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Load Carrying Capacity of Stone Column with and without Horizontal Reinforcing Elements

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***Abstract* - Ground improvement is commonly adopted in civil engineering practice to bring down the ill effects of poor sub soil conditions on civil engineering structures constructed over them. Compaction, reinforcement by inclusion of stiffer elements into soil, drainage, addition of physical and chemical admixtures, heating and freezing are some of the categories of ground improvement techniques, Stone columns are one of the methods of ground improvement to enhance the engineering behavior of soft clays. Stone columns are vertical column or inclusions of dense compact crushed stone penetrating soft clays. The scope and objective of the present investigation is to study the improvement of performance of stone columns with and without horizontal reinforcing elements made from stone dust in a model testing tank simultaneously the factors of Mean particle size (D50) and Density Index (1D) of stone column material, L/D ratio of stone column and consistency Index (IC) of soil bed are kept constant.**

Keywords: Mean particle size, Density Index, consistency Index, model testing tank, reinforcing elements.

I. INTRODUCTION

Almost all Civil Engineering structures are constructed on or in or with the soil. The load from superstructure and substructure are ultimately to be supported by the soil. The soil at the site of construction should be competent enough to receive these loads without affecting the function of the structure.

Conventionally construction on, in, or with problematic soils is avoided. Nowadays the scarcity of land space available for new urban development has prompted a renewed interest from local authorities and engineering community for the end use of various landfills, problematic soils and soft soils or in the extension of the life of existing landfills.

As a result it is necessary to utilize even the poorest sites either by providing special type of foundation or by improving the weak ground. From there the necessity of ground improvement came into the picture.

1.1 Ground Improvement in Soft or Weak Soils

Weak soil, which has very low shear strength and high compressibility to support structures require strengthening to be capable of carrying loads from structures.

Urban and industrial development coupled with scarcity of land made the soil improvement alternative (that is Fourth alternative) to be the best option in good number of cases. In Literature several methods of ground improvement techniques are reported. These techniques can broadly be divided into four categories.

1. Mechanical modification
2. Hydraulic modification
3. Physical and chemical modification
4. Modification by inclusion and confinement

Different ground improvement techniques which fall under each of the above categories are presented in the fallowing subsection.

1.2 Stone Columns

Though this technique was used first in France in 1830s, the wide range of use of this technique spread especially in Europe since 1950s. In this method, the columns consist of compacted gravel or crushed stone arranged by a vibrator. Stone column technique decreases the compressibility of soft and loose fine graded soils leading to increase in strength, accelerates consolidation effect and reduce the liquefaction potential of soils. Stone columns are more preferable than sand drains because of their 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 column acts as a vertical drain and thus speeds up the process of consolidation, replaces the soft soil by a stronger material and initial compaction of soil during the

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process of installation thereby increasing the unit weight. Stone columns also mitigate the potential for liquefaction and damage by preventing build up of high pore pressure by providing drainage path.

The construction of stone columns is generally carried out using either a replacement or a displacement method. In the displacement or dry method, native soil is displaced laterally by a vibratory probe using compressed air. This installation method is appropriate where ground water level is low and in situ soil is firm. In the replacement or wet method, native soil is replaced by stone columns in a regular pattern where the holes are constructed using a vibratory probe accompanied by a water jet. Alternatively, stone columns are constructed by ramming granular materials into the pre bored holes in stages. This method is widely used in practices in India.

II. MATERIALS AND METHODOLOGY

The load carrying capacity and load settlement behavior of a stone column are found to be a function of size of stone columns (length and diameter), strength of soil (consistency index), soil type (liquid limit) and extent of bulging (lateral and vertical) of stone column upon loading. The main objective of present investigation is to quantity the relative effect of factors affecting behavior of stone column and to evolve simple, reliable and empirical models to estimate the load carrying capacity and extent of bulging in terms of influencing factors. For this purpose, a series of load test are conducted on stone columns of varying dimensions embedded in clay bed of varying stiffness and liquid limit. Tests conducted are designed following the principles factorial experimentation which enables not only quantification of the relative effect of each factor on responses of interest but also the interaction effect of factors, on responses of interest. The details of factors considered, principles of design of experiments, materials used, model test conducted, Method of installation of stone column, preparation of test bed, method of load test and test procedures adopted are presented and discussed in the following sections.

2.1 Soils Used

The soils used in the present investigation are obtained from the location namely Ambedkar colony, Tirupathi, Andhra Pradesh. The Liquid Limit of this soil is 112%. The area is largely covered by expansive clayey soil. The required amount of soil is collected from trial pits at a depth of 2 m below the ground level, since the top soil is likely to contain organic matter and samples are fairly homogeneous.

The soils so obtained are air dried, crushed with wooden mallet, passed through 4.75mm sieve, kept in polythene bags and stored in steel drums for further testing. The properties of this soil are given in the table.

Table 1: Properties of Soil Tested

Property	Ambedkar Colony Soil
Gravel (%)	0.5
Sand (%)	41.1
Silt + Clay (%)	58.4
Liquid Limit (%)	112
Plastic Limit (%)	22.97
Plasticity Index (%)	89.03
IS Soil Classification	**CH**
Free Swell Index (%)	490

2.2 Stone Columns materials used

The Stone dust used in the present investigation is obtained from upparapalli highway 18A. The Crushed stone (aggregates) of size below 2.36 mm has been used for formation of stone column. In this stone dust was containing Coefficient uniformity (Cu) is 3.55, Coefficient of curvature (Cc)value is 0.93 and mean particle size (D50) value is 0.55 mm. So, as per Indian standard classification this soil is classified as Uniformly Graded Fine Sand.

A rigid M.S plate of size 25mm X 25mm and thickness 2mm rest on surface of test bed prepared is used as model raft/footing. The capacity of loading frame is 20kN and types of operation electrical and manual.

Table 2: Properties of Stone Dust and Crushed Stones

Property	Stone Dust
Gravel (%)	0.00
Sand (%)	99.09
Silt + Clay (%)	0.91
Effective Size, D_{10} (mm)	0.22
Effective Size, D_{30} (mm)	0.40
Effective Size, D_{60} (mm)	0.78
Coefficient of Uniformity, C_U	3.55
Coefficient of Curvature, C_C	0.93
IS Soil Classification	**SP**
Mean Size, D_{50} (mm)	0.55

Cylindrical model test tank with inside diameter of 150mm and 225mm height with a detachable perforated base plate of 10mm thick is used for preparation of test bed.

2.3 Effect of L/D ratio on Load Carrying Capacity of Stone Column (Critical L/D ratio)

It is clear that ultimate capacity is a function of Ic. I_D, L/D ratio and D_{50} In order to study the L/D ratio on load

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carrying capacity six tests are conducted corresponding to L/D ratio of 0, 6, 7, 8, 10 and 11. The Ic. I_D and D_{50} for these six tests are kept constant at 0.6, 75% and 0.55mm. Load carrying capacity of stone column is plotted against L/D for these six tests.

Table: 3: Tests Conducted on Stone Column

S. No	Stone column material	I_c	I_D	D_{50}	L/D ratio	Load carrying capacity in N
1	No stone column	0.6	0	0	0	37
2	SC with Stone dust material	0.6	75	0.55	6	132
3	SC with Stone dust material	0.6	75	0.55	7	170
4	SC with Stone dust material	0.6	75	0.55	8	183
5	SC with Stone dust material	0.6	75	0.55	10	185
6	SC with Stone dust material	0.6	75	0.55	11	188

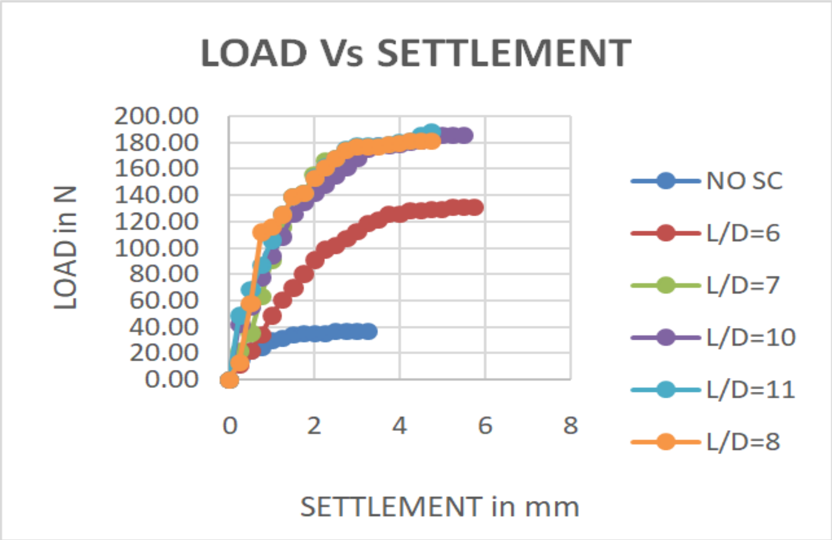

Figure 1: Load Vs Settlement Plot for varying L/d Ratios

2.4 Effect on Load Carrying Capacity of Stone Columns with One plate

The present application study effect on load carrying capacity of horizontal reinforcement consisting of one plate in stone columns 4 tests are conducted correspondingly different spacing's between plates.

Table 4: Tests Conducted on Stone Column with one Plate

S. No	Stone Column Material	Ic	I_D	D_{50}	L/D ratio	Load carrying capacity in N
1	SC with plate being at above of bulging	0.6	75	0.55	8	194
2	SC with plate being at top of bulging	0.6	75	0.55	8	190
3	SC with plate being at center of bulging	0.6	75	0.55	8	198
4	SC with plate being at bottom of bulging	0.6	75	0.55	8	200

III. RESULTS AND DISCUSSIONS

The results of the present investigation encompass studying the load carrying capacity and settlement of rammed stone columns without horizontal reinforcing elements inserted in high plastic clay soils.

IV. CONCLUSION

Load carrying capacity and load-settlement behavior of a stone column are dependent on L/D ratio. Load carrying capacity of a stone column increases with L/D ratio up to certain critical L/D, beyond which there will be no further

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increase in ultimate capacity with L/D. Stone column without horizontal reinforcing elements and constructed with stone dust in a model testing tank for L/D = 8 has increased the load carrying capacity of clay bed by 37N to 183N. Stone column with horizontal reinforcing elements with one plates are constructed with stone dust in small model testing tank for L/D - 8 has increased the load carrying capacity of clay bed by 37N to 200N.

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