Improvement of Clayey Soil Performance using Stone Column Reinforced with Circular Geogrid Discs

K. M. Girija[1], Hamza Sohail[2], Ayyaz Ahmed Sagri[3], Mohammed Abrar Ahmed[4], Md Zubair Khan[5]

[1]*Associate Professor, Dept. of Civil Engineering, P.D.A. College of Engineering, Gulbarga-585102, Karnataka, India*
[2,3,4,5]*UG Scholars, Dept. of Civil Engineering, P.D.A. College of Engineering, Gulbarga-585102, Karnataka, India*

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Abstract – ***Objective:*** *To study the load carrying capacity and settlement behaviour of the soft soils improved with lateral reinforced stone columns.* ***Methods/Analysis:*** *In this study, the soft soil is reinforced with stone columns by providing lateral circular geogrid discs within the column. The tests were conducted on plain clay bed, plain stone column and stone column with geogrid by placing reinforcement at three different spacing in the middle portion of the stone column, i.e., 1, 2 and 3 geogrid disc cover middle portion of column length and investigated the effect of reinforcement to improve the properties of the clay bed.* ***Findings:*** *By improving the soft soil with stone column, the ultimate load of the soil has been increased by about 172% and is increased by 60% for 1 geogrid disc and 125% for 2 geogrid discs and is increased by 203% for 3 geogrid discs, at different spacing in the middle portion as compared with stone column alone. This results shows that the spacing of the reinforcement is influencing the ultimate load of the stone column. The settlement of the soil has been decreased by providing the stone column and further decreased by providing the geogrid reinforcement. Further the ultimate load of soil with stone column reinforced by encapsulated geogrid has been increased by 762% as compared with clay bed alone. Lateral Reinforcement with geogrid discs increases the load carrying capacity of the soft soil and also it varies with varying the spacing of the reinforcement.*

Key Words: Consolidation, Geogrids, Perspex Tube, Reinforcement, Stone Columns, Stratagrid.

1. INTRODUCTION

The stone columns or granular piles are increasingly being used as ground reinforcement elements for supporting a wide variety of structures including buildings and flexible structures. 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 on soft ground. 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. 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 soft 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 situations, the bearing capacity of the stone column can be improved by providing circular lateral discs of a suitable geogrid as a reinforcing material 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 with lateral circular discs by varying the spacing of the discs.

When the stone column is installed in the clay bed, after loading it there is a chances of failure of the stone column.

There are four basic mode of failure of stone column:

1. General shear failure
2. Local shear failure
3. Bulging shear failure
4. Failure by sliding

But in practice, it was found that group of stone columns and that too of length greater than 3D-5D, bulging is the primary mode of failure.

Methods to arrest bulging are:

1. Placing of surcharge
2. Skirting
3. Geogrids and geomembranes

From the past study it was concluded that for load acting on stone column bulging occurs along its middle portion.

So to arrest this bulging we had provided geogrids at the middle portion of the stone column only, at different spacing's and the study of load and settlement is done. And one test is done by encapsulating the stone column inside the geogrid. And the influence of load with and without reinforcement was studied.

2. SPECIFICATION OF MATERIALS USED

SOIL: The locally available clayey soil from water logged area will be used in this study. And will be sieved through 425 micron IS-sieve to remove the coarser fraction. A sample is shown in Figure 1(a).

CRUSHED STONE: Crushed stone aggregate was collected from locally available crushers like M S B stone crusher, Zahor stone crusher. Crushed coarse aggregate of size between 4.75 mm and 10 mm will be sieved and used for the present study. The stone aggregate will be compacted to a density of 1.59 kN/m^3 using a steel tamping rod of 900 g weight by compacting from a height of fall of 10 cm and by giving 10 blows. Figure 1(b) shows the coarse aggregate sample.

GEOGRID: The Geogrid material named as "SG 200" is collected from Strata Geosystems Pvt. Ltd. Mumbai. STRATAGRID is geogrid reinforcement for soil. These high performance geogrids are constructed of high molecular weight and high tenacity knitted polyester yarns with a proprietary coating. Stratagrid is engineered to be mechanically and chemically durable, in both the harsh construction installation phase and in the aggressive soil environment (PH range from 3-9).the geogrid used is in circular disc of diameter same as that of the stone column. The Figure 1(c) shows the circular geogrids used in this study. Ultimate strength of the geogrid is 52.5 kN/m and Creep limited strength is 33.9 kN/m. Thickness being 2mm.

(a) (b) (c)

Figure 1(a) Clay. (b) Coarse aggregate. (c) Geogrids.

3. EXPERIMENTAL STUDY:

Index and engineering properties of clayey soil are listed in Table 1.

Table 1. Index and engineering properties of clayey soil.

Property of soil	Values
Liquid limit	67.30%
Plastic limit	31.79%
Percentage fineness	83%
Specific Gravity	2.53
Optimum Moisture Content (OMC)	24.36%
Maximum Dry Density (MDD)(in g/cc)	1.5
Unconfined compressive strength (in kg/sqcm)	3.126

3.1 Preparation of Clay Bed

The air-dried and pulverized clay sample was mixed with required quantity of water. The moisture content (35%) required for the desired shear strength was determined by conducting several vane shear tests. After adding the water to the clay powder, it will be thoroughly mixed to a consistent paste. This paste will be then filled in the tank in 50 mm thick layers to the desired thickness by hand such that no air voids are left in the soil. The compacted soil is left for 24 hours and covered with wet gunny cloth for moisture equalization.

The tank being used in this study is of 200mm diameter and 300mm height. Before filling the soil in the tank, the inner surface of the tank wall will be first coated with grease to minimize the friction between soil and the tank wall.

The test will be conducted on this clay bed only to get the response of settlement of bed to the respective loading i.e., after construction of clay bed, a sand blanket of 20 mm thick will be laid on the surface of clay bed and load will be applied through the 12mm thick Perspex circular footing. Models will be subjected to strain-controlled compression loading in a conventional loading frame at a fast rate of settlement of 0.25 mm/min to ensure undrained condition up to a maximum footing settlement of 20 mm. The results will be noted.

For each load test, a fresh clay bed will be prepared in the test tank and stone columns will be installed in it. The Figure 7.7(a) shows the clay bed prepared in the cylindrical tank used in this study. Tests will be conducted on stone columns formed in a clay bed of 200 mm diameter and 300 mm height.

(a) (b)

Figure 2(a) Clay bed. (b) Schematic view of stone column.

3.2 Construction of Stone Column

To get the response of load v/s settlement of clay bed having a stone column in it the following procedure will be used.

Clay bed is again prepared as described above, once the clay bed is prepared in tank. A pipe or tube of diameter just greater or equal to that of diameter of stone column being prepared, is applied with grease on either side and slowly pushed into the clay bed.

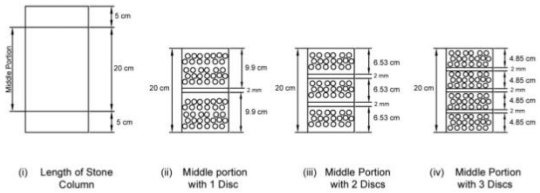
Then with the help of auger of diameter slightly less than that of casing pipe is inserted in pipe by rotating and the clay is removed, after which there forms a hole in clay bed.

Then the stone column was casted in steps by compacting stone aggregate in hole created and withdrawing the casing pipe simultaneously for every 50mm depth along the length of the column. After compaction of each layer, the pipe is lifted up gently to a height such that there will be an overlap of 5mm between the surface of the stone aggregate and bottom of pipe, each layer was compacted by giving 10 blows with a height of 10cm using 900gms tamping rod.

5% of water is added to the coarse aggregate to avoid the absorption of water in clay bed. And this arrangement will be covered with polythene for 24 hours for proper bounding of column and soft soil.

3.3 Placing of Reinforcement at different Spacing.

Since the bulging occurs in the middle portion of the stone column, the middle portion of stone column will be considered in this study, is of 20cm length i.e. by living 5cm from top and 5cm from bottom of the total length of column i.e. 30cm. We are interested to arrest that bulging, so the centre portion will be reinforced with 1, 2 and 3 horizontal discs placed at 9.9cm, 6.53cm, 4.85cm spacing's respectively from the bottom of middle portion. And this is compared with the study of geogrid placed along the circumference of the stone column along its full length. The geogrid will be stitched at ends by nylon threads to form the shape of cylinder.



Schematic representation of geogrid discs placing's.

3.4 Stone Column Testing

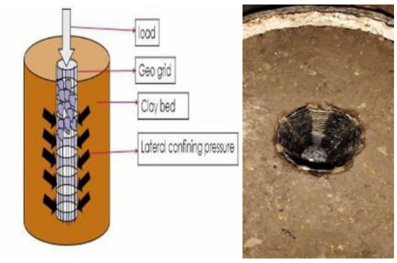
After construction of stone column, a sand blanket of 20 mm thick was laid on the surface of clay bed and load was applied through the 12 mm thick Perspex circular footing having diameter double the diameter of the stone column which represents 25% area replacement ratio. Models were subjected to strain-controlled compression loading in a conventional loading frame at a fast rate of settlement of 0.24 mm/min to ensure undrained condition up to a maximum footing settlement of 20 mm.

(a) (b) (c)

Figure 3 (a) Inserting open ended tube into the soil. (b) Clay bed with central hole. (c) After construction of stone column.

(a) (b)

Figure 4 (a) Geogrid placed at position. (b) Testing of stone column.



(a) (b)

Figure 5 (a) Stone column encapsulated within geogrid. (b) clay bed with geogrid placed in hole.

4 Results and Discussion

The following are the results obtained by performing the different lab tests. The below Figure 6 shows the load-settlement curve obtained from load tests on clay bed, clay bed with stone column alone, clay bed with stone column reinforced with geogrids at different spacing's. Figure 7 Load-settlement curves showing the double tangent curve for clay bed alone. The ultimate load carrying capacity in each case was determined by drawing double tangent to the load settlement curve.

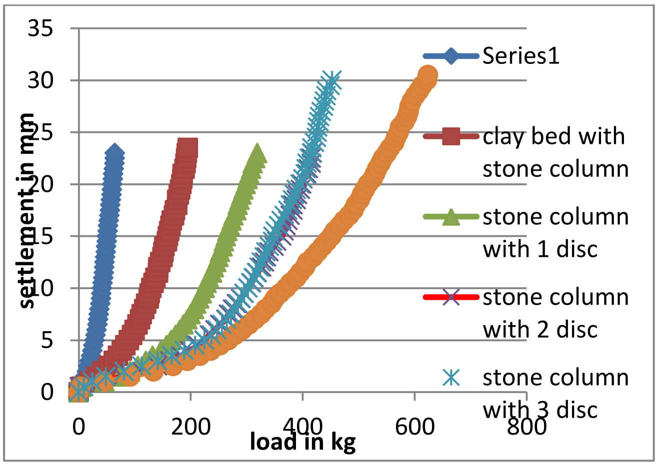


Figure 6 Load-settlement curves of clay bed, clay bed with unreinforced stone column and reinforced with geogrids at different spacings.

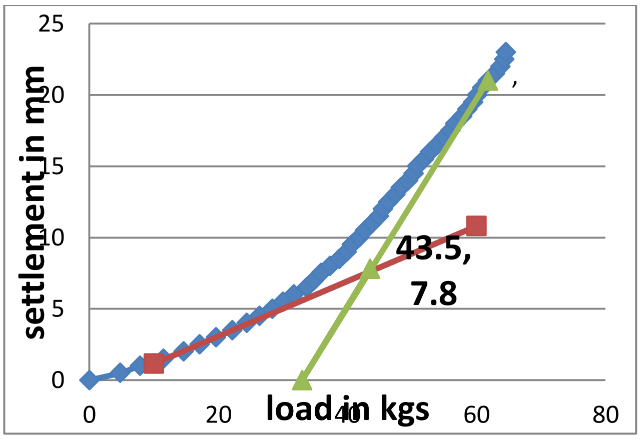


Figure 7 Graph showing load v/s settlement response of clay soil

4.1 Load Settlement Response of Plain Clay Bed

Figure 6 shows the load-settlement curve obtained from load tests on clay bed. The ultimate load carrying capacity in each case was determined by drawing double tangent to the load settlement curve which is shown in figure. The ultimate load carrying capacity of the clay bed is 43.5 kg. The settlement at the ultimate load is 7.8 mm.

4.2 Test Results

Test condition	Ultimate load (in kg)	Settlement (in mm)
plain clay bed	43.5	7.8
clay bed with unreinforced stone column	128	6.5
clay bed with stone column reinforced with 1 geogrid disc in middle portion	206	6.2
clay bed with stone column reinforced with 2 geogrid discs in middle portion	288	5.2
clay bed with stone column reinforced with 3 geogrid discs in middle portion	298	4.85
clay bed with stone column reinforced with circular geogrid	375	5.6

5. Conclusions

- Inclusion of stone column increases the load carrying capacity of the soil by about 172% by densifying the soil.
- The ultimate load of the stone column reinforced with geogrids 3 different spacing i.e, by using 1, 2 &3 discs has been increased by 60% and 125% and 203% respectively as compared with the stone column alone.
- The ultimate load of the stone column reinforced with encapsulated geogrid has been increased by 193% as compared with stone column alone.
- The ultimate load of the stone column reinforced with geogrids 3 different spacing i.e, by using 1, 2 &3 discs has been increased by 373.5% and 562% and 585% respectively as compared with the clay bed alone.
- The ultimate load of the stone column reinforced with encapsulated geogrid has been increased by 762% as compared with clay bed alone.

- 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.
- The settlement of the soil at the ultimate load has been further reduced to 6.2mm and 5.2mm and 4.85mm by inclusion of 1, 2 & 3 geogrid discs respectively.
- The settlement of the soil at the ultimate load has been reduced to 5.6mm when stone column was encapsulated within geogrid.

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