Studies on Floating Under reamed Economical Cemented Stone Columns For Bearing Capacity Improvement of Black Cotton Soil

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Abstract - *Stone column technique are extensively used for improvement soft ground and decrease the compressibility of soft and loose fine graded soils. It is one of the technique which has proved to be easy and effective method for improving soft clay deposits. The analytical and experimental studies undertaken in this paper highlights the relevance of the stone column construction method as an effective ground improvement technique in deeep soft clay deposits especially Black cotton soils. The analytical studies involve conceptual failure mechanism in each case of pile column system and developing accordingly a simples easy use analytical equations for load carrying capacity of stone column treated ground*

Key Words*: *Black Cotton soil, Economical Cemented Stone column,Bearing Capacity, Load vs Settlement

1.INTRODUCTION

Quite often Civil Engineering construction is required to be done even in poor sub-soil deposits.

Such deposits includes fine grained soils like soft highly compressible clays, marine deposits along coastal belts and low lying areas and even loose sandy silts etc. In our country about 20% area of the land is covered by black cotton soils which are also considered as very poor engineer material for construction structure. So when it comes to construction of important civil engineering mega structure or even minor projects, civil engineers are faced with the challenging task of resting these structure on soil deposits having low bearing capacity and causing excessive settlement. Stone column construction has proved to be fairly easy and effective method for improving soft clay deposits.

The Indian black cotton soils which are usually classified as CH group exhibit several undesirable features like very low bearing capacity, high compressibility and high swelling shrinking characteristics. The present available ,a commonly used construction method in these widely distributed clay deposit in the country is the Under Reamed Pile Foundation. The construction of under reamed pile ,which essentially is a bored cast in-situ concrete pile , involves boring and making an enlarged bulb at the bottom of the pile or even in intermediate location. Such a bore hole, with enlarged bulb,can be considered as a radially prepared inclusion for making a stone column foundation on it. In the conventional stone column ,the bearing capacity of treated ground is derived from the passive resistance in the surrounding soil caused by lateral bulging of stone column's granular material under axial load.

2. EXPERIMENTAL INVESTIGATION

In order to evaluate the behavior of cemented granular mixes with different composition and there from deciding the better type of cemented granular mix that can be onsidered to suit the requirement of cemented stone column.

2.1 Installation of the Stone column

For experiment point of view the field condition is stimulated. The dimension of the auger is 15mm width of the auger, 45mm depth of cutter and the length is 35cm with the handle is attached at top is prepared. The position for installation of stone column is attached at top is prepared. The position for installation of stone column is marked properly with the held of rigid M.S plate on which the location of bore hole is marked. On the plate 12nos. Of hole is marked each 16 mm diameter .After compaction of soil, the plate is fixed on the top of the test tank and placing bore hole-loading frame at the center of model width. with the help of M.S. plate hole with fixed position. The bore hole is drilled by auger as per required depth of the stone column. After drilling of bore hole is filled with material with proper compaction. The materials were put in layers of 30mm to 50mm thickness and compacted using 6mm diameter tamping rod. Thus the pile was ready for saturation of 7 days, after completion saturation it was ready for the load test. The procedure is applied for the both single and group of stone column. Over the stone column, base plate of required shape and size was placed. For the group pile test 12 stone columns were made in the test tank with spacing 7.5mm c/c. For single pile test only one stone column made.

2.2 Under-reamed Stone column construction

Under-reaming or enlarging the stem of bore-hole at the required depth is achieved by means of the under-reaming consisting of a set of two collapsible blade,until the bucket rest at the bottom of the bore hole. The guide flaps are than closed. The tool is pressed down constantly and rotated slowly. The cutting blades of the tool widen out and start cutting the side hole. The loose earth is collected at the bottom when the bucket is full the assembly is pu assembly fixed around the central shaft and detachable bucket for receive the cut soil. The equipment is attached to extension rods and lowered down the hole which has been bored to required dell out and the bucket is empty.

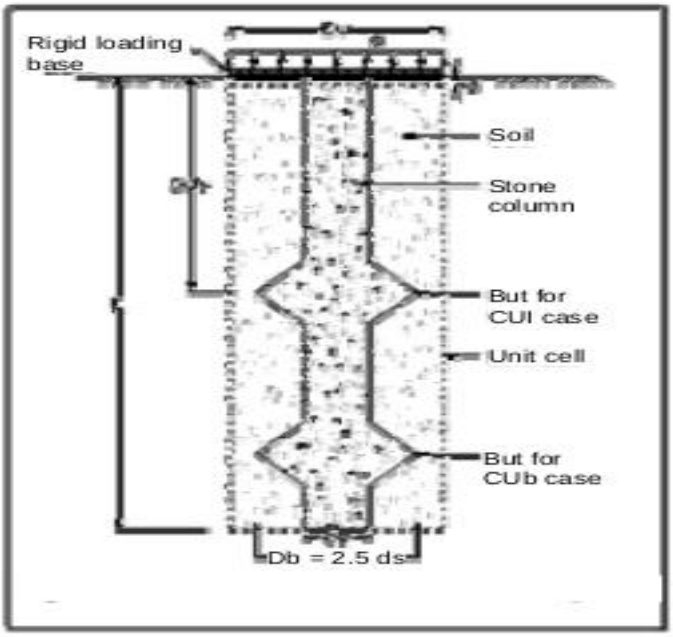


Fig. 1 Unit Cell of Soil Stone Column System

2.3 Saturation of soil deposit

The drum with the soil deposit was placed in water tank for 7 days.

2.4 Measurement of Heave/Swelling

During saturation dial gauge was fixed at a position to measure the swelling of the soil deposit. Two to three readings were taken everyday. Measurement had been taken for 7 days.

2.5 Loading Test

The drum containing the soil deposit was taken out of the water for saturation tank, after complete saturation. Before starting the test the top surface of the soil deposit was checked to ensure a horizontal plain surface. In case of unevenness, fine sand was spread over the undulations. This was done to ensure maximum surface contact of the plate with the soil deposit.

The loading frame was fixed in position as shown in fig. The frame was fixed at one end and the other end was provided with a hook to suspend a hanger, which would carry slotted weights. The plate was placed exactly on top of the stone column. Different shape and size of plate has been used for three group of stone column and single stone column, for 3 group of stone column the plate shown in fig. Single stone column test plate as shown in fig. Between the loading frame and plate, a shaft is placed to transfer the load from the frame to the plate. Dial gauges were fixed on the pedestals welded to the shaft as shown in the fig. For proper movement of shaft the guide is fixed over the test tank.

Loading was done in stage by placing circular slotted weights in the weight hanger. To avoid jerks and impact on effects on the stone column while loading the weight were kept carefully and by slowly making them touch with bottom plate of the weight hanger.

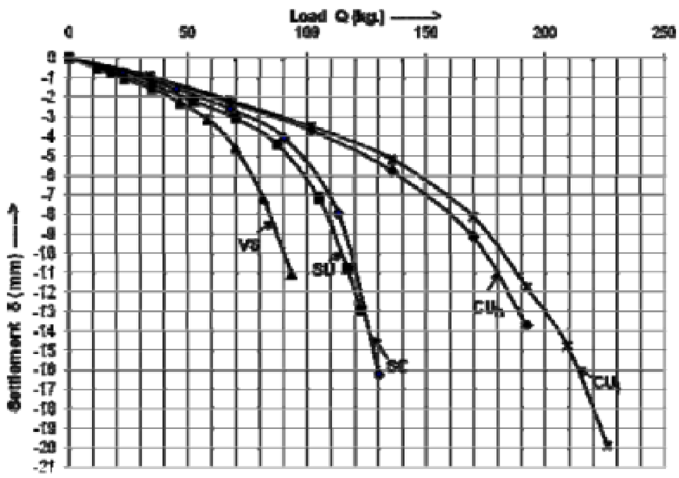
After having thus completed the test, dial gauge and other accessories were removed. The moisture content and density of soil just after the test over, was determined. In order to know the shear strength of soil, the sample of soil in cylindrical micro cutter collected and tested for undrained compressive shear strength (UCS) test. The soil sample has been taken from the tank for water content and bulk density with the help of micro cutter having dimension 2.5 cm. 3.75 cm and unconfined compressive strength of the sample has been carried out.

3. ANALYSIS AND INTERPRETATION OF RESULTS

3.1 Failure Pressure Intensity

The load-settlement curves for unit cells of five categories are shown in Figure 2.

Fig.2 Load-settlement Curves for Various Unit Cells



The curves indicated almost direct proportionality between load and settlement initially over a considerable load range,which is then followed by a non-linear nature leading to plastic yielding characterized by continuous vertical deformation even under constant load. The failure load Q f of the system was determined by double tangent method and the values for five unit cells are: 62 kg (VS), 93 kg (SU), 113 kg (SC), 153 kg (CU b) and 165 kg (CU i). The corresponding failure pressure intensities (q f) are: 0.79, 1.18, 1.44, 1.95 and 2.10 kg/cm 2 respectively. The prediction of failure load (Q f) for CU i case is shown in Figure 3.

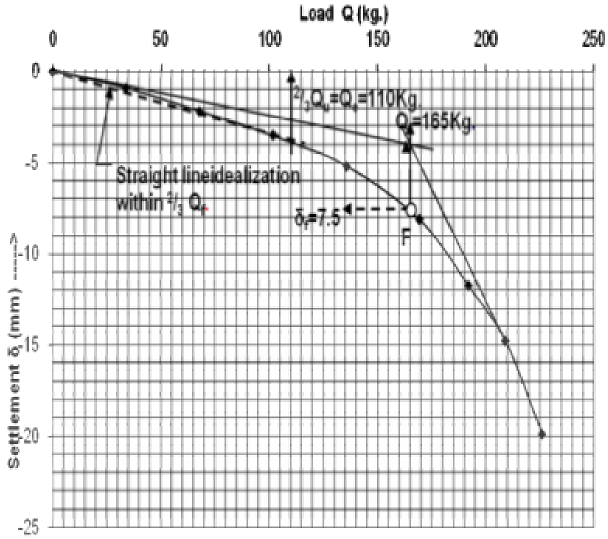


Fig. 3: Determination of Failure Load for CU i Unit Cell

It is seen that there is considerable increase in q f values for cemented stone columned unit cell over the conventional un-cemented stone column case. For the geometry of the stone column layout considered in the present investigations, the percent increase in load carrying capacity of different soil-column systems with reference to VS, SU, SC and CU b is shown in Table 1.

Table -1: Percent Increase in qf Values

Reference System	Soil-Column System	% Increase in q_f values
VS	SU	50.0
	SC	82.3
	CU_b	146.8

	CU_i	166.1
SU	SC	21.5
	CU_b	64.5
	CU_i	77.4
SC	CU_b	35.4
	CU_i	46.5
CU_b	CU_i	7.8

It is observed that compared to 50% improvement in bearing capacity by SU, the improvements by cemented stone column systems viz. SC, CU b and CU i are 82.3 %, 146.8% and 166.1% respectively. In other words, as compared with the bearing capacity of unit cell of conventional un-cemented stone column (SU), the bearing capacity of straight shafted cemented stone column system (SC) is increased by 21.5% and that for CU b and CU i cases the values are 64.5% and 77.4% respectively. The under reamed bulb at bottom or at inter mediate level, improves the bearing capacity by 35.4% for CU b and 46.5 % for CU i case. This is clear indication of high degree of effectiveness of cemented stone column and by provision of under reamed bulb. The under reamed cemented stone column with the bulb located at 5d s is found to be the most effective.

3.2 Bearing Capacity Improvement Factor

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The improvement in the failure pressure intensity of any soil-column system is proposed to be expressed by bearing capacity improvement factor (F b), which is defined as:

Fb = Failure pressure for soil - column system

Failure pressure of untreated soft clay ground

or, Fb = (q f)t/(q f)u

The values of F b are: 1.0 (VS), 1.50 (SU), 1.832 (SC), 2.468 (CU b) and 2.661 (CU i). The graphical representation is shown in Figure 4.

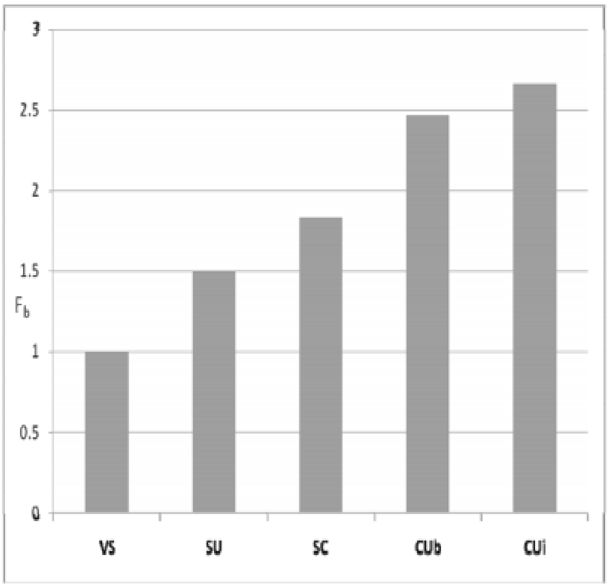

Fig. 4: Bearing Capacity Improvement Factors

Fb value of 2.661 for CU i means the bearing capacity of treated ground by under reamed cemented stone column with bulb at intermediate level is 2.661 times the bearing capacity of untreated soft clay ground.

3.3 Unit Cell Stiffness

The settlement behavior of loading base over circular area of unit cell of soil-stone column system depends on the overall stiffness of the unit cell containing semi-rigid stone column and the surrounding soft clay soil. The unit cell stiffness, k, is defined as the pressure per unit settlement. For a non-linear load-settlement curve, k varies with load level. However, on close examination of observed load-settlement curves for all five unit cells (Fig. 2), it is apparent that the curvature is insignificant up to a load level of approximately two-third failure load (i.e. 2/3 Q f) and this portion can therefore be fitted with a straight line as shown in Figure 3 for typical curve of CU i case. All such straight approximations for respective 2/3 Q f loads are given in Figure 5. The slope of the line is unit cell stiffness, k. The k values thus obtained are shown in Table-2.The values are found to increase sequentially for SU, SC,CU b and CU i .

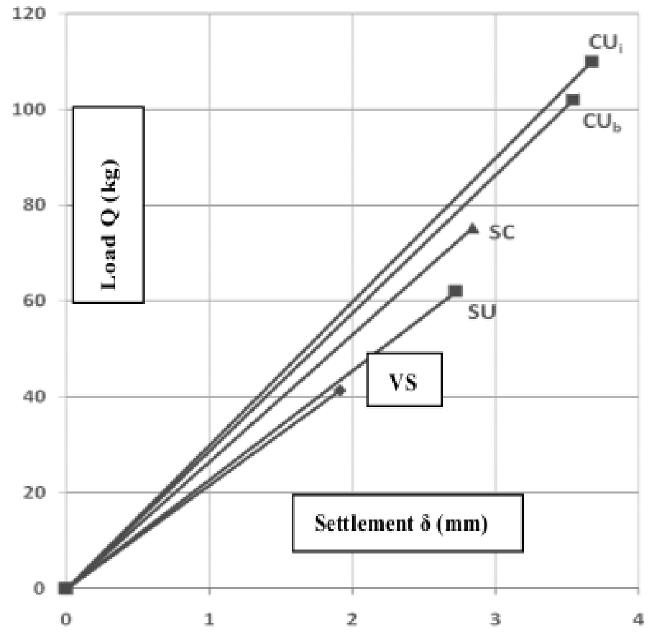

Fig. 5: Straight Line Approximation for Initial Portion of Load-settlement Curves

3.4 Settlement Reduction Factor

For comparing the settlement characteristics of any stone column system with that for untreated soil, the settlement reduction factor F s is introduced. For example, if F s is 0.8 for CU b case, it means the settlement of ground treated with under reamed cemented stone columns with bulb at bottom will be 80% of the settlement of un-treated ground under same applied pressure intensity. For a non-linear load-settlement curve, k varies with load level. However, on close examination of observed load- settlement curves for all five unit cells (Fig. 2), it is apparent that the curvature is insignificant up to a load level of It can also be inferred that 20% reduction in settlement will be caused by installing such columns. The values of Fs and percentage reduction in settlement for all the cases are given in Table 2.

Table- 2: Unit Cell Stiffness Values

Unit cell	Stiffness(k) (kg/cm3)	Settlement reduction factor (fs)	Settlement reduction (%)
VS	2.758	1.0000	0.00
SU	3.092	0.8920	10.80
SC	3.410	0.8088	19.12
CU_b	3.726	0.7402	25.98
CU_i	3.820	0.7220	27.80

It is noteworthy to find that the settlement is considerably reduced by provision of cemented stone columns. As compared to 10.8% reduction in settlement in SU case,19.12% reduction is achieved by SC case. The under reamed bulb at 5ds depth further enhances the reduction in settlement to 27.8%.

4. CONCLUSIONS

The provision of semi-rigid floating type of under reamed cemented stone columns is conceptualized probably for the first time for economical and effective improvement of soft clay ground. The model studies, conducted on single unit cells using a scale reduction factor of 10 for a field stone column layout of 30 cm diameter columns having area replacement ratio of 9% and length ratio of 10, revealed that both the bearing capacity characteristics and settlement characteristics of soft clay ground are significantly improved by the use of under reamed cemented stone columns. However, in order to develop this ground improvement technique,the aspects of load transferring mechanism,analysis for bearing capacity estimation, detailed behavioral features like effects of area replacement ratio, length ratio,column size etc. need to be thoroughly investigated.

REFERENCES

[1] Juran I. & Oraccio R. (1991). "Reinforcing Soft Soils with Artificially Cemented Compacted Sand Columns", J.*Geotech Div., ASCE, Vol. 17.*

[2] *Maher M.H. & Grey D.H (1990). "Static Response of Sands Reinforced with Randomly Distributed Fibres", J. Geotech Div., ASCE, Vol. 116.*

[3] *Ranjan G. & Rao B.G. (1983). "Skirted Granular Piles for Ground Improvement", Proc. VIII, European Conference on SM & FE, Helsinki*

[4] *Gopal Ranjan & A.S.R Rao , Basic and Applied Soil Mechanics (New Age International Publishers , 2004). (9)*

[5] Gautam R.B. (2007). "Studies on Floating Underreamed Cemented Stone Columns for Bearing Capacity Improvement of Black Cotton Soil", *M. Tech Dissertation* (Unpublished) submitted to Nagpur University