EXPERIMENTAL STUDY ON STRENGTH OF CLAYEY SOIL WITH SOIL CEMENT AND SOIL LIME COLUMNS

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Abstract - Soil cement and soil lime columns have been widely used to improve soft soil for constructions of highway embankments, seawalls, and building foundations. The advantage of this method is that it not only improves the strength of ground, but is a superior method for the limitation of settlement. For present study clayey soil with or without soil cement and soil lime columns are studied. Experimental model study was conducted with soil cement and soil lime columns of different area replacement ratio and end conditions. It is inferred that the end bearing column with area replacement ratio 0.197 with diamond pattern have better load carrying capacity. Bearing capacity of soil cement column was found to be 25% more than that of soil lime column. The results shows that when area replacement ratios are large, settlement values are very low.

Key Words*: Clayey soil, Lateritic Soil, Load Settlement Curve*

1. INTRODUCTION

The need for ground improvement technique is to develop engineering properties of weak soils which then provide stability and required bearing capacity. Many types of stabilization techniques are employed for improvement of bearing capacity of ground. Deep mixed column method is employed for reinforcing the soil. Some of the key benefits of this technique are, it is economical, vibration free, flexible in application, reduces construction time and is environment friendly method and some of the typical applications of this method are, embankments on soft soils, bridge foundation and wind turbine foundations, slope stabilization, cut-off walls and barriers. In the region where Clayey soil is available, lateritic soil is used to build embankment, large amount of lateritic soil is used in replacing the existing soil to required depth, or to build new embankment. Soil replacement method is applicable when required embankment depth is very low, in this case deep mixed column technique can be used which is effective and efficient.

1.1 DEEP MIXED COLUMNS

Deep mixed column (DMC) is a stabilization technique which uses cement and other adhesive admixtures as stabilization agent for improving bearing capacity of soil. Weak soil improvement using deep mixing method depends on type of soil and binder type, water-cement ratio, binder content and area replacement ratio on the properties of improved ground. The experimental model study is conducted on soil cement and soil lime columns to check whether the traditional pile foundation can be replaced by this method.

1.2 SOIL COLUMNS

Soil columns are formed by the mechanical blending of soil with cementitious materials to form a soilcrete mixture with increased shear strength, reduced compressibility, reduced permeability and other improved properties. Many structures such as embankments, tanks, commercial/industrial buildings and port facilities can be economically supported by soil mix columns. Soil mix columns can be used to stabilize slopes and levees, create in-situ gravity retaining structures, and can greatly reduce lateral loads on bulkhead walls. Soil mixing can also be used to facilitate tunnel construction and to minimize the impact that the tunnelling may have on nearby structures. Deep soil mixing construction is most often provided on a design and build basis. As part of the design process, soil borings are conducted, and various laboratory mix designs are developed to achieve the required compressive strength and other design requirements.

1.3 Area replacement ratio (Ar)

Area replacement ratio is defined as the ratio of area of soil column to the area of footing. Area replacement ratio is an important parameter in case of composite foundation.

1.4 SCOPE

- Inclusion of Soil cement and soil lime columns can improve long term performance of clayey soils and can replace the traditional pile foundations.
- Offer a cost-effective method for strengthening weak soil.

2. LITERATURE SURVEY

Huu et al (2018) conducted the study on **Lateral Loading Test Results on Single and Groups of Soil-Cement Columns.** This paper described the lateral loading test results on single soil-cement columns and groups of soil- cement columns for supporting foundation of high-rise buildings. The soil profile consists of a silty sand layer with 9 m thickness and underlain by clay layer. The soil-cement columns were

600-mm diameter and constructed into 7m depth below ground surface by deep wet mixing method. Twenty days after construction, the static loading tests were performed on two single columns, the 3-column group and the 5-column group.

Rashid et al (2018) studied the **SettlementEvaluationof Soft Soil Improved by Floating Soil Cement Column**. Construction on soft grounds requires implementation of a ground modification technique to improve the soil strength. The soil improvement methods include densification, reinforcement, use of chemical stabilizers, mechanical stabilization, and preloading. In this study the soft ground model was prepared by using brown kaolin. The test results provides compelling evidences for the potential applications of soil- cement columns in supporting foundation of high-rise buildings for the in sand geology areas.

Esmaeili et al (2016) evaluated the **Mechanical behavior of embankment overlying on loose subgrade stabilized by deep mixed columns.** In this study three laboratory models were constructed in order to conduct the loading test on the railway embankment. The first model consisted of the embankment of 20 cm height, 250 cm length, and 93% maximum dry density, achieved in standard Proctor compaction test, overlying on loose sand with 70 cm thick and 50% relative density. The results show that the role of central columns was more significant than that of the mid and side columns in terms of carrying the applied load.

Yao et al (2016) studied the **Settlement evaluation of soft ground reinforced by deep mixed columns.** According to the similitude theory, a 1-g physical model test for soft ground with deep mixed columns was conducted. The effect of column length, area replacement ratio and surcharge load on foundation settlement was investigated. The column length was varied from 40 cm to 100 cm while the area replacement ratio was changed from 0.023 to 0.093. For the area replacement ratio of 0.093, the settlement of foundation with 10 m column is less than 50% that of foundation with 4 m column.

Rayamajhi et al (2015) studied the **Dynamic Centrifuge Tests to Evaluate Reinforcing Mechanisms of Soil-Cement Columns in Liquefiable Sand**. Liquefaction of cohesionless soils and liquefaction-induced deformations lead to significant damages to foundations of buildings, bridges and other structures during earthquakes. Liquefaction can be remediated by densification of in-situ soils (e.g., using stone columns, deep dynamic compaction, vibro-compaction, compaction piles), providing shorter drainage path for faster excess pore water pressure dissipation (e.g., using gravel or prefabricated drains), reinforcing the soil to reduce the seismic stresses and strains in soils (e.g., using stone columns, cement soil mixing, jet grouting), or removing and replacing the liquefiable soils with competent soils. Soil-cement columns continue to provide effective support for structural foundations after liquefaction is triggered in the surrounding soils, provided the columns are not damaged during strong shaking and extend to firm soils below the depths of liquefaction.

Archeewa et al (2015) Studied the Numerical **Model Studies of Deep Soil Mixing (DSM) Column to Mitigate Bridge Approach Settlements**. The settlement and/or heave related movements of bridge approach slabs relative to bridge decks usually create a bump in the roadway The differential settlement between bridge approach and bridge deck is a common occurrence and can be considered as a major problem to state highway agencies nationwide. The differential settlement at the bridge approach causes not only disturbance to passengers, but also increase the cost of maintenance and repair of the distressed approach slabs. The model also revealed that the area ratio between the treated soil by DSM and a unit cell area has a significant influence when the ratio is less than 0.6. Although the area ratio plays important role to reduce the settlement, it should be noted that the effect of area ratio on the settlement is only significant.

Shao et al (2014) studied the **heavy structures supported by soil cement columns (SCC)** .Deep soil mixing and jet grouting have been widely used for supporting heavy structures such as tanks, cement silos and storage buildings. Heavy structures may apply high soil pressure over very large areas and often requires deep foundations or site ground improvements for support. Deep foundations for these applications become very costly. Deep mixing and jet grouting are two ground improvement techniques that have been used to provide necessary bearing capacity. The design assumed load transfer through the soil mix columns and vibro replacement stone columns. Due to this soilcrete columns and vibro replacement stone column the load carrying capacity of the foundation can be increases and settlement reduced.

3. METHODOLOGY

3.1Materials

3.1.1 Clayey Soil

The soil sample was collected from chengalam, at Alappuzha, Kerala state India. The sample was black coloured clay with a glowing texture. The sample was collected from a construction site from a depth of around 4 to 5 m below ground level. An air tight container was taken and the sample was stored in it to determine the initial moisture content.

Fig 3.1 Clay sample

3.1.2 Laterite Soil

Laterite is a *soil*, which is rich in iron and aluminium and is commonly considered to have formed in hot and wet tropical areas. Nearly all *laterites* are of rusty-red coloration, because of high iron oxide content. They develop by intensive and prolonged weathering of the underlying parent rock. The sample was collected from kottayam.

Fig 3.2 Laterite soil

3.1.3 Cement and lime

Ordinary Portland cement and lime were used as binding agent. These binding agents helps to create bond between soil and water. The amount of added lime were taken as 6% based previous study *(sho et al (2016)).*

4. SAMPLE PREPARATIONS

Soil cement and soil lime columns were prepared by mixing the soil cement/ lime and water in required quantity. It is a compacted mixture of these materials. Columns of different length may prepared separately. 15 cm length and 30 cm length column prepared initially. The quantity of material required for each column can be calculated separately.

4.1 Laboratory Model Testing

Collected clayey soil and lateritic were subjected to soil tests. Laterite soil sample was treated with required quantity of cement and lime. Deep mixed columns of cement and lime were prepared of dimensions 2.5cm diameter and 15 cm & 30 cm height. The columns are considered as floating and end bearing columns. These columns were kept in air tight container for curing periods, and then were placed in tank filled with clayey soil.

Plate load test were conducted in a steel tank with dimension of 60cm* 60 cm with height of 80cm. Taking care of confinement effect the testing tank is taken sufficiently large. Mild steel footing model of size 10cm*10cm with 6mm thickness is placed centrally in tank filled with clayey soil to determine load carrying capacity of clayey soil reinforced with columns of laterite soil. Load carrying capacity of columns of cement and lime were compared.

Table 3.1 Design of soil cement column

Column length	Floating columns	End bearing columns
Volume of mould (Cm^3)	49.08	73.63
Weight of soil (kg)	0.0935	0.140
Weight of water (kg)	0.0117	0.0176
Weight of cement (kg)	0.014	0.022

Table 3.2 Design of soil lime column

Column length	Floating columns	End bearing columns
Volume of mould (Cm^3)	49.08	73.63
Weight of soil (kg)	0.561	0.8448
Weight of water (kg)	0.0561	0.08445
Weight of cement (kg)	0.033	0.0506

4.2 Floating and End bearing columns

The plate load test were conducted with different area replacement ratio having floating and end bearing columns. Floating columns are defined as the column having smaller length as compared with clay bed. Floating columns are not touched at the end of clay bed. The load carried by the column and then transferred to the clay bed. End bearing columns are defined as the column having equal length of clay bed that is the column touches the clay bed.

4.3 Column Arrangements

The experimental model study was conducted at different end conditions with varying column arrangements. The column arrangements are closely related to the area replacement ratio. The two end conditions of columns were studied. They are

1. Floating columns

2. End bearing columns

The columns are arranged in clay bed with different area replacement ratio and also the square and diamond pattern with same area replacement ratio were compared. Different column arrangements are shown in figure 4.1

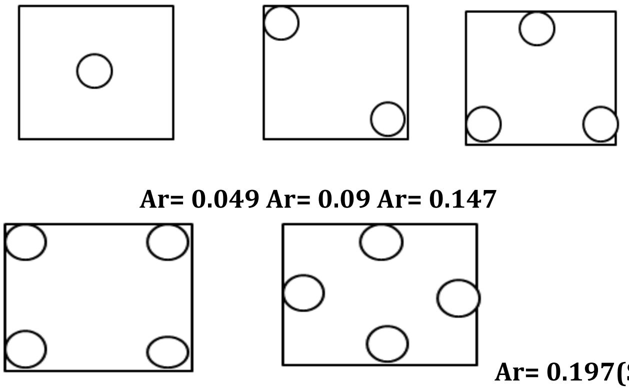


Fig 4.1 Column Arrangements

5. EXPERIMENTAL INVESTIGATION

The strength of the soil cement and soil lime columns were determined by tri axial test. The shear strength parameters cohesion (c) and friction angle (Φ) can be determined by different laboratory tests for different types of soils. A model tank with required dimensions (50mmx50mmx60mm) and loading arrangement has to be fabricated for the present study. Model plate load tests are going to perform on rectangular footings. Footings has to be fabricated from metal plates. The initial tests has to be performed on the soil samples to determine the specific gravity moisture content, gradation, optimum moisture content, dry density. The initial tests has to be performed on the soil samples to determine the specific gravity moisture content, gradation, optimum moisture content, dry density. The model tank (Figure 4.2) has to be rigid in nature, so that it won't undergo any deformations during filling.

Fig 4.2 Test set up

6. RESULTS AND DISCUSSIONS

6.1 PROPERTIES OF CLAY

The basic properties of the soil sample taken were determined. The properties of clayey and lateritic soil determined for the preparation of clay bed. The index properties and engineering properties of the untreated soil sample is calculated. The calculated soil properties are shown in table 6.1

Table 6.1 Soil properties

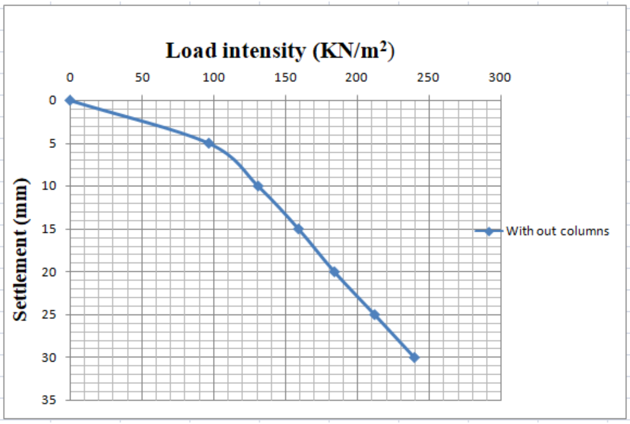
Description	Clayey Soil	Lateritic Soil
Water Content	81%	17%
Specific Gravity	2.49	2.6
Liquid Limit	82%	46%
Plastic Limit	34%	31%
Shrinkage Limit	17%	11 %
% 0f gravel	0	6
% 0f sand	0	44
% 0f silt	12	37
% 0f clay	78	13
Soil Classification	CH	MI-SC

6.2 Plate Load Test results

6.2.1 Bearing capacity of plain clayey soil

Bearing capacity unreinforced clayey soil can be determined by conducting plate load test on plain clayey soil. The bearing capacity soil without reinforcement is approximately 100 KN/m^2.

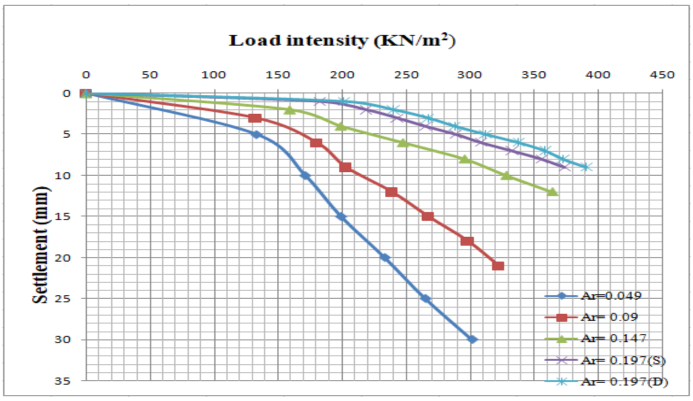
Chart-1: Load intensity V/s settlement curve for plain clayey soil



6.2.2 Bearing capacity of floating SCC with different area replacement ratio at immediately after preparing.

Bearing capacity of soil cement columns can be obtained from load settlement curve. From this curve the ultimate load carrying capacity can be obtained. Prepared floating soil cement column have inserted in to the clayey soil and maximum bearing capacity of 220KN/m² can be obtained for area replacement ratio of 0.197 with diamond pattern.

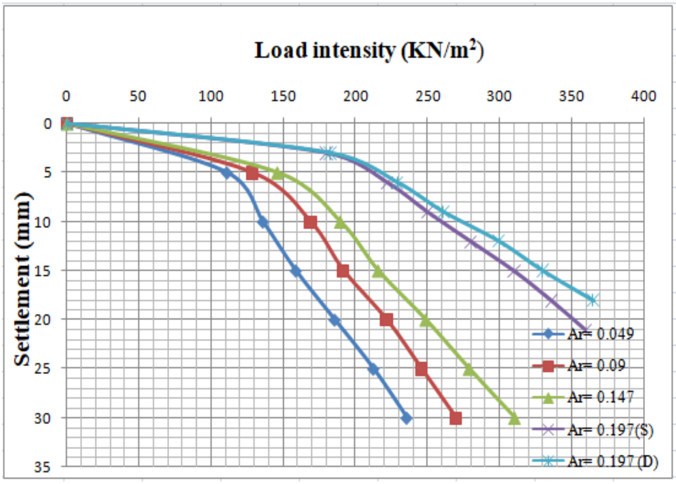
Chart-2: Load intensity V/s settlement curve for Floating SCC with different Area replacement ratio



6.2.3 Bearing capacity of floating SLC with different area replacement ratio at immediately after preparing.

Bearing capacity of soil lime columns can be obtained from load settlement curve. Prepared floating soil lime column have inserted in to the clayey soil and maximum bearing capacity of 190KN/m² can be obtained for area replacement ratio of 0.197 with diamond pattern. By comparing square pattern and diamond pattern with same area replacement ratio, the diamond pattern have better load carrying capacity.

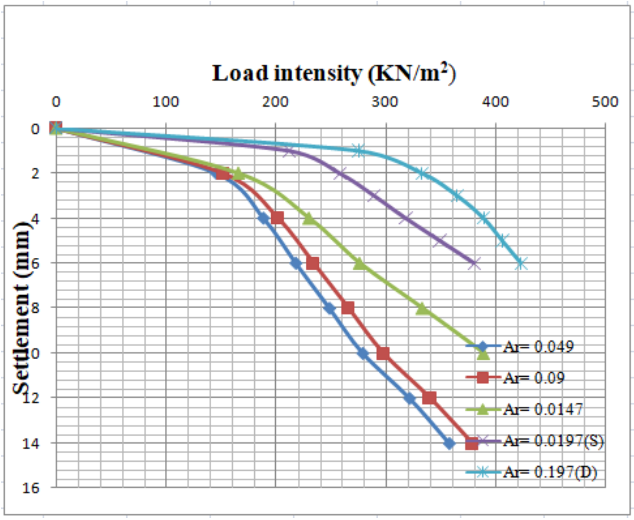
Chart-3: Load intensity V/s settlement curve for Floating SLC with different Area replacement ratio



6.2.4 Bearing capacity of End bearing SCC with different area replacement ratio at immediately after preparing.

Bearing capacity of soil cement columns can be obtained from load settlement curve. From this curve the ultimate load carrying capacity can be obtained. The end bearing columns have touched at the bottom of the column and the load transferred by the end bearing action. This end bearing columns have better load carrying capacity than floating columns. Prepared End bearing soil cement column have inserted in to the clayey soil and maximum bearing capacity of 280KN/m² can be obtained for area replacement ratio of 0.197 with diamond pattern. By comparing square pattern and diamond pattern with same area replacement ratio, the diamond pattern have better load carrying capacity.

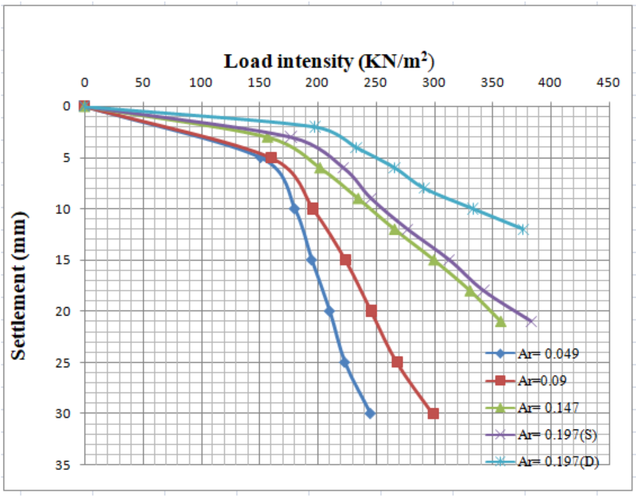
Chart-4: Load intensity V/s settlement curve for End bearing SCC with different Area replacement ratio



6.2.5 Bearing capacity of End bearing SLC with different area replacement ratio at immediately after preparing.

Bearing capacity of soil lime columns can be obtained from load settlement curve. Prepared floating soil lime column have inserted in to the clayey soil and maximum bearing capacity of 240 KN/m² can be obtained for area replacement ratio of 0.197 with diamond pattern. By comparing square pattern and diamond pattern with same area replacement ratio, the diamond pattern have better load carrying capacity.

Chart-5: Load Intensity V/s settlement curve for End bearing SLC with different Area replacement ratio



6.2.6 Comparison of different end conditions of SCC and SLC with different Ar=0.197(D)

By comparing the end condition of soil cement column the end bearing soil cement column have higher bearing capacity than floating soil cement column. The floating soil cement column have bearing capacity of 220KN/m² and end bearing soil cement column have 280KN/m². The floating soil lime column have bearing capacity of 190KN/m² and end bearing soil lime column have 240KN/m². By comparing these bearing capacity the end bearing column have more bearing capacity as in the case of both cement and lime column. For same area replacement ratio soil cement column with end bearing have better load carrying capacity.

Chart-6: Load intensity V/s settlement curve for SLC with different end conditions

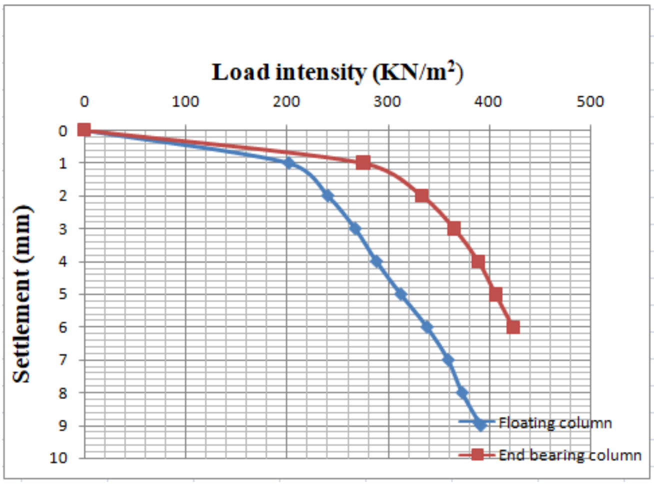
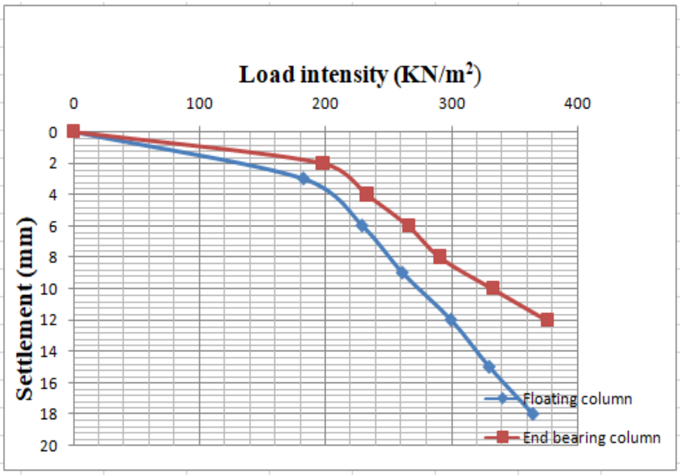


Chart-6: Load intensity V/s settlement curve for SCC with different end conditions



7. CONCLUSIONS

Following conclusions are observed from experimental work;

- For plain Clayey soil, bearing capacity of 100KN/m² were observed .
- The bearng capacity of soil cemment and slc were found maximum for area ratio of .197 and diamond pattern.
- Bearing capacity of soil cement column was found to be 25% more than that of soil lime column.
- End bearing columns have better load carrying capacity compared flc.

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