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GROUND IMPROVEMENT USING STONE COLUMN

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ABSTRACT

The use of stone column (called granular piles) has proved to be an economical and technically viable ground improvement technique for construction on soft soils and has been successfully applied for the foundation structure like oil storage tanks, earth embankments, raft foundation etc. When the stone columns are installed in extremely soft soils, the lateral confinement offered by the surrounding soil may not be adequate to form the stone column. In such soil, encasing the stone column with a geotextile can induce required lateral confinement. Considering the cost aspect of stone columns, the major portion of the cost owes to the cost of stone. If replacing a portion of stone by some other cheaper material, without affecting the performance, can reduce the total cost In the present work experimental studies are carried out to evaluate the behavior of stone column encased with geotextile, in which stone is replaced by cheaper quarry dust The effect of geotextile is also studied. It is revealed from the studies that a portion of stone can be replaced by cheaper quarry dust without with out affecting the performance of the column.

INTRODUCTION

In quest of knowledge and demand, there is ever increasing awareness of new technologies created or found by man. The field of geotechnical engineering is not new to this phenomenon. Over the last century, the field of geotechnical engineering has achieved many milestones with brilliant ideas and advancements. The ground improvement techniques are one of the areas, which have attained lots of interest, and improvements due to an interesting fact that anything can be constructed anywhere- if only proper foundation is laid.

Many methods for ground modification and improvement are available around the world now, including dewatering, compaction, preloading with and without vertical drains, grouting, deep mixing, deep densification and soil reinforcement are among those. Many of these techniques, such as dewatering, compaction, preloading and grouting, have been used for many years. However, there have been rapid advances in the areas of deep densification (vibro-compaction, deep dynamic compaction, compaction piles, and explosive densification), jet and compaction grouting, deep mixing, and vibro-replacement and vibro-displacement in recent years. These methods have become practical and economical alternatives for many ground improvement applications.

While most of these technologies were originally developed for uses other than seismic risk mitigation, many of the recent advances in the areas of deep densification, jet and compaction grouting, and deep mixing methods have been spurred on by the need for practical and cost effective means for mitigating seismic risks. Many of these methods have also been applied to increase the liquefaction resistance of loose, saturated, cohesion less soils. Ground improvement techniques basically utilize the effects of increasing adhesion between soil particles, densification and reinforcement to attain one or more of the following:

- Increased strength to improve stability,
- Reduced deformation due to distortion or compressibility of the soil mass,
- Reduced susceptibility to liquefaction, and
- Reduced natural variability of soils.

Of many techniques of ground improvements, stone column has gained lots of popularity since it has been properly documented in the middle of the last century. Potential applications of stone column include stabilizing foundation soils, supporting structures, landslide stabilization, and reducing liquefaction potential of fine sands.

Considering the cost aspect of stone column, the major portion owes to the cost of stone. If some other cheaper material, can replace the stones, without affecting the performance, the cost of construction can be reduced. Here an attempt is made to replace the stone partly with quarry dust and the performance is studied in terms of load settlement behavior. The effect of geotextile encasement is also studied using a natural geotextle.

LITERATURE REVIEW

Hughes and Withers (1974) carried out series of model tests in normally consolidated clay. The test results indicated that ultimate capacity of stone column was governed primarily by the maximum radial reaction of the soil against the bulging and the extend of vertical movement in the stone column was limited to about four times the diameter. Shankar and Shroff (1997) conducted experimental studies to study the effect of pattern of installation of stone columns and showed that triangular pattern seems to be optimum and rational. Mitra and Chatopadhyay (1999) studied the effect of different factors influencing the capacity of stone column improved ground from the available literature and showed that in the case of columns failing by bulging the critical length is about three to five times the stone column diameter. Mitchell and Huber (1985) compared the field performance of stone columns with the predictions by finite element analysis and reported that the agreement was generally good. It was concluded further that settlement predictions using other simpler methods also gave values, which agreed reasonably with the measured values. However, when used in sensitive clays, stone columns have certain limitations. There is increase in the settlement of the bed because of the absence of the lateral restraint. The clay particles get clogged around the stone column thereby reducing radial drainage. To overcome these limitations, and to improve the efficiency of the stone columns with respect to the strength and the compressibility, stone columns are encased (reinforced) using geogrids/ geocomposites. Deshpande & Vyas (1996) have brought out conceptual performance of stone columns encased in geosynthetic material.

Malarvizhi and llamparuthi (2002) has studied load versus settlement response of the stone column and reinforced stone column i.e., geogrid-encased stone column in the laboratory. Load test were performed on soft clay bed stabilized with single stone column and reinforced stone column having various slenderness ratio and using different type of encasing material. The settlement in reinforced stone column is lesser than the stone column and the settlement decreased with the increasing stiffness of the encasing material.

In recent years stone column have been increasingly used for improvement of soft soils to increase the load bearing and to reduce the settlement. This present experimental work examines the behavior of stone column, in which stone chips are replaced by quarry dust. Considering the cost aspect of stone column, the major portion of the cost owes to the cost of stone. If this can be reduced by replacing other cheaper materials, without affecting the performance, the total cost can be reduced. The effect of a natural geotextile as an encasing material is also studied.

MATERIAL CHARACTERIZATIONS

The clay used is natural clay which is locally available at a place called Maradu in Kochi. Collected sample has been air dried and pulverized. The pulverized sample was sieved through 4.75 mm sieve for easy mixing and quicker hydration. The properties of soil are obtained in the geotechnical engineering laboratory as per IS specification. Properties of clay, quarry dust and stone aggregate and geotextiles are tabulated in Tables 1 to 3 respectively.

Table 1. Properties of Soil (air dried sample)

Property	Value
Specific gravity	2.74
Liquid limit (%)	59
Plastic limit (%)	27
Plasticity index (%)	32
Clay content (%)	12
Silt content (%)	61
Max. dry density(KN/m³)	15
OMC (%)	30

Table 2. Properties of Quarry Dust and Stone

Property	Quarry Dust	Stone
Effective size (mm)	0.041	4.6
Uniformity coefficient	3.85	1.4
Coefficient of curvature	5.6	0.93
Density(KN/m³)	19.5	17.6
Angle of internal friction	37^o	-
Cohesion (kg/cm²)	0.15	-

Table 3 Properties of Coir Geotextile*

TYPE	Non woven lined(NWL)
Mass / Area (g)	1350
Thickness at 2 kPa (mm)	11.35
Wide tensile strength (kN/m) machine direction	3.49

* After Rao and Balan(2000)

EXPERIMENTAL INVESTIGATIONS

Preparation of Clay bed

The air-dried and pulverized clay sample was mixed with required quantity of water to achieve a consistency index of 0.1. Water content of 56% was used. Initially the soil was thoroughly mixed with the water and kept covered for 48 hours in order to achieve uniform consistency. After 48 hours of hydration, the soil was mixed and kneaded well and checked for moisture content. Loss of water, if any due to evaporation was compensated by adding water before forming the bed. Thoroughly mixed clay is filled in the tank in layers of 100 mm thick and the weight of clay was adjusted so as to achieve a uniform wet density of 17 kN/m³. Care was taken to avoid the entrapped air by tapping the clay layers gently with a wooden plank.

Stone Column Installation

The center of the cylindrical tank was properly marked and a PVC pipe of the required diameter was placed at the center of the tank. Around this pipe, clay bed was formed. The clay layer was tamped with a wooden tamper frequently and gently to expel air during the process of filling. The stone required to form the column was carefully charged in the tube in three layers. Each layer was compacted using 12mm diameter rod to achieve a density of 17 kN/m 3.

For reinforced stone columns the reinforcement was stitched and placed around the PVC tube. After preparing the clay bed, the tubes were charged with stone chips and compacted in layers. The PVC tube was withdrawn to certain level and charging of stones for the next layer was continued. The operations of charging of stones, compaction and withdrawal of tubes were carried out simultaneously.

Further the bed thus prepared was left for 24 hours to obtain uniform bed, which also ensured proper contact between clay and reinforced stone column. The test after 24 hours of preparation of the bed has also ensured gain in their strength of disturbed clay.

Experimental Setup for the Load Test

Tests were conducted on a single column of diameter 110 mm for various proportions of the stone column and quarry dust on a standard loading frame as a strain-controlled test. Fig 1 shows the schematic sketch of test set up.

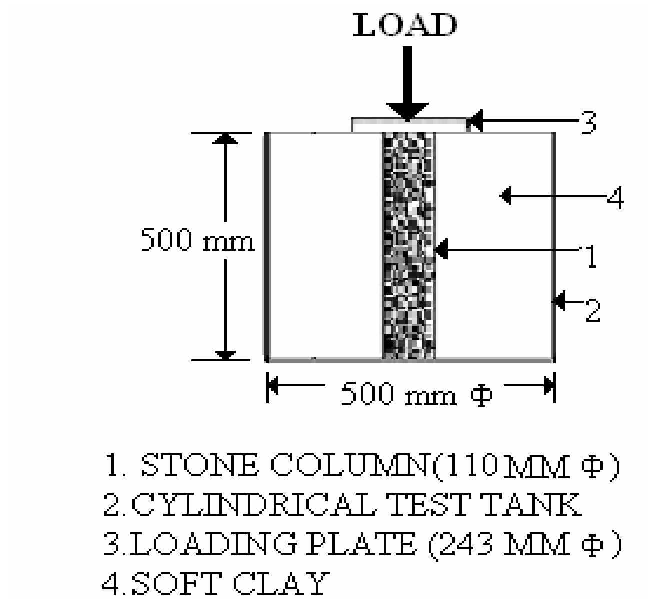

Fig 1 Schematic Sketch of Test Set Up

Load test were carried out on single columns of 110 mm diameter. Loading was done on a plate of 243 mm diameter, which was 2.2 times the diameter of the single column, placed over the clay filled in the tank of size 500 mm diameter and 500mm in height. Loading was done over clay alone, clay stabilized by stone column and clay stabilized with stone column encased within geotextile of the same diameter as that of the stone columns alone. The load was applied through a proving ring at a maintained rate of 1.2 mm/min and the settlement of the plate was recorded by means of two dial gauges set diametrically opposite.

Fig 2 Photograph of the Test Set-up

RESULTS AND DISCUSSION

Effect of stone column without geotextile

Pressure settlement response of clay bed and stone column without geotextile are shown in Fig.3.

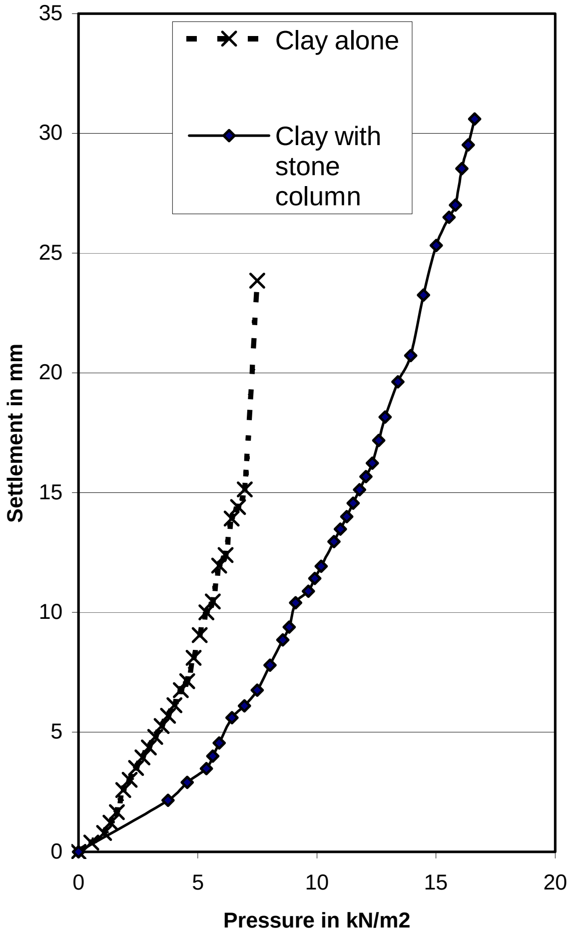

Fig. 3 Effect of Stone Column

The load bearing capacity of clay soil is increased by 74% due to the installation of stone column for 10 mm settlement whereas the ultimate load capacity of clay soil is increased by 52%.

From pressure settlement curve of stone column, initially stone column bears the load and after bulging settlement increases rapidly.

Effect of geotextile

To keep the stones of the column intact, the column is covered with geotextile and the stone column is encapsulated by the geotextile. Pressure settlement response of clay bed with stone column encased with geotextile is shown in Fig. 4.

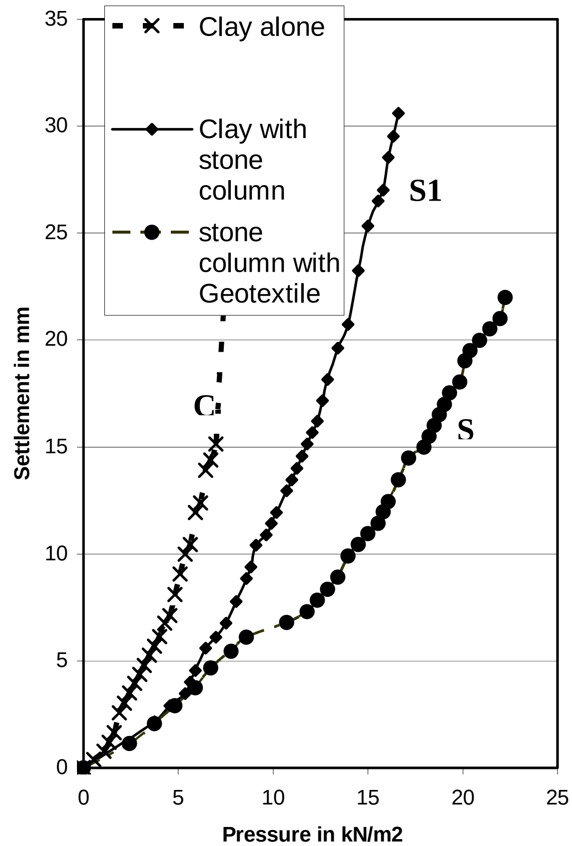

Fig. 4 Effect of Geotextile encapsulated stone column

In the Fig. 4, C represents the experiment with Clay soil alone, S1 represents the experiment with stone column without geotextile and S represents the experiment stone column with geotextile. By using geotextile the load bearing capacity of stone column (S1) is increased by 21% for the 10 mm of settlement and ultimate bearing capacity also increased by 60% compare to that without geotextile. Initially stone column bears load, as load increases bulging occurs in stone column but in case of encapsulated stone column bulging reduces hence the ultimate load and settlement improves.

Effect of Quarry dust

The stone chip in the stone column is replaced by quarry dust with varying proportion in order to reduction the cost of the stone column. The percentage of quarry dust varies as 30 %, 50% 70%, 100%. The pressure settlement behavior for column is as shown in Fig. 5.

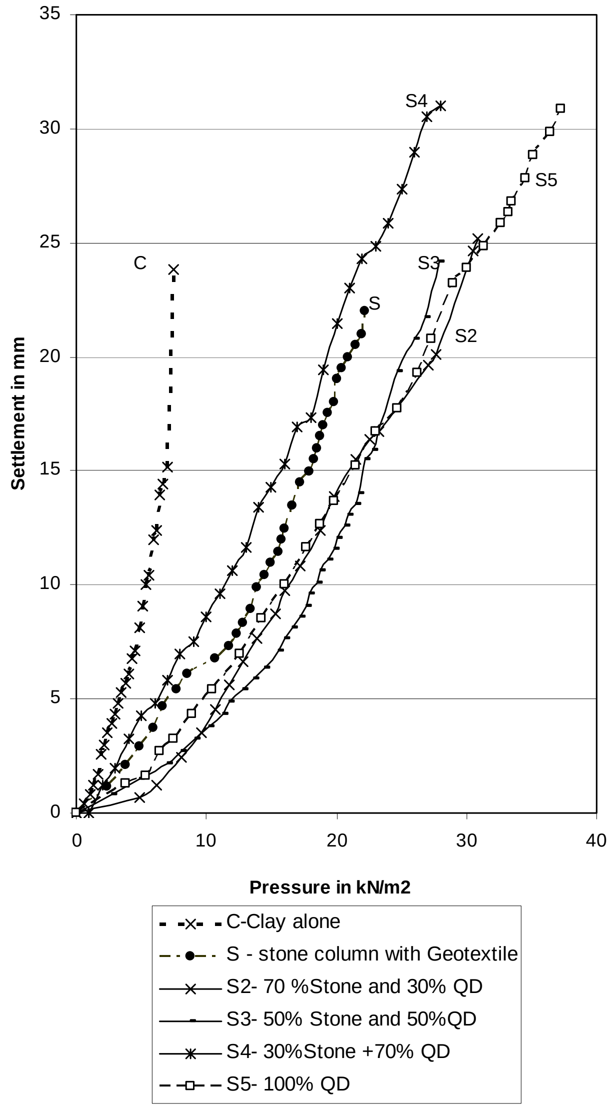

Fig. 5. The effect of various proportion of Quarry dust

In the figure 5, S5 represents the experiment with 100%quarry dust, S4 represents the 30% stone and 70% quarry dust , S3 represents the 50% stone and 50% quarry dust , S2 represents the 70% stone and 30% quarry dust and S represents the 100% stone inside the stone column.

Load bearing capacity for the system corresponding to the test conditions for S2, S3 and S5 were increased by 21%, 29.5%, 13.14% respectively when it is compared to S (100% stone enclosed in geotextile), for 10mm settlement. For the case of S4, a small reduction in capacity is observed with respect to other values, as can be observed from Table 4. The increment in the load bearing capacity is may be due to fill of void by quarry dust. But there is a very small difference in the ultimate load capacity due to varying proportion of quarry dust in stone column with geotextile.

Table 4 Results for Various Proportions of Quarry dust in stone column

Proportion of column	Pressure at 5 mm settlement (KN/m²)	Pressure at 10 mm settlement (KN/m²)	Ultimate load capacity (KN/m²)
C	3.34	5.36	7.10
S1	6.37	9.30	10.60
S	7.25	14.20	17.00
S2 S 70%+ Q 30%	11.8	17.15	18.60
S3 S 50% + Q50%	12.07	18.40	17.40
S4 S 30%+ Q 70%	6.0	11.2	16.50
S5 Q (100%)	9.847	16.067	17.50

CONCLUSIONS

The use of stone column is accepted as a means for ground improvement in soft clayey soils. The cost of construction mainly depends on the cost of stone using for filling the stone column. Here an alternative is thought of, to replace partially, the stones filling the column by cheaper materials. The following observations could be made from this study.

- Stone column improves the bearing capacity and settlement behavior of soft soil.
- Encasing the stone column with geotextile result in an increase in load carrying capacity and reduction in settlement when compared to that with the case without geotextile.
- A portion of stone in the column can be replaced by quarry dust without affecting the strength of the improved ground
- From the studies it is revealed that the replacement of 30% (by weight) of stones by quarry dust can be possible without affecting the strength and performance of the system.
- Further studies in this direction have to be conducted so as to get more understanding of the system specially in the context of liquefaction.

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