

Improving The Performance Of Stone Column Using Geogrid In Black Cotton Soil

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ABSTRACT

Stone columns are widely used as a ground improvement technique to enhance the load-carrying capacity and reduce settlement of soft soils. However, conventional stone columns may suffer from bulging failure under high vertical loads, especially in very soft clay deposits. To overcome this limitation, reinforcing stone columns with geogrids has emerged as an effective and economical solution. In this study, the performance of stone columns reinforced with geogrid is investigated to evaluate improvements in strength, stiffness, and load-settlement behaviour. Geogrid reinforcement provides lateral confinement to the stone column, thereby reducing bulging and increasing its bearing capacity. The reinforced stone columns demonstrate improved stress distribution and enhanced interaction between the column and surrounding soil. Results indicate that geogrid-reinforced stone columns significantly increase load-carrying capacity and reduce settlement when compared to conventional stone columns. The study highlights that geogrid reinforcement is a promising technique for improving the efficiency and durability of stone columns in soft ground conditions, making it suitable for foundations of embankments, buildings, and other civil engineering structures.

Keywords: Stone Column, Black Cotton Soil, Geogrid

INTRODUCTION

Soil deposits in nature exist in an extremely erratic manner producing there by an infinite variety of possible combinations which will affect the strength of the soil and also the procedures to make it useful (purposeful).

Major soil deposits in the various regions of India is the black cotton soil which is occupying nearly 23% of the area and is available up to a depth of 3.7 m on an average. The black cotton soil is very fertile and suitable for agriculture but it is not good for construction of civil engineering structures because of its low bearing capacity, less stability, less shear strength and large expansion and shrinkage in volume with changing seasons.

With rapid industrialisation, increase in population and decrease of available land, the construction of buildings and other civil engineering works has to be carried out on available black cotton soil which is having poor shear strength, which makes it necessary to stabilise the black cotton soil.



Fig. 1.1: Black Cotton Soil

1.1 Properties of black cotton soil

The black cotton soil is black in colour mainly because they are formed by the weathering of rocks (lava rocks) and are rich in iron, magnesium and aluminium content. BC soil is also rich in calcium, potash and carbonate. They hold moisture which makes it sticky when it is wet and cracks appears when it is dry.

Table 1.1: Properties of black cotton soil

Property	Value
Dry density	1300-1800 kg/m ³
Liquid limit	40%-120%
Plastic limit	20%-60%
Specific gravity	2.60-2.75
Maximum dry density	20%-35%
Compression index	0.2-0.5

1.1.1.1 Chemical Stabilization

There are many chemicals that can be added to the soil to improve the stability of the soil, the three most commonly used are:

- Sodium chloride
- Calcium chloride
- Sodium silicate

1.1.1.2 Electrical Stabilization

This is widely used in stabilization of clay-like soils and can also be referred to as electroosmosis. Electrical stabilization of soil is done by inserting the metal electrodes into the earth. Then, a direct current is passed through them and water moves towards one of the electrodes, mostly cathode. This is more expensive form of soil stabilization that is not often used unless requires. As water is removed from the soil, it is compacted which allows it to provide a more suitable foundation for construction vehicles.

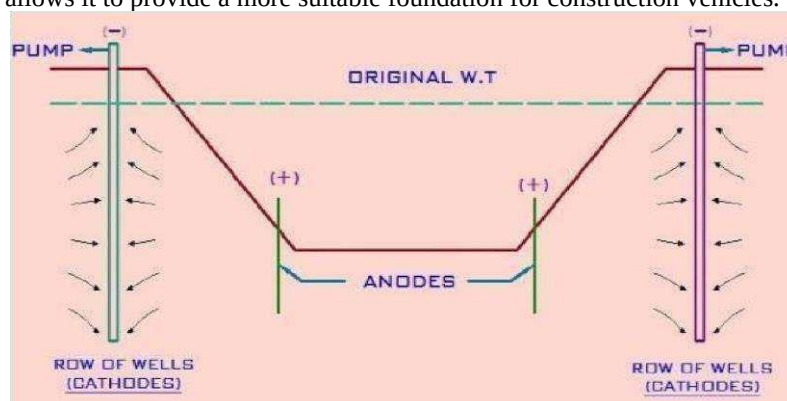


Fig. 1.6: Electrical stabilization

The stone column consists of crushed stone pillars placed into the soil below the proposed structure. It increases the load bearing capacity of the soil and reduces settlements and liquefaction potential.

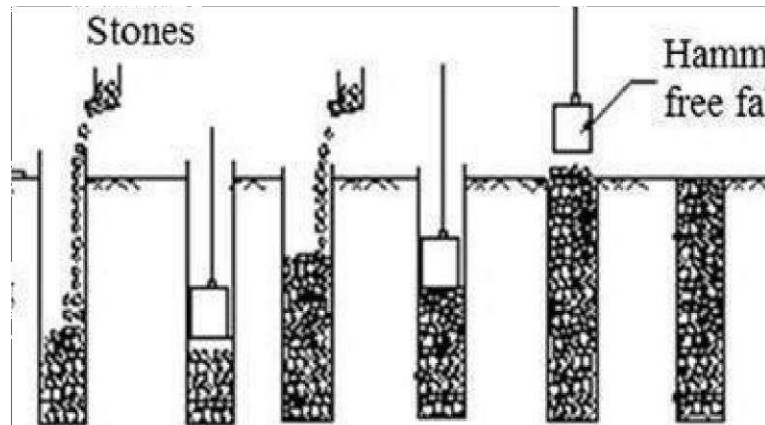


Fig. 1.9: Stone Column

1.2 Stone Column

The stone columns are also known as granular piles. The stone columns are increasingly being used as ground reinforcement elements for supporting a wide variety of structures including buildings and other flexible structures. The stone column consists of crushed stone pillars placed in the various layers with or without reinforcement depending upon the requirements and soil available. Although the use of pile foundation can meet all the design requirements, negative drag force and large length of the pile often result in prohibitive costs. The stone columns derive their load capacity from the confinement offered by the surrounding soil.

Potential applications include stabilizing foundation soils to support embankments and approach fills, supporting retaining structures (including reinforced earth), bridge bent and abutment structures on slightly marginal soft to stiff clays and loose silty sands, landslide stabilization and reducing liquefaction potential of clean sands. Stone columns can also be used to improve slope stability of embankments. Also, stone columns under proper conditions can greatly decrease the time required for primary consolidation. This ground improvement technique has been successfully applied to increase the bearing capacity and to reduce the settlement for foundation of structures like liquid storage tanks, earthen embankments, raft foundations, etc. It also reduces the liquefaction potential of the soil.

In spite of the wide use of stone columns and developments in construction methods/equipment, present design methods are empirical and only limited information is available on the design of stone columns in codes/textbooks.

When the stone columns are installed in extremely clayey soils, the lateral confinement offered by the surrounding soil may not be adequate. Consequently, the stone columns installed in such soils will not be able to develop the required load-bearing capacity. In such conditions, the bearing capacity of the stone column can be improved by reinforcing it with a suitable geogrid along some length of the stone column.

In this case, the load carrying capacity of the columns is increased by the frictional stresses mobilized on the surface of the geogrid owing to lateral movement of loose stone chips. In this paper an alternate method is suggested to enhance the performance of the stone columns by reinforcing it with geogrids.

OBJECTIVES

1. To determine the load carrying capacity of the black cotton soil by inserting a stone column in it.
2. Inserting a stone column in Black- cotton soil to assess its load bearing capacity.

3. To determine the load bearing capacity of stone column and settlement behaviour of black cotton soil reinforcing with geogrids.

LITERATURE STUDY

2.1 Badal Bankar, Dr. Satish Patil, Rajshekhar Rathod et. Al. "Stabilization of black cotton soil with cement and Geogrid", IRJETS Vol-03, Issue-09, (2021)

The study investigated the application of woven biaxial geogrid to subgrade material in the form of reinforcement to road construction. The investigations are carried out to find the improvement in physical and engineering properties of black cotton soil which is considered as problematic for road construction. Based on the experimental research, the following conclusions can be made.

1. The soil is classified under CH. Liquid limit and plastic limit values are 62.8 and 37.20 respectively suggest that the soil is highly compressive, hence the results obtained shows soil falls below standards recommended for most geotechnical work.
 2. With increase in addition of cement the plasticity index of soil decreases from 25.6% to 11.20% at cement percentage of 8%, further increase in cement there is no marginal improvement in soil plasticity.
 3. The specific gravity of soil, there is no marginal improvement observed by addition of cement as an admixture.
 4. The test results shows that there is no marginal improvement in the dry density of soil, whereas, little increase in the optimum moisture content is observed due to addition of cement as admixture.
- . Interfacing of woven biaxial geogrid in road construction on especially with soft subgrade, increases the penetration resistance and hence the CBR strength increases from 7.15% to 17.59%. Hence it is concluded that geogrid reinforced soils present better performance than traditional soil

2.2 P. Naga Venkata Sai1, S. Surendra, N.V. K. Arjun, M. Shirdi Sai, Dr CH. Hanumantha Rao et.Al. "Reinforcement of Black cotton soil by using Geogrid" TEST engineering and Management, Page no 13535-13541. (2020)

Black cotton soils are very problematic soils and not suitable for construction due to the change in volume when it exposes to water. Usually in monsoon they absorb water and swells and in summer it shrinks. Due to these reasons they vary their volume, and also it result in failure of substructure in the form of cracks and settlement of soil, undulations on roads and rutting in subgrade. Based on these critical conditions this type of soils are not preferred for subgrade material and for any embankments. But replacing these soils with another material is huge problem for engineers. Instead of replacing or stabilization with admixtures, we will use geosynthetics in soil. In this geosynthetics, geogrid is used for reinforcement of soils. The Conclusions of their report were:

- 1) The CBR of a soil increases by 77.62% when it is reinforced with a single layer of geo- grid. Soil type, characteristics of soil and position of geogrid will affect the improvement.
- 2) Geogrid reinforcement increases the bearing capacity of soil. CBR values are more when the grid placed top layer of sample.
- 3) The improvement of soil strength and increase in CBR values of soil with geogrid are depends upon the soil characteristics.
- 4) Interfacing soil with a geogrid material increases the penetration resistance and the CBR value in both soaked and un soaked conditions.
- 5) Due to increase in CBR value, even we can reduce the pavement thickness, it will serve similar functions while compared with greater pavement thickness.

Therefore, the performance of a subgrade material in a pavement system is better with the inclusion of a geogrid

2.3 KU.Mani Kandhan, S.Gnana Venkatesh, K.C.Denesh, A.Abdul Hameed et.Al. "Utilization of Geogrids in the Stabilization Progression of Black Cotton Soil". IJETT, Vol-68, and Issue-02 (2020)

The performance of the soil within the styles depends upon the characteristics of soil. So, the testing of soil with relevance to determination of its physical properties, and also the analysis of effects of alternative

factors like discharge conditions etc., forms the foremost essential part of the event of soil engineering. It is through analysis solely that style and construction ways are changed to offer most safety or economy, and new ways are evolved. The information of theoretical soil mechanics presumptuous the soil to be perfect elastic identical and uniform materials helps in predicting the behaviour of the soil within the field. So, this project involves within the soil stabilize parameters of black cotton soil by victimization the geo artificial material referred to as geo grid of woven and non- woven geo textile materials that is employed to strengthen the soil in many conditions. The check involves in substitution the soil in CBR testing mould with four styles of ratios like 1/2, 1/3, 2/3, (1/3 and 2/3)rd. of the equipment conditions so as to search out the CBR % values of woven and non-woven geo textile and compare their results.

The conclusions of their report were

Natural black cotton soil is tested for its index properties. CBR test is conducted to search out its strength parameters. Two styles of Geo grids were used. The Geo grid is supplemented to the soil sample in a fraction of one-third, middle, two-third and both one- third & two-third position. The strength is found to be inflated from 2.49% to 11.12% by accumulating the Woven Geo grids and from 2.49% to 9.17% by adding the Non-Woven Geo grids. The extreme CBR value achieves at the (1/3and 2/3) rd. position. Woven Geo grid indicates better enhancement in strength than Non-woven Geo grid.

2.4 Samuel Thanaraj. M, Freeda Christ. C, Brema. J. et. al. "Investigations on Improving the Compressive Strength of Sand Column with Cement Grout and Chemical Admixture", Turkish Journal of Computer and Mathematics Edition, Vol-12 (2021)

They have conducted a study on the performance of stone column with different materials in soil stabilisation and have studied the behaviour of stone column in local soft and loose layered soil. They have conducted the various tests on the stone column with different materials such as untreated soil aggregate waste marble and pebbles with and without encasement.

On the experimental study conducted, the following conclusions were obtained on the sand column specimens with cement grout added with super plasticizer SMF.

- The value of angle of internal friction decreases with the increased percentage of Cement and water.
- The compressive strength of grouted sand column decreased linearly with increased percentage of water cement ratios whereas the sand columns grouted with cement plus super plasticizer SMF showed an increased values when compared with sand columns grouted with cement alone in all water cement ratios.
- The addition of super plasticizer SMF is very effective at all water cement ratios which in turn will improve the compressive strength which behave well in weak soil stabilizations.
- As this method of installing sand columns grouted with cement plus super plasticizer is very effective and economical, this could be adopted for weak soil stabilization techniques.

METHODOLOGY

3.1 Materials Required

1. Black cotton soil: naturally available black cotton soil was used.



Fig. 3.1: Black cotton soil

In this project, the Black Cotton soil sample was collected from Mecca colony area, Kalaburagi,

Karnataka, India.

2. Coarse Aggregate: crushed coarse aggregate of size ranging from 4.75 mm to 10 mm.



Fig. 3.2: Coarse Aggregate

3. Geo-grid: STRATAGRID (SG200) is used for the reinforcement of stone column which was collected from Strata Geosystems. Pvt .Ltd .Mumbai.



Fig. 3.3: Geogrid

RESULTS AND CALCULATIONS

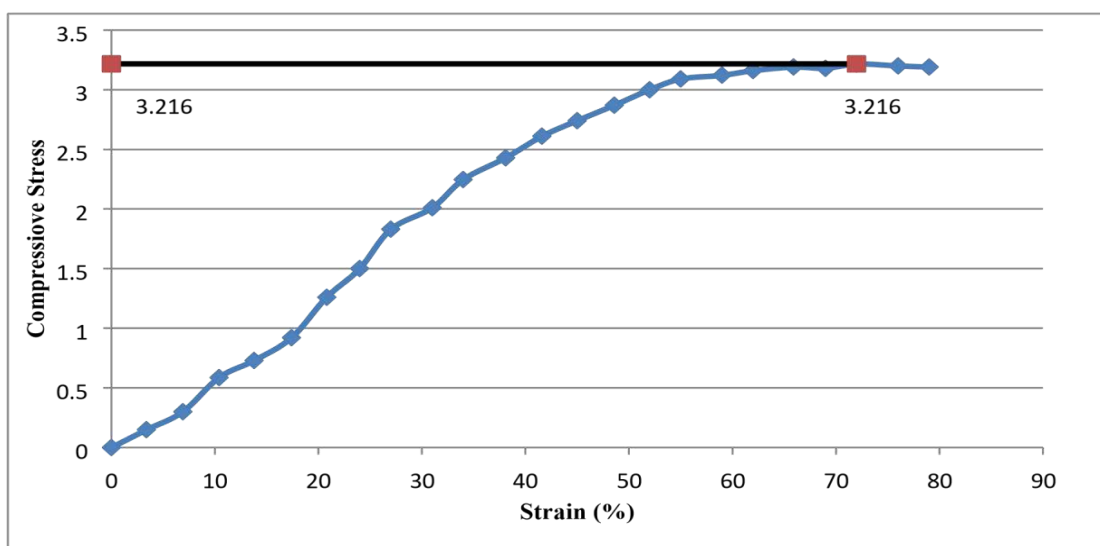
4.1 Unconfined Compression Test:

Table 4.5: Unconfined compressive strength (UCS) test values

train Dial Reading [ΔL]	rain[e] (%)	rected Area 2 (cm)	Proving Ring Reading (Div)	Axial Load (Kg)	Compressive Stress 2) (Kg/cm
0	0	0	0	0	0
25	3.4	11.37	1.5	1.68	0.15
50	6.9	11.41	3	3.36	0.30

75	10.4	11.45	6	6.73	0.587
100	13.8	11.49	7.5	8.42	0.73
125	17.4	11.54	9.5	10.67	0.92
150	20.8	11.58	13	14.6	1.26
175	24	11.62	15.5	17.41	1.5
200	27	11.65	19	21.33	1.83
225	31	11.7	21	23.58	2.01
250	34	11.74	23.5	26.39	2.247
275	38.1	11.79	25.5	28.64	2.429
300	41.6	11.38	27.5	30.88	2.61
325	45	11.87	29	32.56	2.74
350	48.6	11.92	30.5	34.25	2.87
375	52	11.96	32	35.93	3.00
400	55	12	33	37.06	3.09
425	59	12.05	33.5	37.62	3.121
450	62	12.08	34	38.18	3.16
475	65.9	12.14	34.5	38.74	3.19
500	69	12.18	34.5	38.74	3.18
525	72	12.22	35	39.30	3.216
550	76	12.32	35	39.30	3.20

575	79	12.32	35	39.30	3.19
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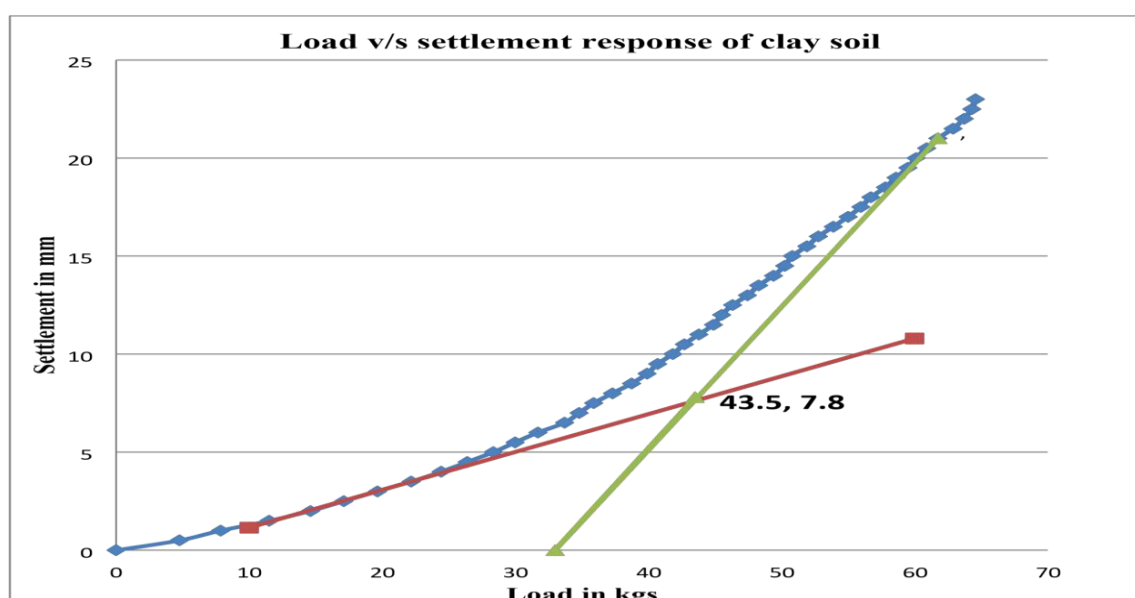
Graph 4.2: Strain and Compressive Stress Curve

4.2 Test on clay bed:

Table 4.7: Loading on clay bed values

Strain dial reading (div)	Settlement (mm)	Proving ring reading (div)	Load (kg)	Strain dial reading (div)	Settlement (mm)	Proving ring reading (div)	Load (kg)
0	0	0	0	1200	12	40.52	45.5
50	0.5	4.25	4.77	1250	12.5	41.25	46.32
100	1	7	7.86	1300	13	42.25	47.45
150	1.5	10.25	11.51	1350	13.5	43	48.29
200	2	13	14.6	1400	14	43.99	49.4
250	2.5	15.24	17.12	1450	14.5	44.75	50.25
300	3	17.5	19.65	1500	15	45.25	50.82
350	3.5	19.75	22.18	1550	15.5	46.22	51.9
400	4	21.75	24.42	1600	16	47	52.78

450	4.5	23.51	26.4	1650	16.5	48	53.9
500	5	25.24	28.35	1700	17	48.98	55
550	5.5	26.71	30	1750	17.5	49.83	55.96
600	6	28.23	31.7	1800	18	50.5	56.71
650	6.5	30.01	33.7	1850	18.5	51.47	57.8
700	7	30.99	34.8	1900	19	52.18	58.6
750	7.5	31.97	35.9	1950	19.5	52.98	59.5
800	8	33.21	37.3	2000	20	53.52	60.1
850	8.5	34.5	38.74	2050	20.5	54.23	60.9
900	9	35.53	39.9	2100	21	55	61.76
950	9.5	36.24	40.7	2150	21.5	55.99	62.88
1000	10	37.25	41.83	2200	22	56.75	63.73
1050	10.5	38.02	42.7	2250	22.5	57.26	64.3
1100	11	38.99	43.79	2300	23	57.5	64.57
1150	11.5	39.98	44.9				



Graph 4.4: Graph showing load v/s settlement response of clay soil

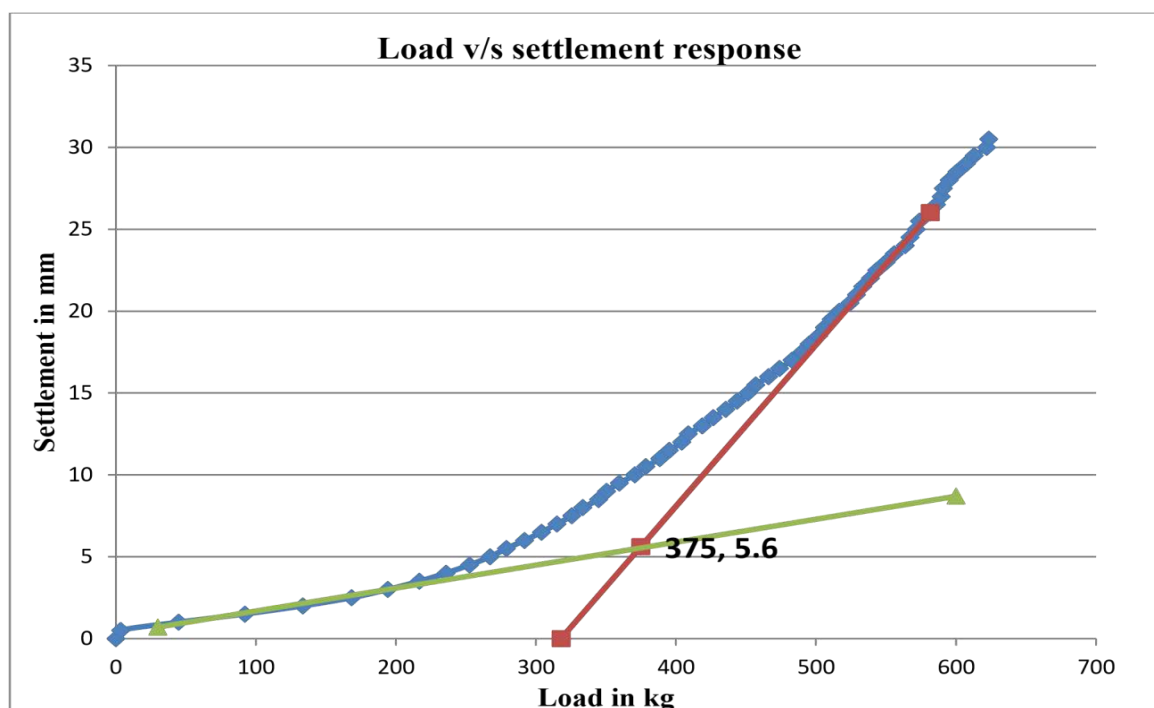
4.3 Clay bed and reinforced stone column with geogrid.

Table 4.11: Clay bed and stone column reinforced with geogrid

Strain dial reading (div)	Settlement (mm)	Proving ring reading (div)	Load (kg)	Strain dial reading (div)	Settlement (mm)	Proving ring reading (div)	Load (kg)
0	0	0	0	1600	16	415	466.1
50	0.5	3	3.4	1650	16.5	422.1	474
100	1	40	44.9	1700	17	430.1	483
150	1.5	82	92.1	1750	17.5	436.5	490.2
200	2	119	133.6	1800	18	441	495.2
250	2.5	150	168.5	1850	18.5	447	502
300	3	173	194.3	1900	19	450.6	506
350	3.5	193	216.7	1950	19.5	455	511
400	4	210	235.8	2000	20	460	516.6
450	4.5	225	252.7	2050	20.5	467	524.4
500	5	238	267.3	2100	21	471.1	529
550	5.5	248.4	279	2150	21.5	475	533.4
600	6	260	292	2200	22	480	539
650	6.5	270.7	304	2250	22.5	484	543.5
700	7	280.5	315	2300	23	490	550.3
750	7.5	290	325.71	2350	23.5	495	555.9
800	8	297	333.5	2400	24	502	563.8
850	8.5	307	344.76	2450	24.5	505	567.1
900	9	312	350.4	2500	25	509	571.6

950	9.5	320.2	359.6	2550	25.5	511.1	574
1000	10	330	370.6	2600	26	518	581.7
1050	10.5	337	378.5	2650	26.5	522	586.2
1100	11	346	388.6	2700	27	524.9	589.5
1150	11.5	352	395.3	2750	27.5	526.3	591
1200	12	360	404.3	2800	28	530	595.2
1250	12.5	364	408.8	2850	28.5	535	600.8
1300	13	373	418.9	2900	29	541	607.5
1350	13.5	380	426.7	2950	29.5	545.9	613
1400	14	388	435.7	3000	30	553.9	622
1450	14.5	395	443.6	3050	30.5	555.2	623.5
1500	15	402	451.5				
1550	15.5	407	457.1				

Load = 3.4kg



Graph 4.6: Load v/s settlement response of clay bed and stone column reinforced with geogrid

The ultimate load carrying capacity in each case was determined by drawing double tangent to the load settlement curve which is shown in figure.

Table 4.12: Results of the above test

Content	Settlement(mm)	Load (kg)
clay bed with circular reinforced stone column	5.6	375

4.4 Clay bed and reinforced stone column with 3 geogrid disc

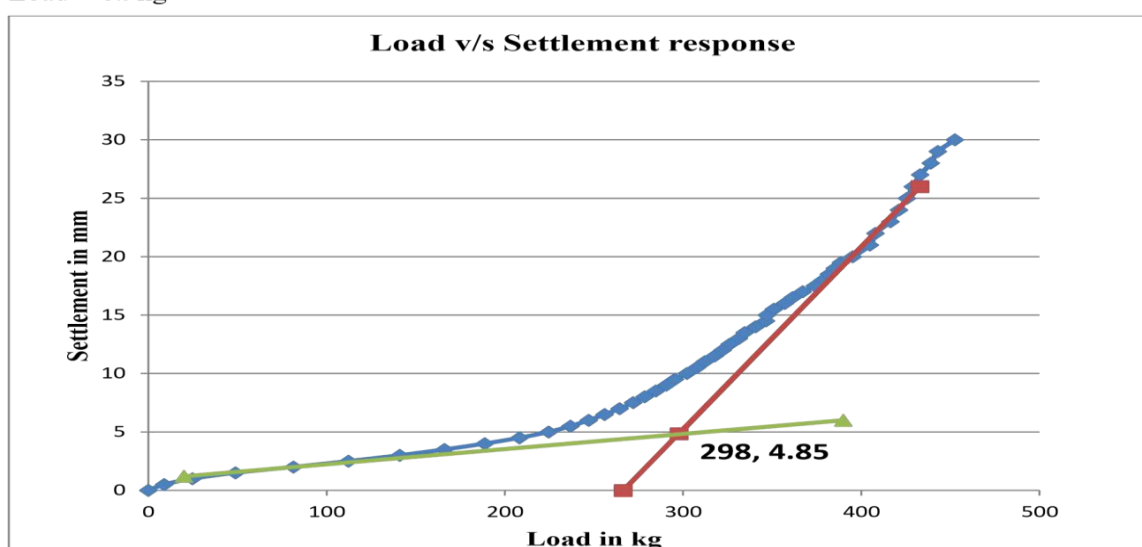
Table 4.13: Values of Clay bed and reinforced stone column with 3 geogrid disc

Strain dial reading (div)	Settlement (mm)	Proving ring reading (div)	Load (kg)	Strain dial reading (div)	Settlement (mm)	Proving ring reading (div)	Load (kg)
0	0	0	0	1300	13	295	331.3
50	0.5	7.9	8.9	1350	13.5	298	334.6
100	1	22	24.7	1400	14	303.5	340.8
150	1.5	43.5	48.8	1450	14.5	308.5	346.5
200	2	72.5	81.4	1500	15	309	347
250	2.5	100	112.3	1550	15.5	312.5	350.9
300	3	125.6	141	1600	16	317.9	357
350	3.5	148	166.2	1650	16.5	322	361.6
400	4	168	188.7	1700	17	327	367.2
450	4.5	185.5	208.3	1750	17.5	333	374
500	5	200	224.6	1800	18	337	378.5
550	5.5	211	236.9	1850	18.5	340	381.8

600	6	219.9	247	1900	19	343	385.2
650	6.5	228	256	1950	19.5	346	388.6
700	7	235.5	264.5	2000	20	352	395.3
750	7.5	242.2	272	2100	21	360.5	404.8
800	8	248	278.5	2200	22	363.3	408
850	8.5	253.5	284.7	2300	23	370.7	416.3
900	9	258.8	290.6	2400	24	375	421.1
950	9.5	263	295.4	2500	25	379	425.61
1000	10	269.2	302.3	2600	26	382	429
1050	10.5	274	307.7	2700	27	385.6	433
1100	11	278	312.2	2800	28	390.9	439
1150	11.5	283	317.8	2900	29	394.5	443
1200	12	287	322.3	3000	30	403	452.6
1250	12.5	290.5	326.2				

Fig 4.7: Load v/s settlement response of clay bed and reinforced stone column with 3 geogrid disc

Load = 8.9kg



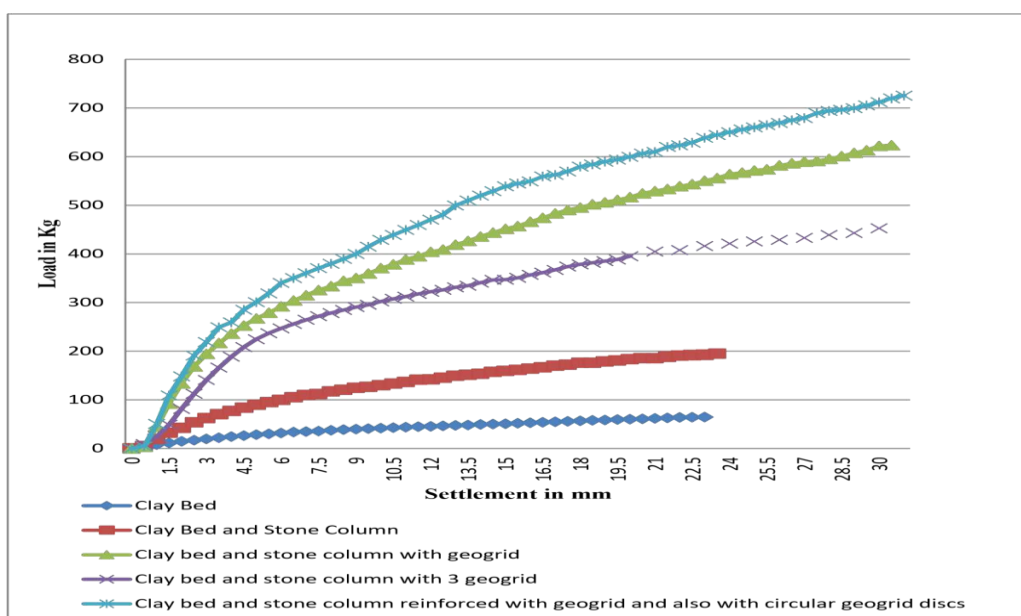
The ultimate load carrying capacity in each case was determined by drawing double tangent to the load settlement curve which is shown in figure.

Table 4.14: Results of the above test

Content	Settlement(mm)	Load (kg)
Clay bed with reinforced stone column with 3 geogrid disc.	4.85	298

Table 4.16: Results of the above test

Content	Settlement(mm)	Load (kg)
Clay bed and stone column reinforced with geogrid and also with circular geogrid discs.	4.5	420



Graph 4.9: Load v/s settlement response for different geogrid arrangements

Final Results

Table 4.17: Final Results

Test condition	Ultimate load (in kg)	Settlement (in mm)
clay bed	43.5	7.8
clay bed with stone column	128	6.5

clay bed and stone column reinforced with geogrid	375	5.6
clay bed and stone column reinforced with 3 geogrid discs in middle portion	298	4.85
Clay bed and stone column reinforced with geogrid and also with circular geogrid discs.	420	4.5

CONCLUSIONS

1. Inclusion of stone column increases the load carrying capacity of the soil by about 3 times by densifying the soil.
2. The ultimate load of the stone column reinforced with encapsulated geogrid has been increased by 2.92 times as compared with stone column alone.
3. The ultimate load of the stone column reinforced with geogrid discs (3 discs) increases by 2.33 times as compared with the stone column alone.
4. The ultimate load of the stone column reinforced with both geogrid and circular geogrid disc increases by 3.3 times as compared with the stone column alone.
5. The ultimate load of the stone column reinforced with encapsulated geogrid has been increased by 8.62 times as compared with clay bed alone.
6. The ultimate load of the stone column reinforced with geogrid discs (3 discs) increases by 6.85 times as compared with the clay bed alone.
7. The ultimate load of the stone column reinforced with both geogrid and circular geogrid disc increases by 10 times as compared with the clay bed alone.
8. The settlement of the soil has been reduced from 8.3 mm to 6.5 mm by placing the stone column alone in the soil.
9. The settlement of the soil at the ultimate load has been reduced from 6.5mm to 5.6mm when stone column was encapsulated within geogrid.
10. The settlement of the soil at the ultimate load has been further reduced from 6.5mm to 4.85mm by inclusion of 3 geogrid discs in the stone column.
11. The settlement of the soil at the ultimate load further reduced from 6.5mm to 4.5mm by placing the stone column reinforced with both geogrid and circular geogrid discs.

SCOPE FOR FUTURE WORK

- Due to the increase in population and requirements of lands for various engineering purposes is increasing day by day, as a result of which soil stabilization is becoming essential to carry out engineering constructions on it.
- The strength of Black cotton soil is less and it is not suitable for carrying out engineering works on it, hence stabilization of Black cotton soil is necessary.
- To determine the other modes of geotextiles that can be used for reinforcement of stone column.
- To determine the economic methods of reinforcing the stone column with good results.
- To determine what else can be done with geogrid method of reinforcement to increase the strength of soil.
- To identify various other modes of soil stabilization.

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