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IMPROVEMENT OF COHESIVE SOILS BY USING STONE COLUMNS

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***Abstract*— Soil being natural and non-manufactured material has proven itself to be most potentially problematic and complex materials to tackle with. The complexity does not arise only because of soil as a material, but also by the fact that various methods to characterize the soil for estimations of constituents, behavior and strength are potentially difficult. In this paper , a study on the effect of stone columns on the behaviour of cohesive soils has been done, it was found that the installation of the stone columns plays a very significant role in improving the bearing capacity of the cohesive soils. The main improvement in cohesive soils takes place by virtue of densification while inserting the stone column, the increase in drainage also plays a great role. The length of the stone columns was found to greatly influence the behaviour of the improvement of the soils. The improvement is very significant for a length of 1B where B is the width/diameter of the footing.**

***Index Terms*— Cohesive, problematic, stone column, improvement.**

I. INTRODUCTION

The degree of improvement of a soft soil by stone columns is due to two factors. The first one is inclusion of a stiffer column material (such as crushed stones, gravel, and so alike) in the soft soil. This is largely reported in the literature [1][2][3][4][5][6]. The second factor is the densification of the surrounding soft soil during the installation of the vibro-compacted stone column itself and the subsequent consolidation process occurring in the soft soil before the final loading of improved soil. The experimental work performed by Wattes et al.[7], and Vautrain [8] verifies that the installation of vibro-compacted stone columns leads to an improvement of the in-situ soft soil characteristics and consequently, enhances the load displacement response of the reinforced soil.

In addition, from field observations, it was reported the mechanical characteristics (Young modulus, undrained cohesion, etc.) of the in situ soft soil surrounding stone columns were much higher than those measured before treatment. For examples measured undrained shear strength values were provided by Vautrai[8], and recorded measurements at the vicinity of the column at various depths of the surrounding soft clay were reported by Al-Khafaji and Craig[9]. Alamgir and Zaher [10] and Sanglerat [11] illustrated, in natural and reinforced soft ground, that the standard penetration resistance of the soft ground has been increased significantly after a stone column installation. N-value ranges from 2 to 7 for natural ground but it increases from 5 to 12 in the reinforced soft ground. A significant increase, averaging three times pre-treatment values in number of blows, was measured in a cohesive soil at one meter distance from the column centre, Wattes et al.[7]. Also a higher increase happened within a granular soil in similar conditions. Vane test results recorded before and after an embankment construction on soft clay rein- forced by columns showed up similar improvement of soft soil characteristics [12]. From measurements recorded at different distances from the column centre it has been checked the decrease of column installation effect as the radial distance increases. Greenwood [13] proposed an empirical design method for estimating the reduction of settlement of rein- forced soil taking into account the installation process of stone columns.

Given the problematic and complex nature of soil, the soil engineering as a practical science has addressed the engineering behavior of soil more seriously and it has taken a real commendable effort to develop unifying concept of understanding which still involves recognizing the uncertainties and applying appropriate conservation's and safety factors. Further also having good sense and ability to predict and calculate risk and behavior of soil, the accuracy of soil science cannot be overestimated and we still need to maintain a healthy sense of skepticism in our way of approach to geotechnical problems. With all efforts and procedures of soil characterization and strength determination apart from the testing and classification of various types of soils, it has been observed that as far as strength aspect is concerned, soil is mostly recognized as weak material. Soil therefore has provided a clear way and wide scope for improvement in its strength, which seems to be inevitable in some cases. Generally the improvement procedure is taken under a heading of Ground Improvement Technique or Soil Strengthening and has emerged as separate and still developing field in soil engineering. With large number of proprietary and available methods for soil strengthening so far, the main aim of these methods or procedures remain to improve various properties of soil like Permeability, Shear Strength, compressibility. Although tensile strength analysis is an important part of structural engineering, geotechnical engineers rarely perform them because soil has very little tensile strength and there are only few occasions where tensile failures occur. Further the introduction of large compressive stresses may result in failure; the ground actually fails in shear, and not in compression. Therefore all geotechnical strength analysis evaluate shear only.

Although soil improvement is generally expensive, it is often cost effective because it reduces the cost of remaining construction. The actual decision and extent of soil strengthening or soil improvement still depends directly upon appropriate technical requirement or changes to be expected and also the economic feasibility of procedures to be taken up by a geotechnical engineer.

II. Materials and Methods

In this study, the soil sample was collected from Jawbara area of south Kashmir falling on the NH-1A, Kashmir and the stone aggregates were collected from pantha chowk stone crushers. The disturbed samples were subjected to various soil tests like gradation, specific gravity, light compaction tests, Consistency limits etc . Unconfined compressive strength and direct shear tests were conducted on in-situ samples to determine shear strength parameters as per the Standard Codal procedures. The physical properties of the selected soil sample are given in Table 1. A series of tests were carried out to evaluate the reinforcing effects of stone column in improving the load carrying capacity of compacted soil samples. The stress strain response of soil reinforced with stone column was determined by Unconfined Compressive Tests. Under the Unconfined Compressive Tests, the compacted soil samples were reinforced with stone columns of varying lengths and varying diameters. In this tests series, Plate Load Tests were also conducted on different soil samples at varying lengths in order to determine the load carrying capacity of the reinforced soil samples.

The experimental setup used for bearing capacity tests consisted of a cylindrical tank 21cm diameter & 50cm deep(performed on universal testing machine). The soil to be tested was compacted in the tank at OMC and MDD. After the compaction, model shallow foundation (circular) was placed on the surface of soil for load application. The frame is designed to transmit load to footing. The loading is applied in increments. Two dial gauges were placed on opposite side of the footing to measure its deformations. The dial gauge readings of the plate are recorded at regular intervals.

The footing used for the present study includes a circular footing of diameter 20 cm. Thickness of footing was 10 mm.

Table.1 Physical properties of the soil sample

S.No	Properties		Site Jawbara NH-1A
1.	Natural Moisture Content (%)		19.04
2.	Bulk Density (kN/m^3)		19.6
3.	Insitu dry density (kN/m3)		16.4
4.	Specific Gravity (G)		2.62
5.	% Finer than 75 µm		90
6.	Clay (%)		15
7.	Silt (%)		75
8.	Sand (%)		10
9.	Gravel (%)		0
10.	Liquid Limit (%)		28.7
11.	Plastic Limit (%)		21
12.	Shrinkage Limit (%)		16.8
13.	Plasticity Index (%)		7.7
14.	P.I, Aline		6.4
15.	P.I, Uline		18.6
16.	Classification		CL
17.	Clay Mineral		Illite
18.	Activity		0.5
19.	DST @ In-situ	Cohesion,c (kN/m2)	12
		Angle of internal friction, Φ (Deg)	20
20.	UC-Test @ In-situ	Unconfined compressive strength, q_u (kPa)	79
21.	UC-Test@ OMC	Unconfined compressive strength, q_u (kPa)	110
22.	Optimum Moisture Content (%)		15
23.	Max^m. Dry Density (kN/m^3)		17.9

III. Results and discussions

A. Effect of size and diameter of the stone column on the unconfined shear strength of the soil:

Unconfined compression test is the simplest and quickest method to determine the shear strength of cohesive soils. Test specimens were prepared, compacted under standard compaction at MDD and optimum moisture content. The stone columns were inserted by carefully removing the soil from the sample in the center with small casing hollow rods upto the required depth. The depth of stone column was varied gradually with respect to the length of the sample as 0.25L, 0.5L, 0.75L respectively. The results clearly show an increase in the qu value at 0.75L and 0.5L when the column diameter is fixed at 2cm and 3 cm respectively as shown in Fig.1 and Fig.2.

B. Effect of L/B ratio on the bearing capacity of the soil:

The comparison between the load carrying capacity obtained at various lengths of the stone column with the footing placed on virgin soil is shown in Fig.3. The load carrying capacity obtained at the various ratios of L/B where L is the length of stone column installed and B is the diameter of footing shows an increasing trend when the stone columns are installed. Further, with the increase in length of the stone column the bearing capacity increases till a length of 1B where B is the width/Diameter of the footing.After this only a marginal increase takes place.

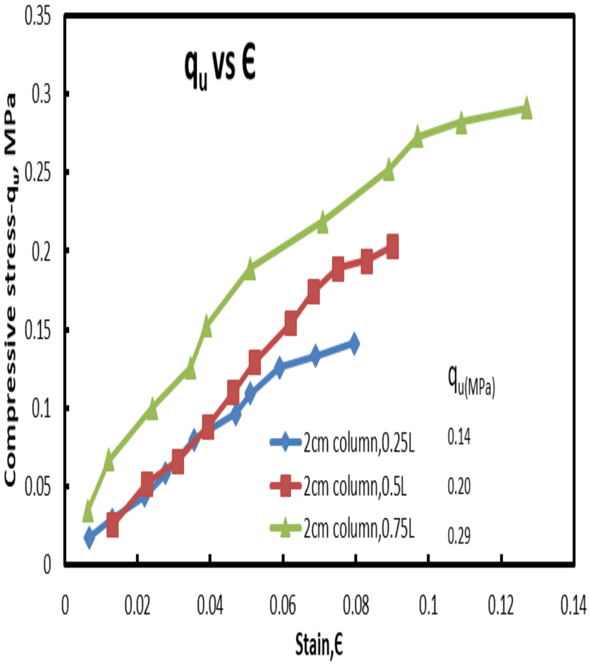

Fig.1 Stess-Strain curve for 2cm dia. Stone column at different depths.

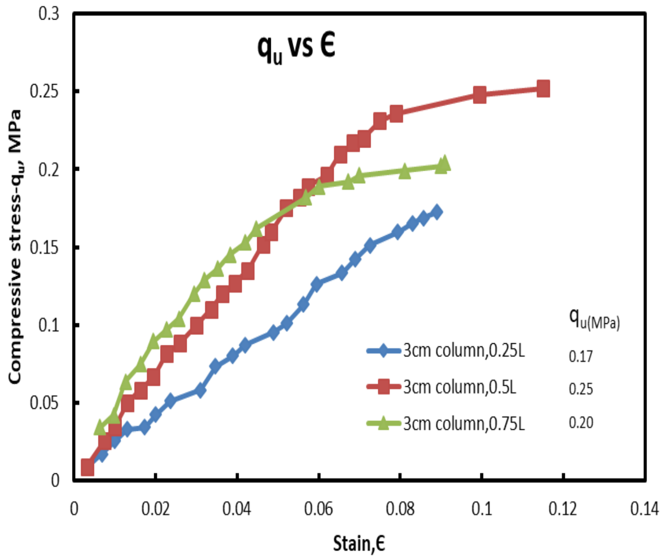

Fig.2 Stess-Strain curve for 3cm dia. Stone column at different depths

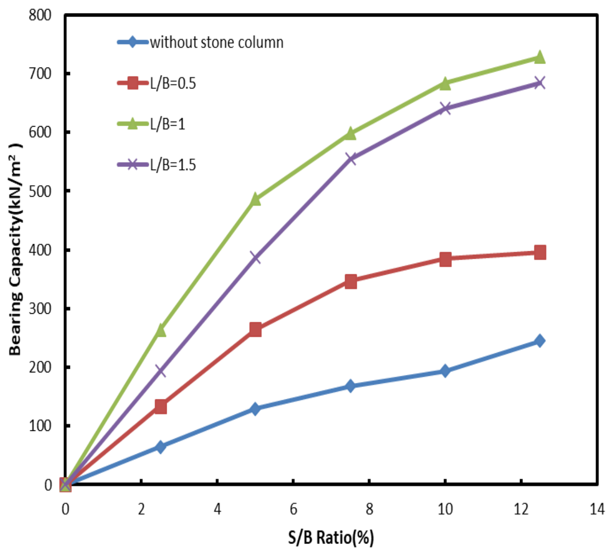

Fig.3 Bearing capacity vs S/B ratio

IV. Summary and Conclusions

With the ever growing need for reducing the overall budget for the project the stone columns can be used a cheap and an efficient alternative to conventional methods of construction. The use of stone columns has a greater application in case of cohesive soils In this study it was found that the installation of the stone columns plays a very significant role in improving the bearing capacity of the cohesive soils. The main improvement in cohesive soils takes place by virtue of densification while inserting the stone column. The increase in drainage also plays a great role.

The length of the stone columns was found to greatly influence the behaviour of the improvement of the soils.

V. SCOPE FOR FUTURE WORK

In the present work, model tests were carried out on soil beds reinforced with stone columns of different length ratios and area ratios. The tests were very encouraging. However, the following few aspects are to be studied before the technique is actually applied in the field:

1) Field tests on large size footings/prototype tests be carried out to validate the findings of model test results.

2) Tests should be carried out on group of stone columns loaded simultaneously.

3) Behaviour of jacketed and anchored stone columns should be studied.

4) Liquefaction susceptibility of the system to be studied.

5) Studies on stone columns with horizontal reinforcement.

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