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An Experimental Study on Performance of Stone Column in Layered Soils through Unit Cell Concept

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ABSTRACT

Improvement of ground is necessary every now and there in projects. Due to rapid growth of population and urbanization, demand for land has been increased abundantly. Because of this land scarcity high raised buildings are constructed in less areas. Due to this heavy constructions the amount of load transferred to soil increases which results in requirement of higher bearing capacity of soil.

Stone column is one of the widely used technique. Stone column method is used to densify the soft clays. It involves adding vertical column into the ground to a depth of at least 4m below the ground surface. A layer of compacted gravel can then be put over the top of the columns. The thickness of top layer considered for study are 2mm, 4mm, & 6mm, of stone column for the optimum value among the above patterns is studied with different diameters of stone column.

KEYWORDS: *Ground Improvement, Bearing Capacity, Stone Column, Model Tests.*

I. INTRODUCTION

India, where the modern generation is claiming a fast and imperative infrastructure development for the overall development of the nation, there is a need to expand the construction activities in a large scale. Hence, now a days the construction activities have been expanded to the zones with poor subsoil condition also. The use of land in such weak strata challenges geotechnical engineers by the presence of various problematic soils with various different engineering characteristics. Pile foundations can be used in large scale projects but in case of small-scale projects where the soil can have some settlement an alternative technique is needed for improving the ground characteristics. The type of soil plays a major role behind the mechanics of ground improvement. A method for increasing the strength of the weak foundation soil is the inclusion of cylindrical columns which are made up of a material having higher strength characteristics.

Due to rapid development of infrastructures availability of suitable construction sites is decreasing day by day. Therefore, the use of marginal sites and weak soils for construction of civil structures has become inevitable. Among a variety of methods used for the ground improvements, stone columns are widely used to improve the bearing capacity of very soft or soft soils and to reduce the total and differential settlements of the super structures. Stone columns are successfully used to support the earthen embankments, raft foundations to increase the stability of slopes and to reduce the liquefaction

potential of loose cohesion less soil. Stone columns acts as a effective ground treatment method because of three primary reasons. First it acts as a stiffer medium and increases the load bearing capacity and It also accelerates the rate of consolidation and reduces the post construction settlements. Third, radial deformation and subsequent increase in the lateral earth pressure co-efficient of the surrounding soft clay occurs the installation of stone columns.

Ground improvement is the modification of soil in foundation so as to provide better efficiency under design and operation loading conditions at the construction operations. These characteristics may be shear strength, swelling and shrinkage characteristics and bearing capacity. There is an increasing use of these techniques in the construction industry where the soils are having poor subsurface conditions. The ground improvement has been of great concern since early times.

1.1 Methods of ground improvement techniques

- Soil improvement using additives
- Soil improvement using mechanical methods
- Soil improvement without using admixtures
- Soil improvement using thermal methods
- Other methods

In all these methods soil improvement using mechanical method is being densified using rollers and vibrators by applying a compressive force on the given soil. In these the mostly used technique is stone

1.2 Stone column

Stone column technique was used first in France in 1830s, the wide range of use of this technique spread especially in Europe since 1950s.Stone column technique decreases the compressibility of soft and loose fine graded soils leading to increase in strength , accelerates consolidation effect and reduces the liquefaction potential of soils. Stone columns are more preferable than sand drains because of there granular nature which provides additional shear strength to the surrounding soils. They are mainly used for stabilization of soft soils such as soft clays, silts and silty-sands. Stone columns are installed using either top or bottom feed systems, either with or without jetted water. Most widely used methods for installation of stone columns are: Vibro-Replacement (wet, top feed method) Vibro-Displacement (Dry, Top and bottom feed method)

1.3 Stone

Stone : crushed stone aggregates of size 10-1.1.8mm were used to form the stone column.

The mixture of the aggregate is classified as poorly graded gravel or GP as per IS classification. The maximum and minimum dry density of the stone aggregates are 17.1 and 14.9 kN/cu.m respectively. Angle of internal friction of the stone aggregates was determined by carrying out a series of direct shear tests at a relative density of 60% on a box at a constant rate of 1.255mm/min under the normal pressure of 100, 150, 200 and 300 kpa to determine its angle of internal friction.

II. Literature Review

Al-Waily et al (2012) investigated the group efficiency of 16 models of lime and stone column installed in soft clay. The group efficiency of stone column is defined as the ratio between the city of each stone column in group to the capacity of single column(lime or stone). The total of 16 model tests of soil treated with stone and lime columns were carried out in cylindrical container to study the efficiency of stone column groups beside two mode tests of untreated soil for comparison purpose. The diameter of test column was 30mm and the length to diameter ratio of the column was taken as equal to 9. The soil used was inorganic sandy silty clay and the crushed stone used as the backfill material for stone column,while the natural calcium carbonate was used as a back fill material for columns. The test tank has a height of 350mm and diameter of 300mm and made of steel plate of thickness 6mm. the thickness of soil bed inside the container was 270mm. the foundation square plate have 120mm of side length and 5mm of thickness.

Ambily and Gandhi (2007) studied stone columns improved ground mainly due to higher stiffness of the columns compared to the soil, hence the most critical factor which controls the design of the stone column improved ground is the stiffnessofthecolumnandloadbetweencolumnandsoil.Thispaperdealswithdevelopingadesignprocedure considering load sharing between columns and soil. The behavior of interior stone columns among a group of large number of stone columns are analysed by varying parameters like spacing between the stone columns, shear strength of the clay, angle of internal friction of stone, sharing etc.

Malekpoor and Poorebrahim (2011) conducted large scale laboratory model tests to

investigate the behavior of Compacted Lime-soil (CL-S) rigid stone columns in soft soils. The unit cell idealization is used for construction of composite specimens to evaluate the influence of different perimeters such as the diameter of the column (D), the slenderness ratio (L/D) and the area ratio (Ar).

Shahu and Reddy (2011) conducted studies on stone columns are used for the settlements and support structures which may tolerate some settlement (structures like storage tank, abutment, embankments etc.). They are constructed either fully penetrating or as a footing column physical modeling plays a fundamental role in development of geotechnical understanding. Model test provide an alternative way to directly reflect the behavior of prototype under simulated conditions which are used for validation purpose. Actual loading conditions of prototype resemble more to the load-controlled loading.

III. METHODOLOGY

3.1 Collection of Soil

The soil samples were collected from surroundings of Rajahmundry.

3.2 Determination of Soil Properties

The tests conducted for determining the properties of soil are Sieve Analysis, Liquid Limit Test, Plastic Limit Test, Specific Gravity Test, Unconfined Compression Test, Standard Proctor Test.

3.3 Model Test

The test planned for finding out the behavior of stone column are given in the Table below

Fig1 placing of stones inside the bored hole

Fig2 placed stones into the soil bed

Fig3 Model testing

Fig4 Stone column after model test.

Table1: Schedule of laboratory model test

Type of column test	Test performed
Soft clay of 2cm over stiff clay + stiff clay of 2cm over soft clay + optimum diameter of 3mm	√
Soft clay of 4cm over stiff clay + stiff clay of 4cm over soft clay + optimum diameter of 4mm	√
Soft clay of 6cm over stiff clay + stiff clay of 4cm over soft clay + optimum diameter of 5mm	√
TOTAL	**9**

IV. Physical Modeling

Evaluating the behavior of soil can be done through physical modeling methods. Since finite element is completely based on the values of the modulus of elasticity, cohesion and angle of internal friction, elasticity value may change from place to place. A physical model is required for obtaining and checking the real behavior of soil in site. For this physical modeling in small scale, steel moulds are used. Dimensions of the model are 14.8cm of diameter and 17.5cm of height. A steel tube sampler of 4cm diameter has been used for boring and making columns. Which by application of force, penetrates into the soil bed while removing comes out with, making a hole in the clay bed prepared

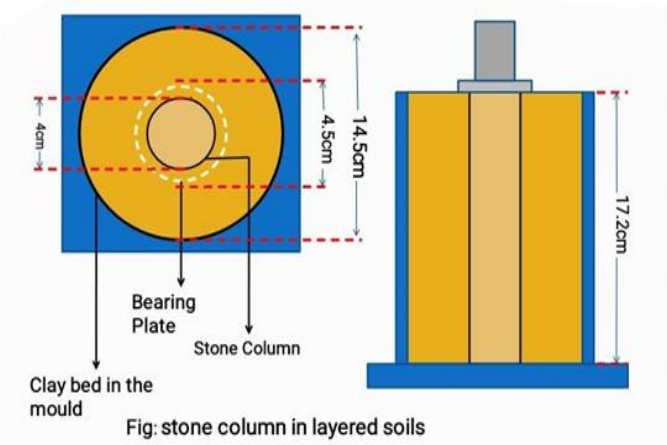


Fig5 Stone column in layered soil

V. Results and Discussions

Physical Modeling Results

A total 9number of model tests were performed as discussed. This section shows its results. Preliminary tests were conducted on soil and its results are discussed below.

The properties of soil found out in laboratory are given below.

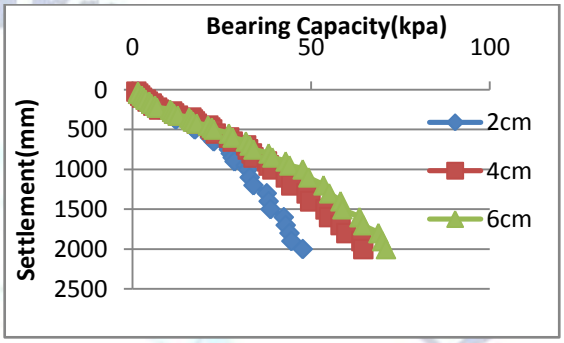
TABLE2: PROPERTIES OF SOIL

Sieve analysis	Soil
Liquid limit (%)	37
Plastic limit (%)	22
Gravel+ sand (%)	34.5
Silt+ clay (%)	65.5
Specific gravity (%)	2.45
Plasticity index	15
OMC (%)	17
MDD (g/cm³)	1.75
Soil classification	CI

Model Test Results:

Comparative study of soft clay over stiff clay:

From the obtained results a comparative study by varying top layer is presented below. With increase in length of soft clay, Bearing Capacity value increases. Bearing Capacity vs Settlement curves for this comparison is plotted in the figure below. Further the Bearing capacity at 20cm Settlement is Compared in the Table



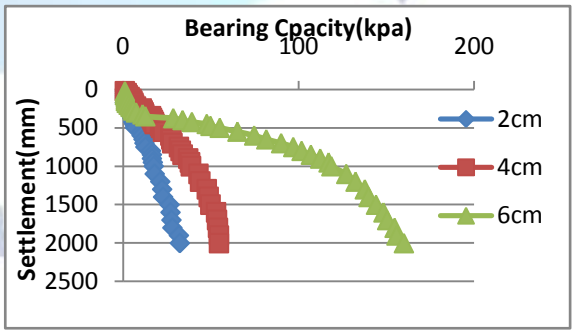
Graph1 :Comparative study of soft clay over stiff clay

Table3: Observation on soft clay over stiff clay

Type of column	Bearing capacity at 20cm settlement
Soft + 2cm	47.660 KN/m²
Soft +4cm	64.605 KN/m²
Soft + 6cm	70.9605 KN/m²

Comparative study of stiff clay over soft clay:

From the obtained results a comparative study by varying top layer is presented below. With increase in length of soft clay, Bearing Capacity value increases. Bearing Capacity vs Settlement curves for this comparison is plotted in the figure below. Further the Bearing capacity at 20cm Settlement is Compared in the Table



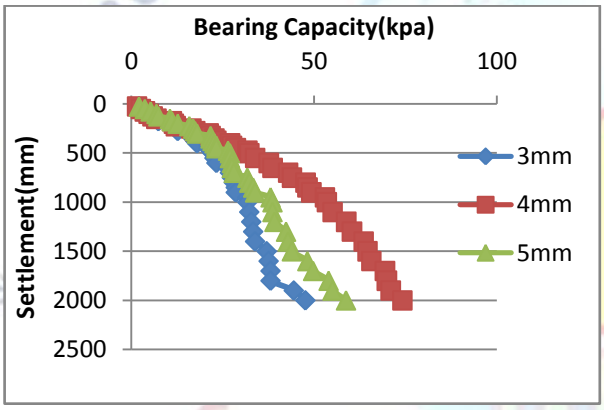
Graph 2: Comparative study of stiff clay over soft clay

Table4: Observations of stiff clay over soft clay

Type of column	Bearing capacity at 40mm settlement
Stiff + 2cm	32.302 KN/m²
Stiff +4cm	54.544 KN/m²
Stiff + 6cm	159.92 KN/m²

Comparative study of layered soils in variable diameter:

From the obtained results a comparative study by varying top layer is presented below. With increase in length of soft clay, Bearing Capacity value increases. Bearing Capacity vs Settlement curves for this comparison is plotted in the figure below. Further the Bearing capacity at 20cm Settlement is Compared in the Table



Graph 3: Comparative study of layered soils in variable diameter

Table5: Observations of layered soils in variable diameter

Type of column	Bearing capacity at 40mm settlement
Optimum dia + 3mm	47.660 KN/m²
Optimum dia + 4mm	58.780 KN/m²
Optimum dia + 5mm	74.137 KN/m²

VI. CONCLUSION

Following are the conclusions obtained from experimental studies, -

- In the model study of soft over stiff the value of bearing capacity increased in the model of 6cm soft clay over stiff clay.
- In the model study of stiff over soft clay the value of bearing capacity increased in the model of 6cm soft clay over stiff clay.
- In this particular study from 4cm to 6cm there is huge amount of increase in bearing capacity by increasing diameter in this model.
- In the model study of variable diameter in layered soils the value of bearing capacity increased in the model of 6cm soft clay over stiff clay.
- From the overall experimental results, we can say that increasing the stiff clay at certain amount is able to improve the bearing capacity of the soft clay of stone column.

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