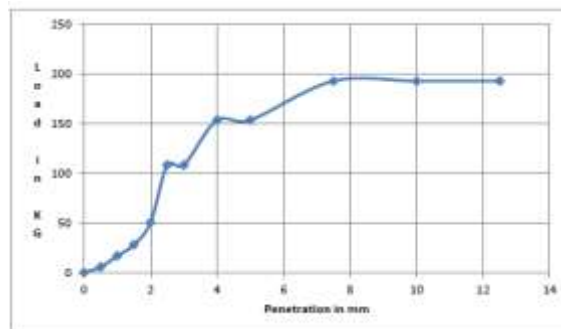


Figure 8: Load penetration curve of BCS with 1 stone column

From graph

$$CBR = (108) / (1370) \times 100 = 7.88\%$$

CBR of Black Cotton soil with a layer of geo textile = 7.88%

Table 12: CBR of Black cotton Soil with 2 stone column with reinforcement

Penetration of Plunger in mm	Proving ring dial gauge reading in divisions	Load in Kg
0	0	0.00
0.5	1	5.61
1	3	36.08
1.5	5	62.38
2	9	108.00
2.5	13	173.00
3	13	173.00
4	16	198.32
5	16	198.32
7.5	16	239.39
10	16	239.39
12.5	16	239.39

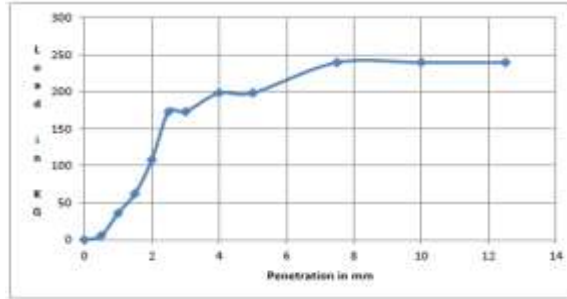


Figure 9: Load penetration curve of BCS with 2 stone column

From graph $CBR = (173) / (1370) \times 100 = 12.62\%$
 CBR of Black Cotton soil with a layer of geo textile = 12.62%

Table 13: CBR of Black cotton Soil with 3 stone column with reinforcement

Penetration of Plunger in mm	Proving ring dial gauge reading in divisions	Load in Kg
0	0	0.00
0.5	1	5.61
1	3	36.08
1.5	5	62.38
2	9	108.00
2.5	13	256.36
3	13	256.36
4	16	295.84
5	16	295.84
7.5	16	346.32
10	16	346.32
12.5	16	346.32

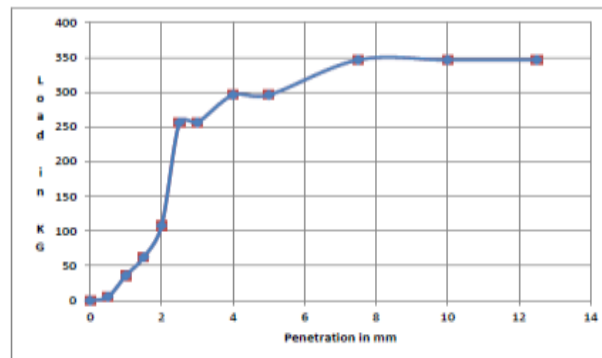


Figure 10: Load penetration curve of BCS with 3 stone column

From graph $CBR = (256.36) / (1370) \times 100 = 18.71\%$
 CBR of Black Cotton soil with a layer of geo textile = 18.71%

4.9 Observation made

Specific gravity	2.94
Moisture content	16.18%
In situ density by core cutter	1.78gm/cc
Liquid limit using casagrande	55.42%
Plastic limit test	26.67%
Optimum moisture content	22%
Maximum dry density	1.46gm/cc

Layers/Numbers	Geo textile (%)	Stone column (%)
1	4.74	7.88
2	4.97	12.62
3	4.99	18.71

It is observed that by using geo textile as layer-by-layer the strength also increasing simultaneously. but when we going to use stone column of desired diameter with reinforcement it shows that the strength is increasing doubly of black cotton soil.

V. Conclusion

A detailed experimental investigation on untreated black cotton soil demonstrates that the installation of ordinary floating stone columns enhances the load-carrying capacity of clay beds by about 20%, with further improvements influenced by the number and diameter of the columns;

Additionally, encasing stone columns with geosynthetics and optimizing the depth of reinforcement significantly increase stiffness and bearing capacity, while substantially reducing settlement (up to 75%) and bulging (by around 50%), thereby improving overall ground stability, minimizing deformation under load, and making the soil more suitable for supporting structural foundations in soft clayey conditions.

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