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An Experimental Study on Improvement of Sub Grade by Laterally Confined Stone Column with Geo Grid

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ABSTRACT

In coastal areas most of the land is covered by soft clay. The construction of a structure on the soft clay is quite miserable due to its inadequate engineering properties. The installation of stone column is cost effective method of improving the strength parameters like bearing capacity, reduce settlements and increased rate of consolidation. when stone column loaded in soft clay undergoes excessive bulging due to inadequate lateral support from the surrounding clay soil. To avoid excessive bulging, stone column is encased with geo grids. In present study experiments done on stone column with and without encasement. The stone column is encased with geo-grids of varying encasement depths of 0.25L, 0.5L, 0.75L, L to improve bearing capacity and lateral bulging.

I. Introduction

Areas particularly coastal region are covered with the thick layers of Soft clay soil deposits having very low shear strength and high compressibility. These Soft clay soil deposits are not suitable for the formation of sub-grade. Due to excessive settlements, large lateral flow of soft clay underlying structures results in loss of global and local stability. In view of the increasing developments in the coastal region in the recent past industries, a number of ports, buildings, roads, tunnels, bridges are being built. Construction of highway embankments using conventional design methods which are preloading, dredging, and soil displacement techniques, among all these methods, the stone column technique is preferred because it provides the primary aspect of reinforcement and also to improve the strength and reduces the deformation. Another major advantage of this technique is the simplicity of its construction. The load carrying capacity of the stone column is a function of the rate of application of the load and the lateral confinement offered by the surrounding soil. In very soft soils this confinement is very low and consequently, failure occurs. The use of compacted stone columns as a technique of soil reinforcement is frequently implemented in soft cohesive soils to increase the bearing capacity of the foundation soil, to reduce the settlement, and to accelerate the consolidation of the surrounding saturated soft soil.

When the stone columns are installed in very soft clay deposits, the surrounding clay cannot provide adequate support to the stone column to withstand loads resulting in excessive bulging, so the performance of stone columns can be improved by providing weak deposits with reinforcement and reducing column bulge effectively. Alternatively, the stone columns are reinforced internally by stabilization of column material using concrete plugs, chemical grouting or by adding internal inclusions (geo-grids, geo-textiles, plastic fibers etc.). In the present study, the encasement of stone column with geo grids at different reinforcement depths is performed in the laboratory through strain controlled load test. The effect of the parameters such as, the depth of geo-grid reinforcement from bottom level, and its lateral bulging at different depths was analyzed.

II. Materials Used

Materials introduction

The materials that are adopted in this study are soft clay, stone aggregate, Geo-grids, Sand. The sources and properties of these materials described below.

Soft clay

Soft clay is excavated from Visakhapatnam port trust at coast guard where piling work is being carried out .The soil is highly compressible clay.

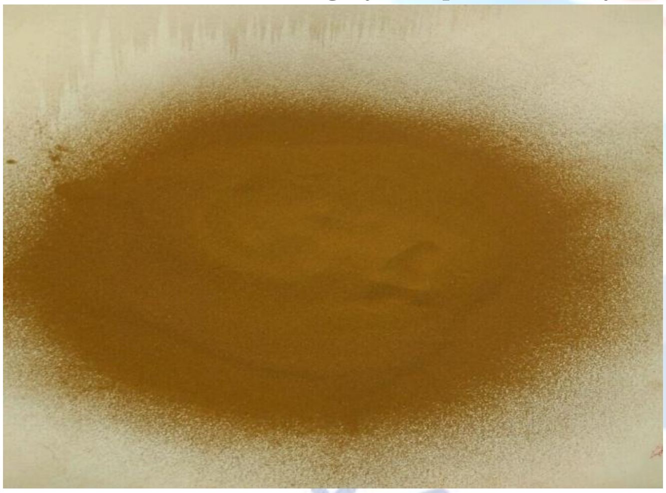

Fig.1 Soft clay sample

Stone aggregate

Pure granite crushed stone aggregate is used as a stone material in this study. These aggregates are collected from madhava crushers in anakapalli and aggregates retained on 10mm and passing through 12.5mm are taken for the present study. The physical properties of stone aggregates are given below.

Fig.2 Stone Aggreate

Table 1 Physical properties of stone aggregates.

Properties	Values
Specific Gravity (Gs)	2.76
Water absorption	0.60%
Unit weight	1.86 g/c.c

Geo-grid;

The geo-grids isused for this study collected from Ayyappa Geo-textile installers, Lankelapalem, Vishakhapatnam. Table 2 shows the Properties of geo grids.fig 3 shows the grid of size 10mmX10mm is taken for the present study

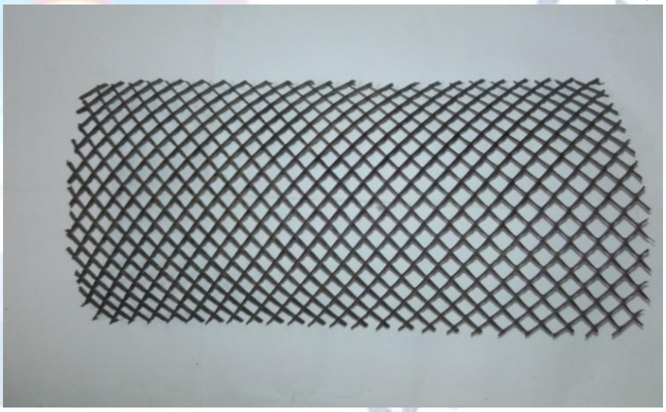

Fig.3 SG350 geo-grid

Table 2 Properties of geo-grid

Properties	Units	SG350
Ultimate Strength(3) (MD) ASTM D 6637 Method A Single-Rib	KN/M	73.0
Creep Limited Strength ASTM D 5262D 6992	KN/M	47.1
Molecular Weight (min)	G/MOL	25,000
Caboxyl End Group (CEG)	MEQ/KG	30

Count (max)		
Area	SQ. M.	167.2/250.8
Product Weight(6)	G/SQ.M.	237.3
Weight per Roli	KG	45.4/64.8

Sand

The sand is collected from government provided ramps in srikakulam. The sand used as a blanket is sieve through 4.75mm sieve and is classified as well graded sand.

Fig. 4 Sand samples

III. EXPERIMENTAL PROGRAM

Experimental program carried out includes the construction and testing procedures of clay bed, ordinary floating stone column and reinforced stone columns.

Preparation of Clay Bed

The air-dried and pulverized clay sample was mixed with required quantity of water to achieve uniform consistency. Moisture content of 30% is added to the soil. Initially soil is thoroughly mixed with water to get uniform consistency. The container walls are coated with grease to decrease adhesion between the walls of the container and the clay bed. The uniformly mixed paste was then filled in the tank in layers of 50mm thickness to the desired depth of 300mm by means of hand compaction to get desired dry density.. For each load test, the clay bed was prepared afresh in the test tank and stone columns were installed in it. After preparation of clay bed, it is covered with wet gunny cloth and then left for 24 hours for moisture equalization. Figure 5 shows the clay bed prepared in the cylindrical tank used in this study. Tests were conducted on stone columns formed in a clay bed of 200mm diameter and 300mm height. Figure 6 shows the Schematic view of stone column foundation for test.

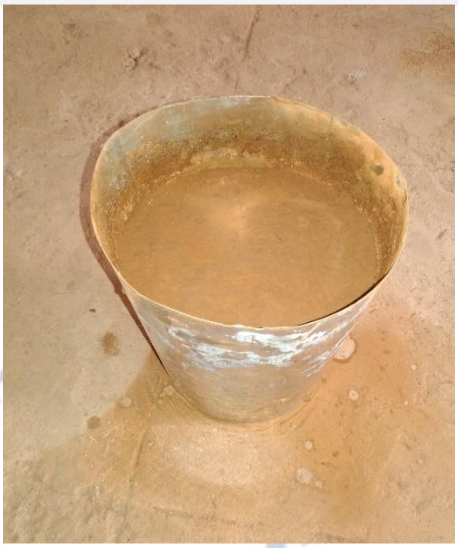

Fig.5 Clay bed

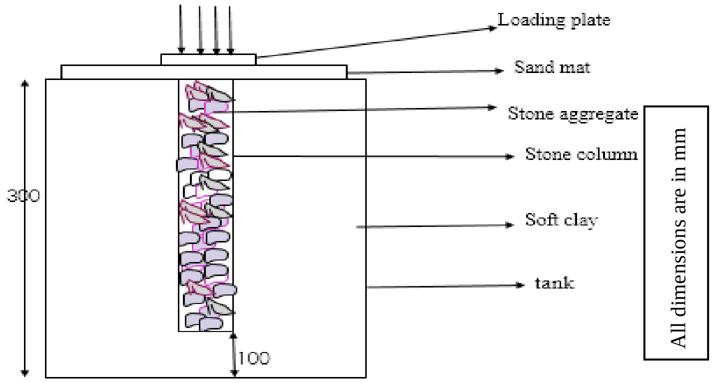

Fig.6 Schematic diagram of stone column

Construction of Ordinary Floating Stone Column

As shown in fig 7 the clay bed was prepared to a desired depth of 100mm ,the centre of the cylindrical mould was properly marked and the pvc pipe of 50mm diameter was placed at the the marked portion of mould. Around this pipe, clay bed was prepared in three layers each of 50mm for compaction till the entire stone column is formed .In this study stone aggregates was used as the backfill. Add 5% of water to the coarse aggregate to avoid the absorption of water from surrounding clay bed. The stone column material charged into pvc pipe to certain level, compacted withdrawal of pipe were carried out simultaneously. After compaction of each layer, the pipe is lifted gently to a height such that there will be an overlap of 5mm between the surface of the stone chips and the bottom of the casing pipe. The aggregates were compacted by 10mm diameter tampering rod with 10 blows from a height of fall of 100 mm. Further the bed prepared should left for 24 hrs covered with polythene cover to ensure proper contact between the clay and stone column and to gain strength of disturbed clay.

Fig.7 Ordinary floating Stone Column

Construction of laterally confined Stone columns with geo-grids:

After the clay bed was prepared to a desired depth of 100mm,the centre of the cylindrical mould was properly marked and the pvc pipe of 50mm diameter was placed at the marked portion of mould. Around this pipe, clay bed was prepared in three layers each of 50mm for compaction till the entire stone column is formed .The reinforced stone column portion is provided after ensuring proper reinforcement depth from bottom. Here geo-grid material is used as an encasement to reinforce the stone column. After ensuring reinforcement depth, the geo grid shell as shown in the figure 8 is placed in the pvc pipe. The stone column material charged into pvc pipe to desired level of reinforcement(0.25L, 0.5L, 0.75L and L from bottom) compacted withdrawal of pipe were carried out simultaneously leaving the geo grid shell with stone aggregates . After compaction of each layer, the pipe is lifted gently to a height such that there will be an overlap of 5mm between the surface of the stone chips and the bottom of the casing pipe. The aggregates were compacted by 10mm diameter tampering rod with 10 blows from a height of fall of 100 mm. Further the bed prepared should left for 24 hrs covered with polythene cover to ensure proper contact between the clay, geo-grid and stone column and to gain strength of disturbed clay.

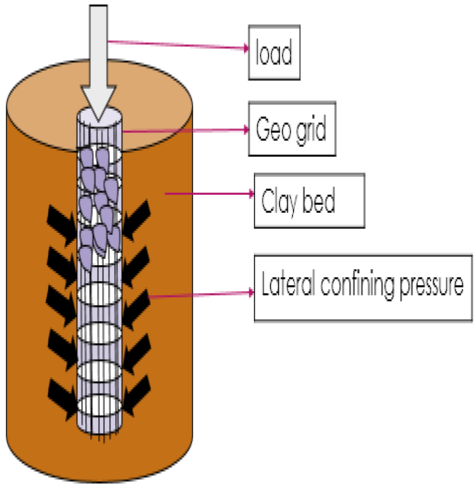

Fig.8 Placing of geo-grids

Testing of clay bed/ Stone columns

After construction of plain clay bed and stone column, load was applied through the 12 mm thick Perspex circular footing having diameter double the diameter of the stone column (10cm) which represents 25% area replacement ratio. Models were subjected to strain-controlled compression loading in a conventional loading frame at a fast rate of settlement of 0.24mm/min to ensure undrained condition up to a maximum footing settlement of 20 mm. The applied load on footing was observed by a proving ring at every 1 mm settlement. A complete test set up arrangement is shown in Figure 9

Fig.9 Test set up for loading

Post Test Analysis

After completion of the test, stone aggregate chips from the column were carefully picked out and a thin paste of Plaster of Paris was poured into the hole and kept it for 24 hours to get the deformed shape of the column. The soil outside the stone column was carefully removed and the hardened Plaster of Paris is taken out and the deformation properties are studied.

IV. Results and Discussion

The following are the results obtained by performing the different lab tests.

Soft clay:

Index and engineering properties of soft clay are listed in the tables given below.

Index properties.

Table 3 Index properties of soil

Property of soil	Values
Liquid limit	64.3%
Plastic limit	21.7.%
Plasticity index	42.6%
Specific Gravity	2.43

Engineering properties:

Table 4 Engineering properties of soil

Property of soil	Values
Optimum Moisture Content (OMC)	30%
Maximum Dry Density (MDD)(in g/cc)	1.56
Unconfined compressive strength (in kPa) at 35% water content	30.0

Presentation of test results:

The results for the basic tests conducted on the soft clay and stone aggregates are given below.

Test results for Atterberg's limits:

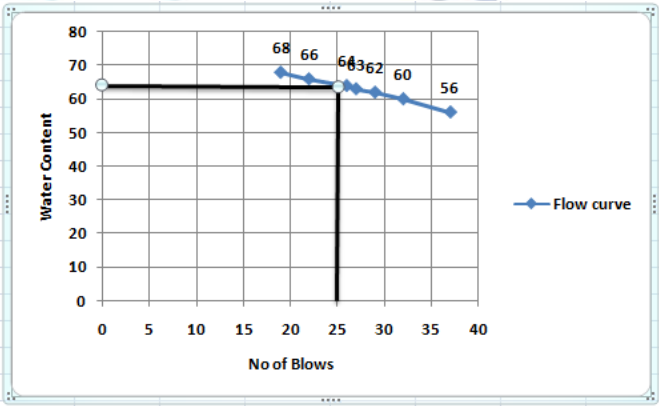

Fig.10 Liquid limit curve for soft clay

From graph liquid limit =64.3

Plastic limit = 21.7 and Plasticity index = 42.6

Compaction test results

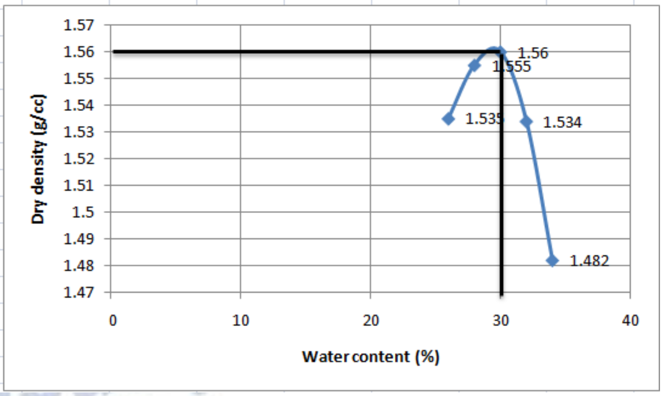

Fig.11 Compaction curve for soft clay

Load settlement response of plain clay bed:

Figure shows the load versus settlement curve obtained from load tests on plain clay bed. The ultimate load carrying capacity can be obtained by drawing double tangent to the load settlement curve which is shown in figure 12. The ultimate load carrying capacity of the un reinforced clay bed is 29 kg. The settlement at the ultimate load is 8.1 mm.

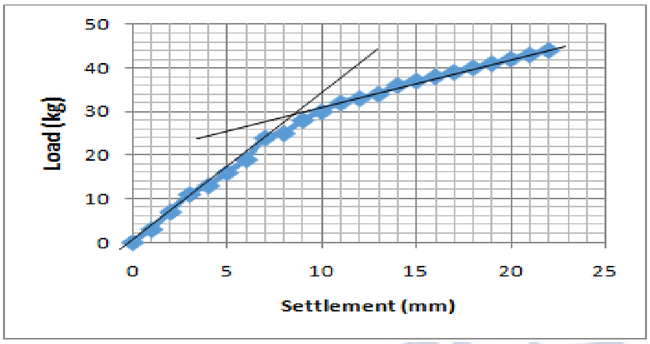

Fig.12 Load-settlement curve of unreinforced clay bed

Load settlement response of ordinary stone column:

Figure 13 shows the load-settlement curve obtained from load tests on clay bed reinforced with stone column. Load -settlement curve for ordinary stone column, the load carrying capacity increased when compared to plain clay bed. This is due to densification of the clay bed by recycled rail ballast. The ultimate load carrying capacity for clay bed without stone column is 29kg and with stone column alone is 38 kg. This shows an increment of 31% to that of clay bed alone The ultimate load carrying capacity of ordinary stone column is 38 kg at 7mm settlement.

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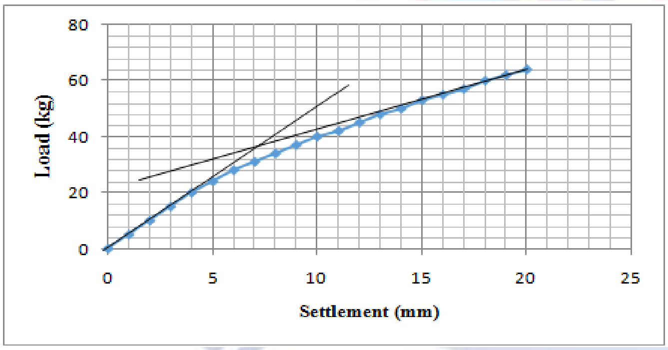

Fig 13 Load-settlement curve of ordinary floating stone column

Load settlement variation of encased stone column of varying lengths:

In the further study the stone is encased with geo-grids of varying lengths from the bottom of the stone column to have lateral confinement .The load settlement variation can be obtained by variation reinforcement lengths(0.25L, 0.5L, 0.75L and L).

Load settlement response of reinforced stone column with reinforcement depth of 0.25L.

The load carrying capacity of an reinforced stone column increased when compared to plain clay bed and ordinary floating column. The ultimate load carrying capacity of reinforced stone column with reinforcement depth of 0.25L is 48kg.The settlement at the ultimate load is 6mm. This shows an increment of 15% to that of ordinary floating stone column. Figure 14 shows the load settlement curve of reinforced stone column with reinforcement depth 0.25L.

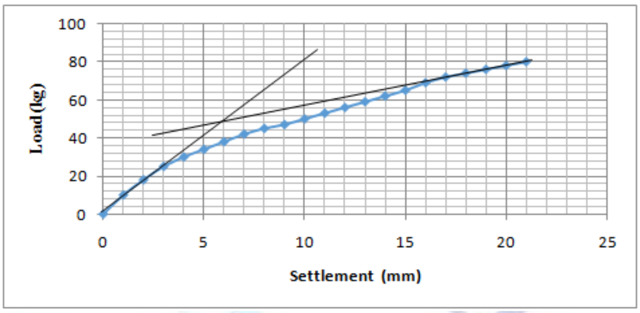

Fig.14 Load settlement curve of reinforced stone column with reinforcement depth of 0.25L

Load settlement variation of reinforced stone column with reinforcement depth of 0.5L depth:

The ultimate load carrying capacity of reinforced stone column with embedment depth 0.5L is 56kg. This shows an increment of 47% to that of ordinary floating stone column and an increment of 12.5% to that of encased stone column of depth 0.25L. The settlement at the ultimate load is 5.5mm. Figure 15 shows the load settlement curve of reinforced stone column with reinforcement depth 0.5

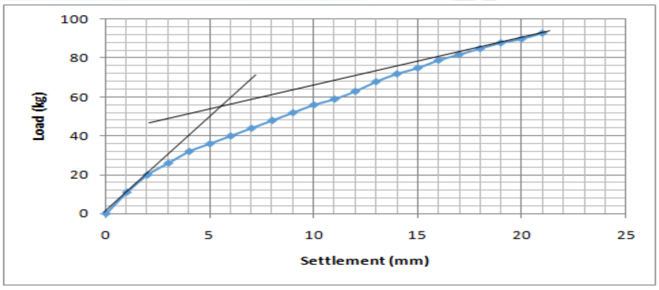

Fig. 15 Load settlement curve of reinforced stone column with reinforcement depth of 0.5L

Load settlement response of reinforced stone column with reinforcement depth of 0.75L

The ultimate load carrying capacity of reinforced stone column with reinforcement depth 0.75L is

68kg. This shows an increment of 78% to that of ordinary floating column. The settlement at the ultimate load is 5mm. Figure 16 shows the load settlement curve of reinforced stone column with reinforcement depth of 0.75L

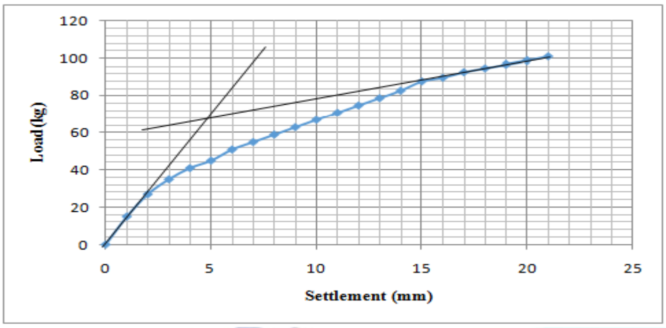

Fig. 16 Load settlement curve of reinforced stone column with reinforcement depth of 0.75L

Load settlement response of reinforced stone column with reinforcement depth of L:

The ultimate load carrying capacity of reinforced stone column with embedment depth L is 76kg. This shows the increment of 100% to that of ordinary floating column. The settlement at the ultimate load is 4mm. Figure 17 shows the load settlement curve of reinforced stone column with reinforcement depth of L.

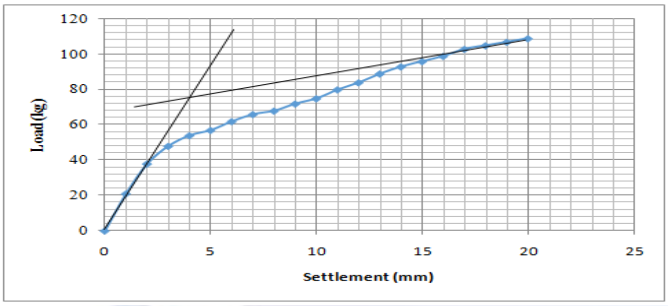

Fig.17 Load settlement curve of reinforced stone column with reinforcement depth of L

Comparison of load-settlement responses of reinforced stone columns with varying reinforcement depths:

The ultimate bearing capacity o reinforced stone column with reinforcement depths of 0.25L, 0.5L, 0.75L and L are 48kg, 56kg, 68kg and 76kg respectively and the corresponding settlements are 6mm, 5.5mm, 5mm and 4mm.

There is an increment of 15%, 47%, 78%, 100% load carrying capacity when compared to ordinary floating stone column. The increase in load carrying capacity is 1.6, 1.9, 2.3, 2.6 times the load carrying capacity of plain clay beds alone.

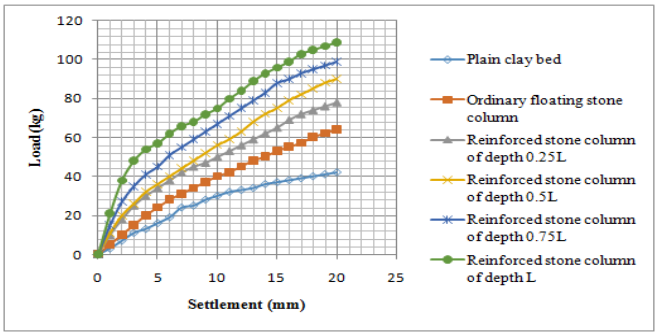

Fig.18 Load Settlement curves of reinforced stone columns with varying reinforcement depths.

Ultimate load and settlement response at different reinforcement depths

Table.5 shows the ultimate load and settlement values at different test conditions

Test condition	Load(Kg)	Settlement (mm)
Plain clay bed	29	8
Ordinary floating column	38	7
Reinforced column with reinforcement depth of 0.25L	48	6
Reinforced column with reinforcement depth of 0.5L	56	5.5
Reinforced column with reinforcement depth of 0.75L	68	5
Reinforced column with reinforcement depth of L	76	4

Bulging of stone columns without reinforcement:

Figure shows the bulging behavior of stone column without reinforcement. The detailed values of the of the horizontal deformations can be obtained at the outer face of the column at an interval of 2.5cm.a graph is plotted between the depths of columns verses horizontal deformation of the stone column in case of clay with stone column alone at depths is shown in figure19. The maximum bulging is 12mm at 150mm.

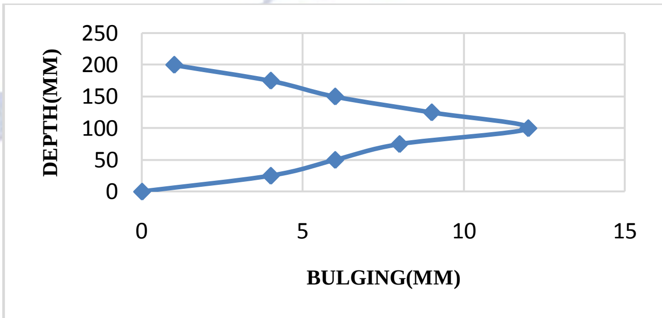

Fig.19 Bulging curve of ordinary stone column

Bulging of stone column with reinforcement depth of 0.25L from bottom:

Figure20 shows the horizontal deformation of encased stone column of depth of 0.25L from the bottom of the stone column. Due to lateral confinement of stone column of depth 50mm from the bottom, the bulging declined to 8mm when compared to unreinforced stone column.

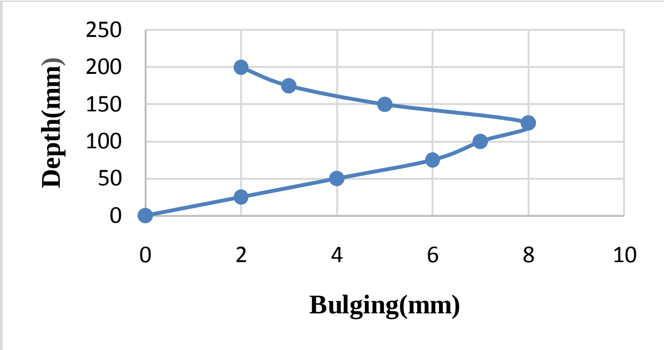

Fig.20 Bulging curve of reinforced stone column of 0.25L depth

Bulging of stone column with reinforcement depth of 0.5L from bottom:

Figure shows the bulging behavior of reinforced stone column of depth 0.5L.The ultimate bulging of stone column is 5mm.Due to lateral confinement of stone column with geo-grid, the bulging reduced to 5mm when compared to unreinforced stone column.

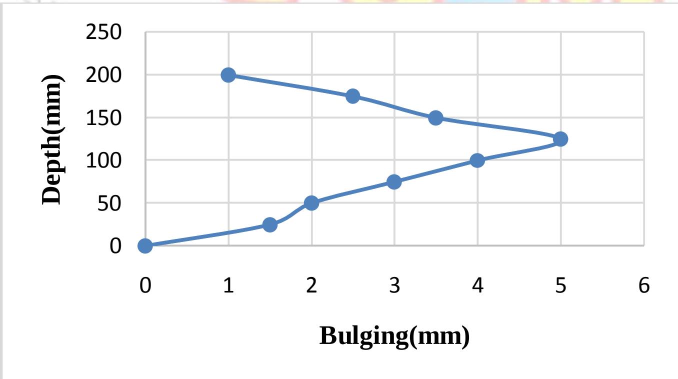

Fig.21 Bulging curve of reinforced stone column of 0.5L depth

Bulging of stone column with reinforcement depth of 0.75L from bottom

Figure shows the bulging behavior of reinforced stone column of depth 0.75L The ultimate bulging of stone column is 3.5mm. Due to lateral confinement of stone column with geo-grid the bulging reduced to 3.5mm when compared to unreinforced stone column.

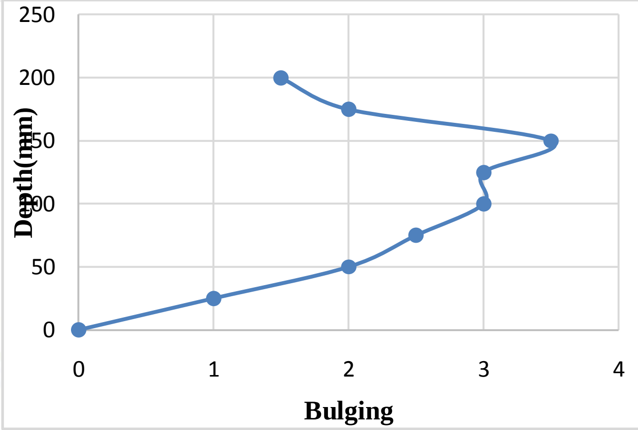

Fig.22 Bulging curve of reinforced stone column of 0.75L depth

Bulging of stone column with reinforcement depth of L from bottom

Figure 23 shows the bulging behavior of reinforced stone column of full depth. The ultimate bulging of stone column is 3 mm. Due to lateral confinement of stone column with geo-grid the bulging reduced to 3 mm when compared to unreinforced stone column. The lateral confinement of stone column to its full depth have a considerable effect in reduction of bulging.

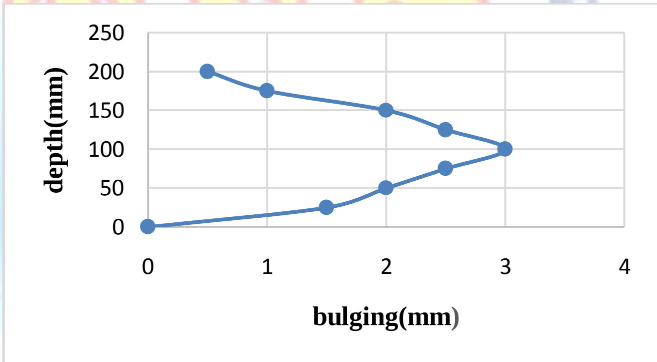

Fig.23 Bulging curve of reinforced stone column of L depth

Bulging effect of reinforced stone column with varying depths of reinforcements

Figure 24 shows the bulging behavior of encased stone columns with varying depths 0.25L, 0.5L , 0.75L, L. The ultimate settlements are 8mm, 5mm, 3.5mm, 3mm of corresponding depths of reinforcements 0.25L, 0.5L, 0.75, L. respectively.

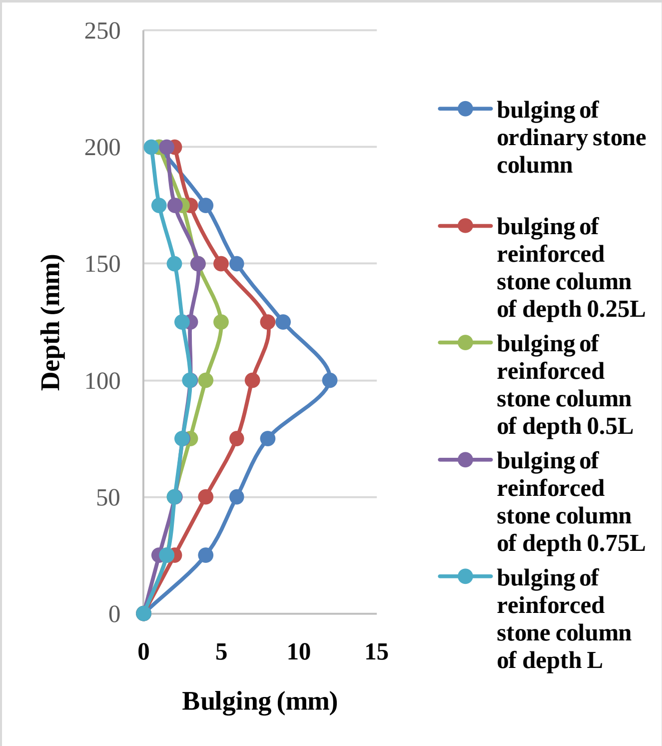

Fig.24 Bulging of reinforced stone column of varying depths

V. Conclusion

1. Installation of ordinary floating stone column increased the load carrying capacity of plain clay bed by 31%
2. The encasement of stone column with geo-grid increases the load carrying capacity and stiffness of the floating stone column.
3. The variation in depths of reinforcement influences the load carrying capacity of stone column. The performance of stone column is increased to its full reinforcement depth by 58% to that of bottom quarter reinforcement and increased by 100% to that of ordinary floating stone column.
4. Reinforcement of stone column with geo-grids results in decrease of settlements. There is a decrement of settlement for reinforced stone column to its full depth by 75% respectively when compared to the ordinary floating stone column.
5. Bulging of ordinary stone column decreased by 50% when it is reinforced with geo grid to its full depth.
6. Reinforcement of stone column to its full depth increases the bearing capacity reduces settlement and bulging in soft clayey soils.

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