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A Study of Behaviour on Stone Column in Homogenous Soil

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Abstract: ***In the modern civilized world ground improvement technique is a great concern to the geotechnical engineers. Stone columns are found effective, feasible and economical to improve the homogenous. Stone columns increase the unit weight and the bearing capacity of soil. It can densify the surrounding soil during construction. The improvement of a soil by stone columns is due to different sizes of aggregate or granular fill (size between 2 to 10 mm) in the soft soil. This deals with the utilization of stone column to improve the load carrying capacity of sandy silt soil with clay in naturally consolidated state. In the compression testing machine the load test are performed on single un-encased stone column in homogenous soil, the bearing carrying capacity of soil will increases with increase in diameter of stone column.***

Keywords: Bearing Capacity, Ground Improvement, Granular Fill, Stone Column.

1. Introduction

Ground improvement is the most imaginative field of geotechnical engineering. It is a field in which the engineer forces the ground to adopt the project's requirements, by altering the natural state of the soil, instead of having to alter the design in response to the ground's natural limitations. The results usually include saving in construction cost and reduction of implementation time. At present a variety of soil improvement techniques are available for making soil to bear any type of structure on it and also for mitigation of seismic hazards. To improve the strength of the soils, especially in case clay, installation of stone column are found as best methods among all type of techniques. The various techniques used to improve the engineering property of soil are given below:

1) Densification techniques.
2) Reinforcement techniques.
3) Stabilization techniques.
4) Miscellaneous methods.

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2. Stone Columns

The techniques for soil improvement have been changing during the last three decades. The concept of soil improvement by reinforcing it with tension resistant elements in various forms has received the attention. This reinforcement can be provided in Vertical as well as in horizontal direction. Stone columns have been used to a large extend for several applications. Stone columns essentially increase the bearing Capacity of cohesive soils. Soils deposits can be improved by the installation of dense columns of gravel known as stone columns. They may be used in both fine and coarse grained soils. In fine-grained soils, stone columns are used to increase the shear strength beneath structures and embankments by accelerating consolidation and introducing columns of stronger material. The stone columns derive their load capacity from the confinement offered by the surrounding soil. In very soft soils this lateral confinement may not be adequate and the formation of the stone column itself may be doubtful. Wrapping the individual stone columns with suitable geosynthetic is one of the ideal forms of improving the performance of stone columns. Stone Columns provide an economical method of ground improvement and act as reinforcement to the ground into which they are installed.

3. Literature

Sharma and Phanikumar (2005) presented the heave behaviour of expansive clay reinforced with geo-piles that are vertical cylindrical cells made of geo-grid and filled with geo-materials. Effect of diameter of geo-pile and the type of the fill material on heave response have been investigated. It is found that heave decreases with increasing diameter of the geo-pile and particle size of the fill material. In the case of a group of geopiles, spacing between the geopiles is varied and its effect on heave is studied. Also heave decreases with closer spacing of geopiles. Ambily and Gandhi (2007) carried out an experimental study on behaviour of single column and group of seven columns by varying the parameters like spacing between the columns, shear strength of soft clay and loading condition. Finite Element Analysis (PLAXIS) is also performed using 15-noded triangular elements and results obtained are compared with the experimental results. Isaac and Girish(2009) studied the performance of stone column using five reinforcement materials like stones, gravel, river sand, sea sand and quarry dust. Load versus settlement response is determined. It is found that there is no significant difference in the load deformation behaviour of stone columns using river sand and sea sand. Finite element analysis is also carried out using PLAXIS. Gniel and Bouazza (2009) discussed the results obtained from series of model tests conducted to investigate the behaviour of geogrid encased stone column. Length is varied to see the behaviour of partially and fully encased stone column. It is found that for a partially encased column there is a steady reduction in vertical strain occurs due to increase in encased length for both isolated columns and group columns. For a fully encased column there is an increase in column stiffness and decrease in column strain with strain reduction in the order of 80%. Murugesan and Rajagopal (2010) performed tests on the qualitative and quantitative improvement of individual load carrying capacity of encased stone column. Load tests are performed on single and group of stone columns with and without encasement. It is found that load carrying capacity of the stone column increases due to encasement. The increase in load capacity depends on the modulus of encasement and the diameter of the stone column. Najjar et al. (2010) evaluate the degree of improvement of mechanical properties of soft clay using sand columns. The height of column, type of column (encased, non-encased) and effective confining pressure is varied. Test results indicated that sand columns improve the un-drained strength.Ayothiraman and Soumya (2011) used shredded waste tyres as an alternative material to stone aggregates in construction of stone columns. It is concluded that waste tyre chips can be used.

4. Materials and Methodology

4.1 Materials used

Soil:
The required amount of soils are collected from trail pits at a depth of 2m below the ground level since the top soil is likely to contain organic matter and other foreign materials. Sufficient care has been exercised to see that the collected soil samples are fairly homogenous. The soils so obtained are air dried, crushed with wooden mallet, passed through 4.75mm sieve, kept in polythene bags and stored in steel drums for further testing. The properties of this soil are given in table. The “soil collected near krishnapuram village”

Sand: The sand is collected from near vinyak nagar ,kadapa. The sand must be uniform and which is passed through 4.75mm and retained on 2mm.

Table 1: Properties of soil tested

Soil Properties	Soil
Index properties	
Sand (%)	16.4
Slit (%)	64.7
Clay (%)	18.8
Liquid limit (%)	55
Plastic limit (%)	30.7
Plasticity index (%)	24.3
IS Soil Classification	CM
Free Swell Index (%)	33.33
Specific gravity	2.46
Engineering properties	
Optimum moisture content	22
Maximum dry density (g/cc)	1.54
Angle of internal friction φ	18^0
Cohesion (kN/m^2)	15.5

Stone dust used:
Crushed stone aggregates of sizes between 4.75mm and 2mm have been collected from market near vinayak nagar, kadapa to form stone column. The finer fraction retained on 2mm was removed by wet sieving and used after drying .properties of the aggregate for stone column are given in table 2 . The stone aggregates were compacted to a required density to from stone columns.

Table 2: Properties of sand and stone dust

Property	Sand	Stone dust
Gravel (%)	0.95	0.35
Sand (%)	98.9	98.3
Silt + clay (%)	0.15	1.3
Effective size D_{10} (mm)	0.3	0.19
Effective size D_{30} (mm)	0.4	0.5
Effective size D_{60} (mm)	0.85	1.5
Coefficient of uniformity ,C_u	2.83	7.89
Coefficient of curvature ,C_c	0.62	0.87
Specific gravity	2.6	2.8

4.2 Model raft/ footing used

A rigid Perspex plate of having double the diameter of stone column and having a thickness of 12mm resting on the surface of the pest bed prepared is used as model raft/ footing.

Figure 1 Model footing

4.3 Load frame used

The capacity of loading frame is 5000 kg and types of operation electrical and manual. The load frame consists of a cabinet which houses the gear system and motor loading systems comprises of screw jack with detachable handle. The lower plate moves up and down. A dailguage mounting bracket is provided on one of the two pillars .rate of strain is 1.25 mm/min

4.4 Model test tank used

The size of tank was designed keeping in view the size of footing to be tested and zones of influence. The dimension of the tank was 30*30*40cm. Testing tank used in experimental study shown in fig:

Figure 2 Model test tank

4.5 Size and Length of the Stone Column

The laboratory experiments were carried out using stone column having a diameter of 50, 60, 75; 90mm for homogenous soil and length of the column is 300mm.

5. Experimental Study

5.1 Preparation of Soil

Weigh the required amount of soil according to the size of tank. Soil should be measured with the help of weighing machine as shown in fig. Quantity of water should be added to soil to form a uniform paste in equals to optimum moisture content by weight of calculated soil. Mix the calculated soil with water at OMC. Mixing should be done properly for 20-30min. Spatula should be used for proper mixing of soil.

5.2 Preparation of Stone Column

Before the soil in the tank, the inner surface of the tank wall was first coated with silicon or lithium grease to minimize the friction between soil and the tank wall. For each load test, the clay bed was prepared afresh in the test tank and stone columns of different diameters were installed in it. Test has been conducted on this soil bed of 50, 60, 75, 90mm diameters and 300mm height.

5.3 Construction of Stone Column

For ordinary end bearing columns a Perspex or PVC pipe having its outer diameter 50, 60, 75, 90mm (diameter of stone column) and 1mm thick was first placed at properly marked centre of the tanks bottom. The inner and outer surface of casing pipe was properly cleaned off and grease is applied to the outer surface. Around this pipe, soil was then filled in the tank in 50mm thick layers to the desired height by hand or wooden compaction such that no air voids are left in the soil. The stone aggregate is used as a column material, 5% of water is added to the aggregate to avoid the absorption of water in the soil bed. The stone column was casted in steps by compact the aggregate chips and withdrawing the casing pipe simultaneously for every 50mm of depth along the length of column. After compaction of each layer the pipe is lifted gently to a height such that there will be an overlap of 5mm between the surface of the stone chips and the bottom of the casing pipe. The aggregates were compacted by using 10mm diameter steel rod with 10 blows from the height of 100mm. After compacting each layer, the pipe is lifted such that there will be 5mm overlap between the two layers. After completion of the stone column the composition with the column inside was again left covered with polythene cover/ wet gunny cloth for 24 hours to develop proper bonding between the stone chips of the column and the soft soil.

5.4 Preparation of Sand Bed

Commercially available graded sand was used to prepare the sand bed placed above the clay bed and the average particle size of sand was ranging between 2 to 4.75mm. To maintain same unit weight of sand in each test, the required weight of sand in each layer was calculated based on bulk unit weight and compacted to achieve the required thickness such as 30mm

6. Stone Column Testing

After construction of stone column, load was applied through 12mm thick fibre circular footing having diameter, double the diameter of the stone column. Models were subjected to strain controlled compression loading test at a rate of settlement of 1.25.mm/min upto a maximum footing settlement of 50mm. The applied load on footing was observed by a proving ring at every 1mm settlement

7. Post Test Analysis

After completion of the test, the stone chips from the column were carefully picked out and a thin paste of Plaster of Paris was poured in to the hole and kept it for 24 hours to get the deformed shape of the column. The soil outside the stone column was carefully removed and the hardened Plaster of Paris is taken out and the deformation properties are studied.

Figure 3: Post test analysis

8. Results and Discussions

8.1 Load Tests

Load tests were conducted on model test tank consisting of homogenous soil .the column were installed with varying diameter 50, 60, 75, 90 mm of stone column having length of column as end bearing column of 300mm.

8.2 Load –Settlement Characteristics

The load-settlement characteristics of the unimproved bed of soil, soil bed improved by stone column along with different diameters without encasing. The improvement in load-carrying capacities under different conditions has been computed at 50mm settlement.

8.3 Behaviour of Stone Column in Homogenous Soil

Test was carried out on end bearing stone columns of length 300 mm and with diameters of 50, 60, 75, 90mm diameters of stone column at every 50mm settlement.

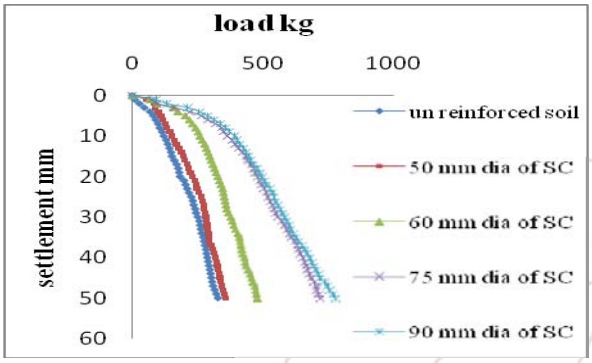

Figure 4 Load settlement curve for homogenous soil

9. Bulging of a Stone Column

The load tests are conducted on stone columns embedded in soil beds prepared in model test tanks by varying with different diameters of stone column. At the end of load test, soil along with stone column is extracted from the model. After completion of the test, the stone chips from the column were carefully picked up and a thin paste of plaster of Paris was poured into the cavity to establish the deformed shape of the column. The hardened plaster of Paris representing the deformed column shape was isolated by removing the surrounding soft soil.

Figure 5: Bulging of a stone column

10. Measurements of Stone Column Tested

After removing the stone column from the soil the column deformations has be measured with the help of steel rule. The measurements has to be taken such as changing length of stone column in terms of original length and the maximum lateral extent bulging in terms of original diameter of stone column and also vertical extent of bulging.

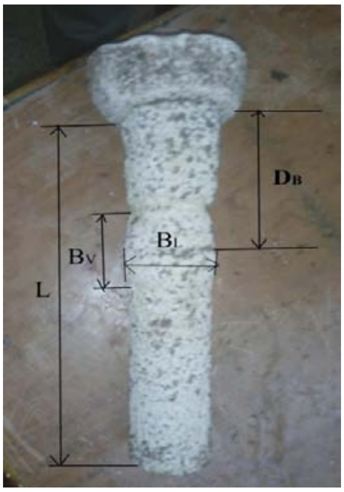

Figure 6: Measurement of bulging

10.1 The Effect of diameter and length of Stone Column on original diameter and length of column in homogenous soil

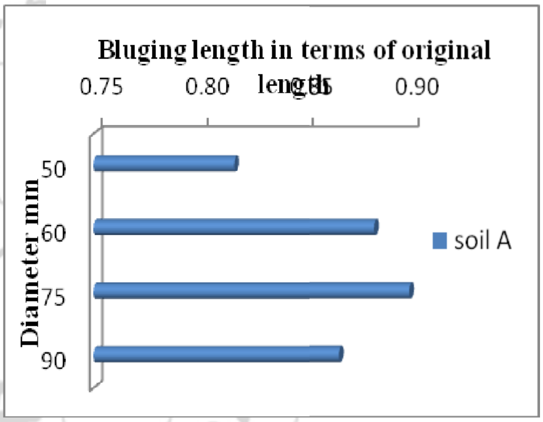

Figure 7: variation of bulging length in terms of original length

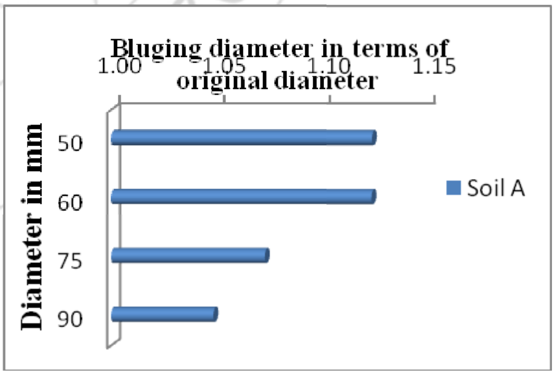

Figure 8: variation of bulging diameter in terms of original diameter

11. Conclusions

The experimental analyses have been carried out to study the behaviour of stone column on the different diameter of stone columns for ground improvement and stabilization of soil. Based on the above results and discussions, the following conclusions may be made:

1) The treated soil with stone column can carry more load than untreated soil.
2) It has been observed from the load –settlement characteristics of homogenous soil for a particular settlement, the load carrying capacity increases with an increase in diameter.
3) The bearing capacity of soil increases when compared to untreated soil to treated soil varying with different diameter of stone column as 50, 60, 75, 90mm is 16.56%, 46.01%, 122.09%, 155.83% in case of homogenous soil.
4) In case of homogenous soil the testing resulted as, the column gets deformed and the original length of column deforms due to load applied through footing plate on the soil.
5) After deformation the length and diameter of the stone column will changes minimum in 90mm diameter of the stone when compared to other diameters.

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